Indira Gandhi National Open University
School of Interdisciplinary and
Trans-disciplinary Studies

MPYE – 009

Philosophy of Science and Cosmology

Block 1

INTRODUCTION

UNIT 1
Science and Philosophy, Science and Philosophy of Science

UNIT 2
Philosophy of Science and Other Disciplines

UNIT 3
Introduction to Cosmology

UNIT 4
History of Cosmology

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BLOCK INTRODUCTION

From the beginning of history of human thought, we find scientific and philosophical inquiry of reality contributed to the human quest for knowing the reality. For instance, by the 3rd BC, Euclid's work made geometry a 'science of space', though philosophers taught this in Plato's Academy. Till 17th century science was known as 'natural philosophy' and scientists were 'natural philosophers'. With Darwin biology was cut off from philosophy. The beginning of 20th century saw the separation of psychology from philosophy. By the middle of the same century computer science hijacked logic that has been with philosophy for more than two thousand years. Science and philosophy, therefore, are not strangers to each other. In the ancient times, Aristotle and many other philosophers were also scientists. Significant philosophers, like Bacon, Descartes, Leibniz and Locke, were influenced by science and their contributions to science were very significant. Great scientists of the 19th century, Maxwell, Hertz and Helmholz, gave serious thought to the above-mentioned philosophical issues. Poincare, a prominent mathematical physicist, came up with insights into the nature of theories and hypotheses, the notions of explanation and probability.

Unit 1 gives a general introduction to what science, philosophy and philosophy of science are all about. The quest for the ultimate foundations and facts of human life and the world is the driving force in these disciplines.

Unit 2 seeks to discuss some important aspects of the interactions of Philosophy of Science with Epistemology and Metaphysics. Science aims at acquiring knowledge and it is related with Epistemology that deals with the nature and validity of knowledge enterprise. Science is particular about revealing the true nature of reality and so it is related with Metaphysics that focuses on the issues of reality.

Unit 3 introduces the students to the basic notions of physical cosmology. It makes them aware of the early (religious) history of cosmology and some of the complex issues related to the origin, nature and end of the universe. Here we dealt with the religious cosmologies and some of the important notions of today's scientific cosmology.

Unit 4 gives a historical basis for scientific cosmology along with key contributions of some of the famous cosmologists. It aims at showcasing the origin of scientific or physical cosmology, as distinct from religious one.

COURSE INTRODUCTION

Sciences (natural and social) also have their own philosophical basics. Philosophy of science is not an isolated inquiry, rather it is related to many other domains of inquiry. Science is by humans and for humans and it is essentially a social enterprise. All that affects human society becomes a serious concern for science, including moral and environmental issues. Philosophy of Science deals with the philosophical issues of science; critiques the methods and assumptions of science. Cosmology refers to the study of the Universe in its totality as it is now (or at least as it can be observed now). The physical cosmology is primarily shaped through both mathematics and astronomical observation by the analysis of the whole universe. Philosophical Cosmology, as distinct from physical cosmology, draws data from physical cosmology and focuses on critical reflection as to the origin, nature and destiny of the universe. In some cases, views about the creation (cosmogony) and the end (eschatology) of the universe play a central role in shaping a framework of religious cosmology for understanding humanity's role in the universe.

Block 1 introduces the disciplines of science, philosophy of science and cosmology. It gives a bird's eye-view of what science, philosophy, philosophy of science are; the relationship and interaction among various disciplines; religious, philosophical and scientific cosmological theories and presuppositions; history of pre-scientific cosmology and gone into some of the important themes of contemporary scientific cosmology. It finally focuses on the history of scientific cosmology.

Block 2 surveys on different strands of philosophy of science especially in modern and contemporary period. Starting from logical positivists' initiative of clarifying the role of language and analysis together with criteria for rationality in field of science, in unravelling the mystery of reality, going through historicists' insistence on the need for socio-cultural, historical and moral factors to understand science and to do philosophy of science, we come to historical realism, the contemporary dominant school of philosophy of science that is said to be a mid-way position between Logical Positivism (LP) and Historicism. Finally we record key issues in philosophy of science.

Block 3 deals with the contemporary theories of science and cosmology. Two of the most revolutionary theories of 20th century were Theory of Relativity and Quantum Mechanics. Einstein's theory of relativity dealt a death blow to the so called absolutes: absolute time, absolute space, absolute frame of reference, absolute objectivity etc. Quantum Mechanics is probably the closest science has come to a fundamental description of the underlying nature of reality. The uncertainty principle with its difficulties and implications has changed the way we normally looked at the nature of particle, velocity, etc., and so opened a totally new way of understanding reality. All these theories and principles in contemporary science have sparked off speculations and theories on the origin of the cosmos and its nature, in a new way.

Block 4 is concerned about special issues of philosophy of science and cosmology such as, space and time, world models, expanding universe and the relation between science and religion. The basic query of what the universe is and where it came from has suggested in the process a bewildering variety of models, theories and ideas, from the Cosmic Egg to the Big Bang and beyond. Finally, the relationship between science and religion is discussed.

UNIT 1 SCIENCE AND PHILOSOPHY, SCIENCE AND PHILOSOPHY OF SCIENCE

Contents

1.0 Objectives
1.1 Introduction
1.2 Science as Subversive
1.3 Philosophy as Raising the Deepest and Widest Questions
1.4 Philosophy of Science as a Second Order Discipline
1.5 Historical Significance of philosophy of science
1.6 Relationship between Science and Philosophy
1.7 What Philosophy of Science Is and Is Not About
1.8 Three Broad Areas of Inquiry
1.9 Let Us Sum Up
1.10 Key Words
1.11 Further Readings and References

1.0 OBJECTIVES

- This unit tries to introduce philosophy of science to the students.
- It tries to study the relationship between science and philosophy.
- It undertakes to define philosophy of science and its broad areas of inquiry..

1.1 INTRODUCTION

In this unit, we want to introduce ourselves to the issues, problems, areas of philosophy of science. We first try to understand what science is and what philosophy is. Then we go to study philosophy of science and a second order discipline. Finally we see the relationship between science and philosophy and then we try to understand philosophy of science better.

1.2 SCIENCE AS SUBVERSIVE

In general science may be understood in two ways. First as "the systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts." Secondly as. "the organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation." (Dictionary of Science & Technology by Academic Press). Science is in fact an intellectual activity carried on by humans that is designed to discover information about the natural world in which humans live and to discover the ways in which this information can be organized into meaningful patterns. So the primary aim of science is to collect facts (data). According to Professor Sheldon Gottlieb the "ultimate purpose of science is to discern the order that exists between and amongst the various facts." Similarly, Robert M. Pirsig, the author of *Zen and the Art of Motorcycle Maintenance* holds: "The real purpose of the scientific method is to make sure Nature hasn't misled you into thinking you know something you don't actually know."
So science involves more than gaining of information and knowledge. It is the systematic and organized inquiry into the natural world and its phenomena. Science is about gaining a deeper and often useful understanding of the world. So "to do science is to search for repeated patterns, not simply to accumulate facts." (Robert H. MacArthur, *Geographical Ecology).* Therefore

science questions things and is not respector of persons. To quote Richard Feynman, Nobel-prize-winning physicist, "science alone of all the subjects contains within itself the lesson of the danger of belief in the infallibility of the greatest teachers in the preceding generation . . .As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts." Science may be contrasted to art and poetry. A modern poet has characterized the personality of art and the impersonality of science as follows: "Art is I; Science is We." (Claude Bernard) The famous English poet Samuel Taylor Coleridge (1772-1834), will agree: "Poetry is not the proper antithesis to prose, but to science. . . . The proper and immediate object of science is the acquirement, or communication, of truth; the proper and immediate object of poetry is the communication of immediate pleasure." If fiction and poetry deals with the real world and takes us to the imaginary and creative dimension, science enables us to focus on the real world and to retain the doubt and criticism. So James Porter, Professor of Ecology could say: "Fiction is about the suspension of disbelief; science is about the suspension of belief." So we can agree with Richard Feynman: "Religion is a culture of faith; science is a culture of doubt."

The focus of science or scientific research is this empirical world. Therefore, Stephen J. Gould, one of the well-known paleontologist, evolutionary biologist would hold: "As a practicing scientist, I share the credo of my colleagues: I believe that a factual reality exists and that science, though often in an obtuse and erratic manner, can learn about it. Galileo was not shown the instruments of torture in an abstract debate about lunar motion. He had threatened the Church's conventional argument for social and doctrinal stability: the static world order with planets circling about a central earth, priests subordinate to the Pope and serfs to their lord. But the Church soon made its peace with Galileo's cosmology. They had no choice; the earth really does revolve around the sun."

In this sense science challenges, criticizes our world-view. It subverts our understanding of ourselves. A long quote from Philip Morris Hauser, a well-known demographer and sociologist will conclude this section: "Science is the most subversive thing that has ever been devised by man. It is a discipline in which the rules of the game require the undermining of that which already exists, in the sense that new knowledge always necessarily crowds out inferior antecedent knowledge. . . . . This is what the patent system is all about. We reward a man for subverting and undermining that which is already known. . . . . Man has a tendency to resist changing his mind. The history of the physical sciences is replete with episode after episode in which the discoveries of science, subversive as they were because they undermined existing knowledge, had a hard time achieving acceptability and respectability. Galileo was forced to recant; Bruno was burned at the stake; and so forth. An interesting thing about the physical sciences is that they did achieve acceptance. Certainly in the more economically advanced areas of the Western World, it has become commonplace to do everything possible to accelerate the undermining of existent knowledge about the physical world. The underdeveloped areas of the world today still live in a pre-Newtonian universe. They are still resistant to anything subversive, anything requiring change; resistant even to the ideas that would change their basic concepts of the physical world."

1.3 PHILOSOPHY AS RAISING THE DEEPEST AND WIDEST QUESTIONS

With philosopher Ayn Rand, we can hold that_ "Philosophy studies the fundamental nature of existence, of man, and of man's relationship to existence. … In the realm of cognition, the special sciences are the trees, but philosophy is the soil which makes the forest possible." In other words philosophy is a comprehensive system of ideas about human nature and the nature of the reality we live in. It is a guide for living, because the issues it addresses are basic and pervasive, determining the course we take in life and how we treat other people (Thomas 2011).

The topics that philosophy addresses fall into several distinct fields. Among those of fundamental concern are:

- Metaphysics (the theory of reality).
- Epistemology (the theory of knowledge)
- Ethics (the theory of moral values)
- Politics (the theory of legal rights and government)
- Aesthetics (the theory of the nature of art)

In Greek, "philosophy" means "love of wisdom." Philosophy is based on rational argument and appeal to facts. The history of the modern sciences begins with philosophical inquiries, and the scientific method of experimentation and proof remains an instance of the general approach that a philosopher tries to bring to a question: one that is logical and rigorous. However, while today the sciences focus on specialized inquiries in restricted domains, the questions addressed by philosophy remain the most general and most basic, the issues that underlie the sciences and stand at the base of a worldview. They are the more fundamental issues that human beings have to grapple with (Thomas 2011).

Philosophy raises some of the deepest and widest questions there are. Addressing the issues in each branch of philosophy requires integrating everything one knows about reality (metaphysics) or humanity (epistemology, ethics, politics, and aesthetics). Proposing reasonable positions in philosophy is therefore a difficult task. Honest philosophers have often disagreed about key issues, and dishonest ones have been able to slip their own positions into the mix as well. For this reason, there is not one philosophy worldwide, as there is one physics. Instead, there are many philosophies.

Over the course of history, philosophers have offered entire systems that pulled together positions in each of the branches of philosophy. Aristotle, the father of logic, wrote such a system in ancient times, teaching that we could know reality and achieve happiness. In more modern times, philosophers such as John Locke and Immanuel Kant have written systematic accounts of their thought (Thomas 2011). Most modern philosophers, however, have specialized in one area or another within philosophy, since philosophy itself has become very specalised today.

Check Your Progress I

Note: Use the space provided for your answers.

1) “Science is a subversive activity” Comment.

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2) What is the primary function of philosophy?

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1.4 PHILOSOPHY OF SCIENCE AS A SECOND ORDER DISCIPLINE

Given the two understandings of science and philosophy as discussed above, we can try to see what philosophy of science means. We may hold that the philosophy of science seeks to describe and understand how science works within a wide range of sciences. This does not have to include every kind of science. But it had better not be confined to a single branch of a single science, for such an understanding would add little to what scientists, on the whole, know. Unfortunately, philosophers and scientists are not in agreement on the nature of their own field of study. Even practising philosophers of science often disagree about the proper subject-matter of their discipline. An example of this lack of agreement is the exchange between Stephen Toulmin and Ernest Nagel on whether philosophy of science should be a study of scientific achievement, or a study of problems of explanation and confirmation through logic.

One view regarding the philosophy of science is that it the formulation of worldviews that are consistent with, and in some sense based on, important scientific theories. According to this view, it is the task of the philosopher of science to elaborate the broader implications of science (Losee 2001).

A second view is that the philosophy of science is an exposition of the presuppositions and predispositions of scientists. The philosopher of science may point out that scientists presuppose that nature is not capricious, and that there exist in nature regularities of sufficiently low complexity to be accessible to the investigator. Further, he may uncover the preferences of scientists for deterministic rather than statistical laws, or for mechanistic rather than teleological explanations. (Losee 2001).

A third view is that the philosophy of science is a discipline in which the concepts and theories of the sciences are analysed and clarified. This is not a matter of giving a semi-popular exposition of the latest theories. It is, rather, a matter of becoming clear about the meaning of such terms as ‘particle’, ‘wave’, ‘potential’, and ‘complex’ in their scientific (or physics) usage.

A fourth view is that philosophy of science is a second-order discipline. It goes more than science and critically reflects on the very discipline of science itself.The philosopher of science seeks answers to such questions as:

- What characteristics distinguish scientific inquiry from other types of investigation?
- What procedures should scientists follow in investigating nature?
- What conditions must be satisfied for a scientific explanation to be correct?
- What is the cognitive status of scientific laws and principles?

To ask these questions is to assume a vantage-point one step removed from the practice of science itself. There is a distinction to be made between doing science and thinking about how science ought to be done. The analysis of scientific method is a second-order discipline, the subject-matter of which is the procedures and structures of the various sciences. (Losee 2001)

Level	Discipline	Subject-matter
2	Philosophy of Science	Analysis of the Procedures and Logic of Scientific Explanation
2	Science	Explanation of Facts Facts

The fourth view of the philosophy of science incorporates certain aspects of the second and third views. For instance, inquiry into the predispositions of scientists may be relevant to the problem of evaluating scientific theories. In addition, analyses of the meanings of concepts may be relevant to the demarcation of scientific inquiry from other types of investigation (Losee 2001). The distinction which has been indicated between science and philosophy of science is not a sharp one.

1.5 HISTORICAL SIGNIFICANCE OF PHILOSOPHY OF SCIENCE

Philosophy of science is an old discipline. Both Plato and Aristotle wrote on the subject, and, arguably, some of the pre-Socratics did also. The Middle Ages, both in its Arabic and high Latin periods, made many commentaries and disputations touching on topics in philosophy of science. Of course, the new science of the seventeenth century brought along widespread ruminations and manifold treatises on the nature of science, scientific knowledge and method. The Enlightenment pushed this project further trying to make science and its hallmark method definitive of the rational life. With the industrial revolution, “science” became a synonym for progress. In many places in the Western world, science was venerated as being the peculiarly modern way of thinking. The nineteenth century saw another resurgence of interest when ideas of evolution melded with those of industrial progress and physics achieved a maturity that led some to believe that science was complete. By the end of the century, mathematics had found alternatives to Euclidean geometry and logic had become a newly re-admired discipline (Machmer 2002).

But just before the turn to the twentieth century, and in those decades that followed, it was physics that led the intellectual way and garnered the attention of the philosophers. Mechanics became more and more unified in form with the work of Maxwell, Hertz and discussions by Poincaré. Plank derived the black body law in 1899, in 1902 Lorenz proved Maxwell’s equations were invariant under transformation, and in 1905 Einstein published his paper on special relativity and the basis of the quantum. At the same time, Hilbert in 1899 published his foundations of geometry, and Bertrand Russell in 1903 published his principles of mathematics. The development of unified classical mechanics and alternative geometries, challenged by the new relativity and quantum theories made for period of unprecedented excitement in science (Machmer 2002).

Then came the era of computer and information technology, including artificial intelligence. But today life-sciences (biology, biotechnology) have taken over. So 21st century is rightly considered as the century of biotechnology and philosophy of science has to confront the possibilities and challenges offered by it. The emergence of postmodernity and relativity has also challenged the way philosophy of science is practiced today.

Check Your Progress II

Note: Use the space provided for your answers.

1) Describe philosophy of science as a second order activity.

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2) Briefly elaborate the historical significance of philosophy of science?

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1.6 RELATIONSHIP BETWEEN SCIENCE AND PHILOSOPHY

The relationship between science and philosophy has always been problematic, ever since science itself slowly evolved from “natural philosophy” during the 16th and 17th centuries. Because of the work of people who thought of themselves as philosophers but were in fact scientists, philosophy of science became a distinct disciple. Names like Francis Bacon, Galileo Galilei and Isaac Newton are examples.

It may be noted that philosophy is the mother and science is the daughter. Earlier they both existed together. But as science developed, it becomes distinct from philosophy. As in any parent-offspring relationship, things can get problematic, with the offspring claiming its territory while denying the parent’s relevance or contribution, and the latter having a difficult time letting go of the now adult and independent offspring. (Pigliucci 2008)

We believe that both scientists and philosophers can give more thought to the relationship between science and philosophy. There are many areas where meaningful bridges can be built, and where the two disciplines can operate largely independently of each other. This is neither an apology on behalf of philosophers nor an invitation to scientists to become philosophers. The first is not needed because philosophy is an autonomous area of scholarship, which certainly does not need any more justification than, say, literary criticism or quantum electrodynamics. The second would be missing the point since, scientists may benefit from a better acquaintance with philosophy. But scientists normally do not have the time to learn philosophy (Pandikattu 2003).

Now we are in a position to see what philosophy of science actually does. We may first what philosophy of science is and is not (Pigliucci 2008).

1.7 WHAT PHILOSOPHY OF SCIENCE IS AND IS NOT ABOUT

Nobel-laureate and physicist Steven Weinberg (1992) took the rather unusual step of writing a whole essay entitled "Against Philosophy." In it, he argued that not only is philosophy not useful to science, but that, in some instances, it can be positively harmful. The example he provided was the alleged slow acceptance of quantum mechanics, due to the philosophical school of positivism endorsed by so many scientists in the early 20th century, beginning with Einstein.

Positivism is a now abandoned philosophical position that takes a rather narrowly naıve view of what counts as science. Most famously, positivists thought that science had no business dealing with "unobservables," i.e., with postulating the existence of entities that cannot be subjected to experimental tests. Quantum mechanics is rife with such unobservables, including electrons and forces, and positivists were indeed highly skeptical of the whole affair, which smelled too much of metaphysics (a bad word, according to them) (Pigliucci 2008).

It is also true that some scientists, first and foremost Einstein, were rather uncomfortable with the wildest implications of quantum mechanics (as in Einstein's famous statement that "God doesn't play dice") and resisted them while searching for alternative interpretations of the theory. But Einstein himself was a philosopher.

A diametrically opposite view to Weinberg's is the one expressed by Daniel Dennett (perhaps not surprisingly, a philosopher), in his *Darwin's Dangerous Idea*: "There is no such thing as philosophy-free science; there is only science whose philosophical baggage is taken on board without examination". This will strike most scientists as preposterously arrogant, but a moment's reflection shows that Dennett, of course, is right. For example, scientific practice requires the assumption of naturalism, i.e., the idea that natural phenomena are indeed natural, and, therefore, scientists do not need to invoke the supernatural to explain them. It is interesting to note that scientists themselves invoke naturalism as a postulate of science (Pigliucci 2008).

The important thing to realize is that naturalism is not an empirically verifiable position, and, therefore, it is by definition outside of science itself (if science is about anything at all, it is about empirically verifiable statements about the world). Attitudes such as Weinberg's are largely the result of ignorance of what philosophy of science is about, and I am convinced that such ignorance hurts science. It certainly does not help to bridge between science and philosophy.

1.8 THREE BROAD AREAS OF INQUIRY

Generally speaking, philosophy of science deals with three broad areas of inquiry, which Pigliucci refers to as nature of science, conceptual and methodological analysis of science, and science criticism (Chalmers 1999).

Regarding Nature of Science: Most scientists, if they are familiar with philosophy at all, have some acquaintance with philosophical studies of the nature of science. Names such as Karl Popper and Thomas Kuhn even make it into the occasional biology textbook, and one can argue that falsificationism and paradigm shifts— the most important respective contributions of these two philosophers—are among the few concepts in modern philosophy of science that are ever mentioned in the halls of science departments. Popper and falsificationism are representative of a *prescriptive* way in philosophy of science; that is, they exemplify a tradition of philosophers seeking to tell scientists how they ought to carry out their work. Popper was motivated by the so-called demarcation problem, the difficulty in distinguishing science from pseudoscience (he included in the latter Freudian psychoanalysis and Marxist theories of history). He was also bothered by Hume's problem of induction, the idea that science is based on inductive reasoning, and yet the only reason we have to trust induction is because it worked in the past (which is itself a form of induction, making the whole thing perilously close to circular). Popper thought he solved both problems with the idea of falsification: science is really based on deductive logic, not induction. This solves Hume's difficulty, but, since deduction cannot truly establish proof of natural phenomena (although it works fine for mathematical proofs), it turns out that science can never prove anything but can only disprove (i.e., falsify) theories. (Pigliucci 2008)

It is rather ironic that many science textbooks have essentially adopted Popper's view of science as an enterprise dealing in falsificationism, with many scientists actually *defining* science in Popperian terms. Popperian falsificationism has long been superseded in philosophy of science, partly through the work of one of Popper's own students, Imre Lakatos , who argued that falsificationism does not work because it is often possible to "rescue" a given theory from demise by modifying some of the ancillary assumptions that went into building it. This is a good thing too, and indeed a reflection of how science really works. Just think of the fact that the original Copernican theory did not actually fit the data very well, and yet it was not rejected as "falsified." Rather, scientists gave it some time to develop because it seemed a promising approach. Subsequently, Kepler modified an important, though not central, assumption of the theory, thus producing results that correlated very well with the data: the sun is indeed (almost) at the center of the solar system, but the planets rotate along elliptical, not circular, orbits, of which the sun occupies not exactly the center, but one of the foci (Pigliucci 2008).

Kuhn's (1970) ideas as developed in *The Structure of Scientific Revolutions*, are an example of the *descriptivist* approach to the study of the nature of science. Kuhn did not pretend to tell scientists how to do their work but was interested in figuring out how science, as a process of discovery, actually proceeds. His idea of paradigm shifts was based on historical studies of astronomy and physics (arguably, biology has never undergone a paradigm shift after Darwin).

Regarding methodological analysis of science: The second major area of inquiry in philosophy of science the conceptual and methodological analysis. It deals largely with tracing the historical use and clarifying the meaning of fundamental ideas and practices in the sciences. Hume (1748) was among the first ones to take this approach, inquiring about what we mean when we talk about causality. (His analysis, still surprisingly challenging today, was not very encouraging.) More recently, critical work on the conceptual foundations of evolutionary theory and the practices of quantitative genetics falls into this group.

Regarding science criticism: The third major type of philosophy of science is what I term science criticism, and it directly addresses the interface between science and society. For example, philosophical issues surrounding the nature-nurture debate are relevant to the uses and, more importantly, the misuses, of genetic engineering. Here the philosopher becomes a critic not just of how the science is being conducted and its findings interpreted, but, primarily, of how such findings are understood by the public and used to guide social policies.

What is a scientist to do with all this? Scientists may largely and safely ignore what philosophers say about how science does or should work in broad terms—after all, scientists want to *do* science, not to think about how it is done (except occasionally, when they are close to retirement). They do, however, have a responsibility to update their understanding of philosophy when it comes to writing science textbooks or teaching the nature of science in the classrooms. Also, philosophers clearly have the intellectual right to pursue such inquiry into the nature of science without having to justify themselves to scientists by defending the "utility" (implicitly, to science) of what they do. (Pigliucci 2008)

When we move to the second and third areas of philosophical inquiry, we come closer to the borderland between science and philosophy, to the point where, in some cases, philosophy may be thought of as "the continuation of science by other means" (Chang 2004). Indeed, in areas from evolutionary biology to quantum mechanics, it is sometimes difficult to tell whether a theoretical paper is written by a scientist or by a philosopher without directly checking the author's institutional affiliation. Here the word "theory" takes on its original and broader meaning of formulation of concepts, not just mathematical treatment (although there are examples of philosophers engaging in the latter as well). What makes this blurred line between philosophy and science interesting is that the two disciplines bring different backgrounds and approaches to the study of the same issues—i.e., this is not just a matter of science-envy by philosophers (or the even more rare phenomenon of philosophy-envy by scientists) (Pigliucci 2008)

1.9 LET US SUM UP

This unit introduces the philosophy of science and takes up some of the basic issues related to it. We have seen how science and philosophy are related and different. Then we saw the specific role of philosophy of science.

Check Your Progress III

Note: Use the space provided for your answers.

1) What is Weinberg's idea of philosophy?

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2) Explain philosophy of science as "science criticism"?

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1.10 KEY WORDS

Falsificationalism: Falsifiability or refutability is the logical possibility that an assertion could be shown false by a particular observation or physical experiment. That something is "falsifiable" does not mean it is false; rather, it means that if the statement were false, then its falsehood could be demonstrated.

Natural philosophy: The study of nature and the physical universe before the advent of modern science.
Naturalism: A theory denying that an event or object has a supernatural significance. It assumes that nature can be explained by itself.

1.11 FURTHER READINGS AND REFERENCES

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UNIT 2 PHILOSOPHY OF SCIENCE AND OTHER DISCIPLINES

Contents

2.0 Objectives
2.1 Introduction
2.2 Philosophy of Science and Epistemology
2.3 Philosophy of Science and Metaphysics
2.4 Feminist Accounts of Science
2.5 Values and Science
2.6 Let Us Sum Up
2.7 Key Words
2.8 Further Reading and References

2.0 OBJECTIVES

As philosophy seems to be the foundation of every discipline, a deeper inquiry into any discipline takes us to the philosophical basics of that discipline. Sciences (natural and social) also have their own philosophical basics. This discipline philosophy of science is not an isolated inquiry, rather it is related to many other domains of inquiry. This short essay seeks to discuss some important aspects of the interactions of Philosophy of Science with *Epistemology* and *Metaphysics*. It also has a cursory look at its relationship with *Values* (Ethics) and *Feminism*, just to give an idea of the vastness and depth of the impact of philosophy of science upon various disciplines.

2.1 INTRODUCTION

Like any other human inquiry and knowledge enterprise, science also involves philosophical issues, like the goals of science, the nature of scientific knowledge and the foundations of science; 'What is Science?', itself is a philosophical question. Though science emerged from philosophy and philosophy is said to be the *mother* of all the disciplines, in course of time all disciplines came of age, and got separated from the mother. For instance, by the 3rd BC, Euclid's work made geometry a 'science of space', though philosophers taught this in Plato's Academy; till 17th century science was known as 'natural philosophy' and scientists were 'natural philosophers'. In fact, the term scientist was coined only 1833, by William Whewell, an English Philosopher and Historian of Science. With Darwin's *The Origin of Species* (1859) biology was cut off from philosophy; the beginning of 20th century saw the separation of psychology from philosophy. By the middle of the same century computer science hijacked logic that has been with philosophy for more than two thousand years. Science and philosophy, therefore, are not strangers to each other. In the ancient times, Aristotle and many other philosophers were also scientists. Significant philosophers, like Bacon, Descartes, Leibniz and Locke, were influenced by science and their contributions to science were also very significant. Great scientists of the 19th century, Maxwell, Hertz and Helmholz, gave serious thought to the above mentioned philosophical issues. Poincare, a prominent mathematical physicist, came up with insights into the nature of theories and hypotheses, the notions of explanation and probability.

Some philosophical Issues in Science: i) To understand certain concepts adequately, science has to go beyond to the realm of philosophy. For instance, the concept of time cannot be defined in terms of hours / minutes of duration, as all these presuppose the notion of time; ii) The relation between the scientific theory and the world out there – realistic or instrumental relationship?; iii) How do the scientists switch over to the new theories? Is it completely based on logic and observations? Or is it through a social process, like Kuhn and other historicists would propose? iv) Evidence is generally based on the assumption that there are 'pure' observations. But there seems to no 'theory-free' observation in science. Even to see the time now as 12 noon, assumes that the clock and observer exist independently of each other and not deluded by a Cartesian demon, and to accept all the theories with which the clock has been manufactured. This raises further questions: Is there any real epistemic distinction between observational and theoretical assertions? Is there any safe and sound basis for science? v) What is the meaning of 'systematically basing' the theories on the evidence? Any theory, with its universal applicability, goes beyond the observable data at hand. Same observational data can yield too many theories, even contradicting ones (notion of Under-determination); vi) What are the extra factors to be considered to decide upon the 'correct' theory? If simplicity and predictive power of theories are considered, are they only pragmatic considerations or some sort of truth-revealing indicators? vii) Philosophical analyses of the aims, methods, assumptions, foundations, practices and achievements of science, are to be undertaken as specific sciences will not have time for such aspects; viii) The study of the very language of science, the methods and the structures of explanation used in science; it checks the validity of arguments used in science; ix) Exploration of the worldviews based on important scientific theories to uncover the preferences of scientists for deterministic rather than statistical laws, or for mechanistic rather than teleological explanations; x) The investigations into the broader implication of science and to see how the socio-cultural factors affect the growth and the subject matter of science.

2.2 PHILOSOPHY OF SCIENCE AND EPISTEMOLOGY

Science aims at acquiring more knowledge about the world, by specific methods of observation and experimentation and it makes conclusions based on evidence. In philosophy also there is a branch, 'Epistemology', which deals with domains of knowledge. 'What is the difference between knowledge and mere beliefs?' 'Can one be sure that one can know at all? 'What are the things that one can know?' "What are the requirements for a proposition to be a piece of knowledge?' - are some of the questions that are crucial to both the disciplines. Science justifies its knowledge through specific method(s). However Hume already pointed out that the inductive reasoning, widely used in science, cannot be completely justified, as its conclusion involves claims about unknown elements. The ampliative inference – where the inference contains some factual content which has not been present in the premises – decides on something about the unexperienced, basing on the experienced. Science functions on many axioms, like the fundamental uniformity of nature, the future will resemble the past etc., which are known, *a posterori*, nor *a apriori*. Philosophy of science critiques the method used in science.

Scientific Methodology

The term 'Method' means 'a way to achieve an end' and the scientific method is way to achieve 'scientific ends', i.e. scientific knowledge [Greek terms, *meta* = after and *hodos* = way]. The basic steps of scientific methodology: i) *Stating the Problem* (success and progress of science greatly depends on the clear understanding of problem at hand); ii) *Framing a Hypothesis* (a tentative solution to the problem, based on one's creative and original imagination); iii) *Observing and Experimenting* (studying an event/phenomenon under varied conditions, controlled by the investigator, with or without instruments); iv) *Interpreting the Data* (making the resulting data – figures, pointer readings, graphical representations etc. – intelligible and useful, by means of analysis, synthesis, comparisons, analogies, models etc.); and v) *Drawing Conclusions and Inferences* (the aim of the whole process).

There are *Mental Devices* used in scientific methodology: i) Logic (the use of *induction*, to arrive at causal connections between events, and *deduction*, to arrive certain conclusion from the given premises; induction gives new information, but need not be certain, while deduction gives certain conclusion, but not new one); ii) *Classification* (to bring order into the multitude of complicated data); iii) Comparison and Analogy (especially useful in forming the hypothesis and in interpreting the data); iv) *Models* (a basic representation, from the known to the unknown); and v) *Mathematics* (a powerful device to make complicated concepts understandable).

Scientific Methods in the Modern Times: Though Aristotle in his *Prior Analytics* and *Posterior Analytics* used both the inductive and deductive reasoning, Francis Bacon, in his *Novum Organum* (1620) emphasized only the method of induction for scientific inquiry. But with the emergence of modern science (17th – 19th centuries) the need was felt to look for a new understanding of method of science and two predominant methods of science emerged: Inductivism and Hypotheism.

Inductivism	**Hypotheism**
i) The method of science is the method of induction.	i) The method of science is the method of hypothesis.
ii) Founder: Francis Bacon.	ii) Rene Descartes
iii) Rooted in Empiricism – (only those ideas that are traceable to sense experiences are to be treated as knowledge).	iii) Based on Rationalism – (At least some portion of human knowledge cannot be traced to, and thus, independent of sense experiences).
iv) Important features of science: Certainty and breadth. Science has to look for definite knowledge and more encompassing knowledge about reality.	iv) Novelty and Depth. Science has to go beyond the observational; it has to reach the depth of reality of unobservables, behind the observed.
v) Since science has to be certain, it has to limit itself only to the observable phenomena; then proceeds from particulars to general conclusions through induction. Science must remain from the beginning till the end at the level of observation; so there is no reference to unobservables.	v) Mere generalization in terms of observations is not enough; science has to explain the observable in terms of the unobservables.
vi) The aim of science: to arrive at laws, (i.e. established inductive generalizations).	vi) To generate hypotheses to explain what we observe. [Hypothesis meant 'a statement regarding unobservable entities & process.

vii) Inductivists are antirealists; they hold that the theoretical terms don't refer to anything real; as empiricists for them only observed reality is real and nothing outside exists; they are only useful tools.	Today it means 'a tentative solution to a problem']. vii) Hypothesists are realists; theoretical terms (like electrons, protons etc.) refer to really existing entities, though they are not given to us in observations.

By the middle of the 19th century science had to deal with many unobservable entities or process (e.g. Franklin's fluid theory of electricity, Vibratory theory of heat, Phlogiston theory of burning and neurophysiological theories of David Hartley etc.), which took science beyond observational methods of inductivism. Within philosophy too there were objections to show that there was no rational justification for induction.

Problems of inductive reasoning

Inductive reasoning is common-sensical and highly successful in sciences and practical lives. However, Hume astutely argued in his *Treatise of Human Nature* (1739) that there is no logical justification for the principle of induction. N.R. Hanson points out the actual problem with the inductive thinking: "It is the problem of showing how 'The Inductive Principle'… can at once be synthetic (in that its negation is not demonstrably self-contradictory), yet necessary (in that its negation describes no intelligible state of affairs at all)" (1971, 248). *The decisive problem* with induction is that to justify induction we need to involve inductive reasoning itself; it can be illustrated as follows: The principle of induction worked successfully on occasion n_1, n_2, n_3….n_x. Therefore the principle of induction always works.

In the past few decades a number of solutions have been propose in order to defend the inductive reasoning: Reichenbach (*Experience and Prediction,* 1938 and *The Theory of Probability*, 1945) is satisfied with a pragmatic justification; Nelson Goodman replaced Hume's old problem of induction with the new problem of induction; Kant offered a transcendental deduction of a principle of universal causation; P. F. Strawson offered an ordinary language dissolution, and thereby making Hume's problem is only a pseudo-problem; Carnap appealed to 'inductive intuition'. (For analyses of all these proposed solutions, see: Wesley Salmon, 1967). Popper (1935, *Logic of Scientific Discovery*) did away with the need for induction in science, because science adopts hypothetico-deductive method. [*Note*: For explanation of this method, kindly see: Block 2, Unit 2: *Historicism*].

Bayesian Theory of Probability - A Reasonable Solution: Bayesian theorem, proposed by Thomas Bayes (an English non-conformist clergyman, a renowned mathematician, a fellow of the Royal Society, lived between 1702-61) is an attempt to supply rational basis for inductive reasoning in science. The degree of certainty of the conclusion of an experiment is measured by the probability of the conclusion. By probability Bayes meant "a rational acceptance: The probability of any event is the ratio between the value at which an expectation depending on the happening of an event ought to be computed, and the value of the thing expected upon it's happening" (1763, 376, as quoted by Barry Gower, 1997, 96). Salmon lists five leading philosophers, Carnap, Reichenbach, L. J. Salvage, Nelson Goodman and Popper, who show inclinations towards the Bayesian theorem, directly or indirectly (Wesley Salmon, 2002, 397-99). Howson and Urbach explain the Bayseian confirmation in simple terms. The relationship between the empirical data (evidence) and the hypothesis is crucial, because it helps in accepting or rejecting a hypothesis. A piece of evidence can be confirming or undermining or neutral to the hypothesis under the test: Say, h – hypothesis; e – evidence, P(h) – the prior probability, and P(h|e) – the posterior probability; e confirms h, if $P(h|e) > P(h)$; and e disconfirms h, if $P(h|e) < P(h)$; i.e. if the posterior probability is more the evidence confirms the hypothesis and vice versa. When the confirmation is at maximum, $P(e|h) = 1$ and then h logically entails e. When the disconfirmation is at maximum, $P(e|h) = 0$ and then h is refuted. No further evidence will confirm it, unless the refuting evidence or part of background knowledge is revoked. Posterior probability depends on prior probability but this dependence is related to the scientists' attitude towards *ad hoc* hypothesis; their preferences with regard to simpler hypotheses and their decision with regard to the credibility of the hypothesis. The authors are, in fact, very optimistic that "Bayesian approach is the only one capable of representing faithfully the basic principles of scientific reasoning" (Colin Howson and Peter Urbach, 1993, 2).

The *most basic objection* to the Bayesian approach is that it gives importance to subjective factors in the scientific appraisal. For instance, Lakatos claims that the states of mind, like one's beliefs, commitments, understanding etc. of the psychological approaches don't affect the cognitive value of a scientific value of a theory, which is actually "independent of the human mind, which creates it or understands it, its scientific value depends only on what objective support these conjectures have in facts" (Lakatos, 1978, 1). But the admirers of Bayesian reasoning seem to suggest that the so-called 'objectivists' of scientific methodologies deliberately close their eyes towards the indispensable subjectivist elements in the scientific reasoning. That is why a leading proponent I.J. Good argued persuasively that "the subjectivist (i.e. Bayesian) states his judgments, whereas the objectivist sweeps them under the carpet by calling assumptions knowledge, and he basks in the glorious objectivity of science" (http://www.cs.ubc.ca/~murphyk/Bayes/bayesrule.html). Given the scenario, Howson is confident that "Eventually we shall all be subjective Bayesians" (Howson, 1991, 82). [For more on the objections against probabilists and Bayesians, kindly see: Karl Popper and D. Miller, 1984, 434].

Finally, conclusiveness always escapes us in inductive reasoning. Nevertheless, it need not make us nervous or skeptic towards the whole enterprise of inductive reasoning. Though we can always reject what has been inductively arrived at, we can still consider it as valid reasoning, "since they have as little chance in fact of going wrong" (Mellor, 1989, 7.). It seems to be reasonable to accept inductive reasoning as a species by itself.

Check Your Progress I

Note: Use the space provided for your answers.

1) Comment on the need and relevance of Philosophy of Science for other intellectual inquiries?

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2) What is a scientific method? Discuss the methods of modern science.

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3. What is the problem with the inductive reasoning? Can it be convincingly solved or conveniently ignored?

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2.3 PHILOSOPHY OF SCIENCE AND METAPHYSICS

When science comes out with theories, especially about the unobservables, a crucial question can be raised: Do they portray the world as it is or are they only a convenient tool to understand the natural phenomena? Science not only describes, but also explains how and why a phenomenon takes place. By explaining the fundamental nature of things, about its existence, about its causation etc, science enters the domain of metaphysics. We focus only on these two aspects of *realism* and *causality* here.

Scientific Realism and Anti-realism

The question of realism and anti-realism arises in the context of the unobservable entities, like, viruses, radio waves, electrons, quarks, genes, atoms and sub-atomic particles, blackholes, etc. Though they are not observable science is able to acquire knowledge about their nature, behaviour, constituents etc. 20th century physics gives a picture of reality that is more abstract and far-removed from common sense. At this juncture, the question of justifying the ontological status of these unobservable entities arises very strongly. There are two opposing trends in philosophy of science with regard to the existence of unobservable entities: *Scientific Realism* and *Scientific Anti-realism*, where the former claims that the unobservables really exist, and the latter denies it.

The Basic Claims of Scientific Realism

i) Unobservable entities exist; ii) They exist independent of our minds; iii) We do make statements about them, with truth-value; iv) These statements are true or false, depending on how the world is, and v) We must believe in their existence and consider much of them as knowledge. For instance, the kinetic theory of gases speaks about the molecules in random motion, because that is what happens in a gas. Thus, they demand three kinds of philosophical commitments: *metaphysical* (mind-independent existence), *semantic* (literal interpretation of the theories and the correspondence theory of truth) and *epistemological* (the unobservable entities do exist and they count as knowledge).

The Basic Claims of Scientific Antirealism

i) Only what is empirically observed does exist, and all the other so-called unobservable entities don't. [*Note*: Most of the antirealists, though they deny the real existence of such entities, yet they agree that science is the most rational enterprise, because of its practical success and growth in accumulation of knowledge. So the issues of 'rationality in science' and 'realistic view of science' are different]; ii) The unobservable entities are only useful instruments to make calculations simpler or predictions more feasible, and the description about them are not true reflections of the state of affairs in the world. There are *different types of anti-realists* in science. To be an anti-realist it is sufficient to disagree with anyone of the above-mentioned five claims of the realists. [Sceptics deny (i), reductive empiricists deny (iii), Social constructivists, like Kuhn, deny (ii), constructive empiricists, like Bas van Fraassen, deny (v) and they are also unsure of (i)].

The major groups among the anti-realists

Instrumentalism: i) Scientific theories don't describe the world, rather they are tools to approach the world and to relate a set of observable states of affairs with other sets; ii) Theories about the unobservable entities are not to be taken literally as they are only logical constructs used as useful instruments to relate with the external world; iii) Theories are judged in terms of their efficiency and usefulness, and not in terms of truth / falsity; iv) Since theories are only instruments they don't have predictive powers; b) *Conventionalism*: i) Scientific theories are only conventions; ii) The theoretical entities don't exist as nothing beyond observational reality exists; iii) The concepts used in a theory, say, 'force' and 'mass' in the Newtonian theories, are mere conventions; however they are empirically significant and useful to explain the world of facts. c**)** *Descriptionism*: The theoretical claims of the unobservable entities are only convenient descriptions of reality, as they don't refer to anything that actually exists.

Remarks

The debates between realists and antirealists seem to go for ever; For, antirealists have to explain how scientific theories, if they are just convenient tools to deal with reality, produce practical successes; on the other hand, realists have to deal with the problems with the theory-ladennes of observation and the fact the whole enterprise of science is increasingly seen as a product of psycho-social and cultural milieu of a given time. [More arguments against 'pure' observations will be given in *Historicism* (Unit 2 of Black 2]. ii) All observational terms are theoretical constructs to a certain extent. Stars, planets, light rays, gases etc. acquire their meaning, to some extent, only from the theoretical contexts in which they occur. For example, instrumentalists argue that only the billiard balls are observable and real, while the force and friction that exist among them are only tools, invented by physicists to understand certain physical phenomena. But one needs to realize that the concept of a billiard ball also involves some theoretical constructs like individuality, rigidity, made of a particular substance etc., without which we cannot speak of those balls. iii) Realists argue that unless we assume the unobservables really exist, how can one justify the efforts of the contemporary scientists to unify various kinds of theories and to arrive at one theory of everything (TOE)? However, instrumentalists would reply that the efforts to unify theories are still worth the trouble, because the scientific community will arrive at one 'big' and 'unified' instrument to deal with nature. Some of them may deny the very effort of unifying as baseless, as science is only a assortment of various tools to deal with variety of problems (Nancy Cartwright,1983). iv) Further, the predictive feature of science gives science a distinguishing characteristic for science and this feature is possible only when science treats theories as true descriptions of reality. v) Given these circumstances, there are authors coming up with nuanced understanding of realism, as instrumentalism seems to have more problems than realism. [e.g. ***'**Unrepresentative Realism'* by A. F. Chalmers, in *What is This Thing Called Science?*, 1992): It is realism, because we need to assume the independent existence of reality and acknowledge the practical and predictive power of scientific theories. It is *unrepresentative*, because it does not involve correspondence theory of truth between theories and the reality out there].

Causality and Science

One of the significant aims of science is to explain events or phenomena in terms of natural laws or cause-effect relationships. A natural law is expected to have authenticity, a measure of certainty and it must be universal (i.e. reliable in all situations, at all the times). For example, Newton's theory of gravitation is true at all times. Accidents (unlike laws) don't have predictive power.

Cause-Effect Relationship

How causes are related to effects is of philosophical interest: *a) Logical Necessity:* Causes necessitate some events that are effects. As causes are sufficient for their effects, the relation of causal necessity between particular events makes one *an inevitable consequence* of another. Due to the inherent connection between the cause and its effect, the effect must happen whenever and wherever the cause exists. If laws are universally valid there must be necessary relationship between the phenomena; thus, when one heats the water, it not only normally evaporates but it must evaporate. *b) Constant Conjunction* (Hume): There is no logical justification for any necessary connection but only "constant conjunctions" (exceptionless regularities) between cause and effect. As we are conditioned by these regularities in our experiences, we form an idea of causal necessity and mistakenly think that second billiard ball not only *will*, but also *must,* move when the first ball strikes it. The idea of necessary connection between them is only a psychological expectation and nothing is based on sense impression. Since any cause is perfectly separable in our mind from their effects, we can imagine any cause (without any absurdity) without its accustomed effect or even with effect with which never accompanies. Only from my experience I learn that when water is heated it boils, instead of freezing; but there is nothing tells me that the latter *cannot* happen. Therefore, since anything might cause anything, an effect cannot be inferred from a cause; both are conjoined, and not connected. *c) Empirical Necessity:* The cause-effect relationship is only *a hypothetical or conditional* necessity, given a set of natural laws. Boiling of water on heating is just a consequence of the law of nature. If there were different sets of laws the effects could have been very different. Such an empirical analysis looks at causation**,** *not in terms of what can and cannot happen, not in terms of what is and what is not possible, but solely in terms of what does happen.*

Remarks

a) Problems with the Hume's notion of *constant conjunction*: i) Basing on this one cannot distinguish *genuine causal* relations and *accidental conjunctions*. Not all constant conjunctions can be taken as causal relationships. (E.g. "Whenever the Minister visits my town it rains". Even if this statement is always true, the visit of the Minister cannot be the cause for the rain. ii) In the Humean understanding the direction of causation cannot be figured out, since constant conjunction has only a relationship of symmetry, whereas the causation is the one of asymmetry.

iii) Does the constant conjunction mean that sometimes the causes don't result in the effects? It is only a probablisitic causation?

b) Problem with Hume's notion *similarity*: Events similar to *A* are always followed by things similar to *B*. The idea of 'similarity' is not clear - Is it exactly similar? If so, the only thing exactly similar to an event is that event itself, and it cannot be reproduced exactly, because at least the space-time factors will differ; or is it 'more-or-less' similar? Humeans claimed that the similarity must be in certain crucial and relevant respects. But what is the basis to decide upon the relevance? If they claim that only those changes which are similar in relevant respects are always followed by other changes which are similar relevant respects, then their analysis of the causal relationship becomes tautological; for it just says that *those changes that are similar in the respects that causally connect them with their effects have similar effects*.

c) Since the concept cause is indispensable not only in our practical lives but also in sciences, there are efforts by philosophers, like D.M. Armstrong, Fred Dretske, Tooley in the late 1970s, to propose some sort of clear notion of necessitation in causal relationships; for *necessitation implies constant conjunction but not conversely*. This necessitation, of course, is not known *a priori*, rather what necessitates is an empirical matter, known by *a posteriori* inspection.

Check Your Progress II

Note: Use the space provided for your answers.

1) Discuss some of the areas where Metaphysics and scientific inquiries come together?

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2) What is more appealing and reasonable: Scientific realism or Scientific anti-relism? Substantiate your position.

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2.4 FEMINIST ACCOUNTS OF SCIENCE

In the recent years, Feminists, Sociologists of Knowledge and Postmodernists criticize science from various angles. From the early 1970s feminism began critiquing science. The research on the gender bias in the fields of science is highly complex and multi-faceted; it includes issues like the research on the presence of women doing hard-core science, the ill-treatments done to them in the scientific circles, the gender partiality exhibited in the content, methodology and epistemology of science, the selection of the problem for scientific investigations, especially in the fields of biology and health sciences, the decisions and policies drafted by the males, and so on. Feminists point out that scientific researches are gender-biased, for instance medical researches use only the males of any species for their study.

Feminist accounts of science, not only reveal the gender bias in theories, practices and assumptions of science, but also most of them go further to show how this androcentric prejudices shape the very notion of rationality, objectivity and scientificity. They substantiate their claims with case studies that there have been systematic omissions or distortions of women / gender issues, which have resulted in faulty conclusions. Case studies show that even contradicting claims are given in order to claim the superiority of the males, in terms of smartness, intelligence and physical robustness. To argue for the natural tendency for women to have subordinate role in the society and family, as Fausto-Sterling maintains, some evidence is consistently not considered, some questions are never raised, some hypotheses are ignored and some experimental controls are never instituted (Okruhlik, 2001). Feminist critiques point out the gender bias of Darwin in his theory that evolutionary development exclusively belongs to males, the hunter-gatherers'. This androcentric bias serves as an auxiliary theory in other disciplines, like Anthropology, to justify the behaviours and social roles of the males. Similarly, Francis Bacon made use of gender metaphors to refer to nature. He saw nature as female, as a wild and uncontrollable female to be restrained and controlled. Feminists argue that a dualistic and detached pursuit of science to study nature should be removed in order to save women from male domination. Even the scientific revolution of the modern science is seen as the reflection of gender ideology, whereby the mechanistic world view looked at the earth and nature as something to be dominated and controlled by humans.
Women's experience and women's epistemology must be taken into consideration in order to have a holistic picture of science. In a reconstructed feminist epistemology of science, according to Anne M. Clifford, "the scientist is not an impersonal authority standing above nature and human concerns, but a person whose thought and feelings, logical capacitates and institutions are all relevant and involved in the process of enquiry" (Clifford, 1992, 77). They argue that the gender does influence the investigations and the conclusions arrived thereupon; they even that feminists can point out the bias in the masculinist science and even produce better science (Harding, 1986, and 1991). Wendey Kohli points out that reason and reasoning need to be addressed historically within the context of gender differences; for centuries down the history masculinity and reason have been treated as synonyms, making feminine inferior, and even subservient to masculine rationality (Fleming, 1992 and Lloyd, 1995).

All are not ready to buy the arguments of the feminists. Some don't see even theoretical possibility of feminist critique, while Ronald Giere (1998) argues for such possibility. Feminists' convictions that women can produce better science and 'feminist epistemology' is privileged are challenged by many critiques. Cassandra Pinnick (1999) for instance does not find any evidence to support such convictions. Though the feminists may exaggerate, there must be, I think, some grains of truth in their claims. For, the traditional understanding of rationality seems to have not paid attention to non-cognitive elements of thoughts and feelings. The rational mind of men and the intuitive mind of women need to be in collaboration with each other for the betterment of humanity; this distinction reveals the complementary nature, not superiority-inferiority divide, between men and women. If women are also involved in the important decisions and policy-making we can certainly expect a better 'human touch' in all those policies. For instance, it is a painful irony to see in India that while we produce millions of surplus food-grains, there are thousands of starvation deaths every year. If women are involved more and more in the administration and decision-making process, I strongly believe, that, with their intuitive and maternal touch, they will not easily tolerate the wastage of food-grains and the starvation deaths. With their in-born quality of dividing the stuff among the children lovingly and equally, they will certainly bring down, if not totally eradicate, the hunger deaths on the streets.

