HISTORY AND PHILOSOPHY OF SCIENCE

COMMON COURSE IN ENGLISH

BBA (I Semester)
BA/BSc (IV Semester)

2011 Admission onwards

UNIVERSITY OF CALICUT

SCHOOL OF DISTANCE EDUCATION

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MODULE I & II

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MODULE 1

ANCIENT HISTORY OF SCIENCE

UNIT – 1

INTRODUCTION

Objectives

This chapter will help you to:

1. Understand what is science
2. Understand what is the so-called scientific truth
3. Know more about the process of discovery

THE HISTORY OF SCIENCE

Science is a cluster of ideas. So studying the history of science is like going deep into the history of ideas. It helps us in various ways.

- To understand the present
- To guide our course for the future
- To have a perspective on what we know and how we know it.
- To be aware of the limitations of our knowledge

Science as a Process

1. Eratosthenes of Alexandria found out 2000 years ago, that the circumstance of the Earth is 39,638 kilometers. The modern estimate is 40,008 kilometers. You can see that the error was less than 1%.
2. The Mesopotamian calculation of the length of the lunar month, as 29.530596 days turned out to be correct to the fifth decimal place.
3. Almost two thousand years ago the Chinese started measuring earth quake intensities using seismographs.
4. About two thousand five hundred years ago complex surgical procedures were described in detail in the Sushruta Samhita.

The above points are truly inspiring, isn't it? There arises a question – why should we give so much importance to such history? The answer is we can do justice to the present only if we have a sense of history. This historical sense can guide us in all our endeavours. Thus the history of science is a history of ideas. It tells us how new ideas germinated in the minds of the ancient scientists, how it flowered, how it failed and eventually revived later. The history of the earth – centered theory giving way to the sun – centered theory, the continent drifting theory are examples.

Various theories that were popular at one time are discarded for want of proofs. But they may be accepted later when they are proved to be true.

Science is not just a ready-made set of answers. We may get the answers in various ways. It is not a product, it is a process – a never ending process.

Glossary

Prudently – wisely

Decimal - a system of members based on numbers

Seismographs - an instrument for recording and measuring the strength of earthquakes

Compiled - gathered

Planetary - related to planets

PHILOSOPHY OF SCIENCE OR SCIENCE AS LOGIC OF IDEAS

The history of science deals with the history of ideas and the philosophy of science deals with the logic of ideas. Both are related but not identical. Now, what is science? What is the so-called scientific truth? What is the nature of this truth?

An important feature of science is its objectivity. Suppose a theory comes out without any proof, it is discarded and a new theory which can explain it, takes its place. Now, think about some fundamental points; what is the reality which scientists are seeking to study? Is there an objective reality? Or, is it all in our minds?

Scientific temper is another important question. All people should possess a scientific temper, spirit of inquiry and reform.

Glossary

Swear - take oath

Hijack - take control of something by force

Stakeholders -people who have an interest in a company's affairs

Multiple Choice Questions

1. It was ______________ who measured the circumference of the Earth for the first time.

a. Aryabhata b. Brahmagupta c. Copernicus d. Da Vinci

2. Aryabhata had suggested ________________

a. that the Earth revolved around the sun

b. that the Earth rotated on its axis

c. that the Earth moved around the sun in elliptic orbits

d.A,B and C are true

3. Evidence for the Continental Drift Theory came from ___________

a. plate tectonics
b .remote sensing
c. satellite imagery
d. observation from space vehicles

4. Philosophy of science deals with ______________

a. the history of ideas in science
b. the logic of ideas in science
c. the relation between science and society
d. the mysteries of science

Short Answer Questions

1. Examine critically, the concept of 'history of science' as a history of ideas, rather than a 'narration of events'

   Ans: The history of science tells us how ideas germinated, grew and flowered, and sometimes weakened under adverse circumstances but were revived later under favourable conditions.

2. Bring out the difference between the 'history of ideas' and the 'logic of ideas'

   Ans: History of ideas helps us to understand the present better while the logic of ideas makes clear to us what we know and how we know it.

3. What did Aryabhatta and many other ancient philosophers suggest about rotation of the earth?

   Ans: Aryabhata and many other ancient philosophers suggested that the earth is rotating on its axis.