2.5 VALUES AND SCIENCE

For the Greeks, the pioneers of the Western thought and culture, there was no significant distinction between science (knowledge) and values (good), science and philosophy, objective and subjective and factual (descriptive) and normative (evaluative). The problem arises with the mechanical view of nature (or Newtonian science). The epistemological and methodological revolution in science and philosophy, initiated by Descartes, insisted upon a sharp distinction between objective and subjective dimensions in the knowledge-seeking enterprise. Since science is said to be rational and objective, factual and experimental, values are beyond the purview of science. However, such value-neutral approach of science is strongly challenged today by philosophers of science, sociologists, historicists, humanists, and even by scientists themselves. For instance, the very fact that there are goals in science shows the need of value- consideration. Science involves several types of goals: i) *Epistemic goals* (e.g. advancing human knowledge with explanations and predictions; teaching science to next generations ...); ii) *practical goals* (e.g. increasing technological power, improving standards of life ...); iii) *Goals of scientists* (their personal interests for name, fame, money ...); Personal goals *at their personal level* (openness, freedom, readiness to take risks, social responsibility, mutual respect, efficiency ...), *at the level of scientific publications* (objectivity in publication, intellectual properties...), *at the level of personal relations among those involved in science* (mentor-mentee relationship, harassment, reporting misconduct in science, sharing & preserving resources) and so on. Thus, the need to discuss the role of value judgments and ethical considerations in science has become more crucial and urgent with the uncontrollable explosion of war technology, ecological degradation and the bio-ethical issues arising from bio-sciences of the 20th century.

Value-neutrality of Science is usually based on two factors: a) *Fact-value dichotomy*: Science is for what 'is', not what 'ought to be'; science can only describe, not prescribe (Perera, 2005). But now it is realized that both facts and values are thoroughly interdependent. There does not seem to be any significant difference between the so-called scientific values, like justification, coherence, truth etc., and moral or aesthetic values (Putnam, 1982). Truth is considered as a scientific value, but relevance, interests and significance of such truths in the social contexts are also equally important scientific values. The latter may be called as extra-scientific values, but they are also equally important. To remove these value-considerations from a scientist is to remove his / her humanity as well. One cannot suppress his/her value judgment unless one is ready to destroy him/her as a human being and as a scientist. Scientists are not seeking for merely objective truths, knowledge, but truths that are interesting, useful and valuable to humanity as a whole. Therefore, knowledge, truth, objectivity and so on are rooted in values and human purposes; b) *Skeptical attitude*: Skepticism abhors authoritarianism and orthodoxy, subjecting everything to a severe scrutiny. It demands openness to check whether one is misguided or not. It is a part of rationality in science. However, consistent and absolute skepticism is not possible, even in science. One needs to be reasonable in being skeptic. Riniold and Nisbet argue that *no one is consistently skeptic but only selectively skeptic*, due to our built-in biases. Even hard core sceptics, therefore, become the *victims* of i) *Confirmation bias* (the tendency to look for evidence that is consistent with our beliefs); ii) *Biased assimilation* (bias in assimilating information that suits our belief system); and iii) *Belief perseverance* (the tendency not to give up a long-cherished belief, though there is pressing evidence against them). (Riniolo and Nisbet, 2007, 50-51).

Moral considerations of science and the social responsibilities of science and scientists are no more at the periphery of philosophy of science but they take the centre-stage. Science does not develop in a void. Technological revolution is not a non-social concept. Therefore, "It would be highly irrational to overestimate the powers at the disposal of science and the scientists in the humanization of advances in science and technology. It is still less rational, in fact, irresponsible, to ignore the active socio-ethical humanistic stand taken by the scientific community" (Froov and Yudin, 1989, 352-3). As long as scientists are humans, who are part and parcel of human society, scientists are bound by, at least, certain final values. One such value demands science to enhance and enrich humanity and alleviate its sufferings and the damage to the environment.

Check Your Progress III

Note: Use the space provided for your answers.

1) "Gender-issues in science is a pseudo problem; it is a waste of time to engage in such meaningless quibbles" – Do you agree with this claim? Substantiate your position.

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2) "Science cannot, and should not, be confused with moral issues, as it is objective and rational" - Give your comments.

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2.6 LET US SUM UP

Philosophy of Science deals with the philosophical issues of science. It critiques, among many other tasks, the methods and assumptions of science. Philosophy of science as a discipline is related with many other disciplines. We have focused in this essay a few of them: i) since science aims at acquiring knowledge, it is related with *Epistemology*, a branch of philosophy that deals with the nature and validity of knowledge enterprise; ii) since science is particular about revealing the *true* nature of reality it is related with *Metaphysics*, a branch of philosophy that focuses on the issues of reality; iii) since science is *by* humans and *for* humans and it is essentially a social enterprise, all that affects human society becomes a serious concern for science, including moral and environmental issues.

2.7 KEY WORDS

Inductive Reasoning: It is a process of inferring conclusions about unknown phenomena based on the known individual instances. It assumes "the uniformity of nature", and that "the future will resemble the past".

Scientific Realism and Anti-realism: Trends in of philosophy of science that deals with issues of actual existence of the theoretical entities and that of the reality independent of the observers as postulated by scientific theories.

The Principle of Causality: It demonstrates the relation between causes and effect. This philosophical concept has serious implications for science.

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UNIT 3 INTRODUCTION TO COSMOLOGY

Contents

3.0 Objectives
3.1 Introduction
3.2 Origin, Nature and Destiny
3.3 Indian Cosmology
3.4 Greek Beginning
3.5 The Arab Contribution
3.6 Some Important Themes Of Scientific Cosmology
3.7 Some Unanswered Questions
3.8 Key Words
3.9 Further Readings and References

3.0 OBJECTIVES

- To introduce the students to the basic notions of physical cosmology.
- To make them aware of the early (religious) history of cosmology
- To familiarise them with some of the complex issues related to the origin, nature and end of the universe.

3.1 INTRODUCTION

This unit tries to introduce the topic of cosmology. After studying the origin, nature and destiny of the universe, it looks into the Indian and Greek cosmologies. Then it takes up some important issues in contemporary scientific cosmology. Our aim is to show the religious beginnings of today's scientific cosmology.

3.2 ORIGIN, NATURE AND DESTINY

Cosmology ("study of universe" from Greek "*kosmos*" meaning "universe"; and "logia, "study"), in strict usage, refers to the study of the Universe in its totality as it is now (or at least as it can be observed now). Though the word cosmology is recent (first used in 1730 by the rationalist philosopher, Christian Wolff), the study of the universe has a long history involving science, philosophy, esotericism, and religion.

In recent times, physics and astrophysics have played a central role in shaping the understanding of the universe through scientific observation and experiment. The physical cosmology is primarily shaped through both mathematics and astronomical observation by the analysis of the whole universe. This discipline focuses on the universe as it exists on the largest scale and at the earliest moments. It is generally understood to begin with the Big Bang that is thought to have emerged roughly 13.5-13.9 billion years ago (Cosmology 2011).

From its beginnings scientific cosmologists propose that the history of the universe has been governed entirely by physical laws. Theories of an objective universe governed by physical laws were first proposed by Roger Bacon. Contemporary cosmologist Steven Weinberg echoes the same sentiment: “The universe itself acts on us as a random, inefficient, and yet in the long run effective, teaching machine.… our way of looking at the universe has gradually evolved through a natural selection of ideas."

Philosophical Cosmology, as distinct from physical cosmology, draws data from physical cosmology and focuses on critical reflection as to the origin, nature and destiny of the universe. Metaphysical assumptions and implications are also brought into it. Between the domains of religion and science, stands the philosophical perspective of metaphysical cosmology. This ancient field of study seeks to draw intuitive conclusions about the nature of the universe, man, the Divine and their relationships based on the extension of some set of presumed facts borrowed from spiritual experience and observation (Cosmology 2011).

But metaphysical cosmology has also been observed as the placing of man in the universe in relationship to all other entities. This is demonstrated by the observation made by Marcus Aurelius of a man's place in that relationship: "He who does not know what the world is does not know where he is, and he who does not know for what purpose the world exists, does not know who he is, nor what the world is." This is the purpose of the ancient metaphysical cosmology. Cosmology is often an important aspect of the creation myths of religions that seek to explain the existence and nature of reality. In some cases, views about the creation (cosmogony) and the end (eschatology) of the universe play a central role in shaping a framework of religious cosmology for understanding humanity's role in the universe.

3.3 INDIAN COSMOLOGY

In India science and religion are not opposed fundamentally are seen as parts of the same great search for truth that inspired the sages of Hinduism, Buddhism, and Jainism. Thus, in the Hindu scientific approach, understanding of external reality depends on also understanding the godhead. In all Hindu traditions the Universe is said to precede from the gods. Fundamental to Hindu concepts of time and space is the notion that the external world is a product of the creative play of *maya (illusion).* Accordingly the world as we know it is not really real but illusionary. The universe is in constant flux with many levels of reality; the task of the saint is find release (*moksha*) from the bonds of time and space (Hindu Cosmology 2006).

Therefore, one of the ancient Hindu books describes thus: "After a cycle of universal dissolution, the Supreme Being decides to recreate the cosmos so that we souls can experience worlds of shape and solidity. Very subtle atoms begin to combine, eventually generating a cosmic wind that blows heavier and heavier atoms together. Souls depending on their karma earned in previous world systems, spontaneously draw to themselves atoms that coalesce into an appropriate body." Hindu cosmology envisaged the universe as having a cyclical nature. The end of each *kalpa* brought about by Shiva's dance is also the beginning of the next. Rebirth follows destruction and the cycle goes on. Thus in Hindu cosmology the universe is, according to mythology and Vedic cosmology, cyclically created and destroyed. The following symbolic

representation of the creation of the world by Brahma is insightful. The life span of Lord Brahma, the creator, is 100 'Brahma-Years'. One day in the life of Brahma is called a *Kalpa* , which is calculated to be 4.32 billion years. Every *Kalpa* Brahma creates 14 Manus one after the other, who in turn manifest and regulate this world. Thus, there are fourteen generations of Manu in each *Kalpa* (one day of Brahma). Each Manu's life consists of 71 *Chaturyugas* (quartets of *Yugas* or eras) which in turn is is composed of four eras or Yugas: *Satya*, *Treta*, *Dwapara* and *Kali*.
The span of the *Satya Yuga* is 1,728,000 human years, *Treta Yuga* is 1,296,000 human years long, the *Dwapara Yuga* 864,000 human years and the *Kali Yuga* 432,000 human years. When Manu perishes at the end of his life, Brahma creates the next Manu and the cycle continues until all fourteen Manus and the Universe perish by the end of Bramhma's day. When 'night' falls, Brahma goes to sleep for a period of 4.32 billion years, which is a period of time equal one day (of Brahma) and the lives of fourteen Manus. The next 'morning', Brahma creates fourteen additional Manus in sequence just as he has done on the previous 'day'. The cycle goes on for 100 'divine years' at the end of which Brahma perishes and is regenerated. Bramha's entire life equals 311 trillion, 40 billion years. Once Bramha dies there is an equal period of unmanifestation for 311 trillion, 40 billion years, until the next Bramha is created (HC 2011).

The present period is the *Kali Yuga* or last era in one of the 71 *Chaturyugis* (set of four Yugas/eras) in the life one of the fourteen Manus. The current Manu is said to be the seventh Manu. As such the Kali Yuga began in 3102 BC, at the end of the *Dvapara Yuga* that was marked by the disappearance of Vishnu's Krishna avatar. The beginning of the new Yuga (era) is known as "*Yugadi*/*Ugadi*", and is celebrated every year on the first day (*Paadyami*) of the first month (*Chaitramu*) of the 12-month annual cycle. The *Ugadi* of 1999 begins the year 1921 of the *Shalivahana* era (5101 *Kali Yuga*, 1999 AD). The end of the Kali Yuga is 426,899 years from 1921.

Overview of Yugas

1. *Satya Yuga* (*Krita Yuga*):- 1,728,000 Human years
2. *Treta Yuga*:- 1,296,000 Human years
3. *Dwapara Yuga*:- 864,000 Human years
4. *Kali Yuga*:- 432,000 Human years (5,111 years have passed; 426,889 years remain). *Kaliyuga* started in 3102 B.C.; CE 2009 corresponds to *Kaliyuga* year 5,111

The *Nasadiya Sukta* of the Rig Veda describes the origin of the universe. The Rig Veda's view of the cosmos also sees one true divine principle self-projecting as the divine word, *Vaak*, 'birthing' the cosmos that we know, from the monistic Hiranyagarbha or Golden Egg. The Hiranyagarbha is alternatively viewed as Brahma, the creator who was in turn created by God, or as God (Brahman) Himself. The Universe is preserved by Vishnu (The God of Preservation) and destroyed by Shiva (The God of Destruction). These three constitute the holy Trinity (*Trimurti*) of the Hindu religion. Once the Universe has been destroyed by Shiva, Brahma starts the creation once again. This creation-destruction cycle repeats itself almost endlessly as described in the section above on Brahma, Manu and the *Yugas* (HC 2011).

The Puranic View

The later Puranic view asserts that the Universe is created, destroyed, and re-created in an eternally repetitive series of cycles. In Hindu cosmology, a universe endures for about 4,320,000 years—one day/*Kalpa* of Brahma, the creator) and is then destroyed by fire or water elements. At this point, Brahma rests for one night, just as long as the day. This process, named *Pralaya* (Cataclysm), repeats for 100 Brahma years (311 trillion, 40 billion human years) that represents Brahma's lifespan. It must be noted that Brahma is the creator but not necessarily regarded as God in Hinduism because there are said to be many creations. Instead, he is regarded as a creation of the Supreme God or Brahman.

We are currently believed to be in the 51st year of the present Brahma's life and so about 158.7 trillion years have elapsed since the birth of Brahma. After Brahma's "death", it is necessary that another 100 Brahma years pass until he is reborn and the whole creation begins anew. This process is repeated again and again, forever (HC 2011 and Raman 2004).

Both the Rig Veda and Brahmanda Purana describe a universe that is cyclical or oscillating and infinite in time. The universe is described as a cosmic egg that cycles between expansion and total collapse. It expanded from a concentrated form — a point called a Bindu. The universe, as a living entity, is bound to the perpetual cycle of birth, death, and rebirth. The *Padma Purana* discusses about the number of different types of life-forms in the universe. According to the *Padma Purana*, there are 8,400,400 life-form species, 900,000 of which are aquatic ones; 2,000,000 are trees and plants; 1,100,000 are small living species, insects and reptiles; 1,000,000 are birds; 3,000,000 are beasts and 400,000 are human species (HC 2011).
Unlike the West, which lives in a historical world, India is rooted in a timeless universe of eternal return: everything which happens has already done so many times before, though in different guises. Hinduism arose from the discoveries of people who felt that they had gained an insight into the nature of reality through deep meditation and ascetic practices. Science uses a heuristic method that requires objective proof of mathematical theories. Yet both have proposed similar scenarios for the creation of the universe. (Hindu Cosmology 2006).

Check Your Progress I
Note: Use the space provided for your answers.

1) How is cosmology related to cosmogony and eschatology?
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2) Give a brief account of the *Puranic* view of the universe.
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3.4 GREEK BEGINNING

The Greek worldview gave us the basis for scientific cosmology. Closely tied to the pseudo-science of astrology, it continued from ancient Greece through medieval Islamic civilization to seventeenth-century Europe (CHP 2011).

Plato and Aristotle

Underlying the Greek worldview was the philosophy of Plato. He sought a deeper level of reality than that accessible to the senses. He also pursued a simple theory about the universe which had incredible explanatory power. The result was a belief in uniform, circular motion. This belief dominated the thinking of many Western astronomers and cosmologists for two thousand years.

The task for astronomers was to ascertain the motions of the planets. Sky-watchers in the ancient Middle East, Central America, and China made many observations. From their tables of numbers, they devised schemes to predict future movements in the heavens, unlike the colorful myths proposed by the Babylonians, Mayans, and early Chinese sky-watchers. It is no exaggeration to claim that scientific cosmology — the search for a picture of the universe that would make sense with no mention of divine beings — began with the Greeks. They sought to look beyond the patterns of numbers to something fundamental. Under Plato's influence, Greek thinkers attempted to devise combinations of uniform circular motions that would reproduce the observed motions, which were far from regular.

Greek philosopher-scientists set themselves the task of envisioning the universe as a set of physical objects. Plato's pupil Aristotle came to dominate thinking in this field. Where Platonists thought in terms of the idealized mathematics of two-dimensional circles, the Aristotelians envisioned actual three-dimensional spheres (CHP 2011)

Aristotle taught that rotating spheres carried the Moon, Sun, planets, and stars around a stationary Earth. The Earth was unique because of its central position and its material composition. All generation and corruption occurred in the "sublunar" region, below the Moon and above the Earth. This region was composed of the four elements: earth, water, air, and fire. Beyond the Moon was the unchanging and perfect celestial region. It was composed of a mysterious fifth element. Greek philosophers estimated the distance to the Moon, and even tried to calculate the size of the entire universe, which believed to be finite. The outer sphere of the stars carried them on their nightly course around the Earth. The natural place for earthy material was down at the center of the universe. Earthy material tended to move to its natural place, toward the center of the world. Flames moved upward to reach their natural place at the top of the sublunar region. There could be no other worlds scattered throughout this universe, because their earthy nature would have forced them to move toward their natural place at the center. With the Earth at its center and the sphere of the stars its outer boundary, the Aristotelian cosmos consisted of little more than our solar system.

Claudius Ptolemy

Continuation of the Greek tradition of Plato and Aristotle is exemplified in the work of Claudius Ptolemy. He systematized hundreds of years of Greek geometrical cosmology with rigorous demonstrations and proofs (CHP 2011). Ptolemy wrote his mathematical treatise, later named the Almagest, in about 150 A.D. He worked out geometrical systems of compound motions on two-dimensional circles to match the observed motions. The heavens were not made of rocks, metal, or other earthy material, but of some divine celestial material. This offered no obstruction to the passage of one part through another. In his later book, Planetary Hypotheses, Ptolemy used three-dimensional hollow spheres, arranged one within another and surrounding the Earth. There was no empty space between the spheres. The thickness of each shell accommodated small motions in and out from the Earth. The rotating sphere itself carried the planet or Sun or Moon in its orbit around the Earth. According to him, the spheres rotated because that was their natural motion. It was proper, Ptolemy believed, to attribute uniform circular motion to the planets because disorder and nonuniformity were alien to divine things. The study of astronomy, dealing with divine things, was especially useful for elevating the human soul.

3.5 THE ARAB CONTRIBUTION

As the Roman Empire fell and civilization in Europe collapsed, the rising Islamic civilization rescued Ptolemy's cosmology — and improved upon it. The entire system was transmitted back to the West as learning revived there toward the end of the Middle Ages. Translations reveal the transitions. Ptolemy's mathematical treatise came to be called "greatest." (CHP 2011) This was transliterated into Arabic and prefaced with the definite article *al* ("the," also seen in words like algebra and star names like Aldebaran). Translated from Arabic into medieval Latin, Ptolemy's book became "The Almagest." The Arabs also taught the West "Arabic" numerals, the place-value system of calculating using zero (which was invented in India), and many trigonometric techniques, all originally from India, and made important mathematical advances of their own.

Islamic civilization enjoyed a high level of scientific work. Astronomy was important for giving times of prayer (from the altitude of the Sun or stars), and the qibla, or sacred orientation: worshippers anywhere in the world needed to know the direction of Mecca so they could face it while praying, and mosques were oriented toward the holy city. The astrolabe was the fundamental astronomical instrument, serving as a clock and navigational tool. Islamic princes also constructed giant instruments to measure the positions of planets and stars for astrological purposes. Among the Arabs and Persians were great calculators and mathematicians who worked to improve the cosmological explanation of astronomical measurements. For example, Nasir al-din al-Tusi at Maragha produced a particularly innovative addition to Ptolemy's circular motions. The "Tusi couple" calculates a linear motion from a combination of uniform circular motions (CHP 2011).

In his revolutionary work on the solar system published in 1543, Copernicus used a strikingly similar device. Also, Copernicus used a model for the Moon's motion identical to one devised two centuries earlier by the astronomer Ibn al-Shatir in Damascus. Copernicus cited the works of Islamic astronomers and certainly learned from them. Historians are still trying to determine the full extent of his intellectual debt. More on the history of cosmology will be taken up in the next unit. Since this is an introduction, we want to focus on some important themes of contemporary scientific cosmology.

Check Your Progress II

Note: Use the space provided for your answers.

1) Where was the natural place for earthly material for Aristotle? Why?

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2) Give a brief account of the Arab contribution to cosmology.
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3.6 SOME IMPORTANT THEMES OF SCIENTIFIC COSMOLOGY

Cosmologists study the universe as a whole: its birth, growth, shape, size and eventual fate. Contemporary cosmology began last century. The vast scale of the universe became clear in the 1920s when Edwin Hubble proved that "spiral nebulae" are actually other galaxies like ours, millions to billions of light years away (Battersby 2006). We take up some important concepts and themes to initiate ourselves into contemporary cosmology.

The Big Bang

Hubble found that most galaxies are red shifted, i.e., the spectrum of their light is moved to longer, redder wavelengths. This can be explained as a doppler shift if the galaxies are moving away from us. Fainter, more distant galaxies have higher red shift, implying that they are receding faster, in a relationship set by the hubble constant. The discovery that the whole universe is expanding led to the big bang theory. This states that if everything is flying apart now, it was once presumably packed much closer together, in a hot dense state. A rival idea, the steady-state theory, holds that new matter is constantly being created to fill the gaps generated by expansion. But the big bang largely triumphed in 1965 when Arno Penzias and Robert Wilson discovered cosmic microwave background radiation (Battersby 2006). This is relic heat radiation emitted by hot matter in the very early universe, 380,000 years after the first instant of the big bang.

Space-time Curve

The growth of the universe can be modelled with Albert Einstein's general theory of relativity, which describes how matter and energy make space-time curve. We feel that curvature as the force of gravity. Assuming the cosmological principle (that on the largest scales the universe is uniform), general relativity produces fairly simple equations to describe how space curves and expands. According to these models, the shape of the universe could be like the surface of a sphere, or curved like the surface of a saddle. But in fact, observations suggest that it is poised between the two, almost exactly flat. One explanation is the theory of inflation. This states that during the first split second of existence, space expanded at terrifying speed, flattening out any original curvature. Then today's observable universe, grew from a microscopic patch of the original fireball. This would also explain the horizon problem - why it is that one side of the universe is almost the same density and temperature as the other (Battersby 2006).

The universe is not totally smooth, however, and in 1990 the COBE satellite detected ripples in the cosmic microwave background, the signature of primordial density fluctuations. These slight ripples in the early universe may have been generated by random quantum fluctuations in the energy field that drove inflation. Topological defects in space could also have caused the fluctuations, but they do not fit the pattern well. Those density fluctuations form the seeds of galaxies and galaxy clusters, which are scattered throughout the universe with a foamy large-scale structure on scales of up to about a billion light years. All these structures form because gravity amplifies the original fluctuations, pulling denser patches of matter together (Battersby 2006).

Dark Matter

In experimental simulations of big bang it is found visible matter does not supply enough gravity to create the structure we see: it has to be helped out by some form of dark matter. More evidence for the dark stuff comes from galaxies that are rotating too fast to hold together without extra gravitational glue. Dark matter can't be like ordinary matter, because it would have made too much deuterium in big-bang nucleosynthesis. When the universe was less than 3 minutes old, some protons and neutrons fused to make light elements, and cosmologists calculate that if there had been much more ordinary matter than we see, then the dense cauldron would have brewed up a lot more deuterium than is observed. Instead, dark matter must be something exotic, probably generated in the hot early moments of the big bang - maybe particles such as WIMPs (weakly interacting massive particles) or, less likely, primordial black holes.

Dark Energy

Another dark mystery emerged in the 1990s, when astronomers found that distant supernovae are surprisingly faint - suggesting that the expansion of the universe is not slowing down as everyone expected, but accelerating. The universe seems to be dominated by some repulsive force, or antigravity, which has been dubbed dark energy. It may be a cosmological constant (or vacuum energy) or a changing energy field such as quintessence. It could stem from the strange properties of neutrinos, or it could be another modification of gravity. The WMAP spacecraft put the standard picture of cosmology on a firm footing by precisely measuring the spectrum of fluctuations in the microwave background, which fits a universe 13.7 billion years old, containing 4% ordinary matter, 22% dark matter, and 74% dark energy. WMAP's picture also fits inflationary theory. However, a sterner test of inflation awaits the detection of cosmic gravitational waves, which the rapid motions of inflation ought to create, and which would leave subtle marks on the microwave background (Battersby 2006).

The density of dark energy is far smaller than the vacuum energy predicted by quantum theory. That is seen as an extreme example of cosmological fine tuning, in that a much larger value would have torn apart gathering gas clouds and prevented any stars from forming. That has led some cosmologists to adopt the anthropic principle - that the properties of our universe have to be suited for life, otherwise we would not be here to observe it.

3.7 SOME UNANSWERED QUESTIONS

In the current cosmology, the biggest questions are still unanswered. We do not know the true size of the universe, even whether it is infinite or not. Nor do we know its topology - whether space wraps around on itself. We do not know what caused inflation, or whether it has created a plethora of parallel universes far from our own, as many inflationary theories imply.

And it is not clear why the universe favours matter over antimatter. Early in the big bang, when particles were being created, there must have been a strong bias towards matter, which the standard model of particle physics cannot explain. Otherwise matter and antimatter would have annihilated each other and there would be almost nothing left but radiation. (Battersby 2006)

The fate of the universe depends on the unknown nature of dark energy and how it behaves in the future: galaxies might become isolated by acceleration, or all matter could be destroyed in a big rip, or the universe might collapse in a big crunch - perhaps re-expanding as a cyclic universe. The universe could even be swallowed by a giant wormhole. And the true beginning, if there was one, is still unknown, because at the initial singularity all known physical theories break down. To understand the origin of the universe we will probably need a theory of quantum gravity. (Battersby 2006)

3.8 LET US SUM UP

This unit was an introductory one on cosmology. Here we dealt with the religious cosmologies and some of the important notions of today's scientific cosmology.

Check Your Progress III

Note: Use the space provided for your answers.

1) What is dark energy?

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2) What are some of the unanswered questions still remaining in contemporary cosmology?

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3.9 KEY WORDS

Cosmological Constant: The cosmological constant is a constant term in field equations of general relativity, represented by the Greek symbol Lambda, which allowed for a static universe. Later evidence supported the fact that the universe was indeed expanding and the cosmological constant was believed to be zero. Evidence in the late 1990s has begun supporting the idea that the universe is not only expanding, but that the expansion rate is actually accelerating due to the presence of dark energy. This meant that the cosmological constant wasn't just zero, as Einstein thought, but had to have a very slight positive value. Einstein quickly accepted the new evidence and told physicist George Gamow that the cosmological constant idea was the "biggest blunder" of his life.

Cosmological Principle: The assumption that on a very large scale all the matter in the universe is distributed evenly, so that hypothetical astronomers a long way from the Earth would see the same universe, on the biggest scale, as we do. The problem with testing the cosmological principle is that it operates on a scale so vast that even galaxies and clusters of galaxies are merely local clumps of material by its standards.

Doppler Shift: change in the apparent frequency of a wave as observer and source move toward or away from each other. Also called Doppler effect, it was named after Austrian physicist Christian Doppler who proposed it in 1842 in Prague, is the change in frequency of a wave for an observer moving relative to the source of the wave.

Horizon Problem: The horizon problem is a problem with the standard cosmological model of the Big Bang which was identified in the 1970s. It points out that different regions of the universe have not "contacted" each other because of the great distances between them, but nevertheless they have the same temperature and other physical properties. This should not be possible, given that the exchange of information (or energy, heat, etc.) can only take place at the speed of light. The horizon problem may have been answered by inflationary theory, and is one of the reasons for that theory's formation. Another proposed, though less accepted, theory is that the speed of light has changed over time,

Hubble Constant: is the ratio of the speed of recession of a galaxy (due to the expansion of the universe) to its distance from the observer; the Hubble constant is not actually a constant, but is regarded as measuring the expansion rate today

Nucleosynthesis: The process by which heavier chemical elements are synthesized from hydrogen nuclei in the interiors of stars.

Spiral Nebulae: a galaxy having a spiral structure; arms containing younger stars spiral out from old stars at the center.

WIMP: A subatomic particle that has a large mass and interacts with other matter primarily through gravitation. [W(eakly) I(nteracting) M(assive) P(article).

WMAP: The Wilkinson Microwave Anisotropy Probe (WMAP) — also known as the Microwave Anisotropy Probe (MAP), and Explorer 80 — is a spacecraft which measures differences in the temperature of the Big Bang's remnant radiant heat — the Cosmic Microwave Background Radiation — across the full sky.

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UNIT 4 HISTORY OF COSMOLOGY

Contents

4.0 Objectives
4.1 Introduction
4.2 Beginning of Scientific Cosmology
4.3 The Mechanical Universe
4.4 From Our Galaxy to Island Universes and More
4.5 Let Us Sum Up
4.6 Key Words
4.7 Further Readings and References

4.0 OBJECTIVES

- To give a historical basis for scientific cosmology.
- To know the key contributions of some of the famous cosmologists of the previous centuries.
- To appreciate the origin of scientific or physical cosmology, as distinct from religious one.

4.1 INTRODUCTION

In the previous unit, we have traced the history of pre-scientific cosmology and gone into some of the important themes of contemporary scientific cosmology. In this unit, we shall primarily focus on the history of scientific cosmology.

4.2 BEGINNING OF SCIENTIFIC COSMOLOGY

Revolutions in science, as in politics, often go beyond the limited changes that the people who started the revolution had in mind. Let us see some great minds who have contributed to the emergence and growth of scientific cosmology.

Nicholas Copernicus (1473-1543)

In 1543 Nicholas Copernicus proposed to switch the places of the Earth and the Sun. He put the Sun in the center of the universe and placed the Earth in revolution around the Sun. To account for the daily motion of the heavens, he set the Earth rotating about its own axis. (CHP 2011) To calculate the positions of planets, Copernicus used elaborate geometrical schemes, much like his Greek and Islamic predecessors (historians are still trying to decide just what sources contributed to his ideas). Ptolemy's system was reasonably satisfactory in matching the observations. Copernicus did not have new and more accurate observations demanding the overthrow of the old theory. It was a yearning for greater mathematical harmony that made him seek something different. In Copernicus's opinion, when Ptolemy had violated the principle of uniform circular motion. Furthermore, from Copernicus's "heliocentric" (sun-centered) theory, several observed phenomena followed automatically, rather than needing to be adjusted as they were in the Ptolemaic theory (Coles 2001).

A heliocentric system was counter to long-established belief and seemed unimaginable to many. This is why Copernicus wrote in the preface to his book that he had "hesitated long whether I should give to the light these my Commentaries written to prove the Earth's motion." His friends, though, had "often urged and even importuned me to publish this work." Copernicus hoped that "my labors contribute somewhat even to the Commonwealth of the Church... For not long since the question of correcting the ecclesiastical calendar was debated." It was true for centuries, the difficult question of calculating the dates of future Easters had been a main motive of astronomical observations and calculations. (CHP 2011)
Further, he admitted: "To ascribe movement to the Earth must indeed seem an absurd performance on my part to those who know that many centuries have consented to the establishment of the contrary judgment, namely that the Earth is placed immovably as the central point in the middle of the Universe." Yet this logical consequence of Copernicus's innovation was not immediately realized, by Copernicus or by others. It was finally recognized by Thomas Digges, an English Mathematician and astronomer, who translated and paraphrased the key parts of Copernicus's work, he said, "to the end such noble English minds might not be altogether defrauded of so noble a part of Philosophie."
Copernican revolution led to the conclusion that the Earth was no longer unique. It was merely one of many similar objects in the solar system. If the Earth were but one of many similar planets, other planets might also have similar inhabitants (Coles 2001). The principle of "plenitude," which interpreted any unrealized potential in nature as a restriction of the Creator's power, further encouraged belief in a plurality of worlds. This conclusion was most dramatically emphasized by Galileo and his new telescopic observations.

Galileo Galilei (1564-1642)

Galileo's father wanted him to study medicine, and he did so briefly at the University of Pisa. But Galileo preferred mathematics. He studied with private tutors in Pisa and then at home, in Florence. Soon he was giving private lessons in mathematics and was later appointed to the vacant mathematics chair at the University of Pisa. Here he is said to have dropped iron balls from the leaning tower, as a public challenge to Aristotelian philosophers, who said that heavier balls should fall faster. They don't. While Galileo probably never acted as this legend tells, it is true to his spirit — challenging authority, thinking clearly, and relying upon actual observation.

Aristotelian professors were certainly not friendly to Galileo, and he soon moved to the University of Padua. Galileo built a telescope and was the first to use this new instrument to systematically explore the heavens, making astonishing discoveries. For example, he discovered four satellites of Jupiter early in 1610. Later in 1610 Galileo returned to Florence as mathematician and philosopher to the grand duke and chief mathematician of the University of Pisa, without obligation to teach. Nothing was so disturbing to old ideas as what Galileo saw when he turned his telescope on the Moon. His observations of the Moon's surface inspired the revolutionary conclusion that the Moon was not a smooth sphere, as Aristotelians had maintained. He wrote: ""The surface of the Moon is not smooth, uniform, and precisely spherical as a great number of philosophers believe it to be, but is uneven, rough, and full of cavities and prominences, being not unlike the face of the Earth, relieved by chains of mountains and deep valleys." Aristotle's assumption that only matter below the sphere of the Moon was earthy and imperfect was proved to be wrong.

Another similarity, this one between Jupiter and the Earth, was furnished by Galileo's discovery of four satellites of Jupiter, similar to the Earth's single moon. How would they possibly fit into the system of spheres used by everyone since Plato? Galileo considered the "four planets never seen from the creation of the world up to our own time" to be his most important discovery.

In 1613, in a long unpublished letter, Galileo began arguing that Bible and Copernicanism were compatible. Aristotelians tried to bring the power of the Church against Galileo, pointing to Bible passages that clearly described the Earth as unmoving. Galileo argued that while the reconciliation of scientific facts with the Bible was a matter for theologians, they should not interfere with scientists studying nature. In 1616 the Church ordered Galileo not to hold or defend Copernicanism. In 1624, Pope Urban VIII, a friend of Galileo, gave him permission to discuss the Copernican system in a book if he gave the Ptolemaic system equal time. The Dialogue Concerning the Two Chief World Systems was published in Florence in 1632, after some changes required by the Pope. This is usually considered Galileo's masterpiece. Despite his claims to the contrary, the Dialogue represents Galileo's strongest endorsement of the Copernican system over its Ptolemaic counterpart, giving devastating refutations of many central tenets of Aristotelian physics.

There were complaints, and the Inquisition ordered Galileo to appear before it in Rome. He was forced, probably under threat of torture, to acknowledge that he had gone too far in his arguments for Copernicus, and to abjure the Copernican "heresy." His book was put on the Index of forbidden books, where it remained until 1835. In 1633, Galileo himself was sentenced to life in prison. The sentence was immediately commuted to permanent house arrest. He spent his remaining years in his villa in the hills above Florence, writing another masterpiece — not on cosmology but on physics and mechanics (CHP 2011). Till the end, he kept close contact with his friends in the Church.

Aristotelian cosmology envisioned spheres carrying the planets around the Earth—solid crystalline spheres, according to some, which provided the physical structure of the universe. Late in the 16th century, Tycho Brahe observed comets moving through the solar system. This fact shattered the crystalline spheres. Tycho was still conservative, however. He was reluctant to set the Earth in motion. As an alternative to the Copernican universe with all planets circling the sun in the center, Tycho had his own system of the world. In it other planets circled the Sun while the Sun circled a stationary Earth at the center.

From his observations of the 1572 nova and 1577 comet, Tycho was convinced of the falsity of the Ptolemaic system. In Tycho's system the Earth is absolutely fixed, so that the daily motion of the fixed stars is ascribed to a daily rotation of the outermost sphere, as in the Ptolemaic system. (A similar planetary system was proposed in antiquity by Heraklides of Pontus (ca. 388-310 BCE) who, however, ascribed to the Earth a daily axial rotation.)

From the standpoint of apparent planetary motions as seen from Earth, this system is observationally indistinguishable from the Copernican model, yet maintains the fixity of the Earth. The latter belief was held by Tycho to the end of his life. A main reason was that he had been unable to detect the annual parallax of the fixed stars predicted by the Copernican model, despite the unprecedented accuracy of the observations carried out with his giant instruments at Uraniborg. Tycho could measure parallax down to 2 minutes of arc (1/30 of a degree). The failure to see parallax for fixed stars implied that they would have to be located hundreds of times farther away than Saturn, the outermost planet known at the time. (CHP 2011)

Johannes Kepler (1571-1630)

Born into an undistinguished and poverty-stricken family, Kepler attended the University of Tübingen (now in Germany) on scholarship, studying mathematics and astronomy. He went on to the theological school, intending to become a Lutheran minister. Soon he was asked to leave and teach mathematics at a school in Graz (now in Austria). It was here that he imagined his quixotic world model based on Platonic solids. The theory was wrong, but it made him famous. After Tycho Brahe moved from Denmark to Prague, Kepler visited him there. Kepler recognized the value of Tycho's voluminous observations, more accurate than any previous. He inherited both Tycho's data and the favor of the Emperor following Tycho's death in 1601. Studying the data, Kepler found what later became famous as his three laws, along with many other supposed regularities, some correct and others now forgotten (Levy 2000).

Kepler believed that God the Creator had created an orderly and harmonious world. Kepler was committed to Copernicus's heliocentric system both for its technical advantages, which made it possible to dispense with some of the complications of Ptolemy's system, and on philosophical grounds, including a symbolic identification of the Sun with God at the center of all things. Kepler's colorful life was marred in the end by, among other things, his mother's trial for witchcraft, and a periodically nomadic and economically uncertain existence under the stress of wars and political upheavals. (CHP 2011)

Belief in uniform circular motion had been a fundamental aspect of Western astronomy for two millennia. This belief was broken early in the 17th century. Kepler, using Tycho's observational data, showed that the Earth and the other planets all travel around the Sun in elliptical orbits. This was the first of Kepler's three laws. It was published in 1609 in Kepler's book on his new astronomy, Astronomia nova. The laws Kepler found for the motions of the planets applied equally to the orbit of the Earth. He had abandoned the ancient distinction between the physics of our earthy sphere below the Moon and the celestial physics of a higher realm (Levy 2000 CHP 2011).

Aristotelian physics no longer worked in the universe of Copernicus and Kepler. A new explanation of how the planets continued to retrace the same paths forever around the Sun remained a central problem of cosmology until Isaac Newton explained how objects move under gravity. He accomplished this by showing how motions in the heavens obey the same laws that determine the movement of bodies on Earth. This led the way to understanding what was increasingly seen as a mechanical universe.

Check Your Progress I

Note: Use the space provided for your answers.

1) What was Galileo's opinion on Bible and science?

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2) Briefly mention the contribution of Kepler to cosmology?
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4.3 THE MECHANICAL UNIVERSE

The mechanical universe was initiated by Newton and taken up by other scientists.

Isaac Newton (1642-1727)

Since his father died before his birth and his mother remarried within 3 years, Newton was left in the care of a grandmother. Difficult early years may have contributed to his difficult personality as an adult. He graduated from Trinity College, Cambridge, and served there as Lucasian Professor. Later Newton was warden of the mint in London and president of the Royal Society. Newton's remarkable intellectual accomplishments include creation of the calculus, invention of the reflecting telescope, development of the corpuscular theory of light, and development of the principles of gravity and terrestrial and celestial motion. A "Newtonian" worldview came to permeate understanding not only of the physical world, but also of such intellectual fields as politics and economics—in which people sought simple and universal laws of the type demonstrated by Newton in physics and astronomy. (CHP 2011)

The omnipresence of God pervaded the Newtonian cosmos. The divine presence operated as an immaterial "*aether*" that offered no resistance to bodies, but could move them through the force of gravitation. Newtonian gravitational theory practically demanded a continual miracle to prevent the Sun and the fixed stars from being pulled together. Newton envisioned an infinitely large universe, in which God had placed the stars at just the right distances so their attractions cancelled, as precisely as balancing needles on their points. Another possible solution was to place the fixed stars at such vast distances from one another that they could not attract each other perceptibly in the few thousand years since the Creation.

The ancient assumption that the stars were fixed in position was not seriously questioned until 1718, when the English astronomer Edmond Halley reported a remarkable discovery. Three bright stars were no longer in the positions determined by ancient observations. The stars were freed to move like normal physical objects. (CHP 2011) Newton treated the motions of the stars and planets as problems in mechanics, governed by the same laws that govern motions on Earth. He described the force of gravity mathematically.

Descartes, Laplace and other Critics

The French philosopher René Descartes, on the other hand, had proposed a non-mathematical model. He suggested that the universe consists of huge whirlpools ("vortices") of cosmic matter. Our solar system would be only one of many such whirlpools. Descartes banned from scientific investigation "occult" phenomena, or causes hidden from the senses. He had celestial matter circulating about the Earth, pushing all terrestrial matter toward the Earth. Descartes' followers distrusted Newton's alternative, a mysterious gravitational force acting at a distance.

Descartes' mechanical, mechanistic cosmology was highly acceptable within the general seventeenth-century conception of the world as a machine. His explanations, though, were but qualitative re-descriptions of phenomena in mechanistic terms. During the course of the eighteenth century, vortex theory proved unable to calculate the observed planetary motions. Meanwhile, the rival Newtonian theory advanced from one precise quantitative success to another (Hollar 2011).

The solar system contains many bodies, and the calculation of the orbit of any planet or satellite is not simply a matter of its gravitational attraction to the body around which it orbits. In addition, other bodies have smaller, but not negligible, effects (called "perturbations"). For example, the Sun alters the Moon's motion around the Earth, and Jupiter and Saturn modify the motions of each other about the Sun. A Swiss mathematician, Leonhard Euler, helped develop the mathematical techniques needed to compute perturbation effects. First he applied them to the Moon, and then, in 1748, to Jupiter and Saturn, with partial success (CHP 2011 and Hollar 2011).

Still unexplained were large anomalies in the motions of Jupiter and Saturn, and an acceleration of the Moon's orbital speed around the Earth. The French mathematical astronomer Pierre-Simon Laplace resolved these in 1785 and 1787. In his book Mécanique Céleste, published in five volumes between 1799 and 1805, Laplace summarized his studies of celestial mechanics. Here he proposed that all physical phenomena in the universe could be reduced to a system of particles, exerting attractive and repulsive forces on one another.
Laplace's writings were not just for scientists. His 1796 book Exposition du Système du Monde summarized for lay people the general state of knowledge about astronomy and cosmology at the close of the 18th century. In the book, Laplace advanced an idea that became known as the "nebular hypothesis." He suggested that our solar system, and indeed all stars, were created from the cooling and condensation of a massive hot rotating "nebula" (a gassy cloud of particles). The nebular hypothesis strongly influenced scientists in the 19th century, as they sought to confirm or challenge it. Elements of the idea remain central to our current understanding of how the solar system was formed. (CHP 2011)

Writers of the Romantic period in the early 19th century— for example William Wordsworth in England and Friedrich Schelling in Germany — reacted against Newtonian cosmology. Convinced that the cosmic order was beyond scientific explanation, they sought to breathe divine life back into what seemed an overly mechanized and increasingly godless universe.
The German philosopher Immanuel Kant argued against the Romantics, insisting that metaphysics could not provide an account of the foundations of physical, corporeal nature, and that the issue of the existence of God was completely divorced from direct sense experience. For him, the Newtonian solar system provided a model for the larger stellar system. Kant reasoned that the same cause which gave the planets their centrifugal force, keeping them in orbits around the Sun, could also have given the stars the power of revolving. And whatever made all the planets orbit in roughly the same plane could have done the same to the stars. Nebulous-appearing objects in the heavens became, in Kant's mind, island universes, like colossal solar systems.

Kant's thoughts about the universe had little observational content. The foundations of his cosmological hypotheses were philosophical and theological. Observation first entered cosmology in a major way late in the 18th century, thanks to an English amateur astronomer, William Herschel (Dougherty 1953).

William Herschel and the Construction of the Heavens

The Newtonian solar system offered a model for the larger stellar system. The arrangement of the stars might well be similar to that of the planets. Furthermore, the Newtonian system provided by analogy a physical explanation for a disk structure. The same cause which gave the planets their motion and directed their orbits into a plane could also have given the power of revolving to the stars and brought their orbits into a plane (CHP 2011).

In the late 18th century, observation at last entered stellar cosmology in a major way, in the person of the English amateur astronomer William Herschel. His discoveries were made possible by large telescopes of his own construction. From his observations, William Herschel reported in 1784: "A very remarkable circumstance attending the nebulae and clusters of stars is that they are arranged into strata, which seem to run to a great length; and some of them I have already been able to pursue, so as to guess pretty well at their form and direction. It is probably enough, that they may surround the whole apparent sphere of the heavens, not unlike the milky way, which undoubtedly is nothing but a stratum of fixed stars" (CHP 2011).

Herschel's telescopes, culminating in 1789 with an awkward monster forty feet tall, were one of the wonders of the world. These powerful telescopes not only revealed more moons about planets and resolved some fuzzy-appearing nebulae into clusters of stars, but also enabled Herschel to reach farther into space than anyone had done before, and to begin to outline the structure of our galaxy. Herschel observed stars seemingly lying between two parallel planes and running on to great distances. He concluded that the Milky Way (a luminous band of light circling the heavens) is the appearance of the projection of the stars in the stratum (CHP 2011 and Coles 2001).

In his 1785 paper "On the Construction of the Heavens," Herschel wrote that our Milky Way is a very extensive, branching, compound Congeries of many millions of stars. Herschel's drawing shows a cross section through the Milky Way, our galaxy, as determined from his observations. In the course of time, remarkable new observational techniques, photography and spectroscopy, did address cosmological questions, but indecisively. In 1835, the prominent French philosopher Auguste Comte, remarked that humans would never be able to understand the chemical composition of stars. He was soon proved wrong, because spectroscopy and photography helped bring about a revolution in people's understanding of the cosmos. For the first time, scientists could investigate what the universe was made of. This was a major turning point in the development of cosmology, as astronomers were able to record and document not only where the stars were but what they were as well. Amateur astronomers — the professionals by definition were already engaged in well-defined research projects such as mapping stars — made photographs that showed some nebulae were made up of many stars. But other nebulae remained obdurately nebulous. And nobody was able to decisively show changes in nebulae over time. (CHP 2011)

Spectroscopy held out a promise of differentiating between nebulae made of many stars and those made of glowing gases, and also of determining if nebulae were rotating . But here also the conclusions were questionable. As, indeed, was cosmology itself as a scientific endeavor. Advances in cosmology during the nineteenth century were considerable, but only in the twentieth century would cosmology be transformed from speculation, based on a minimum of observational evidence and a maximum of philosophical predilection, into a respectable observational science.

Approaching the beginning of the 20th century, the worldview pioneered by Herschel was vastly different from that of Aristotle or even Copernicus. No longer were human beings necessarily at or very near the center of the universe (Coles 2001). The Milky Way was now understood to be an optical effect, with our solar system immersed in a much larger stratum of stars, a roughly disk-shaped stellar system. Possibly other island universes were scattered throughout a possibly infinite space.

Changing cosmological understanding is manifested in changing social views. Now that we Earthlings were but one of possibly many intelligent inhabitants of a possibly infinite universe, there was less reason to believe that we had been created in the best of all possible worlds, and perhaps more sympathy for discontent with the established social hierarchy.

Check Your Progress II

Note: Use the space provided for your answers.

1) How did Kant's contribution differ from other scientists?

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2) Briefly mention the contribution of William Herschel?

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4.4 FROM OUR GALAXY TO ISLAND UNIVERSES AND MORE

At the beginning of the 20th century, astronomers were unsure of the size of our galaxy. Generally, they believed it was not much greater than a few tens of thousands of light years across, and perhaps considerably less. (A light year, nearly six trillion miles, is the distance traveled in a year moving at the speed of light in a vacuum.) Also, observations early in the 20th century made it seem that our solar system was near the center of the galaxy. (CHP 2011). Therefore the English astronomer Arthur Eddington said in 1914: "It is believed that the great mass of the stars … are arranged in the form of a lens- or bun-shaped system … considerably flattened towards one plane … the Sun occupies a fairly central position."

Shapley's New Model of the Universe

This vision of the universe was soon replaced with a revolutionary new conception, based largely on the observations of the American astronomer Harlow Shapley at the Mount Wilson Observatory. The astronomer and scientific entrepreneur George Ellery Hale had founded the observatory on a mountain peak overlooking Los Angeles in 1904, and four years later master instrument-builder George Ritchey completed a 60-inch reflecting telescope designed specifically for astronomical photography.

The first hint of a drastically revised understanding of our galaxy came in 1916. Studying a "globular cluster,"—a group of hundreds of thousands of stars—Shapley noticed faint blue stars. If they were similar to bright blue stars near the Sun, they must be about 50,000 light years away to explain why they looked so faint. He pushed ahead to establish distances more conclusively using a new and ingenious method of measuring the universe (CHP 2011 and Coles 2001)

Shapley built a new understanding of the universe by measuring distances to stars based on properties of a type of variable stars called "Cepheids" (named after the constellation Cepheus, in which a typical such star was first noticed). They are giant stars, and thus visible to great distances. Each Cepheid varies in brightness over time. In 1908 the American astronomer Henrietta Leavitt had pointed to a remarkable rule that Cepheids obey. During routine comparisons of photographs she discovered variable stars, brighter on some photographs and fainter on other photographs taken at different times. Leavitt noticed that the brighter the variable star, the longer its period.

Shapley used the period-luminosity relation to estimate distances. First, he collected all the available data on Cepheid stars, from his own observations and from other astronomers including Leavitt. The distance to some of the nearer Cepheids had been measured, and thus Shapley could figure out their absolute magnitudes. The only physics he needed was the simple rule that brightness decreases with the square of the distance. Then Shapley graphed period versus absolute magnitude (CHP 2011 and Coles 2001).

Shapley made the reasonable assumption that Cepheids in distant globular clusters obey the same physics as nearby Cepheids. He observed the periods of distant Cepheids, read off their presumed absolute magnitudes from his graph of period versus luminosity, and compared that absolute magnitude with the observed apparent magnitude. This produced distances to many far-away Cepheids—and to the globular clusters in which they resided. (Some globular clusters did not have Cepheids he could measure, and he used other, cruder methods to estimate their distances.)

Shapley found that the globular clusters are arranged symmetrically around the galaxy, about as many above the plane of the galaxy as below. The clusters seemed to avoid the plane itself, the Milky Way. Shapley wrote that "this great mid-galactic region, which is peculiarly rich in all types of stars, planetary nebulae, and open clusters, is unquestionably a region unoccupied by globular clusters." Shapley acknowledged that there was an alternative explanation. Maybe globular clusters were not, as he believed, actually missing from the region, but instead were hidden by clouds of absorbing matter along the spine of the Milky Way (CHP 2011).