Short Essay Questions

1. Science and Non-Science

   Studying structure and behaviour of the physical and natural world and society through observation and experiment is called science. The history of science deals with the history of ideas and the philosophy of science deals with the logic of ideas. The history of science is not a narration of events. How ideas are germinated, grew, flowered, failed and revived are the topic of science. All others belong to non-science.

2. Science as a process and not a product

   Some argue that we need to look only at the 'latest' scientific information and need not worry about the earlier theories, which have since been discarded. This approach essentially treats science as a product and not as a process. Science is not just a ready-made set of answers. We may get the answers in various ways. We have to say that we can accept as scientific only those answers which have been arrived at through a particular method, which we call the scientific method. That is why science is a process.

3. Verification and falsification

If a new theory is discovered, its 'reality' has to be tested. After scrutiny and verification, if no clear proof can be provided, it is not accepted as a scientific theory. This happened to the idea that the Earth is rotating on its own axis. The ancient Greek philosophers had propounded this view. The India astronomer Aryabhatta also had put forward this theory. Yet, it was rejected as nonsense. But as evidence in favour of a sun-centered planetary system continued to pile up, the earth-centered view had to be quietly dropped. This means that the scientific truth was proved against the earliest assumptions. And it is done through the process of verification and falsification.

4. What is Scientific truth ?

Scientific truth refers to the objectivity of scientific enquiries. This seems ambiguous to most people. All scientists swear by the objectivity of science. If and when some new facts are discovered, which do not agree with the currently acclaimed theory, then the theory has to go. Then, a new theory, which can explain it successfully, takes its place. Thus we can say it has definite proof and this can be described as objectivity. This objectivity can be described as the scientific reality or scientific truth.

Essay Question

1. Many theories which were hailed as scientific were discarded later. Discuss with examples.

Science is not a product but a process. It's a journey deep into various ideas in search of the scientific truth or is a continuing process. Certain theories which were popular once were discarded due to lack of evidence. If a theory cannot prove itself, that will be rejected. An apt example for this is the earth-centered view of the universe. The Greek philosophers had propounded that the Earth is rotating on its own axis. The Indian astronomer Aryabhatta also had put forward this theory. For a longtime this idea was accepted as a scientific truth. Then it was rejected as nonsense by most of the leading astronomers. But as the evidence in favour of the sun-centered planetary system, continued to pile up, the earth centred view had to be quietly dropped.

Sometimes, we find ideas which originated in vastly different times and places coming together and reinforcing each other when the time and conditions are favourable. This happened to the idea of continental drift The geographer Abraham Ortelius suggested that there is a striking match between the profiles of the east coast of South America and the west coast of Africa. But the very idea that continents could break up and drift apart was so preposterous that few dared to believe it. Later in the 20^{th} century Alfred Wegener resurrected this concept with the help of more evidence from geology and paleontology. He suggested that all the seven continents were once joined together in one single landmass. Still there was no satisfactory explanation for this. However, when the science of plate tectonics developed further in the 1960s, it could give an explanation which was quite convincing.

Thus we find that those theories that were once discarded, become convincing later and they became a part of science.

UNIT – 2

ORIGINS OF SCIENTIFIC ENQUIRY

Objectives

After reading this unit you will be able to:

1. Know the various civilizations that had existed earlier.
2. Understand how scientific developments happened among various civilizations.

THE PALAEOLITHIC (OLD STONE) AGE

The beginning of science was created by observation, understanding of nature.

The main difference between man and animals is that man forms continuing societies. This was so even in the Old Stone Age. Then onwards began our technical progress.

The mastery over fire is another mile stone. Man used fire to warm the body on cold nights and to frighten animals. This helped him to cook his food. Pottery was invented. They also had the knowledge of different types of soils and their properties. They also made tools.

THE NEOLITHIC (NEW STONE) AGE

About 10,000 years ago, there began a revolution in food production. The Old Stone Age humans were hunter-gatherers. They used sharp tools and had the ability to hunt in groups, aided by communication.

The difficulties arising from the crisis of the hunting economy led to an intensive search for new foods. This led to the invention of the technique of agriculture. The period between the first invention of agriculture and the founding of the cities is usually known as the New Stone Age.

Then came up various villages, and the food surplus called for special storage houses. Houses were arranged in patterns along definite streets with buildings constructed of mud, reeds, logs, stone or clay.

During this Neolithic period man achieved a new equilibrium with nature, through the produce of soil and climate.