The dwindling significance of humans and their particular planet had dwindled further still. Shapley noted a historical progression from belief in a small universe, with humankind at its center, to a larger universe with the Earth further from the center. The geometry had been transformed from geocentric to heliocentric to a-centric. The psychological change was no less, he insisted, from homocentric to a-centric. Some astronomers had long doubted that the solar system was near the center of the galaxy and that people enjoyed a privileged place in the universe. They felt that the odds, given a random distribution, were small. Now Shapley gave this philosophical position scientific basis.

Hubble's Important Discoveries

Shapley's galaxy was far larger than any previous estimate (aside from earlier guesses of an infinite stratum of stars). It might indeed be the entire universe. For Shapley had showed that globular clusters were clearly part of the galaxy, not independent island universes. Other nebulae (concentrations of stars and dust), especially spiral-shaped ones, might still lie outside our galaxy. But if they were similar in size to our now enormous galaxy, they seemed implausibly large. Separate island universes were not impossible, but they seemed less likely now that Shapley had multiplied the size of our galaxy many fold. (CHP 2011)

Shapley defended his conclusions in the so-called "Great Debate" before the National Academy of Sciences on 26 April 1920. His major concern was the size of the galaxy. His model of a drastically larger galaxy, with the solar system far from its center, was largely correct. But he was on less solid ground when he argued that the spiral nebulae, which seemed to be much smaller, were part of our galaxy. His opponent, Heber Curtis, argued that the galaxy could be as large as Shapley said, yet still be only one of many island universes, if it happened by chance to be several times larger than the average. Ultimately observations would prove Curtis correct, but in 1920 Shapley had the stronger position (CHP 2011 and Coles 2001).

The centuries-old debate was resolved only by new scientific evidence, produced using larger telescopes and new observational techniques, including photography and spectroscopy. The key proponent of island universes was Edwin Hubble (1889-1953), who like Shapley did his revolutionary work at the Mount Wilson Observatory. Writing in his doctoral thesis in 1917, Hubble noted that catalogs already included some 17,000 small, faint nebulous objects that could ultimately be resolved into groupings of stars. Perhaps 150,000 were within the reach of existing telescopes. Yet, he wrote, "Extremely little is known of the nature of nebulae, and no significant classification has yet been suggested; not even a precise definition has been formulated." The way Hubble discovered to classify nebulae is described here.

After serving in World War I, Hubble joined the Mount Wilson Observatory staff. There he took photographs of nebulae with the new 100-inch reflector, the most powerful telescope in the world. Hubble discovered variable stars in an irregular nebula. By now Shapley had left Mount Wilson for the Harvard College Observatory. Hubble wrote to Shapley in 1923 to tell him of the discovery. Hubble also said he was going to hunt for more variable stars and to investigate their periods. Shapley wrote back, "What a powerful instrument the 100-inch is in bringing out those desperately faint nebulae." (CHP 2011)

Early in 1924 Hubble wrote to Shapley again. This time Hubble reported, "You will be interested to hear that I have found a Cepheid variable [star] in the Andromeda Nebula [M31]. I have followed the nebula this season as closely as the weather permitted and in the last five months have netted nine novae and two variables." When he found a Cepheid variable, Hubble realized he held the key to distance. As Shapley had used the period-luminosity relation for Cepheids to find distances to globular clusters in our galaxy, so Hubble could find the distance to the spiral nebula M31. Hubble found that "the distance [to M31] comes out something over 300,000 parsecs." This was roughly a million light years, and several times more distant than Shapley's estimate of the outer limits of our own galaxy. Hubble continued: "I have a feeling that more [Cepheid] variables will be found by careful examination of long exposures" (CHP 2011).

On reading Hubble's letter, Shapley remarked to a colleague who happened to be in his office, "Here is the letter that has destroyed my universe" (CHP 2011). Shapley admitted that the large number of photographic plates that Hubble had obtained were enough to prove that the stars were genuine variables. By August, Hubble had still more variables to report. Shapley was glad to see this definite solution to the nebula problem, even if it refuted earlier evidence against spiral nebulae as island universes. Hubble's discovery of Cepheid variable stars in spiral nebulae, and the distance determination confirming that spiral nebulae are independent galaxies, were officially announced on New Year's Day, 1925, at a meeting of the American Astronomical Society. He followed this preliminary paper by further work over the next four years, with convincingly voluminous detail. A good part of Hubble's genius, and much of the acceptance that his revolutionary conclusions commanded, were due to lots of hard work.

Before the 1920s ended, astronomers understood that the spiral nebulae lie outside our own galaxy. In the previous decade Shapley had multiplied the size of the universe by about ten times. Hubble multiplied it by another ten - if not more. Hubble's universe was no longer the one all-comprehending galaxy envisioned by Shapley. Henceforth the universe was understood to be composed of innumerable galaxies spread out in space, farther than the largest telescope could see. Hubble next would show that the universe is not static, as nearly everyone then believed, but is expanding. What he had made infinite in space, he would make finite in time (CHP 2011). That was the cosmology till the beginning of 20th century. The story of the contemporary cosmology will be taken up in the following units.

Check Your Progress III

Note: Use the space provided for your answers.

1) What is an island universe?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

2) What are were some of the important discoveries of Shapley?

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4.5 LET US SUM UP

In this unit we traced the origin and development of scientific cosmology till the beginning of 20th century. This is to give a bird's eye-view of the cosmological journey and is a preparation for the coming units.

4.6 KEY WORDS

Aether: According to ancient and medieval science aether also spelled æther or ether, is the material that fills the region of the universe above the terrestrial sphere. Modern science has given up this notion.

Cepheid variable: Any of a class of pulsating, yellow, supergiant stars whose brightness varies in regular periods: from the period-luminosity relation, the distance of such a star can be determined

Island universe: Obsolete term used for the galaxies when it was first realised that they exist separately from our own galaxy and at great distances from each other. Now we do not hold on to this theory any more.

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MPYE – 009

Philosophy of Science and Cosmology

Block 2

SCHOOLS OF CONTEMPORARY PHILOSOPHY OF SCIENCE

UNIT 1
Logical Positivism

UNIT 2
Historicism

UNIT 3
Historical Realism

UNIT 4
Key Issues in Philosophy of Science

Expert Committee

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BLOCK INTRODUCTION

In tracing the specific movement within philosophy of science we find positivism, logical positivism, historicism or social constructivism and historical realism. While logical positivists initiated an analytical approach to understanding linguistic facts in enumerating the reality, historicist philosophers of science have challenged the rational and objective picture of science, proposed by the logical positivists. Some philosophers of science in the later decades of the 20th century made attempts to envisage a picture of science and philosophy of science, which would be more comprehensive, by avoiding the extremes of both Logical Positivism and Historicism. They argue for a realistic view of history. They tend to take 'history' as the exact description of what happened in the past. In understanding all these movement the block finally lists out key issues in philosophy of science.

Unit 1 elaborates on logical positivism as a philosophical movement in Western tradition in the nineteenth century and the beginning of twentieth century. Logical positivism as a movement is traceable to Analytical Philosophy. The development of science brought about rapid changes in Philosophy. The word 'analysis' refers to any philosophy which places its greatest emphasis upon the study of language and its complexities. Philosophical analysis is essentially the study of language, primarily in empirical investigation. There are scientific questions about language which can only be answered through use of scientific method. The analytical philosopher uses the analytical method as a tool to settle philosophical questions.

Unit 2 discusses some of the salient features of Historicism (Social Constructivism) School of Philosophy of Science of the 20th century. It has a very brief description of the trends of Historicism in general and how it differs from Logical Positivism in its approaches of doing Philosophy of Science. The sections in the units seek to familiarize the students with the salient contributions of Kuhn, Feyerabend and Hanson, some of the prominent philosophers of this school.

Unit 3 pays attention to another movement in philosophy of science avoiding both the extremes of Logical positivism and Historicism. Some philosophers, Historical Realist Philosophers of Science, stressed on the historical, social and non-rational aspects of science, while maintaining the rational character and a sort of realistic picture of science intact. This unit elaborates on some of the salient contributions of some of the philosophers of science belonging to the school of Historical Realism.

Unit 4 understands philosophy of science as it is interpreted as a critique of science, an inductive metaphysics, a pragmatic of science. As a critique of science it analyses the language of sciences; the semantics and syntax of scientific language is analysed. As an inductive metaphysics, it uses the inductive method of science, but unlike science it focuses on the study of transcendental entities also. As pragmatics of science philosophy of science tries to relate the findings of the scientists to the human welfare. The unit highlights the key issues in philosophy of science include scientific method, discovery of theory in science, structure and validation of scientific theory and scientific explanation.

UNIT 1 LOGICAL POSITIVISM

Contents

1.0 Objectives
1.1 Introduction
1.2 History of the Movement
1.3 The Criterion of Meaning
1.4 Elimination of Metaphysics
1.5 Logical Analysis of Science
1.6 Logical Positivism and Interpretation of Science
1.7 Other Logical Positivists
1.8 Criticism of Logical Positivism
1.9 Let Us Sum Up
1.10 Key Words
1.11 Further Readings and References

1.0 OBJECTIVES

This unit tries to elaborate on logical positivism as a philosophical movement in Western tradition in the nineteenth century and the beginning of twentieth century.

1.1 INTRODUCTION

Logical positivism as a movement is traceable to Analytical Philosophy. The development of science brought about rapid changes in Philosophy. The word 'analysis' refers to any philosophy which places its greatest emphasis upon the study of language and its complexities. Philosophical analysis is essentially the study of language, but it must not be confused with other important studies of language. Linguists, philologists, grammarians, lexicographers, etc., are also involved in a study of language. Their interest, however, is primarily in empirical investigation. They are interested in discovering facts about how our language is used; what meanings words have; how languages begin, change and die, etc. These are scientific questions about language which can only be answered through use of scientific method. The analytical philosopher uses the analytical method as a tool to settle philosophical questions.

1.2 HISTORY OF THE MOVEMENT

Just as science had to create its own technical vocabulary and introduce concepts (e.g., force, mass, atom) that are more precise than those supplied by common sense, so also, these philosophers argue, philosophy must develop its own vocabulary and set of concepts in order to resolve its problems. Other analysts such as 'ordinary language' philosophers disagreed with the 'artificial language' of the logical positivists. Their contention was that philosophical problems can be solved through natural language we all use to communicate with each other. In logical positivism we find united in a peculiar way the empiricism of Hume, the positivism of Comte and Mach and the logical analysis of Moore, Russell, Wittgenstein, Whitehead and Frege. The adherents of this trend of thought organised themselves into a philosophical group at Vienna in 1928. The group became known as the Vienna circle. The prominent members of this group were Moritz Sehlick, Otto Neurath and Rudolf Carnap. The Movement gradually spread across the world of philosophy. Hans Reichenbach founded a centre at Berlin. At Oxford A.J.Ayer was the advocate of this movement. The two principal aims of Logical positivism were:

1. To provide a secure foundation for the sciences.
2. To demonstrate the meaninglessness of metaphysics.

The method adopted to realize the aims of the logical positivism was logical analysis, specially of language. It is this method which mainly distinguishes this movement from the positivism and empiricism of earlier times. It is distinguished, from the empiricism of Hume. While Hume's empiricism is based on psychological analysis of experience, the logical positivists base their theories on logical analysis of it. While earlier positivists objected to metaphysical speculation either because it is unprofitable or because its truths cannot, be proved, the new positivists object to it because logical analysis of metaphysical language convinces them that all metaphysical propositions are meaningless. The logical positivists dismiss metaphysical questions themselves as non-sensical, so that the question of their solution does not arise at all.

1.3 THE CRITERION OF MEANING

Russell and Moore succeeded in bringing to an end the dominance of Idealism in British Philosophy. American pragmatists C.S.Peirce and William James were influenced by the writings of Russell and Moore. It was Russell's brilliant student Ludwig Wittgenstein through his influential work *Tractatus Logico – Philosophicus* argued that meta physical questions are from their very nature unanswerable. All meaningful discourse is empirical in nature. Metaphysics is not empirical, so it is not meaningful. The necessity of the propositions of mathematics and logic follows from the fact that they are *tautologous*, making no reference to the world. Since the sentences of metaphysicans are neither propositions of empirical science nor tautologies of logic or mathematics, they are nonsensical. Philosophy, Wittgenstein said, is primarily the activity of clarifying language; it is not a source of truth about the universe the way science is. The Philosopher's only, proper task in to show the person who is puzzled by a metaphysical question that it is meaningless and unanswerable. Language is the symbolic representation of facts experienced. It can be analysed into significant assertions called propositions, and all propositions can be shown by further analysis to consist of some elementary propositions. Every elementary proposition, is a picture of some atomic fact experienced. The world is composed of such facts, and can be completely analysed into them. The proposition, 'this book is blue', can be true only if a book is blue, can be true only if a book is experienced as blue. Logical analysis of the world of experience as pictured by propositions asserting the existence of the world brings us thus to facts (or objects related) as the ultimate constituents of the world. This position is different from that of Hume for whom experience is simple impressions (not propositions). Hume analyses experience psychologically and not logically and the impressions yield the knowledge of non-related sense objects (like blue colour) and not of any fact or combination of sense objects (like this object having a blue colour). For Wittgenstein, a proposition which does not refer to 'any' state of affairs i.e., any fact of experience is, therefore, no proposition at all. While the truth of a proposition requires that it should agree with reality the sense of a proposition requires that it should at least refer to possible empirical facts. The sense of a proposition is the method of its verifications. To understand a proposition is to know what is the case, if it is true, that is what facts it stands for which can be expected to be observed or experienced if the proposition is true. But the method of verifying the proposition is also to observe such facts. Hence the very experience which can verify a proposition is also that which constitutes its sense. The verification theory of meaning supplied the point of departure to the positivists of the Vienna circle. They utilized this theory for demonstrating the meaninglessness of metaphysics, as well as for clarifying the propositions of science. In England the most famous logical positivist was A.J.Ayer. Through his famous work *Language, Truth and Logic*, Ayer placed great emphasis upon "The Principle of Verification".

1.4 ELIMINATION OF METAPHYSICS

Metaphysical entities are beyond sense, experience (transcendental). All metaphysical statements do not meet the conditions of verifiability and therefore according to A.J. Ayer such statements are nonsensical. According to him philosophy is nothing but the analysis of language. The fundamental postulate of metaphysics is that there is a super phenomenal reality. Since protocol statements are verifiable in experience, no statements which are not reducible to empirically verifiable protocol propositions can possess any significance. Metaphysical propositions by their very nature purport to assert the existence of unverifiable, trans-empirical entities. They do not possess any sense. Such propositions are not propositions at all. They constitute a body of nonsensical expressions. In Descarte's assertion **'***Cogito Ergo Sum*' (I think therefore I exist), the 'I' refers to the existence of 'self' which is not empirically experienced. Similarly the metaphysical systems of Spinoza and Leibniz assert the existence of trans-empirical entities which are meaningless. Through his logical analysis of language Carnap points out two chief sources that give rise to meaningless sentences. Either the individual words of a sentence are non-sensical or the sentence as a whole becomes non-sensical. For example in the sentence, "Twas brilig and slithy toves", the words have no meaning but in the following sentences the individual words are meaningful, But the sentences are meaningless:

> "Quadratic equations attend races".
> "Caesar is a prime number".

Metaphysicians propound the first kind of non-sense chiefly under the misconception that to every word or phrase that can be the grammatical subject of a sentence, there must somewhere be a real entity corresponding. For as there is no place in the empirical world for many of these 'entities', a special non-empirical world is invented to house them. The metaphysician has to show an entity even to the world 'nothing'. He indulges in the second kind of non-sense, when for example, he speaks of 'thing-in-itself' lying beyond all experience. Everyone of these words 'thing', 'in' 'itself' 'lying' 'beyond' 'all' 'experience' possess meaning in other sentences and context. But as combined here they do not yield any sense, since no empirical verification is possible with regard to what is beyond all experience. Therefore as a knowledge of reality, metaphysics is meaningless.

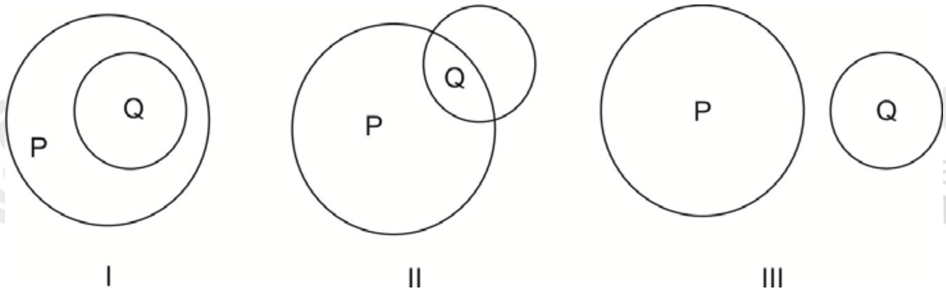
1.5 LOGICAL ANALYSIS OF SCIENCE

The function of Philosophy, according to the Logical positivists is to analyse the statements asserted by scientists, study their kinds and relations, and analyse terms as components of those statements. The logic of science according to Rudolf Carnup consists of two branches. One branch is called logical syntax or formal logic. The logical syntax analyses complex sentences of science into simple ones and discovers the laws governing the combinations of words into meaningful sentences. It enables us to realize the fundamental assertions of the different sciences, and their logical interrelations. The other branch of the logic of science is called semantics. The meaning aspect of the sentence is called semantics. It considers the relations of linguistic expression to objects designated by them. Semantic analysis of the language of science discovers, for example, that a term may designate a certain particular objet (e.g., the sun) or a certain property of things (e.g., iron) or a certain relation between things (e.g., motherhood) or a certain physical function (e.g. temperature). It also analyses synonymous terms such as *homosapiens* person and man. The results of sciences and their relevance to society are pursued by Philosophers.

1.6 LOGICAL POSITIVISM AND INTERPRETATION OF SCIENCE

As the positivists believe in observation and empirical verification they interpret the terms like 'probability', 'induction' and 'laws of nature' in their characteristic ways. There are three different kinds of probability in logical positivism.

1. According to Hans Reichenback probability lies between the two limits of absolute truth and absolute falsity. According to this theory no conclusion follows from any premise with absolute certainty, the latter can only imply the former to some degree of probability.
2. R.Von Mises advocates frequency theory of probability. It attempts to base the idea of probability on the observational frequencies of the happenings of a class of events. Probability can be asserted only on statistical observations and computation.
3. The third conceptions of probability are supported by Wittgenstein and Waismann. In this view probability is a kind of logical relation obtaining between two propositions between any two propositions P and Q there may be three kinds of logical relations. Using Euler's circles these may be shown as follows.


P
Q
P
Q
P
Q
I
II
III

The early analytic philosophers like Bertrand Russell, G.E.Moore and C.D.Broad influenced many thinkers of the west. Some of the other thinkers who contributed to analytic philosophy are A.J.Ayer, Rudolf Carnap, W.V.O. Quine, Carl Hempel, John Wisdom, Gilbert Ryle, P.F.Strawson and J.L.Austin.

A.J. Ayer

The positivism of A.J. Ayer focused on two areas in Philosophy: 1) The Elimination of Metaphysics and 2) The Principle of verification. His book *Language, Truth and Logic* deals with the Principle of verification. Ayer intended it as a criterion of meaning, through which significant discourse could be distinguished from senseless combinations of words. He states the principle of verification in his book and attempts to clarify how it is to be understood and how it can be used to demonstrate the literal meaninglessness of metaphysical sentences.

Rudolf Carnap

Testability and Meaning is a shorter work of Carnap which appeared in Philosophy of Science in 1936 and 1937. In this he discussed the meaning criteria and the requirements of an empiricist language, the use of reduction sentences for analyzing assertions about dispositional properties, and physicalism as a basis for reconstructing the language of science. Two chief problems of the theory of knowledge, are the question of meaning and the question of verification. The first question asks under what conditions a sentence has meaning, in the sense of cognitive, factual meaning. The second one asks how we get to know something, how we can find out whether a given sentence is true or false. The second one presupposes the first one. If by verification is meant a definitive and final establishment of truth then no (synthetic) sentence is ever verifiable. We can only confirm a sentence more and more. Therefore we speak of the problem of confirmation rather than the problem of verification. We shall call a sentence testable if we know such a method of testing for it; and we call it confirmable if we know under what conditions the sentence would be confirmed. A sentence may be confirmable without being testable. The difficulties in discussions of epistemological and methodological problems are often due to mixing up of logical and empirical questions. Carnap attempts to formulate the principle of empiricism in a more exact way by stating a requirement of confirmability or testability as a criterion of meaning. Different requirements are discussed corresponding to different restrictions of the language.

W.V.O. Quine

W.V.O.Quine was a well known logician and analytic philosopher with positivist sympathies. His essay “Two Dogmas of Empiricism” appeared in *The Philosophical Review* in 1950. In his essay Quine challenges two doctrines which many people feel are central to logical positivism: 1) the analytic-synthetic distinction and 2) the belief that there are propositions which future experience can never cause us to reject as false. The analytic-synthetic distinction has a long history in modern philosophy. The distinction between analytic and synthetic statements can be found in the writings of Leibniz, Hume and Kant. According to Kant an analytic statement is one in which the predicate does not add anything new to the subject:

(E.g) a) A bachelor is an unmarried man
b) Iron is a metal

An analytic statement is limited to subject–predicate form. A synthetic statement is one in which the fact can be experienced:

(E.g) Water boils at 100 °c

But W.V.O Quine raises a question of whether there be a distinction between analytic and synthetic statements. He calls the distinction between analytic and synthetic statements as a dogma. The other dogma pertains to the belief that there are certain propositions which no experience can ever lead us to reject. He argues that although there may be propositions whose truth we would abandon only as a last resort, there are nevertheless no propositions which could not in principle by upset by future experience. Quine's view is supportive of a kind of empiricism without the above two dogmas.

Carl Hempel

The fundamental tenet of modern empiricism is the view that all non-analytic knowledge is based on experience. This thesis is called the principle of empiricism. According to the contemporary logical positivist, a sentence makes a cognitively meaningful assertion, and thus can be said to be either true or false. According to the empiricist criterion of cognitive meaning, or of cognitive significance, many of the formulations of traditional metaphysics and large parts of epistemology are devoid of cognitive significance. Hempel attempts to provide in detail the logic and methodology of empirical science and clarify and restate the basic ideas of empiricism. He wants changes in the empiricist criterion of meaning. These changes focus on the testability criterion of empirical meaning. The concept of testability which is to render precise the vague notion of being based – or rather baseable – on experience, has undergone several modifications which reflect an increasingly refined analysis of the structure of empirical knowledge. A sentence has cognitive meaning if and only if it is translatable into an empirical language. According to Hempel there are requirements for both complete verifiability and complete falsifiability in Principle. According to the requirement of complete verifiability in principle, a sentence has empirical meaning if and only if it is not analytic and follows logically from some finite and logically consistent class of observation sentences. According to the requirement of complete falsifiability in principle, a sentence has empirical meaning if and only if its denial is not analytic and follows logically from some finite logically consistent class of observation sentences.

John Wisdom

John Wisdom was a student of Wittgenstein. Through his articles and books, he has brought to Linguistic analysis an original and exciting new kind of philosophical procedure. He is not in agreement with Wittgenstein, A.J.Ayer and other logical positivists in rejecting metaphysics as non-sensical. On the other hand he tries to understand why metaphysicians feel compelled to talk in their linguistically odd ways. By putting stress upon the imperfect similarities between various kinds of statements in our language, he hopes to discover what is and is not valuable in the various attempts to solve metaphysical problems. Wisdom stressed the ‘therapeutic’ conception of philosophy. His articles, “Gods” in Philosophy and Psycho analysis and “Other Minds” reveal his emphasis on the analogy between philosophical and neurotic distress, contrasting them with other kinds of problems. Philosophers reason for and against their doctrines and in doing so show us not new things but old things anew. According to him a purely linguistic treatment of philosophical conflicts is often inadequate. Besides the latent linguistic sources there are others non-linguistic and much more hidden which subtly co-operate with the features of language to produce philosophies. Philosophical disputes can go on too long since there is something queer about philosophical reasons. Philosopher’s chronic indecision, whether it takes the form of enthusiastic oscillation or melancholic inactivity, is due to the fact that besides the reasons revealed in the course of talking over the matter there are others which remain hidden.

Gilbert Ryle

In his popular book, *The concept of Mind***,** Gilbert Ryle tries to refute Descartes myth, prevalent among theorists that man has both a body and a mind; that body is in space, subject to mechanical laws and observable by sense-organs, whereas the mind is an opposite kind of private existence, being not in space, not subject to such laws and not observable by others. According to Ryle, mind- body relation is not that of a ‘Ghost’(mind) in the machine (body). Mind cannot be analogous to a ‘pilot’ in a ‘ship’. Dualists like Descartes commit a logical blunder in counting mind and body as two species of the same genus, ‘existence’. Ryle uses plenty of similes and metaphors to counteract the effects of opposite metaphors lying behind the philosophical conception of mind as an occult and mysterious entity. The family of categories relating to the realm of mind may be divided into three broad classes: 1) terms like ‘mind’, ‘spirit’, ‘self’, etc. which suggest that mind is a kind of substance, 2) adjectival terms signifying some present (occurrent) quantities and acts belonging to mind e.g. ‘conscious’, ‘alert’, ‘attentive’, think’, ‘imagine’ etc. and 3) Similar adjectival terms signifying some capacities and dispositions e.g., ‘intelligent’, clever, ‘rational’, ‘critical’, rash etc. Ryle argues that capacity or potentiality is a mythical entity. He is conscious, alert and so on means he is acting or behaving in particular observable ways. Ryle reduces the dispositions to occurrents, and all occurrents to observed outer activities and tries to do without terms implying, mental phenomena. It is supposed that ‘thinking’ is the cause of ‘doing’. There is no internal evidence of our consciousness to show that the outer act is preceded by another inner act. Moreover if we suppose the necessity of a precedent mental act as the cause of the outer act, we must think of a second mental act preceding the first, and so on ad infinitum. So the supposition of a higher order of inner, mental causes for explaining the outer acts is untenable. Ryle questions the view that consciousness is the essence of mind. Feelings are nothing but bodily sensations. The categories signifying the private, inner, higher order of mental capacities, qualities and acts can be replaced by categories signifying physical processes. Therefore there is no mystical entity called mind. Mind ‘can be replaced by the team ‘person’.

J.L.Austin

Austin exerted great influence on his students through his writings. He agrees with other analysts the conviction that the study of language is of the greatest value in dealing with philosophical questions, Like Wittgenstein and wisdom he believes that a great deal of what philosophers have written is not so much false as it is misleading and confused. However, Austin's procedure for dispelling this confusion is unique. He displayed an amazing talent for articulating the subtle shifts of meaning which result from the most minute grammatical changes. He was clearly of the opinion that the study of grammar is philosophically important, and he attempted to demonstrate this in his later works. He believed that the time was not yet ripe for speculation in philosophy. We must first become as clear as possible about how our language operates before we attempt to settle philosophical problems or even speculate on whether any of them can be solved. Thus Austin never endorsed Wittgenstein's speculations about the ultimate fate of philosophy.

P.F.Strawson

One of the most discussed analytical philosophers of 20th centaury was P.F.Strawson. In his book *Individual***,** he attempts to show that certain general conclusions about the world can be gained from the analysis of how we speak. He argued that there was no real anti thesis between linguistic analysis and a certain kind of metaphysics. He distinguished two kind of metaphysics: that which only attempts to describe the conceptual boundaries on our language (descriptive metaphysics) and that which attempts to revise them (revisionary metaphysics). His essay "On Referring" challenges Russell's theory of descriptions. Strawson argues that Russell made at least two mistakes: He did not fully realize that a sentence can have a variety of uses, and he mistakenly thought that every meaningful sentence must be either true or false. According to Strawson, a sentence such as "The present king of France is wise" when used today, is neither true nor false, for the question of its truth or falsity does not even arise. Such a sentence presupposes but does not assert, that there is a king of France, and since this presupposition is false, the question of truth or falsity cannot be an issue. Russell's theory is unnecessary since the problem it was designed to solve does not exist. The sentence "The king of France is wise" was uttered from the beginning of the seventeenth century onwards, during the reigns of each successive French monarch; it was also uttered during the subsequent periods in which France was not a monarchy. There are also difference between different occasions of the use of this sentences. For instance, if one man uttered it in the reign of Louis XIV and another man uttered it during the reign of Louis XV, it would be natural to say that they were respectively talking about different people. If on the other hand two different men simultaneously uttered the sentence, then, they were both talking about the same person, and in that case in using the sentence, they must either both have made a true assertion or both have made a false assertion. This illustrates the use of a sentence. We cannot talk of the sentence being true or false, but only of its being used to make a true or false assertion. Strawson dealt at length "indefinite References" the problems in making "identification statements" and The logic of "subjects and predicates". The contextual requirement for the referring use of pronouns may be stated with the greatest precision in some cases (e.g. 'I' and 'you') and only with the greatest vagueners in others ("it" and "this"). This sentences may be classified into two classes: 1) those of which the correct referring use is regulated by some general referring-cum-ascriptive conventions (E.g. Pronouns which have the least descriptive meaning) and ii) those of which the correct referring use is regulated by no general conventions, either of the contextual, or the ascriptive kind, but by conventions which are ad hoc for each particular use.

1.8 CRITICISMS OF LOGICAL POSITIVISM

The positivists attack on metaphysics evoked vehement protests and counter attacks from the opponents of logical positivism. The counter attacks made the supporters of the logical positivists to defend their views in different ways. The verificational theory is criticized on many grounds. What is the meaning of verification when it is said that the meaning of a proposition depends on the method of its verification? if it means that the observational context is the criterion for the truth of proposition, then the historical statement and the statements about objects not yet perceived are meaningless. Faced by these difficulties some positivists admit that by verification should be meant verification in theory or principle and not necessarily in practice. If by verification, the positivists believe in the sense of conclusively proving some proposition to be true or false, there are statements which cannot be verified conclusively:

a) Arsenic is poisonous
b) This wire conducts electricity
c) There is other side for the moon.
d) Man is mortal.

The above statements can be verified in indirect ways. Schlick says that the statement. ‘Man is mortal’ is non-sensical, only an important type of nonsense. This makes Karl Popper remark that, ‘Logical positivism destroys not only metaphysics but also natural science’. According to Popper, even limited number of crucial observations can conclusively confute (i.e. falsify) if not establish a general proposition, and that a sentence should be allowed to be significant if it expresses something which can be confuted by experience.

A.J. Ayer rejects the falsification theory and defends his verification theory by introducing the concept of probability in the meaning of statements. The general propositions of science are significant because it is possible to observe facts which render them probable if not certain. He maintains, therefore, that verification, in the definition of meaning should include both strong verification and weak verification. In the case of strong verification it is possible to provide conclusive proof for the truth or falsity of a proposition. (E.g. All a priori analytic propositions). In the case of weak verification it is possible to provide a proof of probability of a proposition. (E.g. All synthetic propositions). Since all synthetic propositions are only probably true, they can be verified only in the weak sense. It is self-contradictory to say that propositions concerning syntax or logical principles possess significance and at the same they are some important types of non-sense. The logical positivist’s aim is to defend science, but by re-interpreting science to suit their principles they don’t defend the sciences. By sense-experience, positivists like Carnap mean introspection and even mystical experience also. This is deviation from the original stand point of the logical positivism. But in spite of its drawbacks, it made an impact on several fields of philosophy such as epistemology and ethics.

1.9 LET US SUM UP

In this unit we have seen the development of logical positivism as a development of philosophy of science in dealing with the question of verification and accuracy of facts and data.

1.10 KEY WORDS

Verification theory: the concept of probability in the meaning of statements. The general propositions of science are significant because it is possible to observe facts which render them probable if not certain.

1.11 FURTHER READINGS AND REFERENCES

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UNIT 2 HISTORICISM

Contents

2.0 Objectives
2.1 Introduction
2.2 Historicists' Challenges to Logical Positivism
2.3 Thomas Samuel Kuhn: Science – A Rational Enterprise
2.4 Paul K. Feyerabend (1924-94): Liberator of Humanity from Science
2.5 Norwood Russell Hanson (1924-67): A Champion of Theory-ladenness of Observations
2.6 Let Us Sum Up
2.7 Key Words
2.8 Further Readings and References

2.0 OBJECTIVES

This lesson aims to discuss some of the salient features of Historicism (Social Constructivism) School of Philosophy of Science of the 20th century. The Introduction includes a very brief description of the trends of Historicism in general and how it differs from Logical Positivism in its approaches of doing Philosophy of Science. The following sections seek to familiarize the students with the salient contributions of Kuhn, Feyerabend and Hanson, some of the prominent philosophers of this school. [*Note*: Philosophy of Science in the 20th century can also be divided into Positivist and Postpositivist Schools. However, for our purpose, we divide the latter further into two groups: *Historicism* and *Historical Realism*, Unit 2 and 3, respectively].

2.1 INTRODUCTION

After the World War II most of the intellectuals became disillusioned with humanity's scientific growth. The historical outlook affected many spheres of humanities and new disciplines, like Historical Materialism, Anthropological Historicism, Eschatological Historicism and so on emerged. Historicism, a popular school of thought in Germany by the 19th century, looks at everything in terms of historical developments. Reacting against the normative view of knowledge and cognition of the Enlightenment period, it argues that *life and reality are nothing but history*. Taking the cue from J. G. Herder's *Outlines of a Philosophy of the History of Man* (1784) and G. W. H. Hegel's *The Philosophy of History* (1837), Historicism gives importance to the historical situatedness of each individual consciousness, which is shaped by *socio-cultural contextuality, contingency and perspectival nature of our existence.* Radical contingency is the distinguishing feature of human life. David Roberts maintains that "Our world . . . cannot be stable, centered, self-identical in the way that the metaphysical tradition led us to expect" (1995, 199) and even if we manage to reach the levels of metaphysics or science, we are still within the framework of history and contingency. The popular names associated with this school of thought are Leopold von Ranke, Wilhelm Dilthey, J. G. Droysen, Freidrich Meineckes, Benedetto Croce and R. G. Collingwood. The powerful critics of historicism are Friedrich Nietzsche, Walter Benjamin, Karl Popper etc. However Martin Heidegger, Edmund Husserl and Hans-Georg Gadamer engage themselves in a constructive approach to the whole ideas of historicism.

The impact of historical outlook towards knowledge enterprise affected philosophy of science also. In the beginning of the 20th century, Logical Positivists (members of the Vienna Circle) and Logical Empiricists (likeminded group from Berlin), insisted that Philosophy of Science should be precise and rigorous giving importance only to the logical and linguistic analyses of the scientific concepts and theories. Positivists like Carnap, Hempel, Reichenbach, Schlick, Popper etc. held scientists as 'little philosophers', incorruptible investigators who are maximally rational and worried about epistemological and ontological issues" (Klee, 1999, 199). But historicists, like Hanson, Feyerabend, Kuhn, Lakatos etc., tried to demythologise the logical positivists' view of science and to arrive at a picture that is more faithful to the actual historical developments and sociological factors of science. In short, one can say: "Hume thought science was inductive and irrational, Popper thought it was non-inductive and rational, and Carnap thought it was inductive and rational", and in contrast to them, "Kuhn seems to argue that science is both non-inductive and non-rational" (Ladyman, 2002, 94).

2.2 HISTORICISTS' CHALLENGES TO LOGICAL POSITIVISM (LP)

a) Rationality of Science – LP claims that science is rational, because it strictly follows scientific method (verification or Popper' s falsification). But Historicism argues that science is non-rational and there can be many methods in science; *b) Cumulative growth* – Science progresses cumulatively, where the latter theories are the betterment of the previous ones, with more empirical content; such progress is not available in any other enterprise, where knowledge grows only in a rough sense. But for Historicism growth is transformative and latter theories are not necessarily better than the previous ones; *c) Objectivity in Science* - Science is objective, while Historicism shows that science has got both subjective and objective elements; *d) Monopoly of Truth* - Science is the storehouse of truths. Historicism challenged this and showed that other resources are also reliable. *e) Reductionism of science* – All sciences can be reduced to physics, as there is a single set of fundamental methods for all of them. Historicism does not agree with this as there can be different methods for science and reductionism becomes more controversial with more growth in various domains of sciences; *f) Superiority of Scientific theories* - Scientific theories are superior to any other belief system as science is immutable. But Historicism argues that scientific theories do change and there is nothing special about scientific enterprise; *g) Dichotomy between the context of discovery and the context of justification* – This distinction is very important because a hypothesis may arise out of any sort of personal or social consideration, but it has to be justified on the basis of observational evidence; the context out of which it emerges is not relevant to philosophy of science as only its justification matters. But Historicism denies any such dichotomy; *g) Clear Distinction between observational terms and theoretical terms:* LP insists on the distinction of observational terms and theoretical terms (and thereby observational and theoretical statements also). The observational terms can be traced to some sort of observational experiences, while there is no such observational basis for theoretical terms. However Historicism denies this distinction because there is no 'pure' observation and all observations are theory-laden; *h) Weltanschauung (World view) of the scientists:* According to LP, the value-system, the passion, prejudices and the whole world-view of scientists have no role in science, as the scientists remain above all these elements. Historicism clearly shows that the *Weltanschauung* of the scientists has a crucial role to play in their science, by colouring and controlling the process of science. (*Weltanschauung* can be understood as the totality of background, upbringing, personal preferences, prejudices, and expectations etc. of the scientists); *i) Role of History in Philosophy of Science:* For LP, history of science is not necessary to do philosophy of science, while for Historicism history of science is important to do philosophy of science, because historical factors do play an important role in having an adequate picture of science.

Check Your Progress I

Note: Use the space provided for your answers.

1) What is the importance of historicist approaches in the intellectual enterprises in general and in philosophy of science in particular?

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2) Explain some of the areas where historicist philosophers of science challenge LP?

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2.3 THOMAS SAMUEL KUHN (1922-96): SCIENCE – A SOCIAL ENTERPRISE

Kuhn is given the credit of bringing Historicism into the Philosophy of Science. He received his Ph.D. theoretical physics from Harvard University in 1949. Soon he became interested in the history of science. His world-shattering work, *The Structure of Scientific Revolutions* (SSR), in 1962, evoked controversial discussions in extremely diverse fields. It has been translated into twenty languages. In 1956 he joined the University of California at Berkeley; he moved on to Princeton University and later to MIT. He suffered from blood cancer and he died rather young in 1996. Some of his papers both on the history and the philosophy of science are given in *The Essential Tension*, 1977. His ideas can be seen in two broad categories: *Early Kuhn* and *Later Kuhn*, focusing on the important Kuhnian concepts like *Paradigm*, *Incommensurability and Theory Choice.*

Early Kuhn (Till late 1970s)

Science - a Cycle of Normal Science and Revolutionary Science**:** Science is basically a long period of *normal science*, occasionally interrupted by crises, which lead to short periods of *revolutionary science*. In the Normal Science period the main preoccupation is puzzle-solving activity. All scientists work as collaborators, not as innovators, applying the known solutions to the problems at hand. When the existing theories get into conflict with the fresh observational data, anomalies arise and mostly anomalies are overlooked. A normal scientist must learn to ignore them, or else she can't carry on with her research: "The scientist who pauses to examine every anomaly he notes will seldom get significant work done" (Kuhn, 1962, 82). But when anomalies grow too many and too strong to tolerate, a crisis sets in, leading to a revolution, where a new paradigm is chosen. Once that is accepted again another period of normal science starts, until anomalies appear, which would ultimately lead to a revolution.

Paradigm - A Primary Concept

Paradigm is almost synonymous with a scientific community, ensuring both the logical and physical closeness. It is a sort of world-view of the community. [E.g. Aristotelian physics, Copernican astronomy, Newtonian physics, Ptolemaic astronomy, the phlogiston and the Oxygen theories of combustion, the caloric theory of heat, particle physics, quantum physics]. *Paradigms are constitutive of science*: Each paradigm has its own problems, its solutions and methodology. It binds the scientists so deeply that the scientists belonging to different paradigms "disagree about what is a problem and what is a solution; they will inevitably talk through each other when debating the relative merits of their respective paradigms" (Kuhn, 1970, 109). *Paradigms are constitutive of meaning*: Paradigms determine the meanings of the terms used in scientific theories. Finally, *paradigms are constitutive of subject matter of discourse*. Within a paradigm there is a strong consensus-thinking. Kuhn demands a very strict adherence to the paradigm on the part of the scientists. They would do anything to be faithful to it, "even in the face of contradictory evidence" (Ladyman, 2002, 119). [Note: With critiques of the notion of paradigm, Kuhn preferred, with his 2nd edition of *SSR* (1970), a *'disciplinary matrix'* to 'paradigm'. The disciplinary matrix includes these important elements: i) symbolic generalizations, ii) models, both ontological and heuristic, iii) values, and iv) exemplars – which are essential for the scientific community to obtain or validate genuine knowledge].

Incommensurability

During revolutionary period scientists suffer from incommensurability (i.e. *communication breakdown*). It arises due to the rejection of an old theory, the changes in the problem-field, the standards of solution and even some of basic scientific concepts. The scientists from both Aristotelian paradigm and the Copernican paradigm may speak of the center of the universe but they mean different realities; for, the former mean the earth, while the latter the sun, which are apart by 150 million KMs. Kuhn says that there is no way in which the communication breakdown can be bridged because the interpreter will have to live in two worlds and he will end up in mental asylum.

The Essential Tension

There is a tension as a scientist essentially needs flexibility and open-mindedness to progress; but at the same time 'convergent thinking' and the rootedness in the given tradition is also needed: "Only investigations firmly rooted in the contemporary scientific tradition are likely to break that tradition and give rise to a new one" (Kuhn 1977, p.227). As the convergent thinking is instilled in the fresh minds through the students' text books, it is very difficult to be innovative as that would go against paradigms. Edwin Hung's analogy of railway tracks: "The rails in one sense constrain the movements of the train, but in doing so guide it smoothly in a definite direction" (Hung, 1997, 358). Being an enthusiastic innovator and a faithful traditionalist at the same time is precisely, as Kuhn puts it, the *essential tension*.

Later Kuhn (Early 1980s Onwards)

In the latter part of Kuhn's career there is a shift to the language considerations of science. From the essays in *The Road since Structure*, a collection of his essays produced between 1970 and 1993, published posthumously in 2000, we learn the four fundamental themes emerging out (Kuhn, 2000, 1-9): i) Science is undoubtedly a cognitive empirical investigation of nature, endowed with a special sort of 'progress'. But this progress is not towards the fullness of truth, but progress in ever-improving technical puzzle-solving ability; ii) Science is basically 'a social enterprise', where the scientists work within the community and only occasionally they move out of it to find solutions for certain anomalies; iii) Modifying the earlier notion of scientific development as a series of long period of normal science, occasionally punctuated by short periods of revolution, now Kuhn maintains that *science is period of development within a coherent tradition divided occasionally by periods of 'speciation'* (like the biological evolution of species of Darwin's theory), into two distinct traditions with somewhat different areas of research; and finally; iv) He distinguishes between *commensurable languages* (where translation is possible, between two languages, and therefore, what is said in one language can be said in another) and *incommensurable languages* (where only paraphrasing is possible between the languages), giving *a linguistic twist to the understanding of incommensurability.*

Theory Choice in Science

When scientists decide from various theories, Kuhn argues that they don't go by rational and epistemic considerations. There is no neutral algorithm or systematic procedure for theory choice, which takes place not only by the shared (or objective) criteria but also by "idiosyncratic factors dependent on individual biography and personality" (Kuhn 2002, 429). The non-epistemic factors are also of philosophical importance. Kuhn identifies five, among many other, important characteristics of a good scientific theory: *accuracy, consistency, scope, simplicity and fruitfulness of the theory*. He thinks that they are individually important and collectively sufficiently varied to make a good choice. Each creative discipline is characterized, among other things, by different sets of shared values. Kuhn prefers to call the shared criteria as *values, rather than rules*. Along with these values there are many personal or subjective criteria shaping theory choice: one's previous experience as a scientist, the duration of her research, extra-scientific persuasions (like philosophical or religious convictions), one's personal preferences, for instance, one may prefer originality to coherence (and therefore readiness for risks), while another may prefer vice versa and end up not taking risks. Thus an adoption of the new theory cannot be regarded as conscious choice on the part of that person. So declares Kuhn, "*No process quite like choice has occurred*, but they are practicing the new theory nonetheless" (2002, 436; emphasis mine).

Popper and Kuhn

Kuhn, in his paper, "Logic of Discovery or Psychology of Research" (1977), compares and contrasts his views with those of Popper. Some of the commonalities between them: i) both focus on the dynamic nature of science, rather than the strict logical structure of science; ii) both give equal importance to facts and the spirit of actual scientific life and thereby turning to the actual history of science and resulting in similar conclusions; iii) both emphasize the revolutionary process of scientific growth; iv) both reject the cumulative growth of science; v) both of them seriously doubt the possibility of any neutral observation language; vi) both agree that the aim of scientists is to arrive at explanatory theories; and finally vii) both of them give due importance to the concept of tradition in the enterprise of scientific knowledge. However, there are also *dissimilarities between them*: i) Popper makes falsification a regular and frequent occurrence, while Kuhn sees the need for this only at revolutionary periods, which occasionally take place; ii) Kuhn' idea of normal science, where most part of the actual science lies, is missing in Popper's framework; a beginner in science is primarily trained to work in normal science not to throw away the existing theories outright! iii) Kuhn does not agree with Popper's sharp distinction between context of discovery and context of justification; iv) For Popper the method of science is the method of falsification, and Kuhn sees no such single method; and v) For Popper science is non-inductive and rational, while for Kuhn science is non-inductive and non-rational.

Remarks

i) Logically and philosophically Kuhn's ideas may not be very attractive yet they are very persuasive; ii) In Kuhn's scheme paradigm a very important concept, but unfortunately, there is no clear understanding of it. Kuhn is vague and inconsistent with regard to the use of paradigm. Masterman enlists twenty-one various uses of the word in Kuhn's 1962 edition of *SSR*. Also it is not clear about the nature of the influence of the paradigms, whether psychological or logical, upon its members; iii) Kuhn's idea of theory-choice abolishes the idea that science is guided by a scientific method. Given this idea Lakatos labels Kuhn's science as "a matter of mob psychology" (Lakatos, 1970); and iv) Kuhn has been strongly criticized for his Incommensurability, as it is likely to land science in irrationality and relativism. Kuhn at the second phase prefers to look at incommensurability *metaphorically* and in terms of *linguistics*. With the change of theories not all the terms change in their meaning. While most of the meanings remain the same only some of the terms change in their meaning. "The terms that preserve their meanings across a theory change", says Kuhn, "provide a sufficient basis for the discussion of differences and for comparisons relevant to theory choice" (Kuhn 2000, 36), and therefore, "Incommensurability thus equals untranslatability" (Kuhn, 1990, 299). Since there can be no perfect translation, among scientists there is no side-by-side or point-to-point comparison; a scientist has to learn from scratch as a learner of a new language does.

Check Your Progress II

Note: Use the space provided for your answers.

1) Write a short note of Kuhn's notions of: a) Paradigm, b) Normal Science c) Revolutionary Science

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2) Kuhn speaks about *Essential Tension*. What is the tension he refers to? Explain what is essential about it?

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3) "Kuhn's view on theory choice leads to mob psychology in science" – Do you agree with this accusation? Substantiate your position.

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2.4 PAUL K. FEYERABEND (1924 - 94): LIBERATOR OF HUMANITY FROM SCIENCE

Feyerabend was born in Austria, in 1924. His studies (Physics) were interrupted by the World War II, in which he served an infantry officer in the German army. A bullet injury in his spine caused severe damages which troubled him till his death. After the war he switched over to philosophy of science. He spent a year in working with Karl Popper and for the rest of his life he lived in the USA. Strongly criticizing the positivists' view of science, he argued that their science was neither unique nor rational. He propagated this conviction, mainly in his celebrated works: *Against Method* (1975) and *Science in a Free Society* (1978). In this section, his significant ideas regarding the non-rational aspects of science and his sincere invitation to free human society from the clutches of science are presented.

Method(s) in Science Denied

Science is claimed to be rational because of its one (allegedly) special method. But history shows that there is no *the* method, suitable for all the domains of science. Feyerabend shows how Galileo systematically went against each of the rules of the methodological monists and this is a strong sign for the need for *methodological radicalism* and *theoretical pluralism*. Scientists violated the rules and even chose the opposite rules; they ignored the demands of rationality. Often these violations were *factual*, *deliberate* and even *absolutely necessary* for further growth in science. When a new theory is proposed it need not have all the empirical support as theories often obtain clarity only after a prolonged usage. To become empirically successful they need non-rational and non-sensical acceptance in the first place. Theoretical pluralism and methodological pluralism are preferable as they don't impose rigid rules on the scientific community and it is necessary for the growth of science, because, "Variety of opinion is necessary for objective knowledge" (1975, 46).

Epistemological Anarchism – Need not Lead to Chaos!

Anarchism, Feyerabend argues, is a requirement for any intellectual enterprise and he calls himself 'anarchist'. Anarchism may be objectionable in politics but certainly not in epistemology and this epistemological anarchism is needed to give the society the right picture of science. This is the aim with which he wrote *Against Method* (1999, 228). The absence of fixed rules in an anarchistic science will not land science in chaos. We need to trust in the well-ordered nervous system that the humans have developed over the millennia and this will save us from chaos (1999, 230). He does not encourage a chaos-like situation, in both theoretical pluralism and methodological pluralism.

Demands of Empiricism Rejected

Radical empiricism insists upon two conditions – *Consistency Condition* and *Meaning Invariance*. Feyerabend explains them as follows: "i) Only such theories are then admissible in a given domain which either contain the theories already used in the domain, or which are at least consistent with them inside the domain and ii) Meanings will have to be invariant with respect to scientific progress; that is, all future theories will have to be phrased in such a manner that their use in explanations does not affect what is said by the theories, or factual reports to be explained" (1999, p.926-7). He finds serious fault with both these criteria. Episodes from the history of science show that both these conditions have been violated, especially at those crucial points where great scientific revolutions took place; for instance, the relativity theory is shown to be violating both the conditions of consistency and meaning invariance. The first criterion, the *consistency condition*, increases the tendency to retain the older theory even in the face of contradictory observational evidence. A new theory is rejected if it goes against the prevalent theories; thus the age and familiarity become the basis for the theory elimination and "Had the younger theory been there first, then the consistency condition would have worked in its favour"

(1975, 36). Against the condition of 'meaning invariance', he maintains that 'contextual theory of meaning', by which, meaning of a term in a theory is determined by the context in which it occurs. For example, gravity was understood as physical force in the Newtonian theory of gravitation, while theory of relativity treats it as geometrical force. This meaning variance aspect leads to incommensurability.

A Strong Version of Incommensurability

Two competing theories are incommensurable. No common standards to evaluate their merits. Positivists argued that with the use of 'statements of purely observational language, uncontaminated by theoretical preconceptions', one can compare two theories. But since there is no pure observation and the meaning of the observation-terms of a theory is embedded in the theory, two theories can never be compared. This fact of incommensurability leads to a strict subjectivity in the realm of theory choice. Since there is no logical way of comparing various theories, we are left only with the "aesthetic judgments, judgments of taste, metaphysical prejudices, religious desires, in short, what remains are *our subjective wishes*" (1975, 285). Thus the notion of incommensurability shakes the claims of rationality in science.