THE BRONZE AGE

The Bronze Age which began about 4000 BC in the great river valleys of Asia and Africa was remarkable for inventions and discoveries. Among its technical contributions are:

i) Copper and bronze
ii) Harnessing of animal power
iii) Wheeled vehicles
iv) The sailboat
v) The potter's wheel
vi) Bricks

The art of melting and casting metals was also developed around this time. By 3000 BC, the wooden plough was being pulled by oxen. The invention of sailing boat helped the expansion of trade. The invention of the potter's wheel caused a revolutionary change in this craft.

THE EMERGENCE OF CIVILIZATIONS

With the flowering of the Bronze Age culture, we find the strengthening trends toward changes in the economic relations of the genders and profound changes in the organization of society from one based on agriculture to one based on trade and craft manufacture. The first appearance of large units of organized society in the Old World occurred in the Valleys of the Tigris-Euphrates, the Nile, the Indus and the Yellow River.

Civilizations first appeared at these particular places because of the presence of a river that could be used for transportation and irrigation and also due to the availability of alluvial soil.

The Tigris – Euphrates Valley

About 7000 years ago a peaceful and creative race left their homes somewhere in Central Asia and descended into Mesopotamia. One of the greatest achievements of the Babylonians was their numerical system and the method of reckoning. They used a simple decimal system. The invention of the calendar epitomized their achievements in science. The waxing and waning of the Moon, the direction in which the sun rose and the backdrop of stars against which it rose were noticed by them. They also knew the solar year of 360 days each. Geometry, too, seems to have had a period of brilliance in Babylonia.

The Nile Valley

Some of the migrants, who descended into the Mesopotamian Valley, seem to have passed on to Egypt, carrying Sumerian influence with them. Thus the Babylonian civilization and the Egyptian civilization have many things in common.

The geographical terrain of the Valley of Nile is different compared to the Valley of Mesopotamia. The Nile Valley created no overwhelming engineering problems. It flooded gently, regularly and predictably from August to October.

The Valley was also favourably endowed with raw materials. Egyptians are good sailors and ship builders. The arts and crafts of Egypt were of very high aesthetic order. Rich cloth was embroidered in gold thread. They were excellent in leather work, cabinet making, jewellery and metal working. Their craftsmen knew smelting, forging, soldering, alloying, engraving and gilding.

They had discovered that they could produce a decorative glazing on pottery by heating sand with potash or soda and a metallic oxide. They were already using pens, inks, and papyrus and were employing an alphabet and a definite numerical system.

Pyramids

From ancient time onwards Egyptians are famous for their perfection in stone masonry. Egyptian Pyramids are the best example for this. The rocks from which these buildings were constructed were quarried utilizing only tools of copper and bronze. The basic tools were the lever and the ramp. They brought the stones in sail boats across the Nile and the pyramids were built stage by stage. The Great pyramid at Giza contains approximately 3 million cubic metres of stone and the area of the base is about 5 hectares. It consists of 2,300,000 blocks each weighing an average of 2 ½ tons.

THE INDUS VALLEY

The well developed urban civilization that flourished on the banks of Indus river system is called the Indus Valley Civilization. It is known to have comprised two large cities called Harappa and Mohenjo-Daro and more than 100 towns and villages.

The cities are remarkable for town planning and municipal control. The houses consisted of rooms around a courtyard and contained stairs to a flat roof or upper storey, a bathroom, latrine and often a well.

A variety of toys, inscribed seals and various other articles were excavated from this site. Different measures of weights were also found.

The Indus Civilization possessed characteristic sculpture and tools-both of stone and bronze. This civilization indicates a cultural interaction with the contemporary Bronze-Age societies of the west.

EARLY CHINA

The earliest inhabitants of China were the settlers of the Yellow River Valley. It is dated from around 5000 BC. The culture is named after Yang-Shao, a place located in the central part of the country, along the Yellow River.

The practices of these people are varied. They cultivated millet and wheat. They kept domestic animals such as pig.

The Yangshao culture is well known for its painted pottery. The documented history of China extends continuously to nearly 6000 BC, since the Chinese were careful about keeping records. They used horse-drawn carriages and the pictographic script. Shadow clocks, the forerunners of the sundial, first appeared in China about 4000 years ago.

Medicine was another area were the Chinese excelled.