Feyerabend – A Great Humanist

Feyerabend cautions humanity not to be carried away by scientism, the tendency to absolutize science. To ignore science is irrational, similarly to absolutize science is equally irrational. Being taken up by one-sided growth of science lot of harm is done to humanity and environment and therefore humanity is to be liberated from the clutches of science. Throughout his life his he voiced out his deep concerns for humanity and its liberty, in politics, science and in all intellectual pursuits. That is why he wanted the world to remember him basically as a simple and ordinary human being, who valued love the most. He wrote in his autobiography, on 11 February, 1994, just a couple of weeks before his demise: "My concern is that after my departure something remains of me, *not* papers, *not* final philosophical declarations, but love… That is what I would like to happen, not intellectual survival but the survival of love" (1995, 181).

Remarks

i) There are mixed reactions about Feyerabend's contributions. On the one hand, people like Gonzalo Munevar (1991) declares Feyerabend to be most important thinker of the 20th century, while on the other, there are people to call him 'a playful and childish thinker' who allows 'anything' to go (Schnädelbach, 1991);

ii) Feyerabend is against only the traditional understanding of rationality, which ignores subjective or rhetorical elements like judgement, emotions, intuitions, reasonableness etc. But he makes it clear that all these are essential components of scientific progress;

iii) It is encouraging to see that he does not reject metaphysics as meaningless. Not only the theoretical terms, but even the observational terms need theoretical background to understand. As Newton-smith has it, "… it is not that our observational judgments may have an ideological component, our observational judgments have no components that are not ideological" (1996, 139). That is why, Feyerabend is also convinced that "*a good empiricist must be a critical metaphysician*" (1998, 944).

iv) True, big scientists have produced very important theories by violating the well-cherished rules of their times and all scientists are not always rational in all the matters. But only a few that too the trend-setters of modern science fit Feyerabend's description; as Laudan says, "It is not scientific charlatans he is describing; rather… the figures he is writing about have always been considered as the folk heroes of our scientific culture" (Laudan 1989, 302), like Kepler, Copernicus, Galileo and Einstein, who come across as persistent 'cheaters' in the game of science, as they always seem to go counter-inductively, just not bothering about even the glaring falsifying evidence. Violation of rule is only an exception and but to make this exception a rule, that science always progresses, or has to progress this way, is a far-fetched claim. [Laudan's analogy: Just because a few cases of cancer spontaneously got cured without any medication, can one say, cancer does not need any treatment at all? Further, "To move from the alleged failure of two or three methodological rules to the presumption that all methodologies are hopeless is *to engage in just that sort of naïve inductivism about which he is otherwise so abusive*" (Laudan, 1989, 305-306)].

v) Feyerabend's idea of strong incommensurability is also problematic. If two theories don't have any point of comparison at all, we will not even know that they are completely different. Shapere proposes 'the chain-of-reasoning connections' between successive theories and the usages of the terms in them, which help us to compare them. At successive stages some properties or the other of the terms are dropped or added for specific reasons (Shapere, 2001, 199). For instance, from the times of Faraday and Thomson till today's quantum theory the idea of electron has changed greatly, but still we know that all these have been referring to something called 'electron'. The continuity and comparability of the usage is not due to some common descriptions or common reference, rather, "the rationale for saying that we have referred to the same thing all along is given by the linkage of reasons which gives continuity to the history" (Shapere, 1989a, 429) and thus incommensurability can be softened.

Check Your Progress III

Note: Use the space provided for your answers.

1) Write a short note on 'Epistemological Anarchism".

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....22) What are the two major conditions of the Classical Empiricism that are challenged by Feyerabend? Explain.

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2.5 NORWOOD RUSSELL HANSON (1924-67): CHAMPION OF THEORY-LADENNESS OF OBSERVATION.

N. R. Hanson, an American philosopher, a versatile personality – a baseball player, a heavyweight boxer and trumpet player, a daring fighter plane pilot and a creative writer in philosophy and history of science - served as a marine fighter during the World War II. He had his studies in Chicago, Oxford and Cambridge. He became the first university lecturer in philosophy of science. He has made significant contributions to the fields of philosophy of science, history of science, epistemology and aerodynamics. His well-known work, *Patterns of Discovery* (1958), clearly argued for the theory-ladenness of observational account. His eventful life was tragically cut short by a plane crash on a mountain near Cortland, New York, with ten of his books in progress.

The Relevance of 'The Context of Observation'

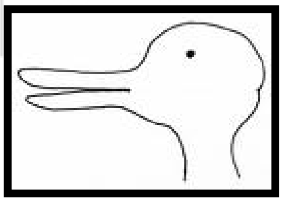
Hanson challenges the views of Logical Positivism (LP) in his very important book, *The Patterns of Discovery*. LP, focusing only on the finished products of science, seems to pay no attention to the *context of discovery*, as they think only the *context of justification* is important for philosophy of science. But Hanson argues that since all observations are theory-laden, this distinction between the contexts cannot be very sharp. He explains it with an example: Kepler and Tycho Brahe watch the sunrise; as Kepler believes in heliocentric universe and Brahe believes in the geocentric universe, do they see the same sun or different things? Traditional people would say, following the sensory core theory, that both see the same thing but interpret it differently but Hanson argues that both see two different things. For, interpretation is part and parcel of observation and 'seeing' already involves conceptions and theoretical frameworks (1967, 4-5).

Hanson explains this better with the examples employed by Wittgenstein in the *Investigations*; for instance, the picture of duck/rabbit or faces/vase. Seeing a picture as rabbit and seeing the same picture as a duck amounts to seeing two things. In seeing as such there is no interpretation involved. The change from rabbit to duck takes place fast and spontaneously. What changes is the organization of what one sees. 'The organization is neither an element in the visual field nor anything that registers on the retina; rather it is the way in which elements in the visual field are appreciated'. Such an appreciation involves theories. Thus what we see is influenced by the theories we hold. Hanson argues, therefore, that *seeing is always seeing that* and 'that' is something depends on the background one has. It is not the eyes or the camera that see things, but the people see and they always see with background theories and "there is more to seeing than meets the eyeball" (Hanson, 1998, 341).

Causality is Theory-laden

Hanson denies the traditional, metaphysical type of cause-effect relationship. Following Hume, Hanson sees causal relationship as psychological, with no necessary connection between them. Causality is human way of understanding the functions of nature, rather than a feature of nature itself. We find causality a convenient tool to explain natural phenomena, to simplify and facilitate inferences. The causal connections are limited to rare and accidental happenings. Causes are found with effects, not because of some cosmic bonds that keep them together, but because our theories connect them.

Logic of Discovery



After careful analyses of case-studies in history of science, Hanson comes out with a pattern of discovery: To solve a problem at hand, first a workable hypothesis is proposed. This must fulfil some expectations, like it must have initial plausibility for solving the problem, be coherent with the existing background assumptions, logical and empirical methods of testing. So for him the logic of discovery is 'inferring novel hypotheses' from problematic situations. He agrees that discovery of hypothesis involves ingenuity, creativity, insight and imagination but along with these psychological factors, there are also some logical aspects involved in the process of proposing a particular hypothesis. There are some reasons to propose hypothesis, *A*, rather than *B*. Testing a hypothesis is different from 'plausibility considerations' which help us to decide whether to propose a hypothesis or not. So the plausibility is also determined based on some evidence. For instance, to explain the velocity of Mars, Kepler considered a non-circular orbit, rather than taking into account the colour of Mars or the presence of other planets etc. He rejected many such factors, and decided upon the orbit of Mars as a plausible hypothesis. To choose this one as a plausible one, he had some reasons, not just psychological factors.

At the time of proposal, one cannot demand 'true' hypothesis, but one can look for 'plausible conjectures'. There is a distinction between 'reasons for accepting a hypothesis' and 'reasons for proposing the hypothesis in the first place'. To show that the context of discovery is not purely ruled by psychological factors and there are reasons to show why a particular hypothesis is considered worthy of testing, following C. S. Peirce, Hanson proposed *logic of abduction*, which investigates the norms used in checking whether a hypothesis is worth considering. [*Abduction* refers to the process of arriving at an explanatory hypothesis for a case at hand; we deduce *P* (e.g. it has rained) from *Q* (e.g. the ground is wet), because *P* is sufficient (or almost sufficient), but not necessary for *Q*. Peirce describes this kind of logical inference as 'guessing', that comes prior to induction and deduction].

Remarks

i) Hanson stirred a lot of controversy and debates in the philosophical and scientific circles, though he could not gain disciples. He seems to be more interested in critiquing others rather than developing his own system of well-thought out logical systems. ii) If Hanson treats causality as mere conjunctions as Hume does, he has to answer all the objections raised against Hume; for instance, how to differentiate accidental conjunctions and more regular law-like relationships between cause and effect? iii) Regarding the logic of discovery, he seems to have mistakenly conflated plausibility arguments (which help us to choose one from many available hypotheses) with discovery as such. Further, though it is meaningful to distinguish the 'plausibility considerations' in proposing a hypothesis from the procedure of confirming it; but it is not clear whether they are merely subjective prejudices and psychological beliefs of the scientists and whether or not they have any legitimate role in science. So, though he gave us the patterns of scientific discoveries, he could not work out logic of discovery.

Check Your Progress IV

Note: Use the space provided for your answers.

1) "Observation cannot be separated from interpretation". Discuss this claim with reference to Hanson's ideas on observation.

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2) What is the 'logic of discovery' of Hanson. Do you agree with it? Explain.

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2.6 LET US SUM UP

Historicist philosophers of science have challenged the rational and objective picture of science, proposed by the logical positivists. Kuhn, Feyerabend and Hanson and others argue that no methodology or criteria for rationality is to be thrust upon science; rather they emerge from the actual practices of the scientific community. They insist on the need for socio-cultural, historical and moral factors to understand science and to do philosophy of science. However, with this approach, one may make science totally relative and irrational if one is not cautious. This is perhaps taken care of by the historical realists (See: Unit 3), who treat science as social enterprise while upholding its rational character as well.

2.7 KEY WORDS

***Incommensurability*:** It simply means 'communication breakdown'. Since historicists stress the 'contextual theory of meaning' of the terms in a scientific theory, they argue that the followers of different scientific paradigms suffer from the problem of incommensurability in understanding each other.

Theory-ladenness of observation: There is no 'pure' observation; no observation is theory-free. Human observation is not like the recoding by an instrument. It is not that we see something and then interpret, but our seeing itself involves interpretation, as our seeing is coloured by our background theories. It is not that 'eyes' see, but 'we' see.

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UNIT 3 HISTORICAL REALISM

Contents

3.0 Objectives
3.1 Introduction
3.2 Lakatos: Enriching Popper and Kuhn
3.3 Shapere: Transcending Classical Empiricism and Rationalism
3.4 Larry Laudan: Science - A Problem-Solving Enterprise
3.5 Let Us Sum Up
3.6 Key Words
3.7 Further Reading and References

3.0 OBJECTIVES

Some philosophers of science in the later decades of the 20th century made attempts to envisage a picture of science and philosophy of science, which would be more comprehensive, by avoiding the extremes of both Logical Positivism and Historicism. They pay due importance to the historical, social and non-rational aspects of science, while maintaining the rational character and a sort of realistic picture of science intact. These postpositivist thinkers can be categorized as Historical Realist Philosophers of Science. This lesson seeks to familiarize the students with some of the salient contributions of some of the philosophers of science belonging to the school of Historical Realism.

3.1 INTRODUCTION

Some historians like, R. G. Collingwood, for whom "perception and history are identical" (1924, 204), argue for a realistic view of history. They tend to take 'history' as the exact description of what happened in the past. But there are strong reactions against this view; history necessarily involves interpretation of what, how and why something happened. It is never a clear description of the past as it all depends on who writes history. Critiques like Goldstein argue that historians cannot be taken to be as 'constituting history' (1976). In philosophy of science also the role of history cannot be exaggerated, as history of science is not a real description of what happened in the past. Historical Realism, the contemporary dominant school of philosophy of science, is said to be a mid-way position between Logical Positivism (LP) and Historicism, in viewing the role of history of science in envisaging science. The historical realists argue that both made the mistake of going to the extremes: LP absolutized science, while Historicism went to the other extreme of relativizing science and rendering it almost irrational. So the historical realists as opposed to Logical Positivism say everything in science is changeable, as nothing is final and absolute; however, against historicists, they show that these changes take place in a rational and responsible manner, and therefore 'anything' cannot go in science. They understand rationality in science in a non-traditional way and new criteria for rationality emerge from the scientific community. All these go to show the compulsory need and relevance of history of science to do philosophy of science. We discuss some of the contributions of three philosophers of science of this school: Lakatos, Laudan and Shapere.

3.2 IMRE LAKATOS (1924-74): ENRICHING POPPER AND KUHN

Lakatos, born in Hungary in 1922, lived in a very disturbed times of the World War II. Though his mother and grandmother were murdered, he could escape. Pursuing a political career, by 1947, he became a powerful figure with the Hungarian Ministry of Education. He was nevertheless imprisoned in 1950; later he escaped to Vienna in 1956; thence to Cambridge, where he worked for his second doctorate under R.B. Braithwaite. Attracted by Popper's ideas he regularly attended his lectures. Lakatos' famous work, *Proofs and Refutations,* a collection of his articles in philosophy of mathematics, posthumously published in 1976. He challenges LP's claim of sharp distinction between *the context of discovery* and *the context of justification.* He started teaching in England. The government did not grant him citizenship, and so he remained technically 'stateless'. In 1974 he had a sudden death of heart attack.

Scientific Research Program (*SRP*)

Science is made up of many *Research Programs*, involving a series of theories. Scientific revolution consists in one research program superseding, not necessarily rejecting, the previous one. There are series of theories which are related to one other like T_1, T_2, T_3, T_4.... T_n, where each being an improvement upon the preceding one. Example: *Research Program of Copernican system*. In 1543, Copernicus gave us the theory of heliocentrism. Though it was rather crude, the basic idea of having the stationary sun at the center was correct. But other aspects like epicycles, circular orbits of the planets were not correct; let this be COP_l; Then came Kepler, who removed the epicycles and replaced the circular orbits with the elliptical ones; but Kepler could not say why planets move in ellipses; this we call COP_2. Then Hookes explained the elliptical path with centrifugal force and this can be COP_3. Newton, with his mathematical maneuver, made it still better and let this be COP_4. Laplace made the theory even better, by explaining scientifically the stability of the solar system, which Newton could not do; in fact, he postulated a plumbing God. Laplace's theory can be COP_5. Thus the Copernican system reached its betterment with the contributions of many, each one improving the previous one. Science must be assessed in terms of such *SRP*, not of individual theories (Popper and logical positivists hold that a theory or a law is the basic unit of inquiry in science). *SRP* is much more comprehensive than a theory. (e.g. Instead of looking at individual kings, like *Karikalan, Raja Raja Cholan*, etc. of the *Chola* period of the ancient South India, we must take the whole of *Chola* period as one unit).

Two Parts of a *SRP*: i) *Negative Heuristic or Hardcore* - Every *SRP* has a core part, giving the very identity of the programme. It is the metaphysical presuppositions of the programme. Individual theories may be rejected but as long as the hard core is kept intact and the programme keeps going. It is the non-negotiable part that cannot be compromised or changed. It is forbidden to modify or reject it; since it forbids any change it is called negative heuristic. (Examples for the hardcore: Sun-centredness in the Copernican system; the mechanical view of the world in the Newtonian system). ii) *Positive Heuristic or Protective Belt* - Positive heuristic is the changeable part of the *SRP* that protects the hardcore from being challenged. It allows changes to keep the hardcore intact. It consists of partially articulated sets of suggestions. It specifies the directions in which the research must proceed. It directs us how to take care of the anomalies and modify the research program. It also contains metaphysical principles. (E.g. Orbits of the planets, either elliptical or circular in the Copernican System).

Evaluation of a *SRP*: It is evaluated in terms of the nature of the problemshift. It is *progressive* if it is able to explain all the problems of the facts of the previous programme and to predict new facts. It is perfectly rational to pursue the new programme even if any one of the conditions is met with. A progressive research program is *theoretically progressive* if every successive theory has some excess empirical content and more predictive power than its predecessor and it is *empirically progre*ssive if some of its excessive empirical content is corroborated. Thus *SRP* seems to give a rational picture of science because at least some of the predictions must be established. A progressive research program is one, which is both theoretically and empirically progressive. A problemshift is *scientific* if it is at least theoretically progressive, and if not, it will be *pseudoscientific*. (Thus he does away with the falsification criterion to demarcate science from non-science). A *Degenerating* programme would be not only not giving new facts but also not explaining those of the previous programme. So it is not progressive both theoretically or empirically.

Rejection of a *SRP*: *SRP* is never rejected in haste even if it is degenerating and it is only shelved aside. According to LP, if a theory cannot be verified (for Popper, if not falsified!), it has to be thrown away. But Lakatos argues that we can know whether a research program is degenerating only by hindsight. For example, Newton initiated the particle theory of light. As a genius, he also knew the wave theory but he realized that the wave theory was not tenable for light. But by the crucial experiment conducted by Fizzau and Foucoult the particle theory was rejected. Einstein resurrected it. Hence it is rational to work on degenerative problems instead of rejecting it outright.

Proliferation of *SRP*: There is no possibility of inductively confirming a theory. There are lots of problems in induction philosophically, though it works in actual practice. The hardcore of a research program is may be false. We can know whether it is true or false only by inductively conforming. But since induction has problems, no amount of testing theories of research program can guarantee the validity of theory. It is irrational to assume that any particular research program is true for ever. So the truth of a research program cannot be absolutely guaranteed. If truth can be guaranteed, then it is enough to have only one research program. If not, then it is good to have many research programs and by comparing them accept what is better. We can only talk of comparative superiority not of absolute superiority of *SRP*.

Lakatos, Kuhn and Popper

Lakatos aims at a sort of a synthesis of Popper and Kuhn, as though grafting the revolutionary ideas of Kuhn on the Popperian tree; Popper gives him, so to say, the frame work and Kuhn gives him the contents. Going along with Kuhn, he saw that the basic unit of analysis in science must be much broader than a single theory. Lakatos' *SRP* is very similar to Kuhn's paradigm but Lakatos demands many *SRP*s at a given time. Paradigm, for Kuhn, gives the worldview but for

Lakatos, *SRP* does not give any worldview. Kuhn's normal science period has a dogmatic nature; the scientists in it cannot easily challenge the paradigm and try to absorb the anomalies into the existing system. But *SRP* rules out such dogmatism, as Lakatos combines it with the Popperian attitude of dropping a degenerating *SRP*, 'under certain objectively defined conditions'. Thus, the continuity in science in Kuhn's scheme is 'socio-psychological', while in Lakatos' framework it is 'normative' (Lakatos, 1978, 90). Further, he finds Kuhn's account of theory change (adoption of a new paradigm) to be not rational; further, it fails to distinguish actual science from pseudo science. But Lakatos, with the notions of 'progressive' or 'degenerating' problemshift, tries to make the Kuhnian account more rational, which would also demarcate science from non-science.

Lakatos called himself a disciple of Popper. In many ways he followed Popper; for instance, like Popper, he also argued for proliferation of theories and comparative superiority of theories. However, though Lakatos began as a popperian, slowly he moved on to critique Popper's views. His paper "Changes in the Problem of Inductive Logic' (1968) was actually a defence of Popper's view of inductive logic, while "Popper on Demarcation and Induction" (1974) was a serious critique of Popper's solution of Hume's problem. Popper and Logical Positivists saw an unbridgeable gap between the 'context of justification' and the 'context of discovery'. They all insisted that science and logic must be concerned only with the context of justification not with the context of discovery. Disagreeing with this, Lakatos proposes a new concept of philosophy of science, which dilutes any such distinction.

The unit of inquiry for Lakatos is not a theory but a *SRP*. Popper rejected a theory if it was not falsifiable, but Lakatos is not for any hasty rejection of *SRP*. Popper's falsification was proved to be untenable, as Duhem-Quine showed that any theory could survive falsification with ad-hoc modifications. Lakatos proposes a modified falsification: A theory can be considered falsified only when an alternative theory is proposed with the following features: the new theory has *more empirical content* than the falsified one; it is able to *predict more novel facts*, which were improbable or even forbidden by the first theory; it *solves all the problems solved by the previous theory*; and it has *more content that is corroborated* (1970, 116). Therefore, unlike Popper, Lakatos argues that a theory cannot be dropped even if it is falsified, unless there is an alternative theory is available. A theory can be dropped, as pointed out above, only when the whole of *SRP*, of which it is a component, becomes degenerative and gets rejected as a whole *SRP*.

Remarks:

i) Lakatos succeeds to a certain extent in integrating Kuhn's ideas of Science as a social enterprise with the Popper's normative methodology. Like Kuhn, Lakatos is convinced that science is always guided by a theoretical framework. But he makes his *SRP* normative, as Popper makes falsification.

ii) In the framework of *SRP*, a theory becomes a better theory by superseding the previous one. With this move towards betterment, Lakatos carefully avoids the issue of truth and verisimilitude of Popper's ideas.

iii) By making problemshift as the criterion for the demarcation of science and pseudoscience, Lakatos is not drawing a strict line between scientific and non-scientific theories, but he recommends a certain methodology, by which, one has to construct theoretically progressive problemshifts, and avoid going in for degenerating ones.

iv) Lakatos gives due importance to historical dimensions of philosophy of science. A methodology must study both successful and not-so successful episodes of history of science and look for influence of the 'external factors' (e.g. political or religious interference) in science. History of science is very essential to do a proper philosophy of science because, as he rightly declares: "Philosophy of science without history of science is empty; history of science without philosophy of science is blind" (Lakatos, 1971, 91).

v) *SRP* is better described as a theory of historiography, rather than a 'methodology of research programme'. For, it does not give us strict rules of practice; it is not very clear as to when to abandon a *SRP*. Critics have pointed out that if a methodology has not given instructions about the choice from competing research programmes, it is not really a methodology. Lakatos seems to give only a 'framework' or 'theory of historical appraisal' and not any 'scientific and practical methodology'.

v) Musgrave argues that 'hardcore' of *SRP* is not historically correct and methodologically effective; for example, the scientists before 1850 did not treat Newtonian gravitation law as a part of hardcore. The elements in the hard-core are also not refutable, but treated as the fundamental theoretical postulates or axioms of a theory. It is a sort of a convention amidst the scientists that makes them hold onto hard-core in spite of anomalies (Musgrave, 1978, 110). The role of the individual scientists is minimized, while the significance of convention is stressed more. Further, Lakatos does not elaborate how certain hypotheses are to be chosen for 'hardcore' category.

vi) Edwin Hung (1997, 403) and other critics point out: Lakatos insists that in a progressive *SRP* the successive theories must have more 'empirical content', but this is a vague concept, as in many of the cases, it is not possible to ascertain this. Also, he claims that the latter theory must have more explanatory power than the previous one, but he has not given a clear notion of explanation, say, whether it is a contextual or causal or edificatory theories of explanation. Finally, if Lakatos distances himself from the question of truth or nearness to truth (Popper's verisimilitude), why are the scientists expected to choose the progressive programmes and what would be the criterion to choose one programme from the other?

Check Your Progress I

Note: Use the space provided for your answers.

1) What is a *SRP* in Lakatos' scheme? What is its significance in understanding science? How is it evaluated?

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2) Compare and Contrast Lakatos' *SRP* with Kuhn's Paradigm.

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3.3 DUDLEY SHAPERE: TRANSCENDING CLASSICAL EMPIRICISM AND RATIONALISM

Shapere, one of the leading philosophers of science of our times, had his doctoral studies at Harvard and worked at several prestigious institutes. His famous works include *Galileo: A Philosophical Study* (1974) and *Reason and the Search for Knowledge – Investigations in the Philosophy of Science* (1984). He critiques both logical positivist and the post-positivist philosophies of science to arrive at a balanced understanding of science. He has taken it up as his life-vocation to delve into the philosophical foundations of science. He is known for his innumerable, even complicated, case studies from history of science to substantiate his position. He has taken philosophy of science as his life-mission. About the project of his recent works, *The Rational Dynamics of Inquiry* and *The Values of Knowledge*, he mentioned to me in a personal interview on 6th October, 2006, at his residence, in North Carolina, USA, "I mainly do it [writing the books] for myself; it clears up what I am".

Shapere's important ideas like methodology, observation, meaning and incommensurability in science, the notions of domain and goal success, the absence of specific doubt in science, the role of 'the given' in experiments, the need to learn how to learn etc. – all seem to be a well-connected web, as though they are different nodes in a fishing net. However this section discusses only two main contributions: the notion of observation and contingent interactional empiricism.

Observation as a "Concept Schema"

To understand the contemporary sophisticated science, Shapere argues, it is better that one treats the important concepts like *observation, meaning, reality, truth, knowledge*, and so on as 'concept schema', rather than individual concepts. For, the meanings of these concepts are not given once and for all as one individual concept; rather they develop over the years, with all related aspects. A concept schema implies that: i) it is formulated in terms of a 'framework' that remains reasonably stable over a significant period of time, or over contemporaneous areas of inquiry; ii) It is treated as part of 'an approach to inquiry' and the interpretation of its results.

Classical empiricism wrongly equates observation with sense perception. With the insistence of sense perception, classical empiricism is not only insufficient to understand science and its problems, but also it is largely irrelevant and even positively obstructing the process. For, even if all our knowledge were shown to be ultimately based on sense perception we would still not know or understand knowledge fully, as our sense perception covers only a limited section in the whole range of Electro Magnetic (EM) spectrum. The normal light, which is visible to our human eyes, is just one portion of the vast spectrum (0.4 – 0.7µm). Gamma rays, with extremely short wavelength as short as a billionth of wavelength of the visible light, are at the one end and at the other end are the radio waves, with trillion times higher wavelength of the visible light. "The eye" therefore, "comes to be regarded as a particular sort of electromagnetic receptor, capable of 'detecting' electromagnetic waves of the 'blue' to 'red' wavelengths, there being other sorts of receptors capable of detecting other ranges of that spectrum. This *generalized notion of a receptor or detector* thus includes the eye as one type" (Shapere, 1982, 505).

There is no 'pure' observation and all observations are theory-laden. Modern science does not hold "evidential as perceptual", because sense perception is often unreliable (seeing the half-immersed stick as bent) and incapable (in the areas of too small or too big in size or with the objects too near or too far) (Shapere, 2000). The conditions for something to be observed (observable) are: i) information is received by appropriate receptor; ii) that information is transmitted directly, without any interference, to the receptor from the entity" (Shapere, 1988b, 308); and iii) "The information is transformed by appropriate devices into humanly-accessible information which is (eventually) perceived by a human being" (Shapere, 1982, 517). This interpretation makes observation intelligible to humans.

What is observable / unobservable is, thus, determined by *a number of factors*, like: the instruments used; the theoretical knowledge which tells us the nature of interactions; the theoretical possibilities of detection of particular interactions, and how the particular interactions give information about its sources. Thus the concept of observation is not a single notion to be captured by a logical or a priroi analysis. It is a concept schema evolving over the years, intertwined with the methodology and background knowledge.

The Scientific Status of Unobservable in Modern Science: There are certain things that can never be perceived directly like the particles in the cloud chamber, as one can observe only the track of the particle. Modern cosmology teaches that the part of the universe will not be observable by us unless it enters our horizon, and "if the universe is infinite, that, at any given time, there will always be regions which are unobservable" (Shapere, 2000, 159). Particle Physics and modern cosmology encounters problems and theories for which observational or experimental tests appear impossible, even in principle. For instance dark matter and dark energy cannot be directly observed but can be known only from the effects they create. Classical empiricism might ignore all such entities and theories as unscientific as they are unobservable and untestable, but Science considers all these as legitimate objects of scientific study, though they are unobservable in principle.

Of course, Shapere does not permit any bizarre entity / theory to be treated as scientific. He gives guidelines to *distinguish between legitimate and wild / loose speculation in accepting something observable in science*: i) If that entity is logically and mathematically implied by something that is already observable or has observable consequences; ii) If it is needed for consistency considerations, even though it is not implied by the observable parts of the theory; and iii) If it provides answers to problems concerning the observable parts of the theory with which no other solution deals successfully. These guidelines of course are to be taken in spirit, not in letters. However, despite the liberality, it is by no means the case that 'anything goes' (Shapere, 2000, 159).

Rational Descendent of Classical Empiricism: Transcending Traditional Rationalism and Empiricism

Traditionally two major epistemological groups, *Empiricism* and *Rationalism*, have tried to clarify the issues related with knowledge and knowing. While empiricism maintains that all pieces of knowledge (concepts & beliefs) are rooted in experience, for their source and justification, rationalism argues that at least some knowledge is attainable by reason, independent of experience, without any interaction with the reality outside. *Problems with empiricism*: i) it fails to clearly clarify what is meant by pure observation, which does not need any interpretation, and to show how all the other non-observational beliefs are rooted in observation; ii) it fails to realize that sense experience does involve inference, as there is no pure 'given' available. If the importance of the 'given' in experience is stretched too far, one would land in 'solipsism', as one cannot justify believing in anything beyond one's own experiences; one can't speak of past or future, which are basically inferential in nature, going beyond the 'given' of here and now (Shapere, 1988b, 301); iii) Empiricism's claim, "all our knowledge is based on sense experience" – is it analytic (a matter of definition)? or empirical (a matter of fact)? In both cases it would be highly problematic: "if analytic, it can, on its own principles, tell us nothing about the matters of fact with which it seems to be concerned; but if it is empirical, it cannot be established with absolute certainty" (Shapere, 2000, 161). Therefore empiricism itself (like its conclusion) is an empirical doctrine, and so it can bring itself to a stage at which it outgrows itself. *Problem with rationalism:* i) It could not establish any substantive truths about reality, totally independent of any connection with the senses; ii) Even the compromise proposed by Kant to synthesize both empiricism and rationalism is also problematic; for, Kant's *a priori* intuitive forms of Space-time category and the Principle of Causality have been seriously questioned by the contemporary physics [See: Shapere, 1988].

Shapere views the knowledge-seeking process (science) as *Rational Descendant of Classical Empiricism:* it is empiricism, because we have to interact with the world to learn about it; and it is rational descendant as well, because we have to learn what it is to interact; with the help of the background information we have to learn to how to learn. It *is neither an aprioristic rationalism nor a sensory empiricism,* though it takes certain important aspects from both of them into consideration: namely, we bring some background information to interpret the data available, however that background information is changeable for specific reasons; *it is neither relativist nor foundationalist,* due to the fact that the observation–situation is infused with background information and there is 'the given' in the whole of inquiry; *it is both historical… and rational*, because even what counts as 'reason' too emerges over the periods of history, and finally it is far more concerned with content than with logical form, though logic is not excluded (Shapere 1995, 25-26).

Remarks

i) *Shapere's balanced approach:* Though Shapere does not take extreme positions his views deserve serious consideration; he evokes a lot of reactions from philosophers and philosophers of science, probably because he attempts at a balanced view between the positivists and the historicists. Not just a compromise, but he seeks to transcend both by inculcating the strengths, and avoids the weaknesses, of each other, offering "a coherent and often attractive vision of scientific inquiry" (Nickles, 1985, 310).

ii) *The Role and the Need for Background Information:* Shapere has shown, rightly so, as to how science bases itself on background information and at the same time preserves its rational character in terms of the 'given'. Modern science has taught us that we need 'to learn how to learn' about reality, how to think and speak about it, how to refer to what we study and how to judge the results of our investigation (Shapere, 2001, 200). The demarcation between the observable and the unobservable, the scientific and the non-scientific, scientific possibilities and impossibilities, scientific problems and pseudo-problems – all these "are not something given once and for all, but rather shift as our knowledge and understanding accumulates" (Shapere, 1978, 1000). Therefore, science is an enterprise that has evolved over generations, building on background information. This reveals the central importance of historical dimension in science.

iii) *Shapere on Observation:* As observation is not sense perception, Shapere argues that humans are needed only at the end of the process of observation, where it has to be interpreted. Jan Faye, however, argues that an observation as such needs some human observers. Observation involves some sort of beliefs and therefore what is done by an instrument is in fact only a measurement. If no such beliefs are involved in observation there is hardly any difference between a camera 'seeing', a scanner 'reading a document' and human observing. Since beliefs are involved in human observation, we are not merely seeing something, but are seeing that 'something is the case' and "this intentional component is that which elevates perception to observation" (Faye, 2000, 173).

In analysing the notion of observation, we suggest, he includes consensus in the scientific community as fourth condition. Perhaps, he thinks that the notion of background information takes care of this aspect. But I think it is so important in modern science that it needs a specific mention. This consensus is also one of the tools to overcome the experimenters' regress in modern science, especially when an experiment is done to decide whether an entity exists or not. The issue is: a correct result of an experiment is one that occurs when the experimental apparatus is functioning properly (and it uses proper method), but we check proper function of the apparatus by whether or not the experiment returns the correct result *(http://www.galilean-library.org/blog/?p=105).* If the results are positive one can conclude that entity/field/force in question exists; if negative, it does not exist. But there can be methodological or mechanical or mathematical errors and because of which the said entity is detected, or not detected. There seems to be no other way of checking it out independent of all these procedures. Such areas of investigations largely rely upon the consensus in the scientific community.

iv) *Shapere, a Seeker of Knowledge with Openness:* Shapere invites us to learn how to learn from nature. He comes across a genuine seeker of knowledge with much openness: "We must be prepared for the possibility that there are indeed more things in heaven and earth that are dreamt of in our present picture of the universe. Even other universes" (Shapere, 1987, 331).

Check Your Progress II

Note: Use the space provided for your answers.

1) How does Shapere enrich the notion of observation? What are its implications in understanding modern sophisticated science?

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2) Shapere claims to have transcended classical empiricism and rationalism to have a holistic picture of science. Is his claim justified? Explain.

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3.4 LARRY LAUDAN: SCIENCE – A PROBLEM-SOLVING ENTERPRISE

As Laudan he acknowledges in his prominent work, *Progress and Its Problems* (1977), he is always happy that he was taught by and / or to work with many stalwarts of philosophy of science, as Hempel, Kuhn, Feyerabend, Popper, Lakatos, Adolf Grunbaum and so on. This in a way makes it clear that all these people have influenced his thinking. He attempts to take the works of Kuhn and Lakatos further to have a better understanding of science and its methodology. In his *Science and Hypothesis* (1981) he traces the method of hypothesis from Galileo and Descartes to Peirce, to show the important role of hypotheses in the natural sciences and to study the philosophical efforts to analyze the structure of hypothetico-deductive explanation. His another important work *Science and Values (1984)* is not about ethics of science and scientists; it is about the cognitive values involved in science and its methodologies. He focuses on rationality in science, rather than morality in science, though the latter is also of great importance.

Empirical Problems in Science

All the questions about the functions of nature - why things fall to the earth, why offspring manifests the characteristics of the parents - and many such queries are empirical problems. He differentiates between *problems and facts,* between *solving a problem and explaining a fact.* Problems arise in a given context; the theoretical background information informs us what, and what not, to expect, and this in turn decides what is normal and peculiar. What is problematic in one domain of inquiry may not be problematic in another context. A scientific theory is a 'solution to an empirical problem'. Here one need not worry about the truth or falsity of the theory, because its ability to solve a problem at a given time is that which matters and it may even turn out to be ineffective to solve later. Science is nothing but a 'problem-solving system'. Science, therefore, does not aim at truth, but only on problem-solving ability.

Science solves empirical problems, roughly in terms of explaining the phenomena. Science has to explain not only the usual phenomena but also anomalies. If an empirical problem *p* has been solved by a theory, then for other theories in the relevant domain, which cannot solve the problem, *p* becomes an anomaly. So unless we have a theory to explain a phenomenon, it will not be considered an anomaly. [According to Newton's theory, there was some discrepancy in determining the orbit of Mercury; they postulated the presence of another unknown planet to explain the discrepancy of Mercury, but unfortunately this planet was never discovered. The discrepancy was not considered as an anomaly, until Einstein's general theory of relativity explained the discrepancy in 1916]. Solving an anomaly, however, is only a secondary aim of science. In fact, anomalies are not in nature, but they reveal the lacuna in theories; "Anomalies are anomalies for theories. They are symptoms of diseases – not disease of nature, but diseases of theories" (Edwin Hung, 408). Thus empirical problems can be either problems of explanation or anomalous problems. The progress of science can be assessed in terms of the problem-solving effectiveness of theories (Laudan, 1977, 68).

Conceptual Problems

In science conceptual problems are more significant than empirical problems. Empirical problems are related to experiments, observation etc., but conceptual problems are richer. More than empirical problems, conceptual problems enable science to grow. When a theory is proposed to solve some empirical problems, very often they end up creating some conceptual problems, which can be either *internal* or *external*: "Conceptual problems arise for a theory, T, in one of the two ways:

(i) When T exhibits certain internal inconsistencies, or when its basic categories of analysis are vague and unclear; these are *internal conceptual problems*. [E.g. Bohr's model of atomic theory can be an example for the internal conceptual problem; his model involved the picture of classical electrons, yet he spoke about their radiating energy in discrete quanta, an idea given by new quantum physics much later].

(ii) When T is in conflict with another theory or doctrine, T', which proponents of T believe to be rationally well founded; these are *external conceptual problems* (Laudan, 1977, 49). [E.g. When Copernicus proposed the heliocentric theory, it had external conceptual problem, as it was inconsistent with the prevailing Aristotelian theory of geocentrism. Conceptual problems can also arise from *differing worldviews of the scientists*. [E.g. When Newton proposed the gravitational theory between the sun and the planets, his critics like Leibniz and Huygens were not ready to accept it because they could not understand the notion of 'action-at-a-distance', as they were engrossed with the Cartesian worldview of action-through-contact]. Further, conceptual problems can also arise due to *the difference in the methodologies*. [E.g. problems due to LP's inductive method or Popper's Hypothetico-deductive method].

Research Tradition (*RT*)

In order to improve upon the notions of Kuhn's paradigm and Lakatos' *SRP*, Laduan proposes 'Research Tradition' (*RT*), which provides science with ontology and methodology.

Like a paradigm, *RT* specifies the kinds of fundamental entities to be used in theories, and it defines its own empirical problems. However the difference between paradigms and *RT* is: the replacement of one paradigm by another is like a gestalt switch, sudden and abrupt, and also like a psychological conversion, whereas the *RT* changes step by step, as they have hard-core, which does not easily give in to changes. Similarly, unlike Kuhn's paradigm, there can be more than one competing *RT* can exist. *RT* can evolve over time, and sometimes two traditions can get amalgamated (Laudan, 1977, 104).

The *efficiency and adequacy* of a *RT* can be assessed at a given time or can be done over a period of its lifetime. The *RT* with the most problem-solving efficiency is accepted; however other traditions are not rejected immediately; they also can be taken for further pursuit, because they may be able to solve it in future. Scientists may decide to pursue a *RT* though they may not accept it and there can be several *RT*s at a time: "while it is only reasonable to accept one research tradition at any one time, it is not unreasonable to pursue several research traditions simultaneously" (Edwin Hung, 412). For Kuhn there can be only one paradigm; Feyerabend insists that scientists work in different paradigms for science to be progressive; and for Lakatos it is better to be with the progressive *SRP*, though it is not irrational to stay with the degenerating *SRP*; but Laudan by cleverly distinguishing between accepted tradition and pursuing tradition, has achieved a sort of compromise between all the three methodologies.

Remarks

i) To say that science aims only at solving the problems may not be a right description. Scientists do expect and believe that theories give some sort of truth or insights about the nature and structure of the world. Only for outsiders science may appear just to be a problem-solving activity and one will not know what scientists do and how they look at science. Problem-solving may be one of the important aspects of science but this fails to capture the richness of what science can and does accomplish. Moreover, in science many problems are not yet solved (may be, never) like the origin of the universe.

ii) One may question that by solving problems science does not actually make progress though one may get better insights. By solving a problem 4-3=1, what has one accomplished?

iii) Laudan does not give any criterion to show what is, and what is not, a satisfactory solution. Also the problem-solving effectiveness is not a quantitative measurement; Further, solving an empirical problem is in fact to explain the problem. But he does not explain what a scientific explanation or a theory is, nor the relationship between them. Without making all these elements clear his methodology is rather empty (Hung, 1997, 413).

iv) Laudan agrees that there is no theory-neutral language or theory-free observation. But the theory-ladenness does not lead to the famous problem of incommensurability. For he explains that the assumptions to understand a problem and those to solve it are different. Different people can propose different theories to solve a problem, but the understanding of the problem may be common. For instance, about the nature of light, particle theory (Newton), longitudinal wave theory (Huygens) and transverse wave theory (Young and Fresnel) were proposed, but since all shared the common problem about light, these theories were comparable. But since Laudan has not analysed what an explanation is, and theory is, we cannot understand cross-theoretical explanation, and thereby the problem of incommensurability is left unaddressed.

Check Your Progress III

Note: Use the space provided for your answers.

1) How does Laudan distinguish between empirical and conceptual problems in science? What are the advantages of the latter ones?

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2) Compare and Contrast Laudan's *RT* and Kuhn's *Paradigm*

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....3) Is Laudan's RT more adequate than Lakatos' SRP in understanding science? If so, how? And if not, why not?

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3.5 LET US SUM UP

The approaches of historical realist philosophy of science have been explained with the help of the salient features of Lakatos, Shapere and Laudan. Each one has tried to enrich the picture of science and the role of history of science in doing philosophy of science. Lakatos' *SRP*, Sphere's notion of observation as *concept schema* and Laudan's *RT* are sincere attempts to show how science can be rational, while still being faithful to the socio-historical and non-rational factors. This lesson has discussed some of their merits and demerits.

3.6 KEY WORDS

Unobservables in Science: It refers to the entities, fields, events or phenomena which cannot directly be observed (e.g. electron, magnetic field, radio waves etc). Scientific realists claim that they exist in reality, independent of us, while antirealists deny it, claiming that they are only convenient tools to deal with nature.
Scientific Research Programme: It is the basic unit of science according to Lakatos. Each programme has unchangeable hardcore and changeable protective belt.
Research Tradition: According to Laudan science is made up of research traditions. Though it is similar to Kuhn's paradigm, it does a better job to maintain the rational character of science.

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UNTI 4 KEY ISSUES IN PHILOSOPHY OF SCIENCE

Contents

4.0 Objectives
4.1 Introduction
4.2 Discovery of Theory of Science
4.3 Perception, Thought and Language
4.4 Generalizations, Hypotheses, Laws, Principles and Theory
4.5 Scientific Explanation
4.6 Methodological Problems in Social Science
4.7 Let Us Sum Up
4.8 Key Words
4.9 Further Readings and References

4.0 OBJECTIVES

The unit tries to dwell on the key issues in philosophy of science such as induction, observation, perception, hypotheses, generalization which are very crucial in understanding the issues in philosophy of science.

4.1 INTRODUCTION

Philosophy of science is interpreted as a critique of science. Another interpretation is that it is an inductive metaphysics. The third interpretation is that it is a pragmatic of science. As a critique of science it analyses the language of sciences; the semantics and syntax of scientific language is analysed. As an inductive metaphysics, it uses the inductive method of science, but unlike science it focuses on the study of transcendental entities also. The key issues in philosophy of science include scientific method, discovery of theory in science, structure and validation of scientific theory and scientific explanation. As pragmatics of science philosophy of science tries to relate the findings of the scientists to the human welfare and upliftment.

4.2 DISCOVERY OF THEORY OF SCIENCE

The philosophy of science considers the various sciences as finished products of a historical process. The historical order of development is determined by curiosity, accident, or the pressure of necessity. Science explains, while philosophy tries to understand. All scientific theories can be traceable to the acceptance of four matters of facts: That something exists; that something can be known; that there is something which matters; and that something makes sense and can be reflected upon. The above four matters of fact correspond to four branches of philosophy; Ontology or the theory of being, deals with what exists; Epistemology or the theory of knowledge, deals with what can be known; the theory of value, sometimes called axiology; Logic. Since scientific knowledge is empirical, there are three problematic steps to be examined; the step from any experience at all to experience of a world of one's own; the step from experience of that world to knowledge of it; and the step from knowledge of that world to knowledge of a world in common.

4.3 PERCEPTION, THOUGHT AND LANGUAGE

In order to understand the transition from experience to knowledge, it is necessary to put oneself in a position of experiencing. For this purpose Edmund Husserl recommended a process called ‘bracketing’; this means for getting all that one has learned in order to take an unprejudiced look at what is presented. Phenomenologically the objects perceived are intentional objects. The world of phenomena reveals the properties, configurations, process, sequences etc., of the objects perception. Perception means a grasping of something through the senses (perception = sensation + interpretation). However the perceptual experience of the world is incomplete because of the limitations of our sense organs. Any scientific theory is structured on the basis of this incomplete sense data. Thought is a mechanism for the synthesis of al full world out of the bits and pieces of experience. It is regarded as a second convenient hypothesis (the external world was the first). Concepts are a set of hypothetical entities which correspond to percepts. Concepts function through recognition, identification, and representation. Concepts have ontological status. They also evoke a habit of expectations. They are functional entities. Any language has the following three essential ingredients; the sign, the thing of which it is the sign and the person to whom it is a sign of that thing or in other words sign, object and the interpreter. A set of signs having understood meanings constitutes a language. The realms corresponding to object, sign and interpreter are percept, term and concept which can be connected in the following way;

All languages begin as ordinary languages, under the pressure of the immediate necessity of communication. Some percepts have corresponding concepts and terms. But it is possible to have some terms and concepts without corresponding percepts. The language of science is a standard language. It has its own special vocabulary, referring to particular kinds of obejcts and process. A language which is being used to talk about the world is called an object language. The language which we use to discuss this first language is then called a meta-language. For instance, the sentence, “The sentence, ‘Copper Sulphate is solvable’ is a metalinguistic philosophic remark mentioning a scientific sentence (belonging to the object language) which actually says something about Copper Sulphate.

The Correlation of Perception, Thought and Language

Starting from perception science proceeds to the construction of conceptual schemes whose order reflects the order of perception and links these with specialized languages for the purposes of making predictions. Language thought and percept can stand alone. In the condition of awareness, in our aesthetic experience we are able to concentrate on perception to the exclusion of language and conceptual thought. In logic two systems are said to be isomorphic if every element of one system can be matched with a unique element of the other and vice versa. A rule linking thought and perception can be found in concept formation – it is the rule which covers the use of language for the expression of thought and the description of perception. A rule linking thought and perception can be found in concept formation – it is the rule by which perception stimulates thought and thought recognizes and represents objects of perception. In the correlation of perception, thought and language the following kinds of relation are relevant; logical and grammatical relations in language, spatial and temporal relations in perception, whatever psychological theory calls for in thought.

Classification

The relation between the term and the object to which it refers in perception maybe thought of as a one-to-one relation, but this is obviously a gross over simplification. To begin with, words do not exist as single entities but as collections of utterances and inscriptions, each one a particular use of the word on a particular occasion. A distinction has been made between the word 'type' which is embodied on each such occasion and the word 'token' which is its concrete physical embodiment as an individual sound or mark. The token is a sign in the original sense; the type belongs to language on a more abstract level. Aristotle developed a theory of universals in the things. According to this theory everything was a combination of two elements, form and matter, the matter accounting for the things being a real thing in the world, and the form accounting for its being the kind of thing it was, and thus p[laying the parts of the universal. The forms were arranged in a hierarchy of definition by genus and species, as is still done for the animal and plant worlds, everything having its place in a logical order. What science aims at is the development of concepts which will stand for any individual in a particular class, on the assumption that there is a similarity between the members of the class which entails a similarity in their behavior under similar circumstances. We may distinguish four different senses of similarity, in descending order of usefulness for purposes of classification. The first may be called genetic similarity that is between objects having similar origins; The second structural similarity, between objects having similar constituent parts, or similar relations between their parts; The third is the functional similarity, between objects having similar behavior.

Definition

The class of actual objects or events to the members of which a term applies correctly is called the denotation of that term and while the term denotes the objects in question, the objects constitute a definition of the term. On the most primitive level a term may be defined by pointing out something to which it applies, that is by showing its meaning, and this procedure is known as ostensive definition. (Ex. 'zebra' is meant animal or striped or four legged.) Terms can be defined away by means of other terms, but there will be at lease some terms left for which no such definitions are available. A list of the properties which an object must possess if it is to be included in the denotation of some term specifies the intention of the term. The more restricted the denotation, the more detailed the intention. The extension of a term is the class of all possible objects, past or future, known or unknown, which if they existed would belong to its denotation; the connotation of a term is specified by a list of the properties which the members of its denotation happen to have in common including those properties which constitutes intention. Definitions of terms by reference to other terms belonging to the same language systems are internal definitions, which go outside the language are external definitions. Where a term is defined by means of other terms the original term (the *definiendum* – that which is to b e defined) is eliminable in favour of the term or terms used to define it (the *definiens)*. A contextual definition is an explicit definition of a context or class of contexts in which the term defined occurs. The decision to call the element of atomic number 100 '*fermium'* was a stipulative definition both in the internal and external senses – internally because it enabled scientists to replace circumlocutions such as the one above (or the next element after '*einsteinium'*) by the term fermium and externally because there is an actual substance which is named fermium. In lexical definition, the definition of a term is derived from a dictionary. In a historical order of definition theories were put together rather unsystematically, depending on accidents of discovery. But in the heuristic order of definition new concepts are introduced in the most appropriate places. The introduction of a formalized language brings about the logical order of definition.

4.4 GENERALIZATIONS, HYPOTHESES, LAWS, PRINCIPLES AND THEORY

A scientist records his observation through a protocol sentence which asserts that something is in fact the case. A protocol sentence can be reached after something is in fact the case. A protocol sentence can be reached after a finite number of observations and it must be intersubjectively corroborated. An empirical generalization "All 'A's are 'B'" is arrived at after every individual observation:

This A is B

This A1 is B

.. All A's are B

One protocol sentence "A1 is not B" (contrary instance) is enough to ruin the empirical generalization. An empirical generalization might be defined as any sentence whose contradictory has the form of a protocol sentence. Sometimes sentences of the form, "If A then B" will also be protocol sentences. Sentences about electron are given the status of 'hypothesis' since electron is not observable. Hypothesis always contain theoretical terms, since any universal sentence containing only observation terms would necessarily have a protocol type sentence for its contradictory. Not all sentences containing theoretical terms or propositions about theoretical constructs, are hypothesis – only those from which empirical generalizations follow. The truth or falsity of a sentence does not affect its logical classification, and tests of truth or falsity on empirical grounds don't belong to logic. A hypothesis may become a generalization through the refinement of techniques of observation. Generalizations emerge naturally after a number of particular observations, while hypothesis have to be invented. Anybody can make the jump from 'many' to all but it takes a genius to jump, ass J.J. Thomson did from the discharge of electricity in gases to the electron. Every sentence of science falls into one or another of these categories; protocol sentences, empirical generalizations or hypothesis.