Glossary

Parasitic	: depending upon another
Harnessing	: controlling
Haphazard	: disordered
Furnace	: heater
Crucibles	: small pot
Cradle	: crib
Terrain	: land
Indigenous	: native
Overwhelming	: overpowering
Forging	: shape metals by heating in fire and hammering
Engraving	: drawing
Gilding	: decorating
Ramps	: slopping surface between two places
Sledges	: a vehicle used for travelling over snow

Multiple Choice Questions

1. Agriculture was started about __________years

a.100,000 b.50,000 c.20,000 d.10,000

2. The period between the first invention of agriculture and _________ is known as the Neolithic Age

a. the use of iron tools

b. the invention of fire

c. the founding of the cities

d. the discovery of the wheel

3.The sexagesimal system of counting was developed by the ___________

a.Indians c. Egyptians

b.Babylonians d. Greeks

Short Answer Questions

1. What led to the beginning of science?

   Ans: The observation and understanding of nature, essential for the hunter gatherer, led to the beginning of science.

2. Why does the beginning of agriculture mark a turning point in the progress of science?

   Ans: With the advent of agriculture people began to use polished stone implements in place of the chipped instruments of the earlier age.

3. What marked the beginning of our technical progress?

   Ans: The stone casually picked up and thrown marked the beginning of our technical progress; the flowering of that process was the development of tools.

4. Discuss the role of calendar-making in the scientific progress of the early civilizations

   Ans: Calendar-making epitomized the achievements of early civilizations. They needed the calendar not only for governance, but even more important, for planning their agricultural operations.

5. 'One refreshing feature of the Chinese civilization is their fastidiousness in keeping written records'. Give some examples and elucidate their value to the history of science.

   Ans: The Chinese have documented the history of China. They used bronze, fine pottery and horse drawn chariots. The Chinese were accurate observers of celestial phenomena and we know that the most ancient verifiable eclipse in the history was recorded by them in 1361 BC.

Short Essay Questions

1. Briefly describe the Tigris-Euphrates Civilization?

   About 7000 years ago a peaceful and creative race left their homes and descended into Mesopotamia. Their numerical system was great and they used a simple decimal system. The invention of the calendar was the best. The waxing and waning of the Moon, the direction in which the sun rose and the back drop of stars against which it rose were noticed by them. They also knew the solar year of 360 days, dividing into 12 months of 30 days each. Geometry too, seems to have had a period of brilliance in Babylonia.

2. Describe the Nile Valley Civilization?

   The Nile Valley civilization or the Egyptian civilization and the Mesopotamian civilization have many things in common.

The geographical terrain of the Valley of Nile is different compared to the Valley of Mesopotamia. The Nile Valley created no overwhelming engineering problems.

The valley was also favourably endowed with raw materials. Egyptians are good sailors and ship builders. The arts and crafts of Egypt were of very high aesthetic order. They had discovered that they could produce a decorative glazing on pottery by heating sand with potash and a metallic oxide. Altogether, they were really modernized.

Some Additional Short Essay Questions

1. Describe and compare the Indus Valley and the early Chinese Civilization?
2. Explain briefly how man and science developed through various civilizations.

Essay Questions

1. What are the contributions of different civilizations to the development of science?

Changes are visible from the Old Stone Age onwards. The beginning of science was created by observation and understanding of nature. At first man was a hunter wandering from one place to the other in search of food. They hunted animals and for that made sharp edged weapons. Then fire and wheel was discovered. All these were milestones in our path of developments.

The difficulties arising from the crisis of the hunting economy led to the invention of the technique of agriculture. Various villages rose up and people began to settle near river valleys. Civilizations first appeared at particular places like the valleys of Tigris-Euphrates, the Nile, the Indus and the Yellow River because of the presence of a river that could be used for transportation and irrigation and also due to the availability of alluvial soil.

About 7000 years ago a race lived in the Valley of Tigris and Euphrates rivers. Their greatest achievement was their numerical system and the method of reckoning. They used the decimal system and later the sexagesimal system, in which 60 became the base. The invention of the calendar was a landmark. They knew that the seasons appeared in cycles.

Some of the migrants, who passed on to Egypt started living in the Nile Valley. Egyptians were good sailors and ship builders. They were excellent in leather work, cabinet making, jewellery and metal making. They were already using pens, inks and papyrus. Egyptian Pyramids are the best example for the perfection that Egyptians showed in stone masonary.

The Indus Valley cities are remarkable for town planning and municipal control. Different measures of weights, sculptures and tools were used by them.

The Chinese Civilization was based on the Yellow River Valley. Their main contribution was documentation. Shadow clocks, the forerunners of the Sundial, were discovered by the Chinese.

Thus we can infer that the development of science started from these civilizations onwards. All the civilizations have contributed something to the great tree of science.

UNIT – 3

EUROPEAN ORIGINS OF SCIENCE

Objectives

At the end of this unit, you will understand;

1. Greek contribution to the development of science
2. various schools that had originated in Greece

IONIAN AND THE EARLY GREEK CONTRIBUTIONS

The fundamental tools required for science seem to have been available in the early civilizations. Apart from Egypt and Babylonia, the quest for knowledge and a scientific spirit can be seen in Ionia, a small Greek colony on the shores of the Aegean Sea.

The essential ingredient missing in Egypt and Babylonia but available in Greece was the development of the alphabetic writing and the liberation of knowledge from priesthood. Greeks were travelers and seafarers. So they had the sense of space, adventurous temperament and resourcefulness.

THE BIRTH OF NATURAL PHILOSOPHY

The first recognized scientist in history is Thales (Ca.625 - 546 BC) of Miletus, the first and the foremost of the Greek natural philosophers. According to Aristotle, Thales was the first person to investigate the basic principles of nature and so he was considered to be the founder of natural philosophy. Thales explained the underlying unity behind diversities and he taught that everything came from water, the primordial basis of life. The earth, he supposed, was a cylinder or a disc with waters below, on which it floated, and with waters above, from which the rains came. He founded the Ionian School of Philosophy.

Thales was interested in almost everything such as philosophy, history, science, mathematics, engineering, geography and politics.

The second Miletian philosopher, Anaximander (Ca.611-547 BC) added a fourth element, namely fire, to the three elements, viz, solids, liquids and gases. He believed that living organisms had arisen from elemental water and that higher animals, like man, had developed from lower living organisms.

The third of the Miletian philosophers, Anaximenes (Ca. 550-475 BC) considered ‘air’ as his primordial substance and derived the other elements from it.

THE PYTHAGOREAN SCHOOL

Pythagoras (Ca.580-500 BC) is believed to have been born in Samos in Ionia and he is the most widely known ancient Greek Mathematician. He founded a school in Croton, in Southern Italy. This was a brotherhood devoted to a life of mathematical speculation and religious contemplation.

The Pythagorean arithmetic was much concerned about the mystical properties of integral numbers. Among many other such discoveries, Pythagoras found that two similar strings equally stretched will sound an octave apart if one is exactly twice the length of the other. Pythagoreans gave much attention to 'regular solids'.

Another philosopher, influenced by the Pythagoreans was Empedocles of Agrigentum (Ca.500-430 BC). He taught that the universe began as a chaotic mixture of the four elements, air, fire, earth and water. A more valuable contribution of Empedocles was his hypothesis that light travels through space at a finite speed.

Among the later Pythagoreans, the most noteworthy was Archytas (Ca.400 BC). He was especially interested in the mechanical applications of science and is said to have worked out the theory of the Pulley.

Pythagorean Cosmogony held that the earth was spherical in shape, as also the sun, the moon and the stars.

GREEK ATOMISM

Leucippus (Ca.400 BC) and his pupil Democritus (Ca.470-400 BC) taught that the universe consisted of nothing but unchanging atoms and voids. The atoms were indivisible, uniform, solid, hard and incompressible.

GREEK MEDICINE

Medicine of the temples was dedicated to Aesculapius, the god of medicine. There was also the Pythagorean School. There was then the practical Ionian School of Hippocrates. Hippocrates (Ca.460-377 BC) was an outstanding figure and he regarded medicine as an art or a technique, rather than a theoretical science. This school put forward the doctrine that the human body contains four humours: the melancholic, the sanguineous, the choleric, and the phlegmatic.

ATHENS AND THE CLASSICAL GREECE

With the decline of the Pythagorean School, a new scientific school developed in Athens. Anaxagoras (Ca.488-428 BC) was the head of this school. He was a rationalist and maintained that the heavenly bodies were of the same general nature as the earth, except that they had become incandescent through rotation. He was the first to explain eclipses in terms of the moon's shadow falling on the earth, and the earth's shadow falling on the moon. Anaxagoras even hypothesized that other worlds besides earth also existed and were inhabited by human beings like ourselves. The Athenians liked their gods very much.