Laws, Principles and Theory

A true empirical generalization, either affirmative (All A's are B) or conditional (If A, then B) is called a law, which is accepted as true. The logical status of the scientific law depends on its being a generalization and nothing else, but its historical status depends on what scientists of the period believe and this reflects what we mean by scientific law. There are no immutable laws of nature as only 'accepted generalization' is defined as a law. The distinction between hypothesis and empirical generalizations suggests a distinction between two different kinds of scientific law, one corresponding to empirical generalizations which are accepted as true and the other to hypothesis which are accepted as true. The law of conservation of energy is a hypothesis accepted as true since energy is not observed, but rather the penetration of bullets is observed. Principles are hypothesis accepted as suitable starting points for theoretical work. All generalizations accepted as true have the status of laws, and all hypotheses accepted as true have the status of principles.

A theory is set of universal propositions asserted by means of a corresponding set of universal sentences. These sets are isomorphic with one another. A theory is constantly changing; new laws are discovered, old ones discarded or forgotten. Scientific theory, finally constitutes a particular outlook on the world. The term comes from the Greek '*theorein*' – to look at; Scientific theory means knowledgeable out look. There are other outlooks of the world also apart from the scientific outlook of the world.

The Structure of Theory

Protocol sentences, empirical generalizations and hypothesis have empirical content. But a scientific theory has a logical structure which can be abstracted from all empirical content and studied in isolation. A theory is a structure of sentences without any accompanying scheme of constructs. The structure of the theory deals with the systematic internal organizations of theory. In the analysis of the structure of theory we have to abandon empirical truth and introduce a new kind of truth called logical truth. Formal logic is one which is concerned more with the relations of sentences rather than the content and meaning of sentences. A set of sentences in which the truth of the last (the conclusion) follows from the truth of the others (the premises) is called an argument and every inference may be expressed in an argument. Deductive logic serves for propositions and hence is often called 'propositional logic'; it is also called sentential logic. Sentential logic does not look as the internal structure of sentences but their external relations. Predicate logic deals with the internal structure of sentences. Set theory which is a recent development is due to Boole who contributed to the logic of classes. Sentential logic and predicate logic are both very ancient disciplines. The first was developed without using symbols by Aristotle and the second by Stoics. The present formulation the both the logic are due to Frege, Russell and Whitehead. In a formalized language system a calculus means a tool of calculation. The sentences from which calculation begins are called axioms. Any sentence arrived at according to the rules, starting from the axioms, is called a theorem, and the series of sentences starting with axioms and ending with the theorem, which exhibits the steps in the process is called a proof of the theorem. Pure logic is not interested in the empirical content and therefore it is an uninterrupted calculus. The concern with content provides the calculus with an interpretation by following the rules of correspondence. A rule of correspondence is as kind of definition. It establishes a relationship between the language we use to talk about the world and the language we use to exhibit purely logical truths. Sometimes the same calculus may have more than one interpretation. The calculus of which the kinetic theory of gases is an interpretation (based on the domain of gas molecules) is the same as that of which the theory of elastic collisions in Newtonian mechanics is an interpretation (based on the domain of homogeneous spherical objects whose masses and elastic module are such as to allow them to undergo collision without permanent deformation and without fracture); it is only that the two calculi have the same form, but they are the same calculus. Therefore it is possible to have the same model for two different calculi. In the structure of a theory, measurement is used as a tool to explain the empirical phenomena. Measurement is a mathematical formalism in which what is qualitatively observed is given in quantities. In measurement a set of numbers operationally generated means nothing unless it is taken as indicating a relationship between aspects of the world, which in their theoretical setting are concepts. A measurement does not establish as connection between theory and the world; it establishes as connection between two theories, as connection between the numbers and what they stand for.

Validation of Theory

In Scientific theory the scheme of constructs is the customary interpretation of the logical calculus. The calculus has been developed to a point, where given suitable techniques of measurement, all the resources of mathematics may in principle be brought to bear on the solution of scientific problems. The truth of the calculus depends deductively on its axioms and is asserted only hypothetically. In the validation of theory we inquire how such a hypothetical system can be grounded in observation in such a way as to render it reliable as an instrument of explanation and prediction. There are three indispensable qualifications which any sentence in the theory ought to possess. The sentences should be: (a) formally correct (b) relevant; and (c) reliable. Both discovery and structure of theory discuss at length the formal correctness and relevance of the sentences to scientific theory. The meaningfulness of a sentence lies in its verifiability. But the criterion of verifiability prevents universal statements from having any meaning, since all that can be confronted in experience is particular. Therefore the criterion was modified in the direction of confirmation rather than of verification. The introduction of conformability raised the question as to how much evidence was required in order to say that a sentence was actually confirmed, and this led to the notion of degrees of confirmation. This development gave rise to an important new branch of inductive logic. The logical problem of induction is inferring a universal statement from a number of particular instantiations of it. But the inductive arguments may be strong or weak, depending on the probability of their conclusion. A successful scientific theory is one which is practically useful for the society. The method of arriving at truth in science has the following pattern: hypothesis, deduction and test. The scientific method has the following stages before arriving scientific laws: observation, analysis of empirical data, hypothesis and laws. Scientific method as a methodological inquiry aims at the reliability of explanations. It is also leading to intellectual exercise tying down of abstract logical systems to empirical contents. In this sense it is relevant to the validation of theory.

4.5 SCIENTIFIC EXPLANATION

There are events taking place around us. These events evoke curiosity in us and therefore naturally we ask, "why at all the events are taking place the way we observe them?' The common man can explain the events from his own perspective. But the scientific explanations are different from the explanations of the common–sense. Scientific explanations not only explain the present occurrence of events but also predict the future occurrence of events. Some philosophers of science find asymmetry between explanation and prediction. But there are some who oppose such asymmetry between explanation and prediction. Those who hold the symmetry thesis believe that scientific explanations not only explains the present occurrence of events but also control the future events. Explanation of events and description of events are not the same. Those who describe the occurrence of events merely describe the state of affairs and do not go beyond it. Empirical phenomena which are explained can be classified as (a) physical (b) Biological and (c) Social. The methodology adopted to explain the physical phenomena is not the same as the methodologies to be followed to explain Biological and Social phenomena. The explanations offered by the scientists will also be questioned by the emergent evolutionists like Lloyd Morgorn. According to the emergent theory the constituents of objects will lead to the 'emergence' of 'novelties' and hence the explanation is inadequate. The explanation must incorporate the novel qualities of the objects for better understanding of the events around us. In scientific explanation the case to be explained is called *Explanandum* and the premises or the statements such as Laws from which Explanation is deduced is called *Explanan.* There is a logical relation between *Explanan* and *Explanandum.* The explanation of individual events is different from the explanation of Scientific Laws. Inductive and deductive are the two patterns of Explanations. Inductive pattern is invariably connected to the probabilistic kind of explanation. There are many kinds of deductive pattern of explanation.

There are four kinds of Explanations; (1) Deductive (2) Probablistic (3) Teleological and (4) Genetic.

Deductive Explanation

In the deductive kind of explanation the *explanan* is a universal law from which Explanation is deduced for an *Explanandum.* Ex. Why the addition of the odd numbers always ends up with a square?

1,3,5,7,9,11……

$1 = 1^2$

$1= 3 = 2^2$, $1+ 3+5 = 3^2$, $1+ 3+ 5+7 = 4^2$ etc….

Here the *explanandum* is explained from an *explanan* which is a universal law of mathematics.

Ex. Why there is moisture on the outer surface of a glass tumbler whenever we pour ice water? Here the *Explanan* in the premise is a law in physics (law of thermodynamics). When we pour ice water into a glass tumbler the atmospheric water vapour comes into contact with the cooler part of the tumbler. The water vapour transforms into droplets of water and hence there is a moisture on the outer surface of the tumbler.

Ex. Why the percentage of Catholics committing suicide was more than the protestants during the last quarter of 19th Century in England? Here the *Explanandum* to be explained is related to historical fact. Therefore the *Explanan* is a historical evidence from which explanation is deduced. In the deductive pattern of *explornation* the relation between *explanan* and *explanandum* is logical. Therefore this kind of explanation fulfills the rules of deductive logic.

Probabilistic Explanation

In the case of deductive explanation, the explanation is deduced from the *explanan* which is an invariably established law of science. The empirical validity of the premise is not verified. The validity of the *explanan* is taken for granted. Only the *explanandum* has the observational element. But in the probabilistic explanation there is a 'jump' from some cases to all cases, i.e., from 'particular' to 'universal.' Inductive generalization is interpreted as probabilistic explanation. When there is a jump from some to all or from particular to universal there is only 'inference' and not 'certainty.' Ex. When we observe clouds causing rain in the 'present,' we 'predict' that there will be rain preceded by clouds. But sometimes there may be clouds not followed by rain. In this circumstance we have to admit that there is no necessary relation between clouds and rain. So also if a physician prescribes a 'drug' for the present aliment we cannot say 'certainly' that in future also the same drug will cure similar ailment. The drug may 'probably' cure similar ailments in future. The 'causal' relation we observe between two sets of circumstances in the present may or may not be true in future. Under these circumstances we can not claim that there is certainly for the future occurrence of events. Hempel's covering-law-model of explanation tries to establish a kind of logical necessity between 'explanation' and 'prediction.' But probabilistic explanation does not support any kind of necessary relation between explanation and prediction. The future occurrence of an event is only probably true. Some of our observations of clouds followed by rain in the present will hold good for the future only probably.

Teleological Explanation

Empirical statements which are 'purposive,' are called teleological statements 'why do we have lungs?" The answer should give the purpose of the lungs in our body – the inhalation of air so that Oxygen can be utilized in blood circulation. Similarly all parts of our body have specific functions t perform. The teleological or functional aspect is relevant not only to the parts of our body but also to several natural or artificial objects around us. These objects have got specific functions to perform. In certain cases the purpose will be achieved in future. The growth of paddy crops will lead to the yield of the grains of paddy. Therefore the 'biological development' of paddy crop is in the process of achieving a purpose. However we cannot say that any biological process will lead to only one purpose. Same biological function may lead to achieving several purposes. A particular biological structure has the function for a particular purpose. However the same purpose can be achieved through different structures. For example for the movement from one place to other different living creatures have different structures. Man, cow, bird, snake and fish have different structures for achieving the purpose of 'movement.' There is no '*termini'* for the biological functions. In other words what is '*terminus*' for a particular biological function is the 'beginning' for several other biological functions. For example the 'corn seeds,' which is the terminus for a particular function, may lead to several other biological developments. The corn seed eaten by birds and goats may lead to different kinds of purposes. In the case of physical and chemical phenomena purpose is invented by human beings. Most of the cosmic and astronomical phenomena are 'accidental' in nature. Man carves out a 'purpose' in a 'purposeless' natural phenomenon.

Genetic Explanation

Some of the questions can be answered only if we have the facts relating to the 'history' of a phenomenon. For example, "why is there Indo-Pakistan conflict which resulted in three wars between the two countries?" The answer can be given by tracing the history of India, partition of the country on the basis of religion, the earlier invasions of India by the Arabs etc. In other words explanation of this kind is based on the analysis of the genesis of the problem. Any phenomenon whether it is physical, biological or social has its own evolutionary history. Unless we have the facts of the past of a process the explanation will not be adequate. The present circumstances or factors which may be seemingly the cause of a particular phenomenon may not be sufficient in offering in adequate explanation. Therefore Genetic explanation plays a important role in the explanation of social phenomenon in particular.

Explanation of Biological phenomena

Explanation of physical phenomena and the methodology adopted to do so is not sufficient to the explanations of biological phenomena. Mechanistic interpretations of biological phenomena hold well when 'biological processes' are understood in terms of 'physical' and 'chemical' concepts. In other words 'reductionism' is followed in understanding biological processes. But reduction of biological process into physical and chemical process will lead to an explanation which is inadequate since biological phenomena are 'organismic' in nature. The whole is more than the sum of the parts in organismic biology. The lower order of a biological system 'conditions' the higher order functioning. Each system such as 'digestion,' 'blood circulation' and 'brain' are too complex in nature. Each complex system is facilitated by the lower order functions. Each complex function has purpose. All the individual systems perfectly coordinate in such away that the human beings or any other biological organisms exhibit 'holistic' activities. Mechanical explanations however are not contradictory in the explanations of biological phenomena. Mechanical explanations are complemented by teleological explanations in the complete understanding of the biological phenomena.

4.6 METHODOLOGICAL PROBLEMS IN SOCIAL SCIENCE

Physical and chemical events can be explained by following universal laws which are nomothetic in nature. Historical phenomena which are individualistic and unique can not be explained on the basis of the laws governed by nomothetic sciences. Social sciences are 'ideographic' in nature and therefore the methodology adopted to explain such phenomena is different. Some of the methodological problems that arise when we explain social phenomena are: (a) controlled inquiry, (2) subjective nature of social subject matter, (3) knowledge of social phenomena as a social variable, (4) value oriented bias in social inquiry and (5) cultural relativity and social laws. Controlled inquiry: unlike in physics and chemistry wherein we can create experimental conditions at our will to conduct study, it is not possible to create experimental conditions in the study of societies which consist of the groups of human individuals. They are all free thinking individuals having 'conscious' goals of their own. Moreover historical phenomena are 'unrepeatable' whereas physical or chemical events can be repeated in the laboratories. Therefore 'controlled inquiry' is not practical. However there are surveys conducted in societies by using some variables to find out some facts.

Subjective Nature of Social Subject Matter

The observation of social phenomena and the observation of physical or chemical phenomena are not the same. Human beings have got subjective attitude which may not be revealed in their overt behavior. J.B. Watson's behaviorism points out that man has got no 'inner' or 'subject' side for his behavior other than his overt behavior. But a man can 'pretend' outwardly that he is a happy individual while inwardly he is sorrowful. In this context a social scientist will not succeed in collecting complete data to draw conclusions.

Knowledge of Social Phenomena as a Social Variable

If the individuals come to know before hand that they are subject to questioning by social scientists for a specific inquiry they may sometimes feed the scientists with false data thereby distorting the outcome of such inquiry.

Value-oriented Bias in social inquiry

Social scientists are biased when reporting an event. It is not possible to get unbiased information about social phenomena. In fact in the very selection of phenomena for study the individuals are not free from value-orientation. To frame universal laws on the basis of such biased inquiry is meaningless.

Cultural relativity and social laws

Physical and chemical laws are universal in nature; but it is very difficult to arrive at universal social laws because of cultural variations in the society. Each social, religious and political group has its own laws. There are no uniform civil or moral laws universally applicable for all the societies. Therefore explanations of social phenomena by following universal laws are not possible.

Requirements for scientific explanation

There are logical and epistemic requirements for scientific explanation. The logical requirements consist in having premises (*explanans*) which are 'more general' than the *explanandum.* The premises must contain at least one universal law. The epistemic requirements consist in the premises to be true; the premises must be 'known to be true.' Both logical and epistemic requirements are necessary in scientific explanations.

4.7 LET US SUM UP

We have seen many crucial issues of the philosophy of science in this unit.

4.8 KEY WORDS

Teleological Explanation: Empirical statements which are 'purposive,' are called teleological statements.

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Philosophy of Science and Cosmology

Block 3

CONTEMPORARY COSMOLOGICAL THEORIES

UNIT 1
Theories of Relativity

UNIT 2
Quantum Mechanics

UNIT 3
Uncertainty Principle

UNIT 4
Origin and End of the Universe

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BLOCK INTRODUCTION

The advent of the theory of relativity and of the quantum mechanics has revolutionized the whole domain of science. By the analysis of the fundamental concepts of space and time, of mass and of force, it has given a new orientation not only to science but also to our approach to philosophical problems in general. It is the theory which says that concepts like space, time, mass, simultaneity, motion etc., are not absolute but relative; absolute to frame of reference. They questioned some of the age old concepts such as absolute motion, absolute space, absolute mass, wave nature of particles, unlimited perfectibility of experimental results etc. They brought in certain radically new concepts and gave new insights into several baffling phenomena in nature. Towards the end of the last century it became abundantly clear to scientists that the real trouble spots in scientific inquiry were in the fathomless depths of intergalactic space at the other end. Quantum mechanics arose in an effort to answer the problems hovering in the subatomic world and relativity in the 'ultra-giant' and 'ultra-fast' world. Heisenberg's Uncertainty Principle has had a major effect upon the philosophy of science and belief in determinism. It means that it is impossible to determine the present state of the world (or any small part of it) with perfect precision. It asserts that the position and the velocity of an object cannot both be measured exactly, at the same time, even in theory. The very concepts of exact position and exact velocity together, in fact, have no meaning in nature. This takes the theorists, speculators and philosophers to revisioning their cosmological theories regarding the origin, existence and destiny of the universe.

Unit 1 focuses on Theory of Relativity which has profoundly changed the whole physics. It shows the all pervasive importance and relevance of relativity in theoretical science of today. According to relativity space and time are relative. Space is the relation of things and time is the relation between the events.

Unit 2 introduces the students to some of the key ideas of quantum mechanics which is one of the major revolutions in twentieth century physics. And yet it is totally bizarre—it flies in the face of all our intuition and common sense. It sounds more like science fiction, or a poorly written fantasy, than notions which serious scientists would entertain. So the unit tries to present also the weird character of quantum mechanics and how it radically changes the way we look at reality.

Unit 3 studies the basics of the uncertainty principle, Copenhagen interpretation of quantum mechanics and its philosophical implications. It also studies the confusion and challenges created by it. "The more precisely the position is determined, the less precisely the momentum is known," is the uncertainty principle in quantum mechanics. The position and momentum of a particle cannot be simultaneously measured with arbitrarily high precision.

Unit 4 familiarizes the students with some general theories on the origin and end of the physical universe. The scientific theories on the universe keep on evolving and changing, although Big Bang and Big Crunch are commonly accepted theories. From the beginning of human thought across the globe there are host of cosmogonies and eschatologies along with mythical and religious traditions, the unit restricts only with different scientific theories.

UNIT 1 THEORIES OF RELATIVITY

Contents

1.0 Objectives
1.1 Introduction
1.2 The Theory of Relativity
1.3 Relativity of Motion, Length, Time, Simultaneity
1.4 Mass and Energy
1.5 General Theory of Relativity
1.6 The Gravitational Field
1.7 Let Us Sum Up
1.8 Key Words
1.9 Further Readings and References

1.0 OBJECTIVES

Relativity has profoundly changed the whole physics. By the analysis of the fundamental concepts of space and time, of mass and of force, it has given a new orientation not only to science but also to our approach to philosophical problems in general. It is the theory which says that concepts like space, time, mass, simultaneity, motion etc., are not absolute but relative; absolute to frame of reference.

1.1 INTRODUCTION

The advent of the theory of relativity and of the quantum mechanics has revolutionized the whole domain of science. They questioned some of the age old concepts such as absolute motion, absolute space, absolute mass, wave nature of particles, unlimited perfectibility of experimental results etc. They brought in certain radically new concepts and gave new insights into several baffling phenomena in nature. Towards the end of the last century it became abundantly clear to scientists that the real trouble spots in scientific inquiry were in the fathomless depths of intergalactic space at the other end. Quantum mechanics arose in an effort to answer the problems hovering in the subatomic world and relativity in the 'ultra-giant' and 'ultra-fast' world.

To show the all pervasive importance and relevance of relativity in theoretical science of today, we give a few quotations from the leading writers. Thus H. Margenau writes, "In fact the theory is now so well corroborated by experience and by assimilation into the whole of modern physics that its denial is almost unthinkable. The physicist is impressed not solely by it's for long empirical verification, but above all by the intrinsic beauty of its conception which predisposes the discriminating mind for acceptance even if there were no experimental evidenced for the theory at all. Again Hutton, "Relativity has profoundly changed the whole of physics. By the analysis of the fundamental concepts of space and time, of mass and of force, it has given a new orientation not only to science but also to our approach to philosophic problems in general."

Before Einstein, physicist were confident which they understood distance, time, and mass. They believed any skilled person could measure distance with a ruler, tell time with a clock, weigh mass with a scale, and get the True values. With his theory of special relativity, Einstein proved that this was wrong that there were no true values and he shook the very foundations of science. Einstein developed two theories of relativity: special relativity and general relativity. Special relativity, published in 1905, covers only special, simple situations, those in which there are no forces. It was followed ten years later by general relativity, which includes Einstein's theory of gravity and is the more complex theory.

1.2 THE THEORY OF RELATIVITY

In everyday language we can say that relativity is a theory which holds that concepts like motion, length, time, mass etc. not absolute. They make sense only when referred to a frame of reference. Thus an astronaut of mass say 80kgs on the surface of the earth (first frame of reference) may have a mass of 100 kgs while inside a fast moving rocket (second frame of reference). A different definition is given by Eddington, "an attitude which leads to the conclusions that we observe only relations between physical entities."

Special and General Theory of Relativity

Einstein published his theory in two papers, one in 1905 and the other in 1916. The forms the special theory and this deals with only uniform motion of bodies. The second is called the general theory and this deal with all moving bodies including those with non-uniform velocities, (i.e. accelerated bodies).

Postulates of the Special Theory of Relativity

Einstein explained the "negative result" of M. M. experiment in the form of two postulates.

Postulate I: it is impossible to determine absolute motion by any experiment whatever. So in the universe no privileged frame of reference with respect to which absolute motion can be measured exists. Hence the phenomena of nature will be the same for two observers who move with any uniform velocity whatever relative to one another. Putting it in another way we can say that uniform motion does not affect physical laws. The general laws of physics are the same in all systems moving uniformly with respect to each other in a straight line. This is called the principle of relativity, from which the theory gets its name.

Postulate II: the velocity of light is a constant absolute quantity. It is independent of the motion of the source or of the observer.

Implications and Consequences of the Postulates

It is impossible to measure the uniform motion of a body by observing events taking place within the body. According to the first postulates all natural events are unaffected by uniform motion. So by observing them from within the body moving with uniform velocity we cannot measure its velocity. Consider a train moving with constant speed. Everything inside it happens as though it is motionless.

1.3 RELATIVITY OF MOTION, LENGTH, TIME, SIMULTANEITY

We must give up the classical platform of an immobile framework of space. It is meaningless to talk of absolute rest. All motion is relative; is makes sense only when referred to a frame of reference. As an illustration consider a station master at the platform and an engine driver in a moving train. The station master will say that the engine driver is moving with respect to him.

The engine driver, on the other hand, will say that the station master is moving with respect to him and his engine.

Relativity of Length

Length is not something absolute in the sense that it has the same value everywhere. The stationary observer will notice the contraction. But the observer in the moving frame will not be able to measure any contraction because his scale also will have contracted by the same amount. Thus it follows that it is meaningless to speak of length without specifying the frame of reference, without specifying whether the length is taken with respect to a moving observer or a 'stationary' observer. (Contraction is perfectly reciprocal. Each observer notices a contraction in the system of the other. It is not a contraction of bodies, but of the measurement of bodies or of length, where 'length is not an intrinsic property of the body a conception we associate with the body')

Relativity of Time

We must give up the classical notion of 'steady, unvarying, inexorable universal time flow, streaming from the infinite past to the infinite future'. In a moving frame time slows down, two observers moving with different uniform velocities will have different values to the duration of an event. Newton assumed time was absolute and universal. He assumed time ran its own intrinsic rate, unaffected by anything else, flowing at the same rate everywhere and always. But Einstein showed that all this was wrong. Time is relative; there is no one, TRUE time. Time runs at different rates in different inertial frames; different clocks will inevitably measure different times. Let us try to see why it is true. Time is our way of measuring how rapidly things change. If nothing ever changed, time would be a meaningless concept. Every clock counts the number of 'times' something changes. In truth, it is time itself that appears to us to be slower in a moving frame; this is called 'time dilation.' Hence according to relativity there is no absolute before and after. Absolute topological time is ruled out. This means that there is no absolute past, present, future applicable to the cosmos as a whole. Also there is no absolute duration. This rule is out absolute metric time.

Space-Time and Four-Dimensional Continuum

Hermann Minkowski, realized Einstein's theory changed our understanding of the geometry of our universe. The three dimensions space can no longer be considered distinct from time; space and time must be viewed as a combined four-dimensional entity that Minkowski named space-time., In four-dimensional space-time, points are called events and four quantities are required to specify an event such as latitude, longitude, altitude, and time. Time measurements and normal three-dimensional distance measurements are relative (different from different observers), but the distance between two events in four-dimensional space-time is invariant (the same for all observers). Space is the relation of things and time is the relation or order of events. They are a relating system expressing certain general features of physical objects. Thus they describe the world in an orderly way. It is true that they are constructs of the mind, but they are not pure, empty concepts. They are concepts fit to describe the physical world. In Hans Reichenbaclis words, "these conceptual systems describe relations holding between physical objects. In addition these relations formulate physical laws of great generality, determining some fundamental features of the physical world. Space and time have as much reality as; say the relation "father" or the Newtonian forces of attraction." Thus the relations we talk of our objective relation.

In ordinary language the word 'space' itself is used as the name of a continuant. We can say, for example, that a part of space has become, or has contained to be, occupied. Space-time, however, is a 'space' in a tense less sense of this word, and because time is already in the representation it is wrong to talk of space-time as itself changing. Thus, in some expositions of relativity it is said that a certain 'world line' is a track along which a material body moves or a light signal is propagated. Here the body or light signal is propagated. The body or light signal, however, cannot correctly be said to move through space-time. What should be said is that the body or the light signal lines (tenselessly) along the world time. To talk of anything moving through space-time is to bring time into the story twice over and in an illegitimate manner. When we are talking about motion in terms of the space-time picture, we must do so in terms of the relative orientations of world lines. Thus, to say that two particles move with a uniform nonzero relative velocity it is expressed by saying that they lie (tenselessly) along straight world lines that are at an angle to one another. Similarly, the recent conception of the position as an electron moving backward in time is misleading because nothing can move, forward or backward, in time. What is meant is that the world lines of a position and electron, which are produced together or which annihilate one another, can be regarded as a single bent world time, and this may indeed be a fruitful way of looking at the matter.

Check Your Progress I

Note: Use the space provided for your answers.

1) What is Einstein's theory of relativity?

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2) Give small explanation on relativity of motion and length.

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3) Write on relativity of time.

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Relativity of Simultaneity

Up to now our considerations have been referred to a particular body of reference, which we have styled as a "railway embankment." We suppose a very long train travelling along the rails with the constant velocity **v** and in the direction indicated. People travelling in this train will with a vantage view the train as a rigid reference-body (co-ordinate system); they regard all events in reference to the train. Then every event which takes place along the line also takes place at a particular point of the train. Also the definition of simultaneity can be given relative to the train in exactly the same way as with respect to the embankment. As a natural consequence, however, the following question arises: are two events (*e.g.* the two strokes of lightning A and B) which are simultaneous with reference *to the railway* embankment also simultaneous relatively to the train? We shall show directly that the answer must be in the negative.

When we say that the lightning strokes A and B are simultaneous with respect to be embankment, we mean: the rays of light emitted at the places A and B, where the lightning occurs, meet each other at the mid-point M of the length A→B of the embankment. But the events A and B also correspond to positions A and B on the train. Let M^1 be the mid-point of the distance A→ B on the travelling train. Just when the flashes (as judged from the embankment) of lightning occur, this point M^1 naturally coincides with the point M but it moves towards the right in the diagram with the velocity v of the train. If an observer sitting in the position M^1 in the train did not possess this velocity, then he would remain permanently at M, and the light rays emitted by the flashes of lightning A and B would reach him simultaneously, *i.e.* they would meet just where he is situated. Now in reality (considered with reference to the railway embankment) he is hastening towards the beam of light coming from B, whilst he is riding on ahead of the beam of light coming from A. Hence the observer will see the beam of light emitted from B earlier than he will see that emitted from A. Observers who take the railway train as their reference-body must therefore come to the conclusion that the lightning flash B took place earlier than the lightning flash A. We thus arrive at the important result: "Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and vice versa (relativity of simultaneity). Every reference-body (co-ordinate system) has its own particular time; unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event."

Now before the advent of the theory of relativity it had always tacitly been assumed in physics that the statement of time had an absolute significance, *i.e.* that it is independent of the state of motion of the body of reference. But we have just seen that this assumption is incompatible with the most natural definition of simultaneity; if we discard this assumption, then the conflict between the laws of the propagation of light *in vacuo* and the principle of relativity disappears.

In it we concluded that the man in the carriage, who traverses the distance w per second relative to the carriage, traverses the same distance also with respect to the embankment in each second of time. But, according to the foregoing considerations, the time required by a particular occurrence with respect to the carriage must not be considered equal to the duration of the same occurrence as judged from the embankment (as reference-body). Hence it cannot be contended that the man in walking travels the distance w relative to the railway line in a time which is equal to one second as judged from the embankment. Moreover, these considerations of are based on yet a second assumption, which, in the light of a strict consideration, appears to be arbitrary, although it was always tacitly made even before the introduction of the theory of relativity.

The Limiting Velocity of Light

No body can travel faster than light. So the law of addition of velocity is such that the combined velocity does not exceed the velocity of light. If a body moves with the velocity of light, it would have contracted to nothing! This can never be reached. At the velocity of light, a clock will stop moving and so then duration will be infinite.

1. 4 MASS AND ENERGY

The fact that nobody can travel faster than light suggests that the inertia (resistance to motion) of a body increases with increasing velocity, approaching infinity as the velocity of light is reached. Now mass is nothing but inertia, a tendency opposing motion. So as velocity increases mass also increases. Mass is not absolute, but relative to the frame of reference. Mass of a body in a moving frame reference is increases and relativist correction is needed thing to move very fast. Energy of motion of a body depends on its inertial mass and the velocity. So energy can increase either with inertial mass or in velocity. But velocity cannot increase indefinitely. Its maximum value is the velocity of light. So as energy increases the inertial mass also should increase. Thus we have the famous mass-energy equation of Einstein: E=mc2 (E = Energy produced due to conversion, M= Mass that is converted, C= Velocity of light).

1.5 GENERAL THEORY OF RELATIVITY

The general theory of relativity was Einstein's crowning achievement. It revolutionized the theory of gravitation and initiated the new field of cosmology, the study of universe. Einstein pumped out the special theory of relativity in a quick five week, in contract the general theory took Einstein almost ten years from first version to final eloquent equations. "The General Theory of Relativity" was initially presented in a paper by Albert Einstein in 1915. Its primary thrust was to add the effects of gravity to "The Special Theory of Relativity," making special relativity a special case of general relativity. In the same way, ten years earlier, Einstein proposed the Theory of Special Relativity with the primary thrust of eliminating the concept of a fixed reference frame in favour of relative inertial frames in conjunction with the newly learned fact that the speed of light was a constant when measured in any inertial reference frame. This theory, in a similar way, makes the Newtonian Euclidian geometry of space a special case of special relativity. So rather than these new theories refuting the old theories, they actually verified that the previous theories were special cases of a more complicated theory that explains more of reality.

Many of us who have studied physics remember an equation that states that force equals mass times acceleration (f = ma) for a mass being accelerated by a constant force. We also remember how strange it was that an almost identical equation, force equals mass times the gravitational acceleration constant (f = mg) was used to determine the weight of a non-accelerating object in a gravitational field. This similarity (or relationship) between "a" and "g" forms the conceptual basis for general relativity. Consider yourself standing on a scale in an enclosed elevator at rest. Also consider yourself standing on a similar scale in an enclosed spaceship accelerating at one "g." Both the equation and our intuitive knowledge tell us that we cannot distinguish between the one situation and the other. We would be standing balanced on the scale with the scale reading our weight in both cases. Also consider the opposite situation where the elevator was in free fall and the spaceship was way out in space away from any star with the rockets off. In both cases, again, we cannot distinguish between being in the elevator or the spaceship. In both cases, the scale would read zero and we would be floating with no forces on our body.

Based on this conceptual foundation, additional general relativity concepts and effects have been developed. One concept is the effect of gravitational fields to cause the space-time continuum to be curved or warped by large masses. Another effect is that gravity, in addition to bending light, also can cause it to slow down. This slowing down of light results in a time dilation effect where time actually slows down. The slowing down effect of earth's gravity on time at its surface is very little. Compared with space, the earth's gravitational field slows down time by only one second per billion seconds. Experiments have verified the validity of general relativity. Some of these experiments include the precession of the perihelion of Mercury, the deflection of light, and the gravitational red shift of light.

Although the earth with its low gravitational field is at one end of the spectrum, black holes predicted by general relativity and observed in space have extremely high gravity and are at the other end of the spectrum. Black holes, in addition to bending light, slowing down light, and slowing down time, can stop light from escaping and make time stand still. For us, watching a space probe speeding toward the event horizon of a black hole, the space probe would appear to slow down and virtually stop. The fact that science can show that time can virtually stop helps our understanding of how a transcendent God, beyond time and space, can exist.

1.6 THE GRAVITATIONAL FIELD

"If we pick up a stone and then let it go, why does it fall to the ground?" The usual answer to this question is: "Because it is attracted by the earth." Modern physics formulates the answer rather differently for the following reason. As a result of the more careful study of electromagnetic phenomena, we have come to regard action at a distance as a process impossible without the intervention of some intermediary medium. If, for instance, a magnet attracts a piece of iron, we cannot be content to regard this as meaning that the magnet acts directly on the iron through the intermediate empty space, but we are constrained to imagine- after the manner of Faraday -that the magnet always calls into being something physically real in the space around it, that something being what we call a "magnetic field." In its turn this magnetic field operates on the piece of iron, so that the latter strives to move towards the magnet. We shall not discuss here the justification for this incidental conception, which is indeed a somewhat arbitrary one. We shall only mention that with its aid electromagnetic phenomena can be theoretically represented, much more satisfactorily than without it, and this applies particularly to the transmission of electromagnetic waves. The effects of gravitation also are regarded in an analogous manner.

The action of the earth on the stone takes place indirectly. The earth produces in its surrounding a gravitational field, which acts on the stone and produces its motion of fall. As we know from experience, the intensity of the action on a body demises according to a quite definite law, as we proceed farther away from the earth. From our point of view this means: The law governing the properties of the gravitational field in space must be a perfectly definite one, in order correctly to represent the diminution of gravitational action with the distance from operative bodies. It is something like this: The body (e.*g.* the earth) produces a field in its immediate neighborhood directly; the intensity and direction of the field at points farther removed from the body are thence determined by the law which governs the properties in space of the gravitational fields themselves.

In contrast to electric and magnetic fields, the gravitational field exhibits a most remarkable property, which is of fundamental importance for what follows. Bodies which are moving under the sole influence of a gravitational field receive an acceleration, which does not in the least depend either on the material or on the physical state of the body. For instance, a piece of lead and a piece of wood fall in exactly the same manner in a gravitational field (in vacuo), when they start off from rest or with the same initial velocity. This law, which holds most accurately, can be expressed in a different form in the light of the following consideration.

According to Newton's law of motion, we have

(Force) = (inertial mass) x (acceleration),

where the "inertial mass" is a characteristic constant of the accelerated body. If now gravitation is the cause of the acceleration, we then have (Force) = (gravitational mass) x (intensity of the gravitational field), where the "gravitational mass" is likewise a characteristic constant for the body. From these two relations follows:

(Acceleration= (gravitational**)** = (intensity of the gravitational field)
(Inertial)

If now, as we find from experience, the acceleration is to be independent of the nature and the condition of the body and always the same for a given gravitational field, then the ratio of the gravitational to the inertial mass must likewise be the same for all bodies. By a suitable choice of units we can thus make this ratio equal to unity. We then have the following law: The gravitational mass of a body is equal to its inertial law. It is true that this important law had hitherto been recorded in mechanics, but it had not been interpreted. A satisfactory interpretation can be obtained only if we recognize the following fact: The *same* quality of a body manifests itself according to circumstances as “inertia” or as “weight “(lit. " heaviness '). In the following section we shall show to what extent this is actually the case, and how this question is connected with the general postulate of relativity.

A New Interpretation of Gravity

Accelerated motion can be as equivalent to a gravitational field only because inertial mass is equivalent to gravitational mass. This was known already in classical physics, but no explanation was given to it. Einstein suggested that ‘the same quality of a body manifests itself according to circumstances as ‘inertia’ or as ‘weight’. Thus because of inertia bodies in ‘empty space’ is travel with uniform velocity in straight lines. Because of gravity bodies in non-empty space (gravitational field) are travel with accelerated motion in parabolic paths. Hence inertia and gravity are two aspects of a single law, ‘Every body tends to move along a geodesic’.

The New Picture of Gravity

According to Newton, gravitation is a force of attraction between two bodies. Thus the sun attracts the earth and because of this gravitational force the earth revolves round the sun. Gravitation causes the earth and other planets to describe curved paths in a straight space. According to Einstein, massive bodies distort the space-time continuum in their neighborhood. The curvature formed because of this distortion deflects the planets and they move in curved paths. Thus the paths of the planets etc., are the shortest courses in a curved space-time continuum. Gravitation is hence reduced to a geometrical property of the space-time continuum.

It is not force acting at a distance, but simply is the ‘path of inertia’ which the bodies follow. A massive body like the sun keeps the space in its neighborhood continually curved. It is as though the sun takes ‘grooves’ around it. The bodies move in these ‘grooves’. Another metaphor used is that the gravitating bodies produce ‘hills’ or other deformities in the continuum and bodies are rolled along the ‘hillside’. We quote from Barnett: “ A gravitational force as much a physical reality as an electromagnetic field, and its structure is defined by the field equations of A. Einstein”.

Gravitational Deflection of Light

Now light can be looked upon as a stream of minute particles called photons. Therefore they also should behave like any other material particles. So in a strong gravitational field a ray of light should undergo deflection. This is called gravitational deflection of light.

Check Your Progress III

Note: Use the space provided for your answers.

1) Give small description General Theory of Relativity.

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2) What is the Gravitational Field?

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3) Give description on the new picture of gravity.

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1.7 LET US SUM UP

Relativity dealt a death blow to the so called absolutes: absolute time, absolute space, absolute frame of reference, absolute objectivity etc. In doing so it has revolutionized the traditional notions of space, time etc. According to relativity space and time are relative. Space is the relation of things and time is the relation between the events. As Jeans says when we question nature through our experiments, we find that nature knows nothing of a space or time common to all people. When we interpret these experiments in the new light of the theory of relativity we find that space means nothing apart from our perception of objects and time means noting apart from the our experience of events. Space and time fade into subjective conceptions, just as subjective as right or left hand and ‘only the four dimensional continuum is objective.’

The denial of absolute space, absolute observer and absolute frame of reference has one important impact on scientific method. This shows that since no preferential frame or absolute observer exists, we can get scientific knowledge not by referring to any special space or frame of reference, but simply by performing the experiments accurately, no matter in whatever frame of reference we are. Thus extreme dexterity and accuracy will underlie any knowledge of the laws of nature. Relativity has sparked off speculations and theories on the origin of the cosmos and its nature.

1.8 KEY WORDS

$E=mc^2$ (E = Energy produced due to conversion, M= Mass that is converted, C= Velocity of light).

In four-dimensional space-time: points are called events and four quantities are required to specify an event such as latitude, longitude, altitude, and time.

Force = inertial mass x acceleration (Acceleration= (gravitational) = (intensity of the gravitational field) (Inertial)

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UNIT 2 QUANTUM MECHANICS

Contents

2.0 Objectives
2.1 Introduction
2.2 The Story of the Atom
2.3 Introducing Quantum Mechanics
2.4 Weirdness of Quantum Mechanics
2.5 Practical Value of Quantum Mechanics
2.6 Final Remarks on Human Intuition
2.7 Let Us Sum Up
2.8 Key Words
2.9 Further Readings and Reference

2.0 OBJECTIVES

- To introduce the students to some of the key ideas of quantum mechanics.
- To show the weirdness of the theory.
- To indicate how successful the theory is, though most people do not understand it.

2.1 INTRODUCTION

Two of the most revolutionary theories of 20th century were Theory of Relativity and Quantum Mechanics. Theory of relativity is a deviation from Newtonian Mechanics (or common sense.). The deviations were not discovered until this Century because they are only noticeable at high speeds and under very intense gravitational fields. There is another 20th Century idea that also violates Newtonian Mechanics. This is called Quantum Mechanics (Tal 2009).
In fact, Quantum mechanics is one of the major revolutions in 20th century Physics. It is probably the closest science has come to a fundamental description of the underlying nature of reality. And yet it is totally bizarre—it flies in the face of all our intuition and common sense. It sounds more like science fiction, or a poorly written fantasy, than notions which serious scientists would entertain (Felder & Felder 1998). So one of the best scientists of last century, R. Feynman has this to say: "It is often stated that of all the theories proposed in this century, the silliest is quantum theory. Some say that the only thing that quantum theory has going for it, in fact, is that it is unquestionably correct." In this unit, we want to study the basic notions of it, its strange (or weird) character, its practical implications and we conclude with some remarks on human intuition.

2.2 THE STORY OF THE ATOM

In this section we will give a taste of the strange and fascinating world of the atom. We will keep it as descriptive and not mathematical. The Ancient Greeks proposed that matter could not be divided indefinitely. They speculated that matter was made up of units called atoms. The word comes from a Greek word meaning single item or a portion. They assumed that atoms were solid, different characteristics of substances being determined by the different shapes that atoms had. This atomic idea never really became popular (Tal 2009).

During the 16th Century, chemists worked out that behaviour of gases. If they doubled the volume of a gas, its pressure halved. If they halved its volume, its temperature doubled. It was also found that chemical reactions always took place in fixed ratios. For example one volume of oxygen always combined with two volumes of hydrogen to produce water (assuming the gases were at the same temperature and pressure). Results like these lead to the idea of atoms. The Atomic Theory was surely the best way to explain these and other phenomena. (Tal 2009)

When the idea of elements came, it was assumed that different elements had different atoms. John Dalton showed that each element had an atom that differed in weight (correctly, mass) to other atoms. So now we say that a Carbon atom has a relative mass of 12, Oxygen has one of 16. The unit is the Hydrogen atom, the lightest of all the atoms. During the middle of the 19th Century, James Maxwell explained the gas laws by applying statistics to the random motions of atoms. He showed that when you heat a gas you make its molecules go faster. These strike the surface of the container with more force, thus increasing the gas pressure. To keep the pressure the same the volume has to be increased. Atoms were now taken for granted and treated as featureless spheres (i.e. little balls). (Tal 2009)

At this point the idea that atoms were featureless spheres was overturned by several discoveries made towards the end of the 19th Century. Firstly, there were experiments in electricity and magnetism which indicated the existence of particles with less mass than the Hydrogen atom. The electron was the most famous of these. Secondly, atoms were found to be more complex that previously thought when radioactivity was discovered. Atoms were throwing out bits and changing to other atoms; atoms could take and give an electric charge.

From various observations and experiments it was eventually decided that an atom was made up of three particles (Tal 2009):

- Protons - these were charged with electricity that was positive and contained most of the mass of atoms.
- Electrons - these were very light particles (1/1800th the mass of a Hydrogen atom.) with a negative electric charge exactly equal to the charge on a proton.
- Neutrons - neutral particles with a mass similar to protons but with no charge.

In an atom, the protons and neutrons were in the central regions of the atom (called the nucleus) while the electrons revolved around at high speed. It was the outer electrons that interacted when atoms reacted chemically with other atoms. It was these electrons that were involved in electrical effects. It was the number of protons that determined how many electrons there were (they had to be the same). This number (called the Atomic Number) determined how the atom behaved, i.e. what element it was. Hydrogen atoms have 1 proton and 1 electron, Oxygen has 8 of each, Uranium has 92 of each. The electrons were held in orbit by electric attraction (positive and negative attract), much as the planets were held in orbit around the sun by the attractive force of gravity.

The above description of the atom is the Newtonian (or Classical) description. It is possible to picture it and it makes sense. Unfortunately, this description violates Maxwell's Laws of Electromagnetism. Maxwell's Laws of Electromagnetism were very powerful tools. However they could not explain how an atom could be stable. Under those laws, an electrically charged object (like an electron) that was changing direction (in orbit around the nucleus of an atom) should be radiating energy away until it spiralled into the nucleus. Clearly this does not happen. Atoms are stable. Furthermore, there were a few other observations about atoms that were not quite right (Tal 2009).

Of course, atoms did absorb and radiate energy. The problem was that this process was strictly controlled. Atoms only absorbed specific wavelengths of energy. Sodium, for example, radiated a lot of yellow light (hence its use in street lamps), Potassium radiated lilac (hence the colour of most fireworks). This was a major flaw in the physics of the turn of the century. Physics had other problems - phenomena that didn't work as predicted: the way a hot, glowing body radiated energy at a given temperature (the Black Body Problem); the way metals produced electricity when light shone on them (the Photoelectric Effect); the way atoms decayed when they were radioactive. Something was wrong with the state of Physics. What was needed was a revolution in Physics. Unlike the onset of relativity which was the brainchild of one man, this new idea would spawn from many minds – in fact the best minds of those days.

Check Your Progress I

Note: Use the space provided for your answers.

1) "Some say that the only thing that quantum theory has going for it, in fact, is that it is unquestionably correct." Give your comments.

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2) Describe the structure of an atom?

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2.3 INTRODUCING QUANTUM MECHANICS

Isaac Newton thought that light was a stream of particles; Thomas Young thought it was a wave. Most people at the turn of the century thought of light as a wave. In 1900 Max Planck found that he could explain the way hot bodies radiate energy only if he assumed that energy occurred as packets. He assumed that his equations were simply tricks with the mathematics and called these packets of energy quanta. The equations were useful but the underlying ideas were not taken seriously. In 1905, Albert Einstein published three scientific papers, any one of which was the mark of a genius. The first was Part One of his Theory of Relativity. The second proved the existence of atoms from direct observations (an effect called Brownian Motion).

The third paper is the relevant one for this essay. In this paper, he applied Planck's quantum idea of 1900 to explain the Photoelectric Effect. These quanta were now being utilised to explain two previously unexplainable phenomena. However, if quanta were real, was light a wave or a particle? It was as if in some experiments (refraction, diffraction) light was clearly a wave; in others (black body radiation, the photoelectric effect) it was a particle. This effect was strange and was known as wave-particle duality (Tal 2009).

In 1912, Louise de Broglie, suggested that if energy could behave as both particles and waves, perhaps matter could also. He nearly didn't get his PhD for that ridiculous suggestion. He produced the mathematics and predicted that under the right conditions a beam of electrons (clearly matter made of particles) might show wave properties. Surprisingly, when the experiment was performed, a beam of electrons was found to diffract just like a wave would have done. That was it. It looked like energy and matter could both exhibit wave-particle duality. It appeared that a moving particle had a wavelength. Neils Bohr decided to work out the wavelength of an electron moving around the nucleus of an atom. He found that for an electron to have a stable orbit, the orbit had to include a whole-number of the electron's wave. Orbits that include fractions of waves were impossible so the electron could not inhabit them. In other words, an electron could have a stable orbit, so that it would not lose energy and spiral in to the nucleus. If an electron absorbed or radiated energy, it would do so in discreet amounts so that it would move to another stable orbit. The analogy is a staircase. You can only stand on the steps, not in the region between steps.

So these quantum ideas explained two things. Why atoms were stable and why atoms absorbed or emitted energy in selected wavelengths. Bohr used his ideas to predict what energy could be radiated from different atoms. His theories corresponded with observation. In 1925, Erwin Schrodinger and Werner Heisenberg separately worked out the mathematics of Quantum Mechanics. Using this new theory, scientists could understand the behaviour of atoms and subatomic particles. The wave-particle duality concept it true for both matter and energy. The 'position' of a particle like an electron is given by a probability. Electrons exist in energy states. When they absorb energy, they absorb a whole number of quanta, disappear, appearing at a different energy state. Gone is the idea of little ball-like particles. The orbit of an electron is a cloud of probability around the nucleus (Tal 2009).

Another quantum effect is the famous Uncertainty Principle. This implies that there is a built-in uncertainty in the Universe. It is possible for something to be created out of nothing, given enough time. On a subatomic level it is impossible to pinpoint things down to an infinite precision. And not because of any technological failings: this is a constraint of the Universe itself. A zero energy is impossible since it would be a precise state. This is the reason that nothing can be cooled below -273 degrees C (Absolute Zero). An atom must retain at least one quantum of energy and this keeps it from cooling below Absolute Zero. This means that nothing can ever be at rest. Quantum effects are not noticeable in the macro world. They only become important as one approaches the dimensions of the atom. (Tal 2009).

Fast and Young

A tumultuous series of events occurred within the three-year period from January 1925 to January 1928 culminating in quantum revolution. We list some of them main events:

• Wolfgang Pauli proposed the exclusion principle, providing a theoretical basis for the Periodic Table.

• Werner Heisenberg, with Max Born and Pascual Jordan, discovered matrix mechanics, the first version of quantum mechanics. The historical goal of understanding electron motion within atoms was abandoned in favour of a systematic method for organizing observable spectral lines.

• Erwin Schrödinger invented wave mechanics, a second form of quantum mechanics in which the state of a system is described by a wave function, the solution to Schrödinger's equation. Matrix mechanics and wave mechanics, apparently incompatible, were shown to be equivalent.

• Electrons were shown to obey a new type of statistical law, Fermi-Dirac statistics. It was recognized that all particles obey either Fermi-Dirac statistics or Bose-Einstein statistics, and that the two classes have fundamentally different properties.

• Heisenberg enunciated the Uncertainty Principle.

• Paul A.M. Dirac developed a relativistic wave equation for the electron that explained electron spin and predicted antimatter.

• Dirac laid the foundations of quantum field theory by providing a quantum description of the electromagnetic field.

• Bohr announced the complementarity principle, a philosophical principle that helped to resolve apparent paradoxes of quantum theory, particularly wave-particle duality.

The principal players in the creation of quantum theory were very young. In 1925 Pauli was 25 years old, Heisenberg and Enrico Fermi were 24, and Dirac and Jordan were 23. Schrödinger, at age 36, was a late bloomer. Born and Bohr were older still, and it is significant that their contributions were largely interpretative. The profoundly radical nature of the intellectual achievement is revealed by Einstein's reaction. Having invented some of the key concepts that led to quantum theory, Einstein rejected it. His paper on Bose-Einstein statistics was his last contribution to quantum physics and his last significant contribution to physics. That a new generation of physicists was needed to create quantum mechanics is hardly surprising. Lord Kelvin described why in a letter to Bohr congratulating him on his 1913 paper on hydrogen. He said that there was much truth in Bohr's paper, but he would never understand it himself. Kelvin recognized that radically new physics would need to come from unfettered minds. In 1928 – just within a span of three years - the revolution was finished and the foundations of quantum mechanics were essentially complete. The main actors were very young and energetic minds in their 20s (Kleppner and Jackiw).

Controversy and Confusion

Alongside these advances, however, fierce debates were taking place on the interpretation and validity of quantum mechanics. Foremost among the protagonists were Bohr and Heisenberg, who embraced the new theory, and Einstein and Schrödinger, who were dissatisfied. To appreciate the reasons for such turmoil, one needs to understand some of the key features of quantum theory, which we summarize here. (Kleppner & Jackiw 2000)

Fundamental description: the wave function. The behavior of a system in quantum mechanics is described by Schrödinger's equation. The solutions to Schrödinger's equation are known as wave functions. The complete knowledge of a system is described by its wave function, and from the wave function one can calculate the possible values of every observable quantity. The probability of finding an electron in a given volume of space is proportional to the square of the magnitude of the wave function. Consequently, the location of the particle is "spread out" over the volume of the wave function. The momentum of a particle depends on the slope of the wave function: The greater the slope, the higher the momentum. Because the slope varies from place to place, momentum is also "spread out." The need to abandon a classical picture in which position and velocity can be determined with arbitrary accuracy, in favor of a blurred picture of probabilities, is at the heart of quantum mechanics (Kleppner & Jackiw 2000).

Waves can interfere. The heights of waves can add or subtract depending on their relative phase. Where the amplitudes are in phase, they add; where they are out of phase, they subtract. If a wave can follow several paths from source to receiver, as a light wave undergoing two-slit interference, then the illumination will generally display interference fringes. Particles obeying a wave equation will do likewise, as in electron diffraction. The analogy seems reasonable until one inquires about the nature of the wave. A wave is generally thought of as a disturbance in a medium. In quantum mechanics there is no medium, and in a sense there is no wave, as the wave function is fundamentally a statement of our knowledge of a system (Kleppner & Jackiw 2000).

Questions such as what a wave function "really is" and what is meant by "making a measurement" were intensely debated in the early years. By 1930, however, a more or less standard interpretation of quantum mechanics had been developed by Bohr and his colleagues, the so-called Copenhagen Interpretation. The key elements are the probabilistic description of matter and events, and reconciliation of the wavelike and particle-like natures of things through Bohr's principle of complementarity. Einstein never accepted quantum theory; he and Bohr debated its principles until Einstein's death in 1955. Nevertheless, the nature of quantum theory continues to attract attention because of the fascination with what is sometimes described as "quantum weirdness." (Kleppner & Jackiw 2000).

Differences from Classical Physics

Now that we have some idea of the basics of quantum mechanics, we can try to compare it with classical mechancis. The main difference of the new theory from classical physics could be summed up as follows:

1. In classical mechanics a particle can have any energy and any speed. In quantum mechanics these quantities are quantized. This means that a particle in a quantum system can only have certain values for its energy, and certain values for its speed (or momentum).
2. Newton's Laws allow one, in principle, to determine the exact location and velocity of a particle at some future time. Quantum mechanics, on the other hand, only determines the probability for a particle to be in a certain location with a certain velocity at some future time. The probabilistic nature of quantum mechanics makes it very different from classical mechanics.
3. Quantum mechanics incorporates what is known as the "Heisenberg Uncertainty Principle." This principle states that one cannot know the location AND velocity of a quantum particle to infinite accuracy. The better you know the particle's location, the more uncertain you must be about its velocity, and vice versa. In practice, the level of

uncertainty that is required is so small that it is only noticeable when you are dealing with very tiny things like atoms. This is why we cannot see the effects of the Uncertainty Principle in our daily lives.

4. Quantum mechanics permits what are called "superpositions of states". This means that a quantum particle can be in two different states at the same time. For instance, a particle can actually be located in two different places at one time. This is certainly not possible in classical mechanics.
5. Quantum mechanical systems can exhibit a number of other very interesting features, such as tunnelling and entanglement. These features also represent significant differences between classical and quantum mechanics, although they will not be as important in our discussion of quantum chaos. (Timberlake 2010)

That is a pretty brief introduction to the ideas of quantum mechanics and many important features have been skipped. But the ideas presented above should make it clear that quantum mechanics is very different from classical (Newtonian) mechanics.

Check Your Progress III

Note: Use the space provided for your answer

1) Why is it that most of the founders of quantum mechanics were very young?

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2) Give some significant differences between classical and quantum mechanics?

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2.4 WEIRDNESS OF QUANTUM MECHANICS

As already noted, the field of quantum mechanics concerns the description of phenomenon on small scales where classical physics breaks down. The biggest difference between the classical and microscopic realm, is that the quantum world cannot be perceived directly, but rather through the use of instruments. And a key assumption to quantum physics is that quantum mechanical principles must reduce to Newtonian principles at the macroscopic level (there is a continuity between Quantum and Newtonian Mechanics).

Quantum mechanics was capable of bringing order to the uncertainty of the microscopic world by treatment of the wave function with new mathematics. Key to this idea was the fact that relative probabilities of different possible states are still determined by laws. Thus, there is a difference between the role of chance in quantum mechanics and the unrestricted chaos of a lawless Universe. Every quantum particle is characterized by a wave function. In 1925 Erwin Schrodinger developed the differential equation which describes the evolution of those wave functions. By using Schrodinger equation, scientists can find the wave function which solves a particular problem in quantum mechanics. Unfortunately, it is usually impossible to find an exact solution to the equation, so certain assumptions are used in order to obtain an approximate answer for the particular problem.

However, some of its findings and principles are distinctly counter-intuitive and fiendishly difficult to explain in simple language, without resorting to complex mathematics way beyond the comfort level of most people (myself included.). This situation is not helped by the fact that the “theory” is largely a patchwork of fragments accrued over the last century or so, that some elements of it are still not well understood by the scientists themselves, and that some of the bizarre behaviour it predicts appears to fly in face of what we have come to think of as common sense.

Richard Feynman, winner of the 1965 Nobel Prize for Physics and arguably one of the greatest physicists of the post-war era, is unapologetically frank: “I think I can safely say that nobody understands quantum mechanics”. Niels Bohr, one the main pioneers of quantum theory, claimed that: “Anyone who is not shocked by quantum theory has not understood it.” (UP 2001)

Below we give two implications of quantum mechanics that makes it weird or strange.

Schrodinger's Cat

In 1935 Schrodinger, who was responsible for formulating much of the wave mechanics in quantum physics, published an essay describing the conceptual problems in quantum mechanics. A brief paragraph in this essay described the, now famous, cat paradox.

One can even set up quite ridiculous cases where quantum physics rebels against common sense. For example, consider a cat is penned up in a steel chamber, along with the following diabolical device (which must be secured against direct interference by the cat). In the device is a Geiger counter with a tiny bit of radioactive substance, so small that perhaps in the course of one hour only one of the atoms decays, but also, with equal probability, perhaps none. If the decay happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The first atomic decay would have poisoned it. The wave function for the entire system would express this by having in it the living and the dead cat mixed or smeared out in equal parts (UP 2001).

It is typical of these cases that an indeterminacy originally restricted to the atomic domain becomes transformed into macroscopic indeterminacy, which can then be resolved by direct observation. That prevents us from so naively accepting as valid a ``blurred model" for representing reality. In itself it would not embody anything unclear or contradictory. There is a difference between a shaky or out-of-focus photograph and a snapshot of clouds and fog banks. We know that superposition of possible outcomes must exist simultaneously at a microscopic level because we can observe interference effects from these. We know (at least most of us know) that the cat in the box is dead, alive or dying and not in a smeared out state between the alternatives. When and how does the model of many microscopic possibilities resolve itself into a particular macroscopic state? When and how does the fog bank of microscopic possibilities transform itself to the blurred picture we have of a definite macroscopic state. That is the collapse of the wave function problem and Schrodinger's cat is a simple and elegant explanation of that problem (UP 2001).

Conclusion from experiment of the Schroedingers cat:

- The paradox is phrased such that a quantum event determines if a cat is killed or not
- From a quantum perspective, the whole system state is tied to the wave function of the quantum event, i.e. the cat is both dead and alive at the same time

- The paradox in some sense is not a paradox, but instead points out the tension between the microscopic and macroscopic worlds and the importance of the observer in a quantum scenario
- Quantum objects exist in superposition, many states, as shown by interference
- The observer (or measurement) collapses the wave function

Quantum Tunnelling

Quantum tunnelling refers to the phenomena of a particle's ability to penetrate energy barriers within electronic structures. The scientific terms for this are: Wave-mechanical tunnelling, Quantum-mechanical tunnelling and the Tunnel effect. Quantum tunnelling was developed from the study of radioactivity, which was discovered in 1896 by Henri Becquerel. It is the study of what happens at the quantum scale. This process cannot be directly perceived, so much of its understanding is shaped by the macroscopic world, which classical mechanics can adequately explain. Particles in that realm are understood to travel between potential barriers as a ball rolls over a hill; in our world, if the ball does not have enough energy to surmount the hill, it comes back down. Classical mechanics predicts that particles that do not have enough energy to climb the hill, it will not be able to reach the other side. In quantum mechanics, these particles can, with a very small probability, tunnel to the other side, thus crossing the barrier.

The reason for this difference comes from the treatment of matter in quantum mechanics as having properties of waves and particles. The wave function of a particle summarizes everything that can be known about a physical system. Therefore, problems in quantum mechanics centre around the analysis of the wave function for a system. Using mathematical formulations of quantum mechanics, such as the Schrödinger equation, the wave function can be solved for. This is directly related to the probability density of the particle's position, which describes the probability that the particle is at any given place. In the limit of large barriers, the probability of tunnelling decreases for taller and wider barriers. Hence, the probability of a particle on the other side is non-zero, which means that cross the high barrier sometimes. And experimentally it is also verified.

2.5 PRACTICAL VALUE OF QUANTUM MECHANICS

The equations developed by Heisenberg, Schrödinger and their colleagues give a glimpse into the nature of reality, but that's not all. They are also essential tools of modern work in key areas of practical technology--including the electronics you are using to read this text. Thousands of physicists use the equations of quantum mechanics every day to understand and improve computer components, metals, lasers, the properties of chemicals, and on and on. Many important physical effects, from fluorescent lights to the shape of a snowflake, cannot be understood at all without quantum mechanics.

Even the Uncertainty Principle isn't "merely" philosophy: it predicts real properties of electrons. Electrons jump at random from one energy state to another state which they could never reach except that their energy is momentarily uncertain. This "tunnelling" makes possible the nuclear reactions that power the sun and many other processes. Physicists have put some of these processes to practical use in microelectronics. For example, delicate superconducting instruments that use electron tunnelling to detect tiny magnetic fields are enormously helpful for safely scanning the human brain.

Quantum theory is used in a huge variety of applications in everyday life, including lasers, CDs, DVDs, solar cells, fibre-optics, digital cameras, photocopiers, bar-code readers, fluorescent lights, LED lights, computer screens, transistors, semi-conductors, super-conductors, spectroscopy, MRI scanners, lasers, super-conducting devices, etc. By some estimates, over 25% of the GDP of developed countries is directly based on quantum physics. It even explains the nuclear fusion processes taking place inside stars. Thus the effects of quantum mechanics are important in all branches of science. Quantum Mechanics is used to understand phenomena like radioactivity, chemical bonding, semi-conductors, solid-state micro-chips, electronics, sub-atomic physics, radiation from black holes, and many others (Tal 2009).

2.6 FINAL REMARKS ON HUMAN INTUITION

In spite of its weirdness, we have a theory which accounts for all of our experimental results. It correctly predicts the results of double slit experiments with photons or electrons, and it correctly predicts that in the case of normal light beams or particles. In fact, thousands of other experiments have been performed since quantum mechanics was developed, and they have continually supported its predictions to a staggering level of accuracy. This theory seems to apply to every process occurring between any kinds of matter or energy in the universe (Felder & Felder 1998).

No one really understands this theory of quantum mechanics. But Quantum mechanics can be used to successfully predict experimental results. So quantum mechanics leads to new ways of looking at existence and reality. The modern view of quantum mechanics states that Schrodinger's cat, or any macroscopic object, does not exist as super positions of existence due to de-coherence. A pristine wave function is coherent, i.e. undisturbed by observation. But Schrodinger's cat is not a pristine wave function it is constantly interacting with other objects, such as air molecules in the box, or the box itself. Thus a macroscopic object becomes de-coherent by many atomic interactions with its surrounding environment.

Decoherence explains why we do not routinely see quantum super positions in the world around us. It is not because quantum mechanics intrinsically stops working for objects larger than some magic size. Instead, macroscopic objects such as cats and cards are almost impossible to keep isolated to the extent needed to prevent de-coherence. Microscopic objects, in contrast, are more easily isolated from their surroundings so that they retain their quantum secrets and quantum behaviour (Uorgaon 2011).

It doesn't seem to make sense. But another school of thought says, why should it make sense? After all, humans evolved in a world of "normal" objects. And we developed a facility called "intuition" that helped us survive in that world by helping us predict the effects of our actions. That physical intuition was, and is, a great asset. But perhaps it shouldn't be too surprising that it becomes a liability when we try to apply it to areas that we didn't evolve for. Quantum mechanical laws generally only have measurable effects when applied to things that are too small to see, so we never evolved an understanding of them, so they seem bizarre (Felder & Felder 1998).

In fact, at roughly the same time that quantum mechanics first began to suggest that *very small* things defy our intuition, Einstein was proposing his special theory of relativity which shows that *very fast* things defy our intuition; and then his general theory of relativity, which concerns the odd behaviour of *very big* things (Felder & Felder 1998). It seems that, more and more, the only way to understand the world is to apply the math, and stop trying to "understand" what's actually going on. If you look at it like this, it seems that quantum physics is not weird and incomprehensible because it describes something completely different from everyday reality. It is weird and incomprehensible precisely because it describes the world we see around us-past, present, and future.

Check Your Progress III

Note: Use the space provided for your answers.

1) What is the significance of quantum tunnelling?

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2) Is quantum mechanics practical?

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2.7 LET US SUM UP

In this unit we have tried to understand the weird character of quantum mechanics, one of the most successful scientific theories. It radically changes the way we look at reality.

2.8 KEY WORDS

De-coherence: In quantum mechanics, quantum de-coherence is the mechanism by which quantum systems interact with their environments to exhibit probabilistically additive behaviour

Quantum tunnelling: It refers to the phenomena of a particle's ability to penetrate energy barriers within electronic structures. The scientific terms for this are Wave-mechanical tunnelling, Quantum-mechanical tunnelling and the Tunnel effect.

Quantum: A discrete quantity of energy proportional in magnitude to the frequency of the radiation it represents. It is the smallest amount of a physical quantity that can exist independently, especially a discrete quantity of electromagnetic radiation

Schrödinger's equation: An equation describing the state and evolution of a quantum mechanical system, given boundary conditions. Different solutions to the equation are associated with different wave functions, usually associated with different energy levels. This equation is fundamental to the study of wave mechanics.

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UNIT 3 UNCERTAINTY PRINCIPLE

Contents

3.0 Objectives
3.1 Introduction
3.2 Simple Definition of Uncertainty Principle
3.3 Beyond Strong Objectivity
3.4 The Historical Origin of Uncertainty Principle
3.5 Some Implications of Uncertainty
3.6 Triumph of Copenhagen Interpretation
3.7 Difficulties and Challenges
3.8 Philosophical Implications of Uncertainty Principle
3.9 Let Us Sum Up
3.10 Key Words
3.11 Further Readings and References

3.0 OBJECTIVES

- To study the basics of the uncertainty principle.
- To see some of its implications, including philosophical implications.
- To have some basic ideas of the Copenhagen interpretation of quantum mechanics.

3.1 INTRODUCTION

This unit takes up one of the fundamental principles from quantum mechanics. It also studies the confusion and challenges created by it. Finally it studies some of the implications of this theory.

3.2 SIMPLE DEFINITION OF UNCERTAINTY PRINCIPLE

"The more precisely the position is determined, the less precisely the momentum is known." This is the simplest statement of the uncertainty principle in quantum mechanics. The position and momentum of a particle cannot be simultaneously measured with arbitrarily high precision. There is a minimum for the product of the uncertainties of these two measurements. There is likewise a minimum for the product of the uncertainties of the energy and time. This is not a statement about the inaccuracy of measurement instruments, nor a reflection on the quality of experimental methods; it arises from the wave properties inherent in the quantum mechanical description of nature. Even with perfect instruments and technique, the uncertainty is inherent in the nature of things. Heisenberg formulated it in 1927 thus: "The more precisely the position is determined, the less precisely the momentum is known in this instant, and vice versa." This is a succinct statement of the "uncertainty relation" between the position and the momentum (mass times velocity) of a subatomic particle, such as an electron. It asserts that the position and the velocity of an object cannot both be measured exactly, at the same time, EVEN IN THEORY. The very concepts of exact position and exact velocity together, in fact, have no meaning in nature.

Because of the scientific and philosophical implications of the seemingly harmless sounding uncertainty relations, physicists speak of an uncertainty principle, which is often called more descriptively the "principle of indeterminacy."

Check Your Progress I

Note: Use the space provided for your answer

1) Give a simple definition of the principle of uncertainty, explaining the various terms?

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2) Is it possible to measure the exact location of a particle, both practically and theoretically? Why?

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3.3 BEYOND STRONG OBJECTIVITY

Classical physics was caught completely off-guard with the discovery of the uncertainty principle. Ordinary experience provides no clue of this principle. It is easy to measure both the position and the velocity of, say, an automobile, because the uncertainties implied by this principle for ordinary objects are too small to be observed. The complete rule stipulates that the product of the uncertainties in position and velocity is equal to or greater than a tiny physical quantity, or constant (about 10^{-34} joule-second, the value of the quantity h (where h is Planck's constant). Only for the exceedingly small masses of atoms and subatomic particles does the product of the uncertainties become significant (Uorgaon 2011).

Any attempt to measure precisely the velocity of a subatomic particle, such as an electron, will knock it about in an unpredictable way, so that a simultaneous measurement of its position has no validity. This result has nothing to do with inadequacies in the measuring instruments, the technique, or the observer; it arises out of the intimate connection in nature between particles and waves in the realm of subatomic dimensions. Every particle has a wave associated with it; each particle actually exhibits wavelike behavior. The particle is most likely to be found in those places where the undulations of the wave are greatest, or most intense. The more intense the undulations of the associated wave become, however, the more ill defined becomes the wavelength, which in turn determines the momentum of the particle. So a strictly localized wave has an indeterminate wavelength; its associated particle, while having a definite position, has no certain velocity. A particle wave having a well-defined wavelength, on the other hand, is spread out; the associated particle, while having a rather precise velocity, may be almost anywhere. A

$$\Delta\chi\Delta\rho \geq \frac{\hbar}{2}$$

momentum precisely, but then its position is unknown. Notice that this is not the measurement problem in another form, the combination of position, energy (momentum) and time are actually undefined for a quantum particle until a measurement is made (then the wave function collapses).

Also notice that the uncertainty principle is unimportant to macroscopic objects since Planck's constant, h, is so small (10^{-34}). For example, the uncertainty in position of a thrown baseball is 10^{-30} millimeters (Uorgaon 2011).

The depth of the uncertainty principle is realized when we ask the question; is our knowledge of reality unlimited? The answer is no, because the uncertainty principle states that there is a built-in uncertainty, indeterminacy, unpredictability to Nature. The field of quantum mechanics concerns the description of phenomenon on small scales where classical physics breaks down. The biggest difference between the classical and microscopic realm, is that the quantum world can be not be perceived directly, but rather through the use of instruments. And a key assumption to an quantum physics is that quantum mechanical principles must reduce to Newtonian principles at the macroscopic level (there is a continuity between quantum and Newtonian mechanics).

Quantum mechanics was capable of bringing order to the uncertainty of the microscopic world by treatment of the wave function with new mathematics. Key to this idea was the fact that relative probabilities of different possible states are still determined by laws. Thus, there is a difference between the role of chance in quantum mechanics and the unrestricted chaos of a lawless Universe. Every quantum particle is characterized by a wave function. In 1925 Erwin Schrodinger developed the differential equation which describes the evolution of those wave functions. By using Schrodinger equation, scientists can find the wave function which solves a particular problem in quantum mechanics. Unfortunately, it is usually impossible to find an exact solution to the equation, so certain assumptions are used in order to obtain an approximate answer for the particular problem (Uorgaon 2011).

The difference between quantum mechanics and Newtonian mechanics is the role of probability and statistics. While the uncertainty principle means that quantum objects have to be described by probability fields, this doesn't mean that the microscopic world fails to conform to deterministic laws. In fact it does. And measurement is an act by which the measurer and the measured interact to produce a result, although this is not simply the determination of a pre-existing property. The quantum description of reality is objective (weak form) in the sense that everyone armed with a quantum physics education can do the same experiments and come to the same conclusions. Strong objectivity, as in classical physics, requires that the picture of the world yielded by the sum total of all experimental results to be not just a picture or model, but identical with the objective world, something that exists outside of us and prior to any measurement we might have of it. Quantum physics does not have this characteristic due to its built-in indeterminacy.

For centuries, scientists have gotten used to the idea that something like strong objectivity is the foundation of knowledge. So much so that we have come to believe that it is an essential part of the scientific method and that without this most solid kind of objectivity science would be pointless and arbitrary. However, the Copenhagen interpretation of quantum physics (see below) denies that there is any such thing as a true and unambiguous reality at the bottom of everything. Reality is what you measure it to be, and no more. No matter how uncomfortable science is with this viewpoint, quantum physics is extremely accurate and is the foundation of modern physics (perhaps then an objective view of reality is not essential to the conduct of physics). And concepts, such as cause and effect, survive only as a consequence of the collective behavior of large quantum systems (Uorgaon 2011).

3.4 THE HISTORICAL ORIGIN OF UNCERTAINTY PRINCIPLE

The origins of uncertainty involve almost as much personality as they do physics. Heisenberg's route to uncertainty lies in a debate that began in early 1926 between Heisenberg and his closest colleagues on the one hand, who espoused the "matrix mechanics" form of quantum mechanics, and Erwin Schrödinger and his colleagues on the other, who espoused the new "wave mechanics." (Cassidy 2011)

Most physicists were slow to accept "matrix mechanics" because of its abstract nature and its unfamiliar mathematics. They gladly welcomed Schrödinger's alternative wave mechanics when it appeared in early 1926, since it entailed more familiar concepts and equations, and it seemed to do away with quantum jumps and discontinuities. French physicist Louis de Broglie had suggested that not only light but also matter might behave like a wave. Drawing on this idea, to which Einstein had lent his support, Schrödinger attributed the quantum energies of the electron orbits in the old quantum theory of the atom to the vibration frequencies of electron "matter waves" around the atom's nucleus. Just as a piano string has a fixed tone, so an electron-wave would have a fixed quantum of energy. This led to much easier calculations and more familiar visualizations of atomic events than did Heisenberg's matrix mechanics, where the energy was found in an abstruse calculation.

In May 1926 Schrödinger published a proof that matrix and wave mechanics gave equivalent results: mathematically they were the same theory. He also argued for the superiority of wave mechanics over matrix mechanics. This provoked an angry reaction, especially from Heisenberg, who insisted on the existence of discontinuous quantum jumps rather than a theory based on continuous waves. Heisenberg had just begun his job as Niels Bohr's assistant in Copenhagen when Schrödinger came to town in October 1926 to debate the alternative theories with Bohr. The intense debates in Copenhagen proved inconclusive. They showed only that neither interpretation of atomic events could be considered satisfactory. Both sides began searching for a satisfactory physical interpretation of the quantum mechanics equations in line with their own preferences (Cassidy 2011).

Studying the papers of fellow scientists, Dirac and Jordan, while in frequent correspondence with Wolfgang Pauli, Heisenberg discovered a problem in the way one could measure basic physical variables appearing in the equations. His analysis showed that uncertainties, or imprecisions, always turned up if one tried to measure the position and the momentum of a particle at the same time. (Similar uncertainties occurred when measuring the energy and the time variables of the particle simultaneously.) These uncertainties or imprecisions in the measurements were not the fault of the experimenter, said Heisenberg, they were inherent in quantum mechanics. Heisenberg presented his discovery and its consequences in a 14-page letter to Pauli in February 1927. The letter evolved into a published paper in which Heisenberg presented to the world for the first time what became known as the uncertainty principle (Cassidy, 2011).

3.5 SOME IMPLICATIONS OF UNCERTAINTY

Heisenberg realized that the uncertainty relations had profound implications. First, if we accept Heisenberg's argument that every concept has a meaning only in terms of the experiments used to measure it, we must agree that things that cannot be measured really have no meaning in physics. Thus, for instance, the path of a particle has no meaning beyond the precision with which it is observed. But a basic assumption of physics since Newton has been that a "real world" exists independently of us, regardless of whether or not we observe it. (This assumption did not go unchallenged, however, by some philosophers.) Heisenberg now argued that such concepts as orbits of electrons do not exist in nature unless and until we observe them (Jammer 1974). There were also far-reaching implications for the concept of causality and the determinacy of past and future events. These are discussed on the page about the origins of uncertainty. Because the uncertainty relations are more than just mathematical relations, but have profound scientific and philosophical implications, physicists sometimes speak of the "uncertainty principle."

In the sharp formulation of the law of causality, Heisenberg in 1927 asserted: "If we know the present exactly, we can calculate the future -it is not the conclusion that is wrong but the premise." This implies that we can never know the present reality exactly. Heisenberg also drew profound implications for the concept of causality, or the determinacy of future events. Schrödinger had earlier attempted to offer an interpretation of his formalism in which the electron waves represent the density of charge of the electron in the orbit around the nucleus. Max Born, however, showed that the "wave function" of Schrödinger's equation does not represent the density of charge or matter. It describes only the probability of finding the electron at a certain point. In other words, quantum mechanics cannot give exact results, but only the probabilities for the occurrence of a variety of possible results. (Cassidy, 2011a)

Heisenberg took this one step further: he challenged the notion of simple causality in nature, that every determinate cause in nature is followed by the resulting effect. Translated into "classical physics," this had meant that the future motion of a particle could be exactly predicted, or "determined," from a knowledge of its present position and momentum and all of the forces acting upon it. The uncertainty principle denies this, Heisenberg declared, because one cannot know the precise position and momentum of a particle at a given instant, so its future cannot be determined. One cannot calculate the precise future motion of a particle, but only a range of possibilities for the future motion of the particle. (However, the probabilities of each motion, and the distribution of many particles following these motions, could be calculated exactly from Schrödinger's wave equation.)

Although Einstein and others objected to Heisenberg's and Bohr's views, even Einstein had to admit that they are indeed a logical consequence of quantum mechanics. For Einstein, this showed that quantum mechanics is "incomplete." Research has continued to the present on these and proposed alternative interpretations of quantum mechanics. One should note that Heisenberg's uncertainty principle does not say "everything is uncertain." Rather, it tells us very exactly where the limits of uncertainty lie when we make measurements of sub-atomic events. Heisenberg's uncertainty principle constituted an essential component of the broader interpretation of quantum mechanics known as the Copenhagen Interpretation (Cassidy, 2011).

Check Your Progress II

Note: Use the space provided for your answers.

1) How does Heisenberg relate the principle of uncertainty to the principle of causality?
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2) Where lies the basic difference between classical and quantum mechanics?
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3.6 TRIUMPH OF COPENHAGEN INTERPRETATION

The Copenhagen interpretation is a commonly taught interpretation of quantum mechanics. Classical physics draws a distinction between particles and energy, holding that only the latter exhibit waveform characteristics, whereas quantum mechanics is based on the fact that matter has both wave and particle aspects and postulates that the state of every subatomic particle can be described by a wave-function—a mathematical representation used to calculate the probability that the particle, if measured, will be in a given location or state of motion (Cassidy, 2011).

The Copenhagen interpretation of quantum mechancis is an attempt to explain the results of the experiments and their mathematical formulations, as formulated by Bohr, Werner Heisenberg and others in the years 1924–27. They theorised a new world of energy quanta, entities which fit neither the classical idea of particles nor the classical idea of waves. They thereby stepped beyond the world of empirical experiments and pragmatic predictions of such phenomena as the frequencies of light emitted under various conditions. According to their interpretation, the act of measurement causes the calculated set of probabilities to "collapse" to the value defined by the measurement. This feature of the mathematics is known as wave-function collapse. The Copenhagen interpretation is, in form, a composite of those statements which can be legitimately made in natural language to complement the statements and predictions made in the language of instrument readings and mathematical operations (Cassidy, 2011). Essentially, it attempts to answer the question, "What do these amazing experimental results really mean?" The concept that quantum mechanics does not yield an objective description of microscopic reality but deals only with probabilities, and that measurement plays an ineradicable role, is the most significant characteristic of the Copenhagen interpretation.

Because it consists of the views developed by a number of scientists and philosophers during the second quarter of the 20th Century, there is no definitive statement of the Copenhagen Interpretation. Thus, various ideas have been associated with it; Some of its key notions are as follows (CI 2011):

1. A system is completely described by a wave function ψ, representing an observer's subjective knowledge of the system. (Heisenberg)
2. The description of nature is essentially probabilistic, with the probability of an event related to the square of the amplitude of the wave function related to it. (The Born rule, after Max Born)
3. It is not possible to know the value of all the properties of the system at the same time; those properties that are not known with precision must be described by probabilities. (Heisenberg's uncertainty principle)
4. Matter exhibits a wave-particle duality. An experiment can show the particle-like properties of matter, or the wave-like properties; in some experiments both of these complementary viewpoints must be invoked to explain the results, according to the complementarity principle of Niels Bohr.
5. Measuring devices are essentially classical devices, and measure only classical properties such as position and momentum.
6. The quantum mechanical description of large systems will closely approximate the classical description. (The correspondence principle of Bohr and Heisenberg.)

We regard quantum mechanics as a complete theory for which the fundamental physical and mathematical hypotheses are no longer susceptible of modification. (Heisenberg and Max Born, paper delivered to Solvay Congress of 1927)

3.7 DIFFICULTIES AND CHALLENGES

Not everyone agreed with the new interpretation, or with Born and Heisenberg's statement about future work. Einstein and Schrödinger were among the most notable dissenters. Until the ends of their lives they never fully accepted the Copenhagen doctrine. Einstein was dissatisfied with the reliance upon probabilities. But even more fundamentally, he believed that nature exists independently of the experimenter, and the motions of particles are precisely determined. It is the job of the physicist to uncover the laws of nature that govern these motions, which, in the end, will not require statistical theories. The fact that quantum mechanics did seem consistent only with statistical results and could not fully describe every motion was for Einstein an indication that quantum mechanics was still incomplete. Alternative interpretations have since been proposed and are now under serious consideration. The objections of Einstein and others notwithstanding, Bohr, Heisenberg and their colleagues managed to ensure the acceptance of their interpretation by the majority of physicists at that time. They did this both by presenting the new interpretation on lecture trips around the world and by demonstrating that it worked. The successes of the theory naturally attracted many of the best students to institutes such as Heisenberg's, some coming from as far away as America, India, and Japan. These bright students, nurtured by the Copenhagen doctrine and educated into the new quantum mechanics, formed a new and dominant generation of physicists. Those in Germany and Central Europe carried the new ideas with them as they dispersed around the world during the 1930s and 1940s in the wake of Hitler's rise to power in Germany (Cassidy 2011).

Albert Einstein was not happy with the uncertainty principle, and he challenged Niels Bohr and Werner Heisenberg with a famous thought experiment we fill a box with a radioactive material which randomly emits radiation. The box has a shutter, which is opened and immediately thereafter shut by a clock at a precise time, thereby allowing some radiation to escape. So the time is already known with precision. We still want to measure the conjugate variable energy precisely. Einstein proposed doing this by weighing the box before and after. The equivalence between mass and energy from special relativity will allow you to determine precisely how much energy was left in the box. Bohr countered as follows: should energy leave, then the now lighter box will rise slightly on the scale. That changes the position of the clock. Thus the clock deviates from our stationary reference frame, and again by special relativity, its measurement of time will be different from ours, leading to some unavoidable margin of error. In fact, a detailed analysis shows that the imprecision is correctly given by Heisenberg's relation.

Within the widely but not universally accepted Copenhagen interpretation of quantum mechanics, the uncertainty principle is taken to mean that on an elementary level, the physical universe does not exist in a deterministic form—but rather as a collection of probabilities, or potentials (Cassidy 2011). For example, the pattern (probability distribution) produced by millions of photons passing through a diffraction slit can be calculated using quantum mechanics, but the exact path of each photon cannot be predicted by any known method. The Copenhagen interpretation holds that it cannot be predicted by any method.

It is this interpretation that Einstein was questioning when he said "I cannot believe that God would choose to play dice with the universe." Bohr, who was one of the authors of the Copenhagen interpretation responded, "Einstein, don't tell God what to do." Einstein was convinced that this interpretation was in error. His reasoning was that all previously known probability distributions arose from deterministic events. The distribution of a flipped coin or a rolled dice can be described with a probability distribution (50% heads, 50% tails). But this does *not* mean that their physical motions are unpredictable. Ordinary mechanics can be used to calculate exactly how each coin will land, if the forces acting on it are known. And the heads/tails distribution will still line up with the probability distribution (given random initial forces). Einstein did not believe that the theory of quantum mechanics was complete. But Heisenberg and Max Born asserted at the famous Solvay Congress of 1927: “We regard quantum mechanics as a complete theory for which the fundamental physical and mathematical hypotheses are no longer susceptible of modification.” That is the basic difference between them.

3.8 PHILOSOPHICAL IMPLICATIONS OF UNCERTAINTY PRINCIPLE

The Uncertainty Principle is often presented as a manifestation of the fact that the act of measurement inevitably perturbs the state that is being measured. Thus, the smaller the particle being observed, the shorter the wavelength of light needed to observe it, and hence the larger the energy of this light and the larger the perturbation it administers to the particle in the process of measurement. This interpretation, while helpful for visualization, has its limitations. It implies that the particle being observed does have a precise position and a precise momentum which we are unable to ascertain because of the clumsiness of the measurement process. However, more correctly, we should view the Uncertainty Principle as telling us that the concepts of position and momentum cannot coexist without some ambiguity. There is no precise state of momentum and position independent of the act of measurement, as naïve realist philosophers had assumed. In large, everyday situations this quantum mechanical uncertainty is insignificant for all practical purposes. In the sub-atomic world it is routinely confirmed by experiment and plays a fundamental role in the stability of matter. Note that if we take the limit in which the quantum aspect of the world is neglected (so Planck's constant, *h,* is set to zero), then the Heisenberg Uncertainty would disappear and we would expect to be able to measure the position and momentum of any object with perfect precision using perfect instruments (of course in practice this is never possible) (Barrow 2006).

The Uncertainty Principle has had a major effect upon the philosophy of science and belief in determinism. It means that it is impossible to determine the present state of the world (or any small part of it) with perfect precision. Even though we may be in possession of the mathematical laws that predict the future from the present with complete accuracy we would not be able to use them to predict the future. The Uncertainty Principle introduces an irreducible indeterminacy, or graininess, in the state of the world below a particular level of observational scrutiny. It is believed that this inevitable level of graininess in the state of matter in the universe during the first moments of its history led to the production of irregularities that eventually evolved into galaxies (Barrow 2006). Experiments are underway in space to test the detailed predictions about the variations left over in the temperature of the universe that such a theory makes. Of the other pairs of physical quantities that Heisenberg showed cannot be measured simultaneously with arbitrarily high precision, the most frequently discussed pair is energy and time. Strictly, this pair is not a true indeterminate pair like position and momentum because time is not an observable in the way that energy, position, and momentum are in quantum mechanics. By using a time defined externally to the system being observed (rather than intrinsically by it), it would be possible to beat the requirement that the product of the uncertainty in energy times the uncertainty in time be always greater than Planck's constant divided by 4π (Barrow 2006).

The physicist Niels Bohr (1885–1962) called quantities, like position and momentum, whose simultaneous measurement accuracy was limited by an uncertainty principle *complementary pairs.* The limitation on simultaneous knowledge of their values is called *complementarity.* Bohr believed that the principle of complementarity had far wider applicability than as a rigorous deduction in quantum mechanics. This approach has also been adopted in some contemporary religious apologetics, notably by Donald Mackay and Charles Coulson. There has also been an interest in using quantum uncertainty, and the breakdown of rigid determinism that it ensures, to defend the concept of free will and to provide a channel for divine action in the world in the face of unbreakable laws of nature. The Uncertainty Principle also changes our conception of the vacuum. Quantum uncertainty does not allow us to say that a volume of space is empty or contains nothing. Such a statement has no operational meaning. The quantum vacuum is therefore defined differently, as the lowest energy state available to the system locally. This may not characterize the vacuum uniquely and usually a physical system will have more than one possible vacuum state. Under external changes it may be possible to change from one to another. It is therefore important to distinguish between the non-scientific term, "nothing" and the quantum mechanical conception of "nothing" when discussing creation out of nothing in modern cosmology (Barrow 2006).

Check Your Progress III

Note: Use the space provided for your answers.

1) Why did Einstein object to some of the elements of quantum mechanics?

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2) What are some of the philosophical implications of uncertainty principle?
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3.9 LET US SUM UP

In this unit we tried to see the uncertainty principle, its difficulties and implications. It has changed the way we normally looked at the nature of particle, velocity, etc., and so opened a totally new way of understanding reality.

3.10 KEYWORDS

Decoherence: quantum decoherence (is how quantum systems interact with their environments to exhibit probabilistically additive behavior. Quantum decoherence gives the appearance of wave function collapse (the reduction of the physical possibilities into a single possibility as seen by an observer) and justifies the framework and intuition of classical physics as an acceptable approximation (See also the previous unit keywords).

Matrix mechanics: Matrix mechanics is a formulation of quantum mechanics created by Werner Heisenberg, Max Born, and Pascual Jordan in 1925. Here physical quantities are represented by matrices and matrix algebra is used to predict the outcome of physical measurements.

Momentum: he quantity of motion of a moving body, measured as a product of its mass and velocity.

Wave function collapse: The reduction of the physical possibilities in quantum mechancis into a single possibility as seen by an observer.

Wave mechanics: A method of analysis of the behavior of atomic phenomena with particles represented by wave equations. It is based on Schrodinger's equation; atomic events are explained as interactions between particle waves

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UNIT 4 THE ORIGIN AND THE END OF THE UNIVERSE

Contents

4.0 Objectives
4.1 Introduction
4.2 The Origin of the Universe
4.3 The End of the Universe
4.4 Let Us Sum Up
4.5 Key Words
4.6 Further Readings and References

4.0 OBJECTIVES

- To familiarise ourselves with some general theories on the origin and end of the physical universe.
- To know that scientific theories on the universe keep on evolving and changing.
- To be familiar with the commonly accepted theory on the origin and end of the universe (Big Bang and Big Crunch)

4.1 INTRODUCTION

According to Stephen Hawking (1988) the problem of the origin of the universe, is a bit like the old question: Which came first, the chicken, or the egg. In other words, Who created the universe? Or perhaps, the universe, or the agency that created it, existed forever, and didn't need to be created. Up to recently, scientists have tended to shy away from such questions, feeling that they belonged to metaphysics or religion, rather than to science. However, in the last few years, it has emerged that the Laws of Science may hold even at the beginning of the universe and also may explain the end of the universe.

The debate about whether, and how, the universe began, has been going on throughout recorded history. Basically, there were two schools of thought. Many early traditions, and the Jewish, Christian and Islamic religions, held that the universe was created in the fairly recent past. For instance, Bishop Usher calculated a date of four thousand and four BC, for the creation of the universe, by adding up the ages of people in the Old Testament. One fact that was used to support the idea of a recent origin, was that the Human race is obviously evolving in culture and technology. We remember who first performed that deed, or developed this technique. Thus, the argument runs, we cannot have been around all that long. Otherwise, we would have already progressed more than we have. In fact, the biblical date for the creation, is not that far off the date of the end of the last Ice Age, which is when modern humans seem first to have appeared.

The universe of 100 years ago was simple: eternal, unchanging, consisting of a single galaxy, containing a few million visible stars. The picture today is more complete and much richer. The cosmos began 13.7 billion years ago with the big bang. A fraction of a second after the beginning, the universe was a hot, formless soup of the most elementary particles, quarks and leptons. As it expanded and cooled, layer on layer of structure developed: neutrons and protons, atomic nuclei, atoms, stars, galaxies, clusters of galaxies, and finally superclusters. The observable part of the universe is now inhabited by 100 billion galaxies, each containing 100 billion stars and probably a similar number of planets. Galaxies themselves are held together by the gravity of the mysterious dark matter. The universe continues to expand and indeed does so at an accelerating pace, driven by dark energy, an even more mysterious form of energy whose gravitational force repels rather than attracts. In this context, this unit attempts to give some of the common theories on the origin and end of the universe from scientific perspectives. The religious perspectives are not considered here.

4.2 THE ORIGIN OF THE UNIVERSE

Some of the common scientific theories explaining the beginning of the universe

Steady State Theory

Steady State Theory proposes that matter is being continuously created, at the rate of a few hundred atoms per year. This would allow the density of the universe to remain constant as it expands. It holds that the universe looks, on the whole, the same at all times and places. The Austrian-British astronomer Hermann Bondi and the Austrian-American astronomer Thomas Gold formulated the theory in 1948. The British astronomer Fred Hoyle soon published a different version of the theory based on his mathematical understanding of the problem. Most astronomers believe that astronomical observations contradict the predictions of the steady-state theory and uphold the big bang theory. The infinite duration of time was the most appealing feature of the steady state theory. Even the notion of creation was used to advantage: the failure to detect a large flux of gamma rays led to the proposal that creation preferentially took place only in dense galactic nuclei and quasars. This proposal initially met with some enthusiasm, because it appeared to solve two problems: continuous creation was revived, and an ample energy source was provided for the most energetic objects in the universe.

However, three shortcomings eventually led to the demise of steady state cosmology. First, astronomers have discovered a large increase in the number of faint radio sources as the limiting flux level is systematically decreased. The number that they estimate is well above that expected for a uniform source distribution in Euclidean space, which suggests that strong evolutionary effects are occurring at great distances. The notion of an excess number of distant faint sources did not find universal acceptance. For several years, Hoyle was able to argue that an equally plausible hypothesis was a deficit of nearby bright sources. Now, however, it seems clear with measured redshifts that the highly red shifted sources, most notably the radio galaxies and the quasars, reveal strong evolutionary effects. Equal volumes of space contain progressively more quasars and powerful radio galaxies at greater distances. Looking at evidence, explanations, rationalizations, and arguments for naturalistic origins of the universe leads to a simple conclusion. Once all of the cards are on the table, recent discoveries have given life to interpretations that are long on theory and short on proof. To put it another way, all scientists have really proven about the origin of the universe is that they don’t really know how it happened, and they may be looking at it the wrong way.

Check Your Progress I

Note: Use the space provided for your answer

1) Give an approximate size of our universe?

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2) Give a brief description of the steady-state theory.

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Big Bang Theory

The Big Bang theory is an effort to explain what happened at the very beginning of our universe. Discoveries in astronomy and physics have shown beyond a reasonable doubt that our universe did in fact have a beginning. According to the standard theory, our universe sprang into existence as "singularity" around 13.7 billion years ago. Our universe is thought to have begun as an infinitesimally small, infinitely hot, infinitely dense, something - a singularity. We don't know where it came from not why did it appear. After its initial appearance, it apparently inflated (the "Big Bang"), expanded and cooled, going from very, very small and very, very hot, to the size and temperature of our current universe. It continues to expand and cool to this day and we are inside of it: incredible creatures living on a unique planet, circling a beautiful star clustered together with several hundred billion other stars in a galaxy soaring through the cosmos.

Evidence for the Theory

First of all, we are reasonably certain that the universe had a beginning. Second, galaxies appear to be moving away from us at speeds proportional to their distance. This is called "Hubble's Law," named after Edwin Hubble (1889-1953) who discovered this phenomenon in 1929. This observation supports the expansion of the universe and suggests that the universe was once compacted. Third, if the universe was initially very, very hot as the Big Bang suggests, we should be able to find some remnant of this heat. In 1965, Radio astronomers Arno Penzias and Robert Wilson discovered a 2.725 degree Kelvin (-454.765 degree Fahrenheit, -270.425 degree Celsius) Cosmic Microwave Background radiation (CMB) which pervades the observable universe. This is thought to be the remnant which scientists were looking for. Penzias and Wilson shared in the 1978 Nobel Prize for Physics for their discovery. Finally, the abundance of the "light elements" Hydrogen and Helium found in the observable universe are thought to support the Big Bang model of origins.

Big Bang Theory - What About God?

Any discussion of the Big Bang theory would be incomplete without asking the question, what about God? This is because cosmogony (the study of the origin of the universe) is an area where science and theology meet. Creation was a supernatural event. That is, it took place outside of the natural realm. This fact begs the question: is there anything else which exists outside of the natural realm? Specifically, is there a master Architect out there? We know that this universe had a beginning. Was God the "First Cause"?

Check Your Progress II

Note: Use the space provided for your answer

1) Give a brief description of Big Bang?

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2) What are some of the evidences for Big Bang Theory.

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4.3 THE END OF THE UNIVERSE

Theories explaining the end of the universe are the following.

Heat Death

German physicist Hermann von Helmholtz made a prediction in the year 1856 that the universe is dying. This prediction was based on the law of thermodynamics. A more thoroughgoing analysis enables this law to be generalized to all closed systems: the entropy never falls. If the universe as a whole can be considered as a closed system, on the basis that there is nothing 'outside' it, then the second law of thermodynamics makes an important prediction: the total entropy of the universe never decreases. In fact it goes on rising remorselessly. When heat flows from hot to cold, the entropy rises, but eventually the cold body will warm up and the hot body will cool down so that they reach the same temperature. When the state is achieved, there will be no further heat transfer. The system inside the container will have reached a uniform temperature – a stable state of maximum entropy referred to as thermodynamic equilibrium. No further change is expected, as long as the system remains isolated. All physical activity in the universe tends toward a final state of thermodynamic equilibrium, or maximum entropy, following which nothing of value is likely to happen for all eternity. This one-way slide toward equilibrium became known to the early thermodynamicists as the 'heat death' of the universe.

Big Freeze

Observations suggest that the expansion of the universe will continue forever. If so, the universe will cool as it expands, eventually becoming too cold to sustain life. For this reason, this future scenario is popularly called the Big Freeze. The future of an expanding universe is bleak. If a cosmological constant accelerates the expansion of the universe, the space between clusters of galaxies will grow at an increasing rate. Redshift will have stretched ancient, incoming photons (even gamma rays) to undetectably long wavelengths and low energies. Stars are expected to form normally for 1×1012 to 1×1014 years, but eventually the supply of gas needed for star formation will be exhausted. Once the last star has exhausted its fuel, stars will cease to shine. According to theories that predict proton decay, the stellar remnants left behind would disappear, leaving behind only black holes which themselves eventually disappear as they emit Hawking radiation. Ultimately, if the universe reaches a state in which the temperature approaches a uniform value, no further work will be possible, resulting in a final heat death of the universe.

The Big Rip

A new and somewhat sinister theory about the long-term future of the universe is emerging. It has been called the "Big Rip", and it forecasts that our bodies will be literally torn apart. Its leading proponent Robert Caldwell of Dartmouth University calls it a "pretty fantastic possibility", but he and his colleagues cannot see how it can be avoided if the present acceleration of the cosmos continues. The idea is like this: the universe, driven by that mysterious force called "dark energy", or repulsive gravity, is flying apart. The furthest galaxies are moving ever further from us. But the rate of expansion is itself accelerating. The accelerating acceleration continues unchecked. Eventually the increased acceleration comes every 100 yards, and at last every foot. Finally everything explodes. "The expansion becomes so fast that it literally rips apart all bound objects," says Caldwell.

There is no need for immediate panic, since this dreadful sequence of events will not become noticeable for another 20 billion years. At this point all galaxies beyond our own, traveling much faster than light, will have flown so far away from us that they become invisible. (This is not a violation of Einstein's special relativity. The galaxies are not flying through space. In the expanding universe, space itself expands.) Our Milky Way galaxy alone can be seen. Then the Milky Way begins to fly apart, and at this point there are only 60 million years left. Long before this, of course, other events will have destroyed our Sun and planets. But imagine some part of humanity inhabiting the planets of another stellar system. When there are only three months left, these planets and their parent Sun explode. "There's about 30 minutes left before atoms and their nuclei break apart," says Caldwell, "but it's not quality time. We're not sure what happens after that. On the face of it, it would look like time ends." Repulsive dark energy, although we know next to nothing about its cause, comprises 73 per cent of all the energy in the cosmos. It exists everywhere in the vacuum of space.

Check Your Progress III

Note: Use the space provided for your answers.

1) What is heat death theory?

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2) Give your comments on the Big Rip theory.

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Big Bounce

The Big Bounce is a theorized scientific model related to the formation of the known universe. It derives from the cyclic model or oscillatory universe interpretation of the Big Bang where the first cosmological event was the result of the collapse of a previous universe. According to some oscillatory universe theorists, the Big Bang was simply the beginning of a period of expansion that followed a period of contraction. In this view, one could talk of a Big Crunch followed by a

Big Bang, or more simply, a Big Bounce. This suggests that we might be living in the first of all universes, but are equally likely to be living in the 2 billionth universe (or any of an infinite other sequential universes).

Multiverse: No Complete End

The multiverse (or meta-universe, metaverse) is the hypothetical set of multiple possible universes (including the historical universe we consistently experience) that together comprise everything that exists: the entirety of space, time, matter, and energy as well as the physical laws and constants that describe them. The term was coined in 1895 by the American philosopher and psychologist William James. The various universes within the multiverse are sometimes called parallel universes. The structure of the multiverse, the nature of each universe within it and the relationship between the various constituent universes, depend on the specific multiverse hypothesis considered. Multiverses have been hypothesized in cosmology, physics, astronomy, religion, philosophy, transpersonal psychology and fiction, particularly in science fiction and fantasy. In these contexts, parallel universes are also called "alternative universes", "quantum universes", "interpenetrating dimensions", "parallel dimensions", "parallel worlds", "alternative realities", and "alternative timelines", among others.

Cyclic Theories

In several theories there is a series of infinite, self-sustaining cycles (for example: an eternity of Big Bang-Big crunches). A multiverse of a somewhat different kind has been envisaged within the multi-dimensional extension of string theory known as M-theory, also known as Membrane Theory. In M-theory our universe and others are created by collisions between p-branes in a space with 11 and 26 dimensions (the number of dimensions depends on the chirality of the observer); each universe takes the form of a D-brane. Objects in each universe are essentially confined to the D-brane of their universe, but may be able to interact with other universes via gravity, a force which is not restricted to D-branes. This is unlike the universes in the "quantum multiverse", but both concepts can operate at the same time.

The concept of other universes has been proposed to explain why our universe seems to be fine-tuned for conscious life as we experience it. If there were a large number (possibly infinite) of different physical laws (or fundamental constants) in as many universes, some of these would have laws that were suitable for stars, planets and life to exist. The weak anthropic principle could then be applied to conclude that we would only consciously exist in those universes which were finely-tuned for our conscious existence. Thus, while the probability might be extremely small that there is life in most of the universes, this scarcity of life-supporting universes does not imply intelligent design as the only explanation of our existence.

Critics claim that many of these theories lack empirical testability, and without hard physical evidence are unfalsifiable; outside the methodology of scientific investigation to confirm or disprove. Reasons why such claims lack empirical evidence or testability according to most Multiverse theories is that other universes are in a different spacetime framework, so in principle they cannot be observed.

The logical foundation of modern science is hypothetico-deductive logic which permits a theory to propose unobservable entities if these help explain observable outcomes, either by theory based predictions (of future observations) or retroductionism (of already known observations).

False vacuum

In quantum field theory, a false vacuum is a metastable sector of space that appears to be a perturbative vacuum, but is unstable due to instant on effects that may tunnel to a lower energy state. This tunneling can be caused by quantum fluctuations or the creation of high-energy particles. Simply put, the false vacuum is a local minimum, but not the lowest energy state, even though it may remain stable for some time. This is analogous to metastability for first-order phase transitions. The possibility that we are living in a false vacuum has been considered. If a bubble of lower energy vacuum were nucleated, it would approach at nearly the speed of light and destroy the Earth instantaneously, without any forewarning. Thus, this vacuum metastability event is a theoretical doomsday event. This was used in a science-fiction story in 1988 by Geoffrey A. Landis, in 2000 by Stephen Baxter, and in 2002 by Greg Egan. According to the many-worlds interpretation of quantum mechanics, the universe will not end this way. Instead, each time a quantum event happens that causes the universe to decay from a false vacuum to a true vacuum state, the universe splits into several new worlds. In some of the new worlds the universe decays; in some others the universe continues as before.

The big crunch

In physical cosmology, the Big Crunch is one possible scenario for the ultimate fate of the universe, in which the metric expansion of space eventually reverses and the universe recollapses, ultimately ending as a black hole singularity. If the universe is finite in extent and the cosmological principle (not to be confused with the cosmological constant) does not apply, and the expansion speed does not exceed the escape velocity, then the mutual gravitational attraction of all its matter will eventually cause it to contract. Because entropy continues to increase in the contracting phase, the contraction would appear very different from the time reversal of the expansion. While the early universe was highly uniform, a contracting universe would become increasingly clumped. Eventually all matter would collapse into black holes, which would then coalesce producing a unified black hole or Big Crunch singularity.

The Hubble Constant measures the current state of expansion in the universe, and the strength of the gravitational force depends on the density and pressure of the matter and in the universe, or in other words, the critical density of the universe. If the density of the universe is greater than the critical density, then the strength of the gravitational force will stop the universe from expanding and the universe will collapse back on itself. Conversely, if the density of the universe is less than the critical density, the universe will continue to expand and the gravitational pull will not be enough to stop the universe from expanding. This scenario would result in the 'Big Freeze', where the universe cools as it expands and reaches a state of entropy. Some theorize that the universe could collapse to the state where it began and then initiate another Big Bang, so in this way the universe would last forever, but would pass through phases of expansion (Big Bang) and contraction (Big Crunch).

Recent experimental evidence (namely the observation of distant supernova as standard candles, and the well-resolved mapping of the cosmic microwave background) have led to speculation that the expansion of the universe is not being slowed down by gravity but rather accelerating. However, since the nature of the dark energy that drives the acceleration is unknown, it is still possible (though not observationally supported as of today) that it might eventually reverse sign and cause a collapse.

Check Your Progress IV

Note: Use the space provided for your answers.

1) Give an evaluation of the cyclic theory of the universe?

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2) What is a false vacuum?

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4.4 LET US SUM UP

In this unit after having seen some of the theories on the origin of the universe, we have focussed on the end of the universe. The whole unit has been dealing with the different scientific theories and not the religious theories of the origin and destiny of our universe.

4.5 KEY WORDS

Singularities are zones which defy our current understanding of physics. They are thought to exist at the core of "black holes." Black holes are areas of intense gravitational pressure. The pressure is thought to be so intense that finite matter is actually squished into infinite density (a mathematical concept which truly boggles the mind). These zones of infinite density are called "singularities."

Big Crunch: In physical cosmology, the Big Crunch is one possible scenario for the ultimate fate of the universe, in which the metric expansion of space eventually reverses and the universe recollapses, ultimately ending as a black hole singularity.

Big Rip: The Big Rip is a cosmological hypothesis first published in 2003, about the ultimate fate of the universe, in which the matter of the universe, from stars and galaxies to atoms and subatomic particles, are progressively torn apart by the expansion of the universe at a certain time in the future.

The Big Bounce is a theorized scientific model related to the formation of the known Universe. It derives from the cyclic model or oscillatory universe interpretation of the Big Bang where the first cosmological event was the result of the collapse of a previous universe

Big Freeze: Recent observations suggest that the expansion of the universe will continue forever. If so, the universe will cool as it expands, eventually becoming too cold to sustain life. For this reason, this future scenario is popularly called the Big Freeze.

Heat Death and Cold Death: In a simple definition, heat death will occur when all energy (heat) is supposedly evenly distributed throughout the universe, so that there is no place for it to go. In thermodynamics, energy is continuously being transferred through objects in the form of work or heat. The heat-death of the universe is when the universe has reached a state of maximum entropy. This happens when all available energy (such as from a hot source) has moved to places of less energy (such as a colder source). Once this has happened, no more work can be extracted from the universe. Since heat ceases to flow, no more work can be acquired from heat transfer. This same kind of equilibrium state will also happen with all other forms of energy (mechanical, electrical, etc.). Since no more work can be extracted from the universe at that point, it is effectively dead, especially for the purposes of humankind. This concept is quite different from what is commonly referred to as cold death. Cold death is when the universe continues to expand forever. Because of this expansion, the universe continues to cool down. Eventually, the universe will be too cold to support any life; it will end in a whimper. The opposite of cold death, is NOT "heat death" but actually the Big Crunch. The big crunch occurs when the universe has enough matter density to contract back on itself, eventually shrinking to a point. This shrinking will cause the temperature to rise, resulting in a very hot end of the universe.

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Philosophy of Science and Cosmology

Block 4

SPECIAL ISSUES IN CONTEMPORARY PHILOSOPHY OF SCIENCE AND COSMOLOGY

UNIT 1
Space and Time

UNIT 2
Expanding Universe

UNIT 3
World Models

UNIT 4
Science and Religion

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BLOCK INTRODUCTION

Philosophical issue of understanding the ontological status of Space and Time remains an important issue in science and cosmology. The question if space and time ultimately real is answered variously by different theories and philosophical positions. Einstein's theory of relativity showed variant character of space and time. It gave a broader and more profound picture of the dialectics of time-space relations. One of the features of the Big Bang cosmological model is an expanding universe. The idea that the Universe is expanding has far-reaching ramifications in the field of physics than simply being another amazing astronomical phenomena. A study of different models of universe reveals that our view of the world keeps on evolving. Religion is the outcome of man's quest for freedom and is the outer manifestation of this great hunger for the infinite. "Science without religion is lame, religion without science is blind".

Unit 1 takes us to philosophical notions of space and time. Space and Time remain as one of the riddles in philosophy since ancient period. Perceptual space and time are experienced by us through events. Perceptual space is finite. Conceptual space and time are infinite, unlimited, and abstract and has no directions. There are other theories of space and time like, Idealistic theory of space and time (Kant) Realistic theory of space and time (Samuel Alexander) Anti-Intellectualistic theory of space and time (William James and Henri Bergson) Realitivistic theory of space and time (Albert Einstein).

Unit 2 gives a brief idea of the nature, history and end of universe. The understanding of expanding universe is that starting from a very hot and very dense singularity, the components that evolved into what is now our universe first experienced a cataclysmic event. What followed was a continuous expansion, cooling, and thinning out of these components. The unit explores the phenomenon of expanding universe and how it has given rise to the contemporary cosmological theories. the universe.

Unit 3 studies some of the theories or models – ancient and modern – universe and discusses in length about the most important world model we have today. An observation is made how our present world model is the result of continuous evolution of older ones. History tells us that best model we have (the modified standard model) will give way to a better one in the near future.

Unit 4 takes up the relation between science and religion that is getting their due important to man in the modern age. They are two great disciplines which, when relied on separately can be counter-productive, but when combined harmoniously can being about an all-round expression of human genius and total fulfillment. Albert Einstein says, "Now, even though the realms of religion and science in themselves are clearly marked off from each other, nevertheless, there exist between the two strong reciprocal relationships and dependencies. Though religion may be that which determines the goal, it has nevertheless, learned from science, in the broadest sense, what means will contribute to the attainment of the goals it has set up. But science can only be created by those who are thoroughly imbued with the aspiration towards truth and understanding. This source of feeling, however, springs from the sphere of religion."

UNIT 1 SPACE AND TIME

Contents

1.0 Objectives
1.1 Introduction
1.2 Perceptual and Conceptual Space and Time
1.3 Idealistic Theory of Space and Time
1.4 Realistic Theory of Space and Time
1.5 Space-Time: The Ultimate Stuff or Matrix
1.6 Categories, Qualities and Values
1.7 Anti-Intellectualistic Interpretation of Space and Time
1.8 Relativistic Theory of Space and Time
1.9 Einstein's Relativity Theory
1.10 Infinity of Space and Time
1.11 Let Us Sum Up
1.12 Key Words
1.13 Further Readings and References

1.0 OBJECTIVES

This unit takes the students to the speculative, philosophical and scientific notions of space and time.

1.1 INTRODUCTION

Space and Time remain as one of the riddles in philosophy since ancient period. Are space and time ultimately real? Or they are real only with reference to phenomena or event is still a debatable question. Those who support the absolute theory of space and time argue that space and time are ultimately real. But those who disagree with the absolute existence of space and time argue that space and time are real only with reference to phenomena. Space and time are non-existent if they are divorced from events. Space and time act as receptacle of events. Events are meaningless without spatio-temporal characteristics. They are also thinkers who support the theory that space and time are 'empty.' Are space and time finite or infinite? There is no 'beginning' and 'end' for space and time accounting to the infinite theory of space and time. There is also no 'direction' for space and time. We do not know where is the starting point for this cosmos nor do we know the terminus of it.

1.2 PERCEPTUAL AND CONCEPTUAL SPACE AND TIME

When we perceive the external world we see in front of us the perceptual world. When we slowly turn our heads, the 'horizon' of the perceptual world changes and there is continuity in our perception. 'Far,' 'near,' 'above,' 'below,' 'by the side of,' 'under' etc. are some of the words we use to refer to the spatial quality of our perception. Perceptual space is 'sensibly continuous.' Perceptual time is the experience of an event when it 'endures.' The duration of the event is a continuation of the past to the present and the future. Perceptual space and time are experienced by us through events. Perceptual space is finite. It can be divided into smaller units.

The divided segments of the infinite space can be quantitatively measured. Perceptual space has got directions and reversible.

But perceptual time is irreversible. It can be divided into smaller units. Both percpetual space and time are limited and can be specified to particular contexts or phenomena. Conceptual space and time are infinite, unlimited, and abstract and has no directions. They are indivisible and imagined. It is possible to go to the present from the past or from the past to the present. Conceptual space is infitite in the sense that our imagination cannot limit the space. The mind can form an idea about small or big space. Once can also imagine future time. Since the space or time which are imagined are called conceptual space or time, they are not limited.
There are other theories of space and time too apart from the perceptual and conceptual theories of space and time.

1) Idealistic theory of space and time (Kant)
2) Realistic theory of space and time (Samuel Alexander)
3) Anti-Intellectualistic theory of space and time (William James and Henri Bergson)
4) Realitivistic theory of space and time (Albert Einstein)

1.3 IDEALISTIC THEORY OF SPACE AND TIME

Immanuel Kant is the exponent of Idealistic theory of space and time. His views on space and time are discussed in his *The Critique of Pure Reason.* According to him our perception (which he calls '*phenomenon'*) consists of two parts: that due to object, which he calls 'sensation,' and that due to our subjective apparatus, which, he says, causes the manifold to be ordered in certain relations. This latter part he calls the form of the phenomenon. This part is not itself sensation, and therefore not dependent upon the accident of environment; it is always the same, since we carry it about with us, and it is *a priori* in the sense that it is not dependent upon experience. A pure form of sensibility is called a 'pure intutition'; there are two such forms namely spasce and time, one for the outer sense, one for the inner. As pure forms of intuition the mind projects spatio-temporal characteristics to the objects of perception. Therefore the external objects themselves do not have space and time. They are the subjective (as forms of intuition) projections of the inner mind. Idealistic view of Kant with regard to space and time are established by him by using antinomicial concepts. Antinomical concepts are opposite concepts. In case space and time are not subjective, but objective, it is inevitable that the following possibilities will exist simultaneously:

1) That space and time are both finite and infinite
2) That space and time are both divisible and indivisible
3) That space and time are both part and whole

If space and time are assumed to be objective, realistic or empirical, the above possibilities will exist simultaneously. It is non-sensical to say that space and time are finite and infinite divisible and indivisible, and part and whole simultaneously. Therefore according, to Kant to overcome this problem it is necessary to say that space and time are Idealistic. The antinomical (opposite) concepts such as finite-infinite, divisible-indivisible, part-whole are used by Kant to prove his Idealistic theory of space and time. Kant also uses tow classes of arguments to prove that space and time are *a priori* forms of intuition: (1) metaphysical and (2) epistemological (which he calls transcendental). The metaphysical arguments are taken directly from the nature of space and time and the transcendental arguments are taken indirectly from the possibility of pure mathematics. As regards space metaphysical arguments are four in number:

1) Space is not an empirical concept, abstracted from outer experiences, for space is presupposed in referring sensations to something external, and external experience is only possible through the presentation of space.

2) Space is a necessary presentation *a priori*, which underlies all external perceptions; for we can not imagine that there should be no space, although we can imagine that there should be nothing in space.

3) Space is not a discursive or general concept of the relations of things in general, for there is only one space, of which we call 'spaces' are parts, not instances.

4) Space is presented as an infinite given magnitude, which holds within itself all the parts of space; this relation is different from that of a concept to its instances and therefore space is not a concept.

The transcendental argument concerning space is derived from geometry. Kant holds that Euclidean geometry is known *a priori,* although it is synthetic, i.e., not deducible form logic alone. Geometrical proofs depend upon the figures. The objects of sense must obey geometry, because geometry is concerned with our ways of perceiving, and therefore we can not perceive otherwise. This explains why geometry, through synthetic, is *apriori* and *apodeitic.* The arguments with regard to time are essentially the same, except that arithmetic replaces geometry with the contention that counting takes time.

1.4 REALISTIC THEORY OF SPACE AND TIME

Samuel Alexander is the exponent of the realistic theory of space and time. The basic elements of Alexander's system can be traced to the great philosophers of the past, and the scientific thinkers of his time but his greatness lies in synthesizing them into an original form all his own. Like Lloyd Morgan, Alexander was a naturalist and an empiricist. But whereas Morgan starts from physical events related in space and time and tries to show how, out of these, all inorganic material substance, life and mind can be conceived to emerge, Alexander pushes the idea of emergence still further and shows how the entire universe including all physical events, life, mind and even deity can be conceived to evolve out of Space-Time emerges out of the matrix of Space-Time. Space-Time is the basic of a 'Pyramid' structure of emergent evolution and out of it emerges the higher levels, matter, life, mind and deity. Deity forms the apex of the pyramid, and there is *anisus* toward the deity inherent in the process of evolution. This explains the upward direction of the process. For Alexander epistemology is not the necessary preliminary to metaphysics and mind is a natural phenomenon. Every experience may be analysed into two district elements and their relation to one another. The two elements which are the terms of the relation are, on the one hand the act of mind or the awareness and on the other the object of which it is aware; the relation between them is that they are together or compresent in the world which is thus so far experienced. I am aware of my awareness and my awareness and my being aware of it are identical. But I am aware of an object, as something distinct from awareness and present before it. To keep the distinction between subjective and objective knowledge clear, Alexander calls the former enjoyment, and the latter contemplation. The mind enjoys itself; but the mind contemplates a true (in perception), an image (in memory) etc. While for Berkeley 'reality is ideas,' for Alexander 'ideas are reality.' Since he keeps the identity between the object contemplated and the object existing he is an epistemological monist or a neo-realist.

1.5 SPACE-TIME: THE ULTIMATE STUFF OR MATRIX

Space-Time, conceived as 'a system of motion' is hypothetically posited by Alexander as the stuff or matrix (or matrices) out of which things or events emerge. All finite beings are in some sense complexes of space and time. His procedure is not deductive, but, like that of science, empirical. He starts with the hypothesis of space-time and shows gradually that it can account for all observable phenomena, and thus the hypothesis becomes verified and justified. Unlike Spinoza and Kant, for Alexander space and time are inseparable system of motion. In this regard he agrees with Einstein's space-time continuum. Our experience of the finite space and time are parts of the imagined space and time. Therefore there is no reason to say that infinite space and time are unreal. Space and Time are ordinarily regarded as separate and independent. But their separation is the result of abstraction. For Alexander space and time are interdependent so that there neither is space without Time nor Time without space; that space is in its very nature temporal and Time spatial. Time, apart from space, would be nothing more than a mere succession of discrete instants, and there would be nothing to unite these discrete members into a continuous whole. If, therefore, the past instant is not to be lost as it otherwise would be, or rather since this is not the case in fact, there needs must be some continuum other than Time which can secure and sustain the togetherness of past and present, of earlier and later. This other form of being is space; that is space supplies us with the second continuum needed to save Time from being a mere 'now.' As Time in so far as it was temporal became a mere 'now,' so space as merely spatial becomes a blank. It would be without distinguishable elements. But a continuum without elements is not a continuum at all. Time distinguishes and separates the parts of space. Thus Space and Time depend each upon the other. Without space there would be no connection in Time. Without Time there would be no points to connect. There are no such things as points or instants by themselves. There are only point-instants or pure events. In fact there is no instant of time without a position in space and no point of space without an instant of time. A point occurs at an instant and an instant occupies a point. We can not think of the existence of a portionof space without thinking of it as existing at a particular date or time; and similarly we can not think of a particular time without thinking of it as the time of objects existing in space. Ideas of space and time are, therefore, mutually interdependent. Space-Time presents a very complex system which can be grasped by the idea of motion. Even a particle and its motion is a made of Space-Time, Mind is made of Space-Time. Mental acts are really identical with neural processes, so that awareness of enjoyment of an act of mind is nothing but the enjoyment of a neural process with its own time and space. Therefore mind also is made of the stuff of Space-Time.

1.6 CATEGORIES, QUALITIES AND VALUES

Space-Time matrix gives rise to all existents by its internal differentiation. All objects have two different kinds of characters, pervasive and variable. The pervasive characters follow from the spatio-temporal nature common to all objects. These are called categories. The variable characters are those which are generated by special kinds of grouping of Space-Time and are found in special classes of existents. These are called qualities. The categories are the essential and universal constituents of whatever is experienced and they are common to the mental and non-mental. They are *a priori,* whereas qualities are empirical. The categories are *a priori,* not in the sense that they are not experienced; but in the sense of being pervasive and universal like the a priori categories of Kant. Alexander gives the natures of the different groups of categories such as; (1) Identity, diversity and existence (2) Universal, particular and individual (3)relation (4) order (5) substance, causality, reciprocity (6) quantity and intensity (7) whole and parts and number (8) motion. These categories are derived from the different aspects of the Space-Time system. Space-Time relationship is analogous to mind-body relationship. As the mind intitiates, guides and organizes the activities of the body, so also does Time with regard to space. The first thing to emerge out of space-time (or motion) by the activity of Time on space is finite motion. By a further grouping and complexity there emerges the next quality: Matter with primary qualities. Similarly in the course of further complexities and motions, the qualities such as matter with secondary qualities, life, mind and deity emerge. According to Alexander even deity is a product of emergent evolution from Space-Time (motion). For Bergson *Elan Vital* or reality pushes from behind the species and therefore evolution is creative. But deity according to Alexander is neither transcendental nor a force pushing from behind as the cause of evolution. Just like matter life and mind even deity is a product or quality emerging out of Space-Time matrix. However it must be admitted that Deity is the finest quality to be evolved from Space-Time.

As far Alexander's realistic conception of Space and Time, it must be stated that Space and Time have independent existence of their own. For Kant, Space and Time have no objective or independent existence. They are subjective or *a priori* forms of intuition. Such an idealistic view of space and time is refuted by Samuel Alexander by accepting space and time to be objectively real. On the contrary even the mind is a by product of Space-Time matrix. The values such as truth, goodness and beauty though dependent on mind are not the qualities of Reality. They are the products of interaction between mind and Reality. They arise out of mind's interpretation, utilization and appreciation, or in a word valuation of Reality. They should be called, therefore, values rather than qualities (of Reality). Reality in itself is neither true, nor, good nor beautiful. What is more important to remember here is that even values are product of Space-Time.

1.7 ANTI-INTELLECTUALISTIC INTERPRETATION OF SPACE AND TIME

The anti-intellectualistic trend in philosophy was advocated by philosophers like William James and Henri Bergson. Their attitudes revolted against Absolute Idealism. The study of Biology left a permanent impression on Bergson, and moulded his metaphysical outlook. While the materialist tries to interpret the whole world-matter, life and mind-in terms of matter alone, and the idealist in terms of mind alone, Bergson attempts to understand everything in terms of life. The fundamental idea of Bergson's thought is the life-force which we feel throbbing within us. The world of matter lying extended before us and ideas appearing within our mind are understood as products of the same life-impetus which Bergson calls as *Elan Vital.* The vital force, *elan vital,* is in a flux or change. Due to change there is evolution which is creative. Man, plants and animals are the three dimensional changes brought about by the vital impetus. The metaphysics of Bergson is based on the philosophy of change. His philosophy of change is based on his philosophy of time. He calls time as *duree* (duration). Time is popularly understood as the succession of homogeneous moments which do not differ from one another in respect of character of quality. Motion, too is conceived, according to this idea of time, as the occupation of different positions in space at successive instants of time and it becomes thus a source of endless puzzles and paradoxes as Zero points out. This popular conception of time is mechanical and mathematical which is static. Bergson does not agree with the mathematical and mechanical conception of time. According to him time is duration, *duree,* which is the basis for all changes or for events to take place. Events take place in time in the internal world as well as in the external world. The states of consciousness succeed one another in our mind and things which are perceived are simultaneous, extended in space, outside one another. They are present all together. There is thus neither past nor future in space, and therefore, no succession. The external world is the simultaneous togetherness of many objects existing side by side. The so called successive states of the external world are nothing but different simultaneous presentations of the world arranged successively by the mind. If we deduct mental activity there would be nothing left but simultaneity and the external world would be devoid of time or succession. There are two aspects of our mental life a superficial one, and a deeper one. In its superficial aspect it consists of sensations, emotion, thoughts etc., which are separated, isolated, named and arranged one after another. Succession belongs only to this superficial aspect. But in its deeper aspect the different experiences of the mind are inseparably intermingled, they interpenetrate and form one concrete whole, in which no element is outside another and the elements, are not, therefore, arranged in any order of succession. In every intense experience we have an undistinquished multiplicity of elements blending into a moving whole whose intensity is due to the cumulative force of the interpenetrating elements. If we accept the view that time can be measured like space, the most fatal consequence of spatialisation, is that we come to believe that the past is left behind, and is dead and gone, and the future lies ahead and therefore the present is all that is left, and is of any consequence. But for Bergson real time is an unbroken concrete unity or whole which are not abstract or independent units. The spatialised and abstract conception of time can not grasp the Reality which is unceasing action or change. Motion or change can be understood only through a time which is dynamic and not static. There must be something continuing and developing through the different states to unify them into one process of change, or rather there would be only a discrete and discontinuous multiplicity. Therefore for Bergson time does not mean succession, and change does not mean mere succession of states – the replacement of one state by another. But time is duration which is the nature of real change itself. "Duration is the continuous progress of the past which gnaws into the future and which swells as it advances. And as the past grows without ceasing, so also there is no limit to its presentation." Every present experience is felt as duration. It is as James says, like a 'saddle back,' and not like a 'needle point' or a 'knife edge.' The past, present and future interpenetrate into a dynamic whole which is analysed by the intellect into successive static ideas. The different aspects of Bergson's philosophy centre round this conception of Time or change. Time, change and consciousness are related to each other. Bergson tries to show through his philosophy the dialectical nature of *Elan Vital* by using the opposites such as matter-memory, space-time, intellect-intuition, closed morality-open morality and static religion-dynamic religion. The forward movement of *Elan Vital* overcomes the obstacles created by matter, space, intellect, closed morality and static religion.

1.8 RELATIVISTIC THEORY OF SPACE AND TIME

The classical physics of Newton was not challenged by the scientists till the beginning of the 20th century. However some of the new discoveries in science during the 20th century could not be explained by the Newtonian concepts adequately. The Newtonian mechanics and his absolute theory of space and time were criticised by scientists like Albert Einstein. Newtonian theory of classical mechanics considered the ether as the medium of motion and space. Time and motion were independent of each other. The three dimensional space and one dimensional time were separable with each other. The invention of electro magnetic field, sub atomic particles and quantum mechanics challenged the Newtonian classical mechanics. Newton's proofs of absolute space were proved to be fallacious by the modern science. His first proof that absolute motion proves absolute space and the former is proved by force, is a vicious circle, for the forces are only postulated to explain motion. His second proof is derived from circular motion such as what produces the concavity of the surface of a rotating pail of water, but this is now thought to be due not to empty space but to them matter filling it. Newton's third proof that relative motions are differences of absolute ones is not tenable for an absolute motion or translation of a body from one part of absolute space to another cannot be known because these parts are indistinguishable. A body can move not with reference to absolute space but to other bodies. The ideas of absolute space were finally abandoned after the experiments of Michelson-Morley who did not find any difference in the velocity of light when measured once in the direction of and then perpendicular to earth's movement. Such a difference ought to have there if light were electromagnetic vibrations in a medium, called ether, pervading all space. By absolute space Newton understood the empty and motionless space of the universe. He used the term 'absolute' to characterise the invariance of lengths and time intervals. In classical mechanics the concept of absolute time found its expression in the recognition of absolute simultaneity; if any two events occurred simultaneously in one inertial system of reference, they were also found to occur simultaneously in another. The conclusion ensuing from the principle of the constancy of velocity of light was entirely different: Two events which took place simultaneously in one system of reference could not be simultaneous in another. In other words, simultaneity according to this principle is relative.

1.9 EINSTEIN'S RELATIVITY THEORY

To overcome the difficulties faced by the scientists due to Newton's absolute theory of space and time, Einstein gave his historical theory of Relativity. Einstein did not agree with Newtonian conception of the independent existence of space, time and motion. For him all three are interdependent to each other. It is space-time and not space and time. In other words space-time continuum with energy (matter) was well received by the world of science. According to Einstein the position of the observer and the gravitational force play an important role in the relativity of the units of measurement in science. For example if one's weight is 60 kg. on earth, his weight on the moon will be only 12 kg., since the gravitational force of moon is only $1/5^{th}$ of that of earth. Hence the weight of an individual is relative to his position (with reference to particular location and time). Position of the observer as 'relative' factor is discussed in Einstein's *Special Theory of Relativity.* His *General Theory of Relativity* discusses the influence of gravitation as a factor of relativity in science. There are no simultaneities in the occurrence of events since the time of occurrence of an event and the time of observation of the same are not simultaneous. The stars we see on the sky would be the effect of the light caused by the stars during the period of Emperor Asoka. The light would have taken more than two thousand years to reach our eyes yesterday. Therefore our observation of celestial phenomena is misleading if we assume that there is simultaneity of the occurrence of an event and our observation of the same. Moreover there is bending of light due to gravitation and therefore the location of the star we observe is shifted to some other place.

Gravitation influences not only space but also time. The velocity of light will change depending upon the gravitational pulls of the celestial bodies. The velocity of the spin of earth and the distance between stars and planets are not absolute. We take for granted that these measured units will not change. What we measure in everyday life is relative to so many other factors mentioned above. Euclids' geometry is also not acceptable to Einstein. According to Euclid the sum of the three angles of a triangle must be 180 degree. But if this rule is applied to Matter and Motion, it is not correct. The classical physics of Newton and the assumption that matter should occupy space has been disproved by the modern interpretation of matter as 'energy.' Einstein's theory of relativity showed variant character of space and time. It is correct in the sense that the theory revealed new links and relationships which had not been taken into account by classical physics and thus gave a broader and more profound picture of the dialectics of time-space relations.

1.10 INFINITY OF SPACE AND TIME

Can we fix the starting point or beginning and the terminus for space and time? We can be conscious of space and time as long as we live. Does it mean that there was no space and time before our births and there will be no space and time after our deaths? If we travel upwards can we reach the end of the sky? These are some of the perplexing questions which evoke curiosity in the human mind. There are millions of galaxies in the universe. The Milky Way, our galaxy is only a fraction of the whole universe. Therefore we are not at the centre of the universe. We don't know the beginning and the end of this vast universe. Space and time have no privileged axis. There is no arrow of time so that we can indicate the direction of the movement of our galaxy. Milky way is one the connecting chains of the continuity of the universe. The cosmic phenomena involving infinite quantities of matter and space are still a mystery. Man is completely lost in the infinity of space and time.

1.11 LET US SUM UP

We have given representation of different traditions of human thought and discovery on reality of space and time.

1.12 KEY WORDS

General Theory of Relativity discusses the influence of gravitation as a factor of relativity in science.

1.13 FURTHER READINGS AND REFERENCES

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UNIT 2 EXPANDING UNIVERSE

Contents

2.0 Objectives
2.1 Introduction
2.2 The Phenomenon of Expanding Universe
2.3 Historical Beginnings
2.4 The Expanding Universe: An Overview
2.5 Infinite or Finite?
2.6 The Big Bang and the History of the Universe
2.7 The End of the Universe
2.8 Let Us Sum Up
2.9 Key Words
2.10 Further Readings and References

2.0 OBJECTIVES

- To study the expanding universe.
- To see how expanding universe has given rise to the contemporary cosmological theories.
- To a brief idea of the nature, history and end of the universe.

2.1 INTRODUCTION

In this unit, we explore the phenomenon of expanding universe and see how it has given rise to the scientist cosmology of today. The unit is written depending heavily on the scholarly and reader-friendly article of an American Physicist, Gary Felder (2000).

2.2 THE PHENOMENON OF EXPANDING UNIVERSE

One of the features of the Big Bang cosmological model is an expanding universe. That is, starting from a very hot and very dense singularity, the components that evolved into what is now our universe first experienced a cataclysmic event. What followed was a continuous expansion, cooling, and thinning out of these components. The idea that the Universe is expanding has far-reaching ramifications in the field of physics than simply being another amazing astronomical phenomena. For one, it allows for a unification between those who have spent their lives studying the very small (particle physicists) and those who have dedicated theirs with the very large (astrophysicists). For a long time, particle physicists toiled in the middle of a particle zoo. The discoveries of quarks, leptons, as well as the strong, electromagnetic, weak, and gravitational forces filled their labs with mixed feelings (Villanueva 2009).

On one hand, they were constantly excited with the wealth of discoveries of these numerous tiny particles and their interactions, while on the other, they were conscious of the fact that the diversity of these forces deviated from the idea that nature was biased towards simplicity. They realized these forces should eventually unite for simplicity to prevail. From their calculations, this was only possible in the presence of very high energies. But since these energies were not present anywhere in the Universe, then the possibility was useless. This puzzle was solved when scientists studying cosmology realized that the Universe was expanding and as a result, was cooling and becoming less dense (Villanueva 2009 and Hawking 2002).

Scientists analyzed that if this were true, then it could be possible that the Universe was once very hot and very dense. In these conditions, the energies would have been extremely high.

There are proofs that the Universe experienced a cataclysmic event (Big Bang) and, subsequently, that it is expanding even now. One of the proofs is the detection of the cosmic microwave background radiation exhibiting a thermal black body spectrum of about 3 K. Another is the collection of red shift observations for galaxies, i.e., the further from us the galaxies are, the greater their measured red-shifts. That means, the outermost galaxies are speeding away much faster than the innermost ones. These two alone support the Big Bang theory (Villanueva 2009).

2.3 HISTORICAL BEGINNINGS

In 1929 an astronomer named Edwin Hubble announced a remarkable observation that changed our view of the world more than almost any other single discovery made this century. In every direction he looked, every galaxy in the sky was moving away from us. The nearby ones were moving relatively slowly, but the farther away a galaxy was the faster it was heading out. What can account for our great unpopularity? Is our galaxy somehow different from all others?

It turns out that there is another, arguably simpler explanation that is well supported by many other observations. It is that the entire universe itself is expanding! This expansion indicates not only that we should see every other galaxy moving away from us, but that observers in another galaxy should see exactly the same thing. In a uniform expanding universe, every observer sees herself at the center of the expansion, with everything else moving outwards from her (Felder 2000).

This statement forms the basis of our current theories of the structure and history of the universe. The study of the overall structure of the universe is called cosmology. The theory that has come to dominate cosmology since Hubble's observations goes by several names, but is most commonly known as the *big bang model.* This rest of this unit describes the big bang model. Next section describes what it means to say the universe is expanding, and subsequent sections address some questions that commonly arise in connection with the model.

Then the following Section discuss whether the universe is infinite or finite. While we don't yet know the answer to this question, Einstein's general theory of relativity predicts that finite universes contain a larger density of matter than infinite ones, so by measuring the density in the universe we should hopefully be able to make the determination. We end section by describing what it would mean for the universe to be infinite or finite (Felder 2000 and Brown 2007).

In the next Section we talk about the origin and history of the universe. As the universe expands and galaxies move apart from each other the average density is decreasing (Brown 2007). If we extrapolate the expansion backwards we conclude that there was a time roughly 10-15 billion years ago when the density was nearly infinite. In this section we briefly outline the history of the universe from that time to the present. In the final Section we continue the story, describing what relativity theory predicts will happen to the universe in the future. The two possibilities are that the universe will continue to expand forever or that it will eventually slow down and begin contracting. The theory tells us that which one will happen depends on whether or not the average density of the universe exceeds a certain value, the same value that determines whether the universe is infinite or finite. Relativity predicts that an infinite universe will continue to expand forever, whereas a finite universe will expand for a finite time and then contract (Russell 2009 and Felder 2000).

Check Your Progress I

Note: Use the space provided for your answers.

1) What are some of the proofs for Big Bang?

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2) What is the big bang model?

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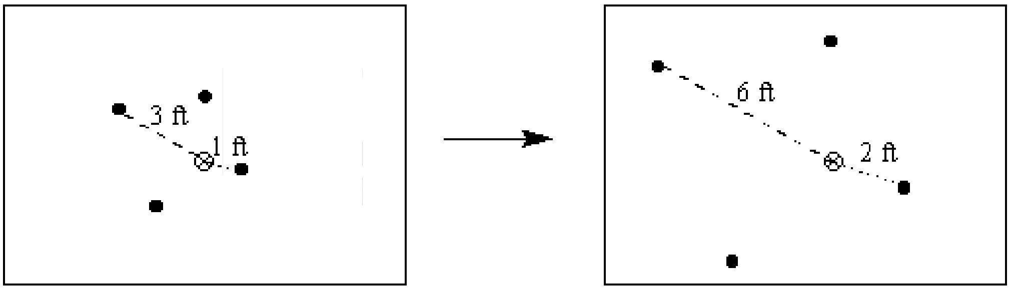
2.4 THE EXPANDING UNIVERSE: AN OVERVIEW

Simple analogies can clarify what it means for the universe to expand, but they can also be misleading. We can use one analogy, attempting to point out its shortcomings as we proceed. Think of the universe as a rubber sheet being stretched out. (If you are comfortable with visualization in three dimensions you can imagine a raisin cake expanding instead, but for the purpose of illustration we will stick with the two dimensional case.) Now imagine that there are drawing pins stuck into the rubber at various points representing galaxies. (In the raisin cake analogy these would be the raisins.) As the rubber (the universe) is stretched (expands), the drawing pins (galaxies) all get farther apart. Note that we haven't said anything yet about how big the rubber sheet is. For all we know it might be infinite. (This point will be addressed in a later section.) What we mean when we talk about expansion is that the rubber is being stretched out, causing the distances between the drawing pins to increase (Felder 2000 and Brown 2007).

To see what this expansion should look like to us, imagine an observer sitting on one of the drawing pins. This observer imagines himself to be at rest and measures all movement relative to his drawing pin (galaxy). Since the distance between any two drawing pins is increasing, it will appear to him that all the other ones are moving away from him. How fast will another drawing pin appear to move? That depends in part on how fast the rubber sheet is being stretched out, *i.e.*, how fast the universe is expanding. In addition, however, the apparent speed of the other drawing pins is also dependent on their positions relative to the observer. The nearby drawing pins will appear to be moving away very slowly, whereas the distant ones will appear to be moving away much faster. To see why this is so, suppose the rubber sheet doubles in size in one second.



The drawing pin that began one foot away from you is two feet away, meaning it appears to have moved by a foot. Its apparent velocity is therefore 1 foot per second. In the same time the drawing pin that started out three feet away also ends up twice as far away (six feet), but this means that it appears to have moved away at three times the speed of the first drawing pin (three feet per second). In terms of the expanding universe, this means that not only will every galaxy appear to be moving away from us, but the speed with which it does so will be directly proportional to its distance from us. A galaxy that is four million light years away will have twice the apparent velocity of one that is two million light years away (Felder 2000).

This pattern is precisely what Hubble observed. Not only did he see that all distant galaxies are moving away from us and that the more distant ones are moving away more rapidly, but he found that the rate at which they were receding from us was proportional to their distance from us (Felder 2000). In other words, his observations exactly matched what we just predicted for an expanding universe. This proportionality is known as Hubble's Law.

A problem arises when we consider an expanding universe. Suppose everything in the universe were to double in size. The distances between galaxies would double, the size of the Earth would double, the size of all our meter sticks would double, and so on. It would seem to an observer (who will also have doubled in size) as if nothing had happened at all. So what do we mean by saying the universe expands?

In fact, not everything grows as the universe expands. In the example of the rubber sheet, the distance between drawing pins keeps increasing but the drawing pins themselves remain the same size. Similarly, while distant galaxies are pulled away from each other by the expansion, smaller objects like meter sticks, people, and the galaxies themselves are held together by forces that prevent them from expanding. So we expect that billions of years from now galaxies will still be roughly the same size they are today, but the distances between them will on average be much larger.

2.5 INFINITE OR FINITE?

People have wondered for millennia whether the universe is limited in size or goes on forever. Fortunately we now have modern science to step in and supply us with the answer, which is that we don't know. We believe that the universe is governed by Einstein's theory of general relativity, which among other things addresses such matters as the overall structure of the universe. In the early 1920s Alexander Friedmann showed that using one assumption the equations of general relativity can be solved to show that a finite universe must have a larger density of matter and energy inside it than an infinite universe would have (Felder 2000). There is a certain *critical density* that determines the overall structure of the universe. If the density of the universe is lower than this value, the universe must be infinite, whereas a greater density would indicate a finite universe. These two cases are referred to as an *open* and *closed* universe respectively. The critical density is about 10^{-29} g/cm^3, which is equivalent to about five hydrogen atoms per cubic meter (Felder 2000). This may not seem like a lot; by comparison the density of water is roughly 1 g/cm^3 or about 500 billion billion billion hydrogen atoms per cubic meter. However, we live in a very dense part of the universe. Most of the universe is made up of intergalactic space, for which a density as low as the critical density is plausible.

Aside from the theory of relativity itself, Friedmann's only other assumption in deriving his results was that on average the density of the universe was the same everywhere. This doesn't mean that every place in the universe is exactly the same. We already mentioned that the Earth is much more dense than space. However, if we measure the average density in our galaxy it will be about the same as the average density in any other galaxy, and the number of galaxies per unit volume should be roughly the same in different parts of the universe. This assumption matches all our observations to date. Individual galaxies differ from one another in some of their specific properties, but on average their properties don't appear to change from one region of the sky to another. Nonetheless, the idea that the universe is roughly the same everywhere—a property known as *homogeneity*—is still an assumption. We can probably only see a tiny fraction of the universe and we have no guarantee that the parts we cannot see look like the parts we can. Lacking any evidence to the contrary, however, we will assume that the property of homogeneity holds true.

So we should be able to answer the question of the universe being infinite or finite by measuring the density of everything around us and seeing whether it is above or below the critical value. This is true in principle, and measuring the average density of the universe is a very active field of research right now. The problem is that the measured density turns out to be pretty close to the critical density. Right now the evidence seems to favor an infinite universe, but it is not yet conclusive.

To recap, one of the assumptions of the standard big bang model is that the universe is more or less homogeneous—the same everywhere. As far as we can see, which is billions of light years in every direction, this assumption appears to be correct. Under this assumption general relativity says that whether the universe is infinite or finite depends on its density. Measurements of that density reveal that it is close to the critical value. Right now the data seem to point more towards an open (infinite) universe, but new data coming in the next 10-20 years should resolve the question much more definitively (Felder 2000).

Given our uncertainty about this question, we will briefly comment on what it would mean if the universe is infinite or finite and how those two possibilities relate to the idea of the universe expanding. An infinite universe is in some ways easier to imagine than a finite one. Since the universe is supposed to be everything that exists, it seems intuitive that it should go on forever. Of course an infinite universe is impossible to picture, but we can get at what it means by saying that no matter how far you go there will always be more space and galaxies. It is hard, however, to reconcile this picture with the idea that the universe is expanding. If it's already infinite, how can it expand?

To see how, remember that by expansion we mean that the distance between galaxies is increasing. Suppose right now there is a galaxy every million light years or so. After a long enough time this infinite grid of galaxies will stretch out so that there is a galaxy every two million light years. The total size of the universe hasn't changed—it's still infinite—but the volume of space containing any particular group of galaxies has grown because the separation between the galaxies is now larger.

What about a finite universe? This phrase sounds like a contradiction because if the universe ends somewhere then we would naturally want to know what was beyond it, and since the universe includes everything, whatever is beyond that edge should still be called part of the universe. The resolution of this paradox is that even if the universe is finite, it still doesn't have an edge. If we head off in one direction and resolve to keep going until we find the end of the universe, we eventually find ourself right back where we started. A finite universe is *periodic*, meaning that if you go far enough in any direction you come back to where you started (Felder 2000).

Trying to picture a closed (finite) universe is in some ways even harder than trying to picture an open (infinite) universe because it is easy to mislead yourself. For example, people often compare a two-dimensional closed universe to the surface of a balloon. This analogy is helpful because such a surface has the property of being periodic in all directions, and it is easy to picture the expansion of such a universe by imagining the balloon being blown up. In fact, this analogy is like the rubber sheet analogy we used before, except now the sheet has been wrapped up to form a sphere. The problem is that this picture immediately leads to the question of what is inside the balloon.

This question comes from taking the analogy too literally. Nothing in general relativity says that a two-dimensional closed universe would have to exist as a sphere inside a three-dimensional space; the theory only says that such a universe would have certain properties (*e.g.* periodicity) in common with such a sphere. For this reason, as shown by Gary Felder (2000), it is useful to keep the balloon in mind as a convenient analogy but it is ultimately best to think of the closed universe as a three-dimensional space with the strange property that things which go off to the right eventually come back again from the left.

What does expansion mean in a closed universe? Since this universe has a finite size, it makes sense to talk about that size increasing. Again suppose that there is now a galaxy every million light years. Suppose also that if we were to head off in a straight line we would travel 100 billion light years before coming back to where I started, passing about 100,000 galaxies on the way. If we take the same journey billions of years later, the number of galaxies won't have changed but the distances between them will have doubled, so the total distance for the round trip will now be 200 billion light years.

Check Your Progress II

Note: Use the space provided for your answers.

1) What is the importance of Hubble's Law?

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2) Is the universe finite?

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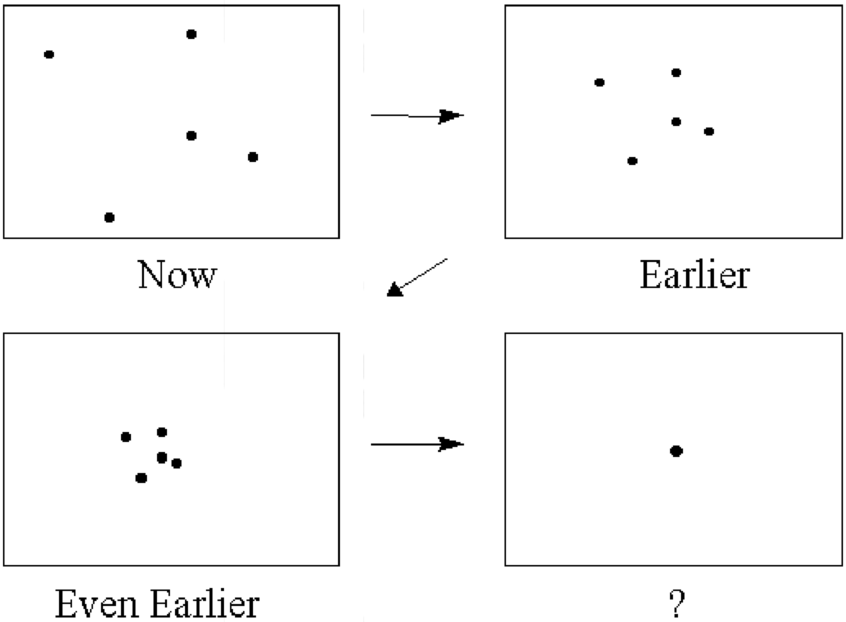
2.6 THE BIG BANG AND THE HISTORY OF THE UNIVERSE

At the beginning of this century, physicists generally had a strong bias toward the idea that the universe was essentially unchanging. Local phenomena would of course change from minute to minute, and stars and galaxies might be born and die, but taken as a whole the universe was assumed to be more or less the same now as it had been billions or trillions of years ago, with no beginning or end (Felder 2000). Einstein, disturbed that his theory of general relativity seemed to be inconsistent with a static universe, tried to modify the equations of the theory. When Hubble's observations showed that the universe was indeed expanding, Einstein retracted this modification and called it the biggest blunder of his life. Given that the universe is growing, the question of whether the expansion started at some point in the past inevitably arises. Our current theories say the expansion *did* have a beginning. This section discusses why we believe this and what it means to even say so. It also contains a brief outline of the history of the universe from that beginning to the present day.

The Big Bang

To see what it means to say the universe had a beginning, consider a group of galaxies chosen at random throughout the universe. The illustration below shows five galaxies as they appear now and as they would have appeared at several times in the distant past. At some point in the past (about 6-10 billion years ago), all of these galaxies would have been half as far apart as they are now. At an earlier time they would have been half as far apart as that, and so on. If you extrapolate this process backwards you eventually come to a time in the past when the galaxies would have been right on top of one another. Put another way, the density of matter (or energy) in the universe was higher at earlier times, and extrapolating this process backwards we come eventually to a time when that density would have been infinite. This moment of infinite density is called the *big bang*.



Having defined the moment of the big bang in this way—the time when all distances between objects were zero— we cannot talk about that time. A point of infinite density, known in physics as a "singularity," makes no sense. Moreover, our current theories do not predict that such a moment occurred in the past. Our best physical theories, including general relativity and quantum mechanics, stop working when we try to describe matter that is almost infinitely dense. That word "almost" is important. The theories don't simply break down at the instant of the big bang singularity; rather, they break down a short time afterwards when the density has a certain value called the *Planck density* (Felder 2000).

The Planck density, which is the highest density we can hope to describe with our current physics, is over 10^{93} g/cm^3, which corresponds to roughly 100 billion galaxies squeezed into a space the size of an atomic nucleus. For virtually any application we can imagine this limitation of our theories is completely irrelevant, but it means we can't describe the universe immediately after the big bang. We can only say that our current model of the universe begins when the density was somewhere below the Planck density and we can say virtually nothing about what the universe was like before that. We therefore take as our initial condition a universe at or just below the Planck density, and any questions about the instant of the big bang itself are eliminated from consideration.

Is this a cop-out? It certainly is. Physicists have not given up on understanding what happened before this time, but we admit that right now we have no theory to describe it. Many people are working to develop such a theory, but until that happens we are left having to start our description of the universe when the density was large but still finite. Once we impose this limitation on ourselves, our picture of the universe works equally well for an infinite or a finite universe. If the universe is finite then it may very well have been extremely small at the moment when the density was at the Planck level. If the universe is infinite then it was also infinite at that early time. The density was enormous and the distances between particles vanishingly small, but that dense mass of particles went on forever.

The History of the Universe

Describing the history of the universe is obviously a fairly large task, so we can only with mentioning a few highlights. For a very good description of much of the early history the book *The First Three Minutes* by Steven Weinberg is excellent. At the moment when the density of matter equalled the Planck constant, the universe consisted of a hot soup of elementary particles. When we say this medium was hot that means that the particles, on average, had very high energies. All of the fundamental particles such as quarks, electrons, and photons were present. At present these particles are mostly combined into larger units such as atoms, molecules, penguins, and so on, but at the extremely high temperatures of the early universe they remained separate. If several particles were to have combined into a more complicated structure such as an atom they would have been instantly ripped apart in collisions with the high energy particles flying around everywhere. As the universe expanded, the density and temperature of this mixture decreased. After a small fraction of a second the quarks combined into protons and neutrons in a process called *baryogenesis.* A few minutes later the protons and neutrons combined into atomic nuclei in a process referred to as *nucleosynthesis.* Hundreds of thousands of years later these protons and neutrons combined with electrons to form atoms.

In the period of recombination the universe was still almost perfectly homogeneous, meaning that the density was the same everywhere. While the density still is the same everywhere when averaged over huge regions of space, it certainly varies locally. The density of the Earth is vastly larger than the density of interstellar space, which is in turn much greater than the density of intergalactic space. In contrast, the difference in density between the most and least dense regions at the time of recombination was about one part in 100,000. Between then and now the converging of matter into galaxies, stars, etc. took place (Felder 2000).

The mechanism by which this converging occurred is fairly simple, although its details continue to be studied and debated. At the time of recombination the universe consisted of a nearly uniform hot gas with regions very slightly denser than the average and others very slightly less dense. If the density had been *exactly* the same everywhere then it would have always stayed that way. However, a region slightly denser than the surrounding gas would have a stronger gravitational attraction, and mass would tend to flow into it. This process would make this region even denser, causing it to attract matter even more strongly. In this way the almost uniformly dense universe gradually became less and less uniform, resulting in the dense grouping of matter we see around us now. On a fairly large scale these groupings make up galaxies, and matter that grouped on a smaller scale makes up the stars inside those galaxies. A very small portion formed into smaller objects orbiting around those stars and a small portion of that matter formed into people reading physics papers on the Internet.

2.7 THE END OF THE UNIVERSE

Hubble's observation that the universe is expanding suggested more generally that the universe is changing with time. As in most subjects, we know more about the past than we do about the future, but if we assume that our current physical theories are correct then we can predict a great deal about the future of our universe. Is the universe going to exist forever or will it someday come to an end as it began? Put another way, will the expansion of the universe continue forever? If the universe keeps on expanding it will presumably continue to exist for an infinitely long time. On the other hand, if the expansion ever stops, then the universe will contract until it once again reaches the Planck density (and after that we have no idea what it will do). In what follows we will explain what determines which of these scenarios is going to occur and say more about what each of them means (Felder 2000).

We know from general relativity that expansion of the universe is slowed down by the mutual gravity of all the matter inside it. Whether or not the expansion will continue forever depends on whether or not there is enough matter in the universe to reverse it. If the density of matter in the universe is less than a certain critical value, then the universe will never stop expanding. If, on the other hand, the density of matter is greater than the critical value, then the pull of gravity will eventually be strong enough to stop the expansion and the universe will begin contracting. In Section III we saw that whether or not the universe is finite or infinite depends on whether the density of matter is above or below a critical value. That value turns out to be exactly the same as the critical value that determines whether or not the expansion will reverse. In other words, general relativity says that an open (infinite) universe will expand forever and a closed (finite) universe will eventually re-collapse.

If the universe expands forever, the clusters of galaxies in it will move farther and farther apart. Eventually each galaxy cluster will be alone in a vast empty space. The stars will burn out their fuel and collapse, leaving nothing but cold rocks behind. Eventually these will disintegrate as well. This whole process will take an unimaginably long time but it will occur eventually, and the universe will thereafter consist of nothing but loosely spread out elementary particles. All of the energy in the universe will then be distributed in a more or less uniform way at some extremely low temperature, and as the universe continues to expand this temperature will fall and the universe will become ever more empty and cold. This scenario is sometimes referred to as the heat death of the universe.

On the other hand, if the universe has a high enough density, then the galaxies will eventually start moving back towards each other. Once they are close enough together all galaxies and stars will collapse, until at some point the universe will once again consist of nothing but densely packed, highly energetic particles. Eventually all matter will be compressed to the Planck density, the density at which our current theories fail. Lacking a theory for such densities, we cannot predict what will happen then. One possibility is that the universe will bounce back—indeed, perhaps it has been in a cycle of expanding and contracting forever. Then again perhaps the universe will simply annihilate itself and cease to exist. Determining which of these possibilities would occur will require the development of a theory of physics at extremely high densities (Felder 2000).

Check Your Progress III

Note: Use the space provided for your answers.

1) Why did Einstein object to some of the elements of quantum mechanics?
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2) What is baryogenesis and what is its significance?

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2.8 LET US SUM UP

In this unit we discussed the expanding universe and some of the cosmological consequences that are derived from it. This gives rise to a world that is so gigantic and magnificient.

2.9 KEY WORDS

Baryogenesis*:* In physical cosmology, baryogenesis is the generic term for hypothetical physical processes that produced an asymmetry between baryons and antibaryons in the very early universe, resulting in the substantial amounts of residual matter that make up the universe

Hubble's Law: A law stating that the redshifts in the spectra of distant galaxies (and hence their speeds of recession) are proportional to their distance.

2.10 FURTHER READINGS AND REFERENCES

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UNIT 3 WORLD MODELS

Contents

3.0 Objectives
3.1 Introduction
3.2 Ancient Theories
3.3 Philosophical Theories
3.4 Early Scientific Theories
3.5 Contemporary Scientific Theories
3.6 The Big Bang And Beyond
3.7 Concluding Comments
3.8 Let Us Sum Up
3.9 Further Readings and References

3.0 OBJECTIVES

- To study some of the theories or models – ancient and modern - universe.
- To see how our view of the world keeps on evolving.
- To a brief study the most important world model we have today.

3.1 INTRODUCTION

"Cosmos" is just another word for universe, and "cosmology" is the study of the origin, evolution and fate of the universe. Some of the best minds in history - both philosophers and scientists - have applied themselves to an understanding of just what the universe is and where it came from, suggesting in the process a bewildering variety of models, theories and ideas, from the Cosmic Egg to the Big Bang and beyond. Below are some of the main ones, in approximate chronological order. The main purpose of this unit is to see how our present world model is the result of continuous evolution of older ones. For convenience sake we have divided the different world models into a. ancient, b. philosophical, c. early scientific and d. contemporary scientific theories. For this part we shall base ourselves on "The Physics of the Universe" website (CTH 2011). After studying these models we focus a bit more on Big Bang model and beyond.

3.2 ANCIENT THEORIES

Brahmanda (Cosmic Egg) Universe: The Hindu Rigveda, written in India around the 15th - 12th Century B.C., describes a cyclical or oscillating universe in which a "cosmic egg", or Brahmanda, containing the whole universe (including the Sun, Moon, planets and all of space) expands out of a single concentrated point called a *Bindu* before subsequently collapsing again. The universe cycles infinitely between expansion and total collapse and so the process goes on without end.

Anaxagorian Universe: The 5th Century B.C. Greek philosopher Anaxagoras believed that the original state of the cosmos was a primordial mixture of all its ingredients which existed in infinitesimally small fragments of themselves. This mixture was not entirely uniform, and some ingredients were present in higher concentrations than others, as well as varying from place to place. At some point in time, this mixture was set in motion by the action of “nous” (mind), and the whirling motion shifted and separated out the ingredients, ultimately producing the cosmos of separate material objects, all with different properties, that we see today (CTH 2011).

Atomist Universe: Later in the 5th Century B.C., the Greek philosophers Leucippus and Democritus founded the school of Atomism, which held that the universe was composed of very small, indivisible and indestructible building blocks known as atoms (from the Greek “atomos”, meaning “uncuttable”). All of reality and all the objects in the universe are composed of different arrangements of these eternal atoms and an infinite void, in which they form different combinations and shapes.

3.3 PHILOSOPHICAL THEORIES

Aristotelian Universe: The Greek philosopher Aristotle, in the 4th Century B.C., established a geocentric universe in which the fixed, spherical Earth is at the centre, surrounded by concentric celestial spheres of planets and stars. Although he believed the universe to be finite in size, he stressed that it exists unchanged and static throughout eternity. Aristotle definitively established the four classical elements of fire, air, earth and water, which were acted on by two forces, gravity (the tendency of earth and water to sink) and levity (the tendency of air and fire to rise). He later added a fifth element, ether, to describe the void that fills the universe above the terrestrial sphere.

Stoic Universe: The Stoic philosophers of ancient Greece (3rd Century B.C. and after) believed in a kind of island universe in which a finite cosmos is surrounded by an infinite void (not dissimilar in principle to a galaxy). They held that the cosmos is in a constant state of flux, and pulsates in size and periodically passes through upheavals and conflagrations. In the Stoic view, the universe is like a giant living body, with its leading part being the stars and the Sun, but in which all parts are interconnected, so that what happens in one place affects what happens elsewhere. They also held a cyclical view of history, in which the world was once pure fire and would become fire again, which is an idea borrowed from Heraclitus. (CTH 2011)

Heliocentric Universe: The 3rd Century B.C. Greek astronomer and mathematician Aristarchus of Samos was the first to present an explicit argument for a heliocentric model of the Solar System, placing the Sun, not the Earth, at the center of the known universe. He described the Earth as rotating daily on its axis and revolving annually about the Sun in a circular orbit, along with a sphere of fixed stars. His ideas were generally rejected in favour of the geocentric theories of Aristotle and Ptolemy until they were successfully revived nearly 1800 years later by Copernicus. However, there were exceptions: Seleucus of Seleucia, who lived about a century after Aristarchus, supported his theories and used the tides to explain heliocentricity and the influence of the Moon; the Indian astonomer and mathematician Aryabhata described elliptical orbits around the Sun at the end of the 5th Century A.D.; as did the Muslim astronomer Ja’far ibn Muhammad Abu Ma’shar al-Balkhi in the 9th Century (CTH 2011).

Ptolemic Universe: The 2nd Century A.D. Roman-Egyptian mathematician and astronomer Ptolemy (Claudius Ptolemaeus) described a geocentric model largely based on Aristotelian ideas, in which the planets and the rest of the universe orbit about a stationary Earth in circular epicycles. In terms of longevity, it was perhaps the most successful cosmological model of all time. Modifications to the basic Ptolemic system were suggested by the Islamic Maragha School in the 13th, 14th and 15th Centuries including the first accurate lunar model by Ibn al-Shatir, and the rejection of a stationery Earth in favour of a rotating Earth by Ali Qushji.

Abrahamic Universe: Several medieval Christian, Muslim and Jewish scholars put forward the idea of a universe which was finite in time. In the 6th Century A.D., the Christian philospher John Philoponus of Alexandria argued against the ancient Greek notion of an infinite past, and was perhaps the first commentator to argue that the universe is finite in time and therefore had a beginning. Early Muslim theologians such as Al-Kindi (9th Century) and Al-Ghazali (11th Century) offered logical arguments supporting a finite universe, as did the 10th Century Jewish philosopher Saadia Gaon.

Partially Heliocentric Universe: In the 15th and early 16th Century, Somayaji Nilakantha of the Kerala school of astronomy and mathematics in southern India developed a computational system for a partially heliocentric planetary model in which Mercury, Venus, Mars, Jupiter and Saturn orbited the Sun, which in turn orbited the Earth. This was very similar to the Tychonic system proposed by the Danish nobleman Tycho Brahe later in the 16th Century as a kind of hybrid of the Ptolemaic and Copernican models (CTH 2011).

Check Your Progress III

Note: Use the space provided for your answers.

1) How do Brahmanda and Bindu contribute to the ancient Indian view of the cosmos?
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2) What is Partially Heliocentric Universe?
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3.4 EARLY SCIENTIFIC THEORIES

Copernican Universe: In 1543, the Polish astronomer and polymath Nicolaus Copernicus adapted the geocentric Maragha model of Ibn al-Shatir to meet the requirements of the ancient heliocentric universe of Aristarchus. His publication of a scientific theory of heliocentrism, demonstrating that the motions of celestial objects can be explained without putting the Earth at rest in the centre of the universe, stimulated further scientific investigations and became a landmark in the history of modern science, sometimes known as the Copernican Revolution. His Copernican Principle (that the Earth is not in a central, specially favoured position) and its implication that celestial bodies obey physical laws identical to those on Earth, first established cosmology as a science rather than a branch of metaphysics. In 1576, the English astronomer Thomas Digges popularized Copernicus' ideas and also extended them by positing the existence of a multitude of stars extending to infinity, rather than just Copernicus' narrow band of fixed stars. The Italian philosopher Giordano Bruno took the Copernican Principle a stage further in 1584 by suggesting that even the Solar System is not the centre of the universe, but rather a relatively insignificant star system among an infinite multitude of others. In 1605, Johannes Kepler made further refinements by finally abandoning the classical assumption of circular orbits in favour of elliptical orbits which could explain the strange apparent movements of the planets. Galileo's controversial support of Copernicus' heliocentric model in the early 17th Century was denounced by the Inquisition but nevertheless helped to popularize the idea.

Cartesian Vortex Universe: In the mid-17th Century, the French philosopher René Descartes outlined a model of the universe with many of the characteristics of Newton's later static, infinite universe. But, according to Descartes, the vacuum of space was not empty at all, but was filled with matter that swirled around in large and small vortices. His model involved a system of huge swirling whirlpools of ethereal or fine matter, producing what would later be called gravitational effects.

Static (or Newtonian) Universe: In 1687, Sir Isaac Newton published his "Principia", which described, among other things, a static, steady state, infinite universe which even Einstein, in the early 20th Century, took as true (at least until events proved otherwise). In Newton's universe, matter on the large scale is uniformly distributed, and the universe is gravitationally balanced but essentially unstable.

Hierarchical Universe and the Nebular Hypothesis: Although still generally based on a Newtonian static universe, the matter in a hierarchical universe is clustered on ever larger scales of hierarchy, and is endlessly being recycled. It was first proposed in 1734 by the Swedish scientist and philosopher Emanuel Swedenborg, and developed further (independently) by Thomas Wright (1750), Immanuel Kant (1755) and Johann Heinrich Lambert (1761), and a similar model was proposed in 1796 by the Frenchman Pierre-Simon Laplace (CTH 2011).

3.5 CONTEMPORARY SCIENTIFIC THEORIES

Einsteinian Universe: The model of the universe assumed by Albert Einstein in his groundbreaking theory of gravity in the early 20th Century was not dissimilar to Newton's in that it was a static, dynamically stable universe which was neither expanding or contracting. However, he had to add in a "cosmological constant" to his general relativity equations to counteract the dynamical effects of gravity which would otherwise have caused the universe to collapse in on itself (although he later abandoned that part of his theory when Edwin Hubble definitively showed in 1929 that the universe was not in fact static)

Big Bang Model of the Universe: After Hubble's demonstration of the continuously expanding universe in 1929 (and especially after the discovery of cosmic microwave background radiation by Arno Penzias and Robert Wilson in 1965), some version of the Big Bang theory has generally been the mainsteam scientific view. The theory describes the universe as originating in an infinitely tiny, infinitely dense point (or singularity) between 13 and 14 billion years ago, from where it has been expanding ever since. The essential statement of the theory is usually attributed to the Belgian Roman Catholic priest and physicist Georges Lemaître in 1927 (even before Hubble's corroborating evidence), although a similar theory had been proposed, although not pursued, 1922 by the Russian Alexander Friedmann in 1922. Friedmann actually developed two models of an expanding universe based on Einstein's general relativity equations, one with positive curvature or spherical space, and one with negative curvature or hyperbolic space. (CTH 2011 and Pandikattu 1999)

Oscillating Universe: This was Einstein's favoured model after he rejected his own original model in the 1930s. The oscillating universe followed from Alexander Friedmann's model of an expanding universe based on the general relativity equations for a universe with positive curvature (spherical space), which results in the universe expanding for a time and then contracting due to the pull of its gravity, in a perpetual cycle of Big Bang followed by Big Crunch. Time is thus endless and beginningless, and the beginning-of-time paradox is avoided (Pandikattu 1999).

Steady State Universe: This non-standard cosmology (i.e. opposed to the standard Big Bang model) has occurred in various versions since the Big Bang theory was generally adopted by the scientific community. A popular variant of the steady state universe was proposed in 1948 by the English astronomer Fred Hoyle and the and Austrians Thomas Gold and Hermann Bondi. It predicted a universe that expanded but did not change its density, with matter being inserted into the universe as it expanded in order to maintain a constant density. Despite its drawbacks, this was quite a popular idea until the discovery of the cosmic microwave background radiation in 1965 which supported the Big Bang model. It may be noted that Jayan*t* Narlikar, one of the most famous Indian astronomers is an ardent supporter of a modified steady state universe (Narlikar 2010).

Inflationary (or Inflating) Universe: In 1980, the American physicist Alan Guth proposed a model of the universe based on the Big Bang, but incorporating a short, early period of exponential cosmic inflation in order to solve the horizon and flatness problems of the standard Big Bang model. Another variation of the inflationary universe is the cyclic model developed by Paul Steinhardt and Neil Turok in 2002 using state-of-the-art M-theory, superstring theory and brane cosmology, which involves an inflationary universe expanding and contracting in cycles.

Bubble Universe: Drawing from the recent quantum mechanics Russian-American physicist Andrei D. Linde proposes a "bubble universe." The universe consisting of a whole set of bubbles has no clear development or final state; new bubbles will begin as offspring of others. He therefore argues that life appears again and again in the bubbles. Even more strongly he hints at the possibility of travelling or at least communicating between bubbles. The conditions within the bubbles is that the vacuum energy density is extremely close to zero. This shows the potential practical importance of research on the vacuum energy density. According to Drees, "unfortunately (or, may be, fortunately) it may take as much as 10-5000000 years until the significance of the current work on this problem will be fully appreciated." The pioneering work of physicists Sidney Coleman and Frank De Luccia on "Gravitational Effects on and of Vacuum Decay" throws prospects for the entire cosmos based on such a quantum cosmology. From quantum mechanical perspective what appears to us as vacuum may be in reality "seething with ephemeral quantum activity, as ghostly virtual particles appear and disappear again in a random frolic." Such a vacuum state may not be unique; there could be several quantum states, all apparently empty but enjoying different levels of quantum activity and having different energy levels (Pandikattu 1999).

Multiverse: Going beyond the "bubble universe" the theory of multiverse is proposed, that grew as part of a multiverse owing to a vacuum that had not decayed to its ground state. The American physicists Hugh Everett III and Bryce DeWitt had initially developed and popularized their "many worlds" formulation of the multiverse in the 1960s and 1970s. Alternative versions have also been developed where our observable universe is just one tiny organized part of an infinitely big cosmos which is largely in a state of chaos, or where our organized universe is just one temporary episode in an infinite sequence of largely chaotic and unorganized arrangements (CTH 2011).

Check Your Progress II

Note: Use the space provided for your answers.

1) What is oscillating Universe?
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2) What is the significance of Bubble Universe?
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3.6 THE BIG BANG AND BEYOND

This paper elaborates the theory of Big Bang and later introduces the theory *inflation*, a modification of the standard "big bang" model of the history of the universe.

When Einstein formulated the general theory of relativity, he found that it was incompatible with a static universe; the equations predicted that the universe must either be expanding or shrinking. The prevalent bias against this conclusion was so strong that Einstein altered the equations of relativity in order to allow for a static solution. When Edwin Hubble found that the universe was indeed expanding, Einstein retracted this alteration, calling it the biggest blunder of his life. From that point forward the prevailing scientific viewpoint has been that of an expanding universe that at earlier times was much hotter and denser than it is today. Extrapolating this expansion backwards, we find that at a specific time in the past the universe would have been infinitely dense. This time, the beginning of the universe's expansion, has come to be known as the "big bang." (Felder 2002)

The big bang model has been extremely successful at explaining known aspects of the universe and correctly predicting new observations. Nonetheless, there are certain problems with the model. There are several features of our current universe that seem to emerge as strange coincidences in big bang theory. Even worse, there are some predictions of the theory that are in contradiction with observation. These problems have motivated people to look for ways to extend or modify the theory without losing all of the successful predictions it has made. In 1980 a theory was developed that solved many of the problems plaguing the big bang model while leaving intact its basic structure. More specifically, this new theory modified our picture of what happened in the first fraction of a second of the universe's expansion. This change in our view of that first fraction of a second has proven to have profound influences on our view of the universe and the big bang itself. This new theory is called *inflation.* (Felder 2002)

The Big Bang Model

For most of this century our view of the large-scale structure and history of the universe has been dominated by the big bang model. According to this model the universe at early times was a nearly uniform expanding collection of high energy, high temperature particles. A system that is uniform—the same everywhere—is known in physics as *homogeneous.* The small differences in density that did exist from one point to another are called *inhomogeneities.* As the universe expanded and cooled these small inhomogeneities were then amplified by gravity. The matter in regions with slightly higher than average density collapsed to form the structures we see today such as clusters and galaxies. Extrapolating backwards, on the other hand, that nearly homogeneous fireball would have had higher temperatures and densities at earlier times, ultimately reaching infinite density at a moment about 15 billion years ago. That moment is called the big bang (Ratcliffe 2009).

This model is in perfect accord with the theory of general relativity, which predicts that a homogeneous universe would expand and cool in exactly that way. Moreover, there have been many observational confirmations of the big bang model. These confirmations include the apparent motions of distant objects relative to us, the microwave radiation left over from the early universe, and the abundances of light elements formed in the first few minutes after the big bang. (Felder 2002 and Teerikorpi 2009)

We want to focus momentarily on the latter of these. An element is defined by the number of protons in a nucleus—one for hydrogen, two for helium, and so on. For roughly three minutes after the big bang the temperature of the universe was so high that protons and neutrons couldn't bind together into nuclei; the particles all had so much energy that the forces that hold nuclei together were too weak to make them stick to each other. Thus for those first three minutes the only element in the universe was hydrogen, i.e. single protons not bound to anything else. (A neutron with no proton is not considered an element.) As the universe expanded and cooled it eventually reached a temperature where the protons and neutrons could bind together, and different elements were formed. The formation of these nuclei from their constituent particles (i.e. protons and neutrons) is known as *nucleosynthesis* (Felder 2002).

Nuclear theory is well tested and understood. By applying it to a homogeneous, expanding medium at high temperature we can predict what relative abundances of different elements should have emerged when these nuclei were formed in the early universe. It turns out that only the three lightest elements, hydrogen, helium, and lithium, would have been able to form at that time. All of the heavier elements were formed much later in stars, and currently make up a tiny percentage of the matter we see in the universe. The predictions of the relative abundances of these light elements accurately match the observational data. This match is particularly important because it strongly suggests that the big bang model is an accurate description of the universe at least as far back as nucleosynthesis, i.e. three minutes after the predicted moment of the big bang. All of the other evidence for the theory, such as the microwave background and the motions of distant galaxies, relate to the universe at much later times, so we have no direct evidence for the accuracy of the big bang model before nucleosynthesis.

Despite this lack of direct evidence, it would be tempting to extrapolate further backwards and assume the big bang model to be an accurate description of the universe all the way back to the big bang. Such a complete extrapolation of the theory is not possible, however, because of certain limitations of our theories of high energy physics. When we talk about extrapolating backwards in the big bang model we are referring to running the equations of general relativity backwards to earlier times and higher densities. We know, however, that general relativity ceases to be valid when we try to describe a region of spacetime whose density exceeds a certain value known as the *Planck density,* roughly 10^{93} g/cm^3. If we try to consistently apply quantum mechanics and general relativity at such a density we find that quantum fluctuations of spacetime become important, and we have no theory that describes such a situation (Felder 2002).

It is almost certain that the big bang model gives an accurate description of the universe back at least as far as the time of nucleosynthesis. The earliest it could possibly be applied would be the Planck era. If we were to consider it valid all the way back to the Planck era we would have to suppose that all the very fine-tuned initial conditions we observe such as homogeneity and flatness were present from the beginning, presumably as a result of some unknown quantum gravity effects. Even given this assumption, however, it is unclear how the theory could avoid the production of relic particles that would destroy the successful description it has made of the later universe (Ratcliffe 2009).

It would be wonderful if a theory existed that with a minimum of assumptions could explain the initial conditions such as flatness and homogeneity, eliminate all high energy relic particles, and then segue into the big bang model itself by the time of nucleosynthesis. In 1980 Alan Guth proposed such a theory, known as *inflation.*

Inflation

The basic idea of inflation has to do with the rate at which the universe is expanding. When I use the term "rate" in this context I don't mean a speed. In an expanding universe the distances between galaxies are increasing, and the rate of expansion essentially refers to how long it takes for all of those distances to double. In the standard big bang model the universe experiences *power law expansion,* meaning the doubling time gets longer as the universe expands. For example, in our current power law expansion distances in the universe were roughly half their current value about 10 billion years ago, but they won't be twice their current value until about 30 billion years from now. By contrast, if the doubling time stays constant then the expansion is referred to as *exponential.* Inflationary theory says that before our current power law expansion there was a brief period of exponential expansion (Felder 2002).

Exponential growth can be much faster than power-law growth. In the simplest models of inflation the universe would have expanded by a factor of over ten to the ten million in a fraction of a second. There are two obvious questions raised by this idea: What mechanism would cause such an expansion to occur and what would be the consequences if it did?

It is nothing short of remarkable that from our vantage point, sitting at one point in space and at one time in cosmic history, we have been able to discover as much as we have about the history of our universe. While there is a great deal we do not understand about the very early times after the moment we call the big bang, the last twenty years have seen an explosion of progress in both our theories and our observations. As we improve in both of these arenas our understanding will undoubtedly change.

Will the theory of inflation survive those changes? I believe it's too early to answer that question with any confidence. As a model it has great appeal for a number of reasons. In particular, it explains a lot of features of the universe in a simple way with relatively few assumptions, and it seems to arise naturally in the context of our current theories of physics. In other words it seems highly likely that inflation would have occurred in the early universe, and if it did it would give rise to a universe much like the one we see. Moreover no other known theory can explain these features. Andrei Linde, one of the leading experts in inflation, once told me “Inflation hasn’t won the race, but so far it’s the only horse.” My personal suspicion is that if in a hundred years the theory of inflation isn’t part of our understanding of the early universe then it will have to have been replaced by something very similar to it.

In the meanwhile we can look forward to a lot of good tests of early universe physics in the next couple of decades. High sensitivity probes of the microwave background, searches for waves of gravity surviving from the early universe, and many other experiments are going to give us excellent tests, not only of inflation, but of our understanding of the universe in general (Felder 2002).

The Inflationary Theory

In 1981, a particle physicist named Alan Guth created a new theory. Guth knew about the matter in physics that explained how elementary particles got their mass. This matter is called scalar field matter. Combining the mathematical equations for scalar field with Einstein’s equations describing the expansion of the universe, Guth developed a theory in which large amounts of matter and energy were created from nothing! After matter and energy were created, the universe experienced an accelerated expansion, becoming exponentially large prior to continuing its evolution according to the big bang model. This theory has been worked on and modified by many cosmologists since its introduction (Felder 2002?).

3.7 CONCLUDING COMMENTS

Most scientists now believe that we live in a finite expanding universe which has not existed forever, and that all the matter, energy and space in the universe was once squeezed into an infinitesimally small volume, which erupted in a cataclysmic “explosion” which has become known as the Big Bang. Thus, space, time, energy and matter all came into being at an infinitely dense, infinitely hot gravitational singularity, and began expanding everywhere at once. Current best estimates are that this occurred some 13.7 billion years ago, although you may sometimes see estimates of anywhere between 11 and 18 billion years. The Big Bang is usually considered to be a theory of the birth of the universe, although technically it does not exactly describe the origin of the universe, but rather attempts to explain how the universe developed from a very tiny, dense state into what it is today. It is just a model to convey what happened and not a description of an actual explosion, and the Big Bang was neither Big (in the beginning the universe was incomparably smaller than the size of a single proton), nor a Bang (it was more of a snap or a sudden inflation) (BBBC 2010).

In fact, “explosion” is really just an often-used analogy and is slightly misleading in that it conveys the image that the Big Bang was triggered in some way at some particular centre. In reality, however, the same pattern of expansion would be observed from anywhere in the universe, so there is no particular location in our present universe which could claim to be the origin. It really describes a very rapid expansion or stretching of space itself rather than an explosion in pre-existing space. Perhaps a better analogy sometimes used to describe the even expansion of galaxies throughout the universe is that of raisins baked in a cake becoming more distant from each other as the cake rises and expands, or alternatively of a balloon inflating. Neither does it attempt to explain what initiated the creation of the universe, or what came before the Big Bang, or even what lies outside the universe (BBBC 2010). All of this is generally considered to be outside the remit of physics, and more the concern of philosophy. Given that time and space as we understand it began with the Big Bang, the phase "before the Big Bang" is as meaningless as "north of the North Pole".

Therefore, to those who claim that the very idea of a Big Bang violates the First Law of Thermodynamics (also known as the Law of Conservation of Energy) that matter and energy cannot be created or destroyed, proponents respond that the Big Bang does not address the creation of the universe, only its evolution, and that, as the laws of science break down anyway as we approach the creation of the universe, there is no reason to believe that the First Law of Thermodynamics would apply. (BBBC 2010)

The Second Law of Thermodynamics, on the other hand, lends theoretical (though inconclusive) support to the idea of a finite universe originating in a Big Bang type event. If disorder and entropy in the universe as a whole is constantly increasing until it reaches thermodynamic equilibrium, as the Law suggests, then it follows that the universe cannot have existed forever, otherwise it would have reached its equilibrium end state an infinite time ago, our Sun would have exhausted its fuel reserves and died long ago, and the constant cycle of death and rebirth of stars would have ground to a halt after an eternity of dissipation of energy, losses of material to black holes, etc.

The Big Bang model rests on two main theoretical pillars: the General Theory of Relativity (Albert Einstein's generalization of Sir Isaac Newton's original theory of gravity) and the Cosmological Principle (the assumption that the matter in the universe is uniformly distributed on the large scales, that the universe is homogeneous and isotropic). The Big Bang (a phrase coined, incidentally, by the English astronomer Fred Hoyle during a 1949 radio broadcast as a derisive description of a theory he disagreed with) is currently considered by most scientists as by far the most likely scenario for the birth of universe. However, this has not always been the case, as the following discussion illustrates (BBBC 2010).

Check Your Progress III

Note: Use the space provided for your answers.

1) How do you respond to the question: 'What happened before the Big Bang?'?
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2) How is the first law of thermodynamics related to Big Bang?
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3.8 LET US SUM UP

We have studied the different world models. History tells us that best model we have (the modified standard model) will give way to a better one in the near future.

3.9 KEY WORDS

Brahmanda: "Egg of God," or "Cosmic egg." The cosmos; inner and outer universe. It also designates a division of infinite time.

3.10 FURTHER READINGS AND REFERENCES

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UNIT 4 SCIENCE AND RELIGION

Contents

4.0 Objectives
4.1 Introduction
4.2 The Journey from Pre-Science to Science
4.3 Scientific Investigation
4.4 Scientific and Religious Outlooks
4.5 Scientific Perspective of Truth
4.6 Religious Perspective of Truth
4.7 Reason and Faith
4.8 Let Us Sum Up
4.9 Key Words
4.10 Further Readings and References

4.0 OBJECTIVES

The unit attempts to bring in the contemporary discussion on the relation between the science and religion which was seen as opposing each other in the modern period.

4.1 INTRODUCTION

The subjects of science and religion are getting more important to man in the modern age. They are two great disciplines which, when relied on separately can be counter-productive, but when combined harmoniously can being about an all-round expression of human genius and total fulfillment. The literal meaning of the term religion is traceable to '*Religare*' which means bind together. Religion is the outcome of man's age for freedom. It is the outer manifestation of this great hunger for the infinite. Different religions represent different aspects of that struggle, but the whole of mankind, consciously or unconsciously, is moving towards that goal which is the end of religion. For Swami Vivekananda religion is realizing the divinity already in man. But majority of people go to church or temple or mosque for various favours of God and Goddess. There are rituals associated with religion and worship. There are two types of devotion to God: devotion without any motive and devotion for particular ends. But to-day, religion is used by some misguided youth for disrupting social harmony. We see tensions between Muslims and Jews in the Middle-East, Protestants and Catholics in Northern Ireland and Muslims and Hindus in the Indian sub-continent. Though religion is blamed for the evils of the society, really religion is not at fault. Persons misuse religion for their selfish gains either in the domain of politics or even in the domain of religious organizations.

4.2 THE JOURNEY FROM PRE-SCIENCE TO SCIENCE

In ancient times, conditions were not conducive for the development of scientific thought. Uncertainty, danger from natural forces, from wild animals and poisonous insects plagued the early man everywhere. He had neither an assumed home nor an assured food supply. He almost knew nothing as to why events around him happened the way they happened. Thousands of years must have passed in this scared and bewildered conditions of human mind. The conditions around early man confused him more than giving him knowledge. His explanations of the phenomenon around were actuated by unscientific wish-fulfilling and ego-guarding aims. Since knowledge was scant, imagination dominated the then explanations. Behind every natural process was posited an invisible deity. There came up wind-god, fire-god, river-goddess, mountain-god, death-god and so on. The sun, moon and the shining bodies in the sky, each one, became a deity to be feared, praised, prayed to and worshipped for favours. People started worshipping these deities out of fear and also for favours. Such worships became a regular routine and were even passed on to the following generations. All this is more a religion than a science. Yet we must accept that at that time those were the only explanations available and people were even satisfied with them. The rudimentary religions later on developed into ritualistic religions. The people were submissive and loyal to such religions. Religions came up much earlier to sciences.

The ancient religions had the following common features:

1. The invisible deities govern the visible
2. The invisible is better, more real and more virtuous than the visible
3. The invisible deities are omnipotent and anthropocentric conception of God was prevalent in those days.
4. The gods have heavenly existence and will curse human beings if they are angry and bless them when pleased. So the Vedic way of worship focused on worshipping the natural forces such as Agni, Varuna, Vayu etc to please them.
5. Rituals and traditions were followed to propitiate these deities
6. The religious person must surrender to the will of the God.
7. Any deviations from established religious tradition is the worst crime and to be severely punished.
8. Since God and religion control every activity of ours (individual - soul), before death, after death, one must be faithful to such a God.

If there has to be science, the individuals must liberate themselves from God and religion. This liberation may not always be absolute. In science we search for natural antecedents as the cause of any natural event. But such a thinking cannot even arise as long as we intensely believe that in the world everything is caused and governed by God. If we believe that every event is caused by the will of God, then scientific explanation of natural events is not possible. If in religions the transcendental explains the natural, in sciences we search for a natural explanation of the natural events. Unfortunately, even this seemingly obvious development did not take place for thousands of years. The Lokayatas who tried to adopt a natural and empirical position were not allowed to do that. They were harassed, condemned, ridiculed and even out cast. In ancient Greece similar attempts of Anaxagoras, Lucretius, Pythagoras, Thales, Socrates and others met with a similar fate. Religious fanaticism was an obstacle for the growth of science. Ages of faith have invariably been ages of persecution and cruelty. With renaissance, winds of free thinking started blowing. As a result of printing, knowledge became a common man’s property. With the increase of travel and commerce, people became a little more broad-minded. People started realizing that independent thinking and human efforts pay more than what faith and prayer do. Then started, the trend of study at comprehensive explanation of the worldly events. The explanation of individual entities was replaced with the explanation of processes. Experimentation and instrumentation got a singe fillip. As a result, we are on the way to developing a science-founded and science oriented life. But even after renaissance the intolerant attitude of the orthodoxy continued. The priests refused to accept scientific explanations of natural events. The scientists were ridiculed, harassed and even jailed. Bruno was burnt to death for his heterodox views. The journey from pre-science to science has also been a journey of naturalisation of human outlook. As a cumulative effect of sciences over the past few centuries, the epistemology and ontology of sciences have been completely naturalised. The subject matter of the study of sources, the objectives of scientific study, the sciences of scientific knowledge obtained, theories of truth and error, concept of truth and reality, criteria of verification and falsification, methods the sciences adopt, the nature and general effects of scientific knowledge are all mundane phenomena, natural phenomena. The epistemology of science has been so much naturalized, has become so much objective in nature that the subjective element in the seekers of scientific knowledge has absolutely no place in it. There is nothing unnatural, anti-natural or super-natural in the scientific epistemology. There are three constituents of epistemology : the knowing subject, the known object and the sources and the nature of knowledge obtained. In sciences all these three factors are of natural type and there is nothing super-natural or divine in them. The knowing subject is a psycho-physical person and not the spiritual type of soul; the objects of knowledge belong to this world only and the sources of knowledge and the nature of knowledge obtained also belong only to this empirical world. For science there is no transcendental world or heavenly entities. Its epistemology as well as ontology is completely naturalized.

4.3 SCIENTIFIC INVESTIGATION

Investigations of the scientists differ from the mystical methods of theologians. Even religious persons claim that their statements are scientific. Therefore we should be clear in stating the conditions which must be fulfilled if some investigations can be called scientific. An investigation can be called scientific if it fulfills the following conditions: (i) The phenomenon under investigation must be of a publicly verifiable nature (ii) During the investigation scientific method is followed; (iii) The outlook of the investigator is scientific and (iv) Acquisition of knowledge should be the aim of the investigator.

Now let us take the case of the claims of astrology in India being a science. It does not fulfil any one of the conditions seen above. It believes that there are nine planets who affect our individual life in one way or the other. They are some sort of deities controlling our fate. The fate of the person is fixed by the position of these nine planets at the time of his birth. The nine planets of Indian astrology are: the sun, the moon, the Saturn, the Jupiter, the Mars, the Venus, the Mercury, *Rahu* and *Ketu*. The assumptions of Indian astrology are not corroborated by the findings of modern science. *Rahu* and *Ketu* do not exist at all. Modern science has proved that the sun is a star and not a planet; moon is a satellite of the earth and is not an independent planet; our earth, very much a planet and affecting us the most does not find a place in the list of planets of Indian astrology. The recently discovered planets, Neptune, Pluto and Harshal do not figure in it. Moreover, science has found that these planets are masses of inert matter revolving in the sky and cannot be considered to be deities who could be appeased by our offerings. Indian astrology even now speaks in the very terminology that it spoke when it was founded centuries ago. This unchanging but defective character of Indian astrology in spite of changes in facts prevents it from becoming a science and makes it more a part of religion. Astrologers all over the world do not accept the foundation of Indian astrology. Any science should be universal in its nature and claim. It should be a definite public fact. Unlike science the religious claims of different religions differ with one another. The objects of study of sciences are universal and unanimous in nature. But in religions the views on God, soul and Heaven are not the same for all religions. The Jains and the Buddhists do not accept God. And even those who accept God, e.g., the Christian, the Hindus and the Muslims differ widely about their conception of God and liberation. Scientific conclusion does not differ with one another. Even if there are differences though further investigations and research such differences are narrowed down so that universality is maintained. An investigation can be called scientific only if the field of study is empirical, public, verifiable and objective. For any investigation to be scientific, scientific method should be followed. The scientific method consists the following stages of investigation: (i) Observation (and experimentation) (ii) Hypothesis formation (iii) Generalisation and (iv) Verification. All these steps are public and verifiable. A scientist should be liberal, flexible, relative, dispassionate and shun all finalism, absolutism and sentimentalism: Scientific investigation should he carried out purely with the intention of obtaining knowledge.

4.4 SCIENTIFIC AND RELIGIOUS OUTLOOKS

1. Theologians criticise the empirical knowledge of the scientists. According to them, the scriptures cannot be disputed. Only the scriptures are infallible and not the conclusion of the scientists. But the scientists are not rigid in their outlook. For them the scientific quest is a continuous process that will go on for ever. All the scientific truths are only provisional. If the future findings invalidate the present truths, the scientific truths will also change accordingly. There are no permanent and absolute truths in science. But religion does not accept relative truths.
2. Scientific attitude is an open-minded approach. It is always open to correction. But a religious approach is a closed-minded approach. If two scientists argue about something, they will have enough common ground. But in a debate when different religions are arguing their case, no one will yield to the others even an inch of ground. They will not hear what the others are saying. They will go on insisting upon their own point. The scene will be full of emotional out bursts coming to no understanding.
3. Religions hold that complete truth had been given to us by the prophets, they are always looking backward to the past; but scientists look to the future possibilities for human welfare.
4. Scientific and religions attitudes are distinguishable not from the contents of the beliefs but from the manner in which the beliefs are held. If they are held passionately and expressed emotionally, the outlook is religious. If the beliefs are held dispassionately and are expressed in a cool way, the outlook is scientific.
5. The scientific outlook treats facts as its ultimate authority and not certain persons or scriptures. It is concerned with what is true and false. It does not think that “our” truth is higher than “their” truth. Truth according to it is universal and common to all.
6. Scientific outlook is a rational enquiry attempting to find out cause-effect relations among events. Any scientific hypothesis must be verifiable.

7. In religions we are told that one who has faith will benefit and are also warned that one who doubts will perish. In the field of sciences the case will be just the opposite. Here one who only keeps faith and does not enquire any further will perish while the one who keeps on doubting and examining the current explanations, his knowledge will improve and will be benefitted.

Check Your Progress I

Note: Use the space provided for your answers.

1) Demonstrate the evolution of science from pre-scientific era.

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2) Briefly explain the Scientific investigation.

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4.5 SCIENTIFIC PERSPECTIVE OF TRUTH

In the process of acquiring knowledge there is a tripartite unity between the knower, the known and the knowledge. The truth according to the scientists is Matter or the objective world. For religion, the truth is God which is both immanent and transcendent. Since the scientists don't consider the trans-empirical existence as real, they don't accept God for the object of study. We can find the scientific approach to Reality even in ancient India and Greece. The great and original thinkers like Kapila, Gautama, Kanada and others worked out their empirical systems entirely based upon methodical knowledge and scientific analysis. As for example, modern science has discovered that various forces of nature like electricity, light, heat motion gravitation etc., are so many expressions of eternal cosmic energy. The atomic theory states that matter can be reduced to ultimate particles called atoms. It was first discovered in India by Kanada, the author of the Vaisesika philosophy and in Greece by Democritus, Leucippus and Lucretius. It is said that many Greek philosophers from Democritus onward had also imagined matter to consist, in the last resort, of hard indivisible pellets and those pellets were at first called "atoms" which were incapable of being divided. Anaxagoras maintained that those pellets possessed in itself all the characteristic properties of the substance to which it belonged. After a long time John Dalton, Lavoisier, Maxwell and other scientists made experiments on atom and considered it to be an essential ingredient of physical science. The physicist of the 19th century found that all matter is possessed of inertia and is capable of motion. They said that energy is matter, or is in atom which can exist in a number of forms and can change about almost endlessly from one form to another, but it can never be utterly destroyed.

In 20th century Dalton's atomic theory was disproved. His theory that atom cannot be divided was rejected by the scientists. Their theories proved that atoms can be divided into sub-atomic particles such as electron, proton, neutron, positron, meson etc. Albert Einstein proved that matter can be transformed into energy through the following equation : $E = mc^2$ where 'E' is energy ‘m’ is the mass of the object and ‘c’ is the velocity of light. The credit for rejecting Dalton’s atomic theory goes to Crookes, Lenard and J.J. Thompson. In 1897 Thomson showed that the fragments of atoms were identical no matter what type of atom they came from; they were of equal weight and they carried equal charges of magnetic electricity. On account of this last property they were called “electrons”. In 1911 Ernest Rutherford through his experiments revealed the architecture of atom; the atom to be constructed like the solar system, the heavy central nucleus playing the part of the sun and the electrons acting the parts of the planets. Rutherford’s experiments were afterwards extended by Niels Bohr and others. Modern science believes in the law of conservation of energy according to which the total amount of energy present in the universe is constant. Therefore the atoms and sub-atomic particles of the atoms are indestructible. However the scientists are unable to provide the causal explanation for the existence of matter in the universe. Matter and energy present in the universe are taken for granted by the scientists. To the question, ‘who created the matter’ (which is the Truth for the scientists) there is no satisfactory answer from the scientists.

To know the truth in science, the scientists depend upon sense perception and experimentation. The scientific method has the following stages: (1) observation (2) Hypothesis (3) verification and (4) scientific law. The intellectual analysis of the data collected through observation and verification of the hypothesis helps the scientists to arrive at conclusions. The scientists don’t consider mystical intuition or insight to arrive at conclusions. The scientists don’t consider mystical intuition or insight as the valid methods to arrive at conclusions.

4.6 RELIGIOUS PERSPECTIVE OF TRUTH

Truth according to religions is God. The truth which is absolute is called Brahman by the Vedantins. The Vedantic conception of Brahman is impersonal and the Hindu religion believes many personal gods. For the Vaisnava sect the God is Vishnu who incarnates as Rama, Krishna, Narasimha etc. For the Saiva sect, the God is Siva who appears as Ardhanareeswara (the dual form of Siva and Parvathi). The seekers of truth follow the method of meditation if the goal is self-realisation. Those who believe in personal God follow the paths of *Jnana*, *Bhakti* and *Karma* to have communion with God. However *yoga* and meditation are conducive in realizing the goals where the goal is spiritual union with the Brahma or communion with God. The Hindu religion believes in the Immortality of Soul, *Karma* and Rebirth which are interrelated with each other. Therefore whether the truth is Absolute Brahman or personal God, there is no disagreement among the believers about the interrelatedness of the Immortality of soul, *Karma* and Rebirth.

Taoism

The Chinese looked upon Tao as the Absolute Reality, anterior to and higher than heaven. It existed even before manifested God arose and before time began. It is the first cause of all existence, manifesting itself in the creator and the created universe. It is the eternal, unchanging and all-pervasive principle from which all things proceed, the goal to which all things tend. Only one who is eternally free from earthly passions can apprehend the spiritual essence of Tao. Out of Tao comes the one which produces the two primary essences, the ‘Yang’ and the ‘Yin’, the male and the female, light and shade, which give birth to heaven, earth and man. The interactions of yang and yin result in the production of all creatures. Tao is in man though it is generally unmanifested. If we are to regain our tranquility, we should set out on the quest of Tao. The Tao is potentially available to all and so each one has to treat others with sympathy.

Judaism

The religion of the Jewish people is called Judaism. The Jewish doetrine believes in God who is both immanent and transcendent. He is greater then the world and separate from it and yet he works in the universe by means of his "wisdom" which is an emanation from him and yet has no separate existence from him. God is in heaven and yet the earth is his footstool. The universe is one uninterrupted revelation of the Divine. Only angels can come into relations with the holy God and not the impure men. Only through deep spirituality and prayer men can bring about changes in the material world.

Greek Religion

There are two currents of thought in the ancient Greek religion, the Homeric and the Mystic. According to Plato the end of life is "to become like God". True piety is to be a fellow worker with God. Like Hindu Pantheon wherein there is a god each for fire (Agni) air (Vayu), Rain (Varuna) etc, in the Greek mythology too there are goddesses for prosperity, underworld, love etc. The Dionysiac mysteries are marked by wild ecstasy and several barabaric rites. The Orphic societies were generally attached to the workship of Dionysus. Those who were eager for communion with the Divine and anxious to attain peace of mind and position of hope and confidence were attached to the mystery religious. According to Plotinus, the Supreme in beyond existence, beyond life. It abides in a state of wakefulness beyond being. We cannot call it good; it is perfection. It is beauty, not the beautiful. The God whom we worship is the revelation, not the revealer. The source of revelation cannot be revealed. The goal of the intellect is the One, the goal of will is goodness; the goal of love and admiration is beauty. We can know the Absolute because we are ourselves, in the ultimate spirit not through discursive reason, but by some spiritual contact. The ecstatic state is a rare phenomenon gained only at the summit of spiritual development.

Zoroastrianism

Zoroastrianism is the religion of the Persians (Iranians). It has many common elements with the Vedic religion of the Indian Aryans. The *Avesta's asha* and the vedic *rta* are two variants of the same word and the underlying thought was fully developed in the period before the Indian Aryans and the Iranians separated. The highest principle is 'Ahura-Mazda' which acts according to changeless laws. It is believed that Zarasthura was born in response to the appeal of Mother Earth to help mankind to overcome evil. Ahura-Mazda is the Supreme being, the Lord of life and matter, the Cosmic Lord Iswara from whom have sprung '*Purusa*' and *Prakrti*'. The cosmic process is progressing towards the fulfillment according to the law of *asha*. Only those acts done out of love for the Supreme give us happiness and not those which are performed for one's own good. Unselfish work is the way by which human individuals attain their spiritual welfare and help the progress of the world. Love in Zoroastrian religion embraces the animal world also. Zarasthura promises those who follow his teaching everlasting life. To know the Supreme Ahura-Mazda and act according to his law *asha* one has to perfect one's nature through prayer and meditation. When we reach the goal we realize peace and unity.

Buddhism

Buddhism was founded by Gautama Buddha. The Buddha speaks of *bodhi* or enlightenment. It is an immediate, non-discursive, intuitive relation with Absolute Truth. It is not theatrical knowledge. It is knowledge that cut the roots of desire and is the result of concentration on the nature of Being. Since Buddhism preaches the philosophy of change it doesn't believe in a permanent soul. Man is ignorant and forgets his real nature and identifies himself with what he is not. He must get to know the truth beyond all phenomenal existence. *Prajna* is consciousness that transcends subject-object distinctions. The path to Nirvana is ethical path (eight fold path) Adopting the method of reason, the Buddha declined to answer certain ontological questions which he considered to be useless. His position is termed as Agnosticism. He rejected the rituals of Vedic religion and inequality in the society. He rejected the principle of authority, for truths accepted on authority and not ascertained and realized by personal effort are of no avail. In Mahayana Buddhism, the relation of the devotee to the absolute is medicated by faith and prayer and the devotee is helped by the grace and guidance of the divine Buddha. In all types of Buddhism, methods of concentration of thought are emphasized.

Christianity

Jesus Christ, the founder of Christianity was in disagreement with the teachings of the prophets of Israel. His reforming views over the Jewish religion made him the messenger of God. Jesus's personal experience is a supreme example of direct knowledge. His acts and utterances are penetrated with a feeling of fellowship with God. Jesus demands an inward renewal, and inner change. The Kingdom of Heaven is not a place in space but a state of mind. The Kingdom is present, here, immediate. "Repent, for the Kingdom of Heaven is at hand". It is the attainment of Truth which makes for freedom or liberation. Jesus refers to the inner perfecting, the possible evolution of man. When he asks us to "repent", he means not penitence or regret but inward revolution. True religion is the remaking of the soul by contemplative prayer and ascetic practice. The popularity of Christian religion in the world is due to its Mysticism which includes the "service to humanity" as its essential theme.

Islamic Religion

The central feature of Islam is the worship of God and acknowledgement of Him as the Absolute Lord. Muhammed, the founder of Islam rejected the worship of men and idols, of stars and planets on the principle that whatever rises must set, whatever is born must die, whatever is corruptible must decay and perish. For Muhammed, God is an infinite and Eternal being without form or place. God is what remains when we abstract from the unknown. He is present in our most secret thoughts, exists necessarily of his own nature, and derives from himself all moral and intellectual perfections. Quran is the sacred book of Islam. The Sufi tradition of Islam lays stress on personal experience of God. The human soul is a part of the absolute. God and man become one in the perfect man, the prophet is the final cause of creation. Unlike Hinduism, Islam lays stress more on ethical teachings than on metaphysics. The mysticism of Judaism, Christianity and Islam regards the theistic conception of God as determinate and inadequate.

The above account of Truth portrayed by different religions are like various languages in which God has spoken to man. Western forms of religion are inclined to hold that one definition is final and absolute and others are false. In India, each definition represents a *darsana* or a view point. If religious truth is seen by different groups in different ways, it is not to deny that truth is ultimately one. It is wrong to exaggerate the doctrinal differences, overlooking the common basis, the universal fact underlying the historical formulation. The diversity of dogmatic interpretations tends to diminish as we climb up the ladder of spiritual perfection. The variety of religious symbolism is due, not to the nature of the experience as such, but to the prevailing theological or metaphysical conception of time and place. If any one tells us that his view of the Supreme is final, it is only human judgement which need not be taken as infallible.

4.7 REASON AND FAITH

Science and religion as subjects of study focus on the two essential concepts: Reason and Faith. There is no science without reason and there is no religion without Faith. Attempts to synthesis reason and faith were made as early as 13^{th} century by the Franciscan school men of Christianity. Franciscans were less orthodox than Dominicans. Between the two orders there was keen rivalry. St Thomas gave his proofs for the existence of God by using Aristotle's logic and argument. There are there ways of knowing: by reason, by revelation and by intuition. Therefore even in matters of faith, logical reasoning and sense-perception played a vital role in medieval period. Scholasticism as a school of philosophy paved the way for bringing reason closer to faith. The very fact that St. Thomas accepted a posteriori proof of God's existence reveal that reason and faith cannot be separated. Among the five proofs for the existence of God the first there proofs proceed directly from the given facts of experience.

1. First, proof is from motion
2. Second, the series of efficient causes
3. Thirdly, from the series of contingent causes.

According to Aquinas there is fundamental difference between man and God. Man is finite and a creative of God whereas God is infinite and the creator of man. He transcends both the world and the man. Human intellect can know God through sensible objects.

From the Indian perspective faith becomes the very basis of rational investigation. But this faith (*Sraddha*) is different from that usual idea of faith as mere static *visvasa* or belief, swallowing everything that is said by any authority without subjecting it to evidential tests. We can see the scientific and rational and human aspects of *sraddha*; and all physical science, all religion, and all human life itself needs this type of *sraddha*. What does *sraddha* means in the physical sciences? It means a faith in the meaningfulness of the universe. A scientist cannot investigate into nature unless he has a prior feeling that nature is worth investigating. Without that faith he cannot get even the impulse to undertake his scientific inquiry. Viewing faith from the point of view of scientific reason, Sir Arthur Eddington (The philosophy of physical science, p.222) says : "*In the age of reason, faith yet remains supreme : for reason is one of the articles of faith*".

Check Your Progress II

Note: Use the space provided for your answers.

1) How do Religions approach truth?

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2) Critique on role of Reason and Faith in quest for truth.

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4.8 LET US SUM UP

Albert Einstein in his essay on, *Science and Religion* says, "Now, even though the realms of religion and science in themselves are clearly marked off from each other, nevertheless, there exist between the two strong reciprocal relationships and dependencies. Though religion may be that which determines the goal, it has nevertheless, learned from science, in the broadest sense, what means will contribute to the attainment of the goals it has set up. But science can only be created by those who are thoroughly imbued with the aspiration towards truth and understanding. This source of feeling, however, springs from the sphere of religion. To this there also belongs the faith in the possibility that the regulations valid for the world of existence are rational that is, comprehensible to reason. I cannot conceive of a genuine scientist without that profound faith. The situation may be expressed by an image: *"Science without religion is lame, religion without science is blind"*. The above passage from Einstein's book, *of My Later Years*, reveals that he is in agreement with the Indian view that Faith and Reason are complimentary to each other. The conflict between Reason and Faith can be overcome in Spiritual life according to Vedanta.

4.9 KEY WORDS

Sraddha: Faith which is dynamic.

Visvasa: Belief which is static.

4.10 FURTHER READINGS AND REFERENCES

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