Plato (429-349 BC) was born in Athens. He founded the 'Academy', the first institution devoted to the pursuit of knowledge in the western world. Plato was a great philosopher and he saw the mind as the only fundamental reality and the material world as only a shadow of that reality. Only these mental forms or the ideas in the mind were perfect, and the material objects were only fleeting glimpses and imperfect representations of the perfect forms.

Aristotle (Ca.384 – 322 BC) was the disciple of Plato. He wrote on a variety of subjects. Aristotle was a brilliant biologist but a poor physicist. He saw the universe as a system of concentric spheres, all having earth as their common centre. Aristotle is generally credited with the invention of formal logic or the deductive method. Aristotle had setup the Lyceum in opposition to the Academy. He was succeeded by Theophrastus.

Theophrastus (Ca.372 – 287 BC) maintained that only efficient causes were the concern of science. Strato of Lampascus was the head of the Lyceum from 287 to 269 BC. Ecphantus and Heraclides of Pontus were the other prominent Phythagoreans of classical Greece.

THE DECLINE OF ATHENS

The period after the death of Aristotle was filled with general confusion and ferment in all fields. Greeks felt the need for philosophy and religion, which would instruct them how to tide over adversity. The result was the origin of Epicureanism and Stoicism.

Epicurus of Samos (Ca.342 – 270 BC) taught the pursuit of the simple life, of mental calm and inward quiet. He denied the divinity of heavenly bodies and wanted to set man free from the 'burden of religion'.

Stoicism was found by Zeno, who taught renunciation of the world. Men were to be guided by their conscience and reasons than by their desires, affections or emotions. Two thousand years before Newton, the stoics introduced the idea that every event occurred in accordance with the universal law.

However the physical theories of stoics and Epicureans had little effect on the development of scientific thought in Greece.

A THOUSAND YEARS OF ALEXANDRIA
(Ca.322 BC – 642 AD)

Alexander the Great built a new city and named it the still unborn city of Alexandria. Alexander died and Ptolemy, one his generals, wished to make Alexandria the world's capital not only for government and commerce but for culture and intellect as well. He started a 'Museum' or 'Temple of Muses'. When Ptolemy died in 283 BC, his successor Ptolemy II, started the famous Royal Library.

The golden age lasted almost a long as the Ptolemaic dynasty, which ended with the death of Cleopatra and the annexation of Egypt by Rome. The Romans didn't have much interest for science. But the Romans allowed the Greek language and a Greek atmosphere to prevail in Alexandria.

But the real danger came later from Christianity. Christianity bought about a new approach to life and for them the real reward was in heaven. They were not sympathetic to the study of science. Subsequently, Rome too embraced Christian faith. Thus the so-called 'dark ages' fell upon Europe. And the notorious Archbishop Theophilus destructed the Great Library in 390.

MATHEMATICS IN ALEXANDRIA

The first of the Great Alexandrian Mathematicians was Euclid (Ca.330 – 275 BC). He was a curator and librarian of the Mathematics section of the Great Library. His most important contribution is his text-book *Elements of Geometry*, which determined the way geometry, was taught all over the western world. He has written at least four books on geometry, and also on astronomy, music and optics.

Archimedes (Ca.287 – 212 BC) was the greatest of all Alexandrian mathematicians. He is best known for his method of measuring the specific gravities of substances. He arrived at a very good approximation for the value of π. Principles of the lever and the pulley, the spirals, the parabola are also written by him.

Apollonius (Ca.250 – 190 BC), Menachmus (Ca.375 – 325 BC) and Diophantus (Ca.200 – 298 AD) were other mathematicians of Alexandria. Diophantus has sometimes been called 'The Father of Algebra'. Menaechmus gave curves their present names, parabola meaning 'the application', ellipse 'the deficiency', and hyperbola 'the excess'.

ASTRONOMY IN ALEXANDRIA

Aristarchus of Samos (Ca.310 – 230 BC) was a renowned scientist. He contributed much to astronomy. His calculations showed that the sun was more distant than the moon. He came out with the astounding pronouncement, 'that the fixed stars and the sun remain motionless, that the earth and the other planets revolve about the sun in circles and so on.

Eratosthenes (Ca.276 – 195 BC) was a curator at the Great Library. He is remembered for his simple but ingenious experiments he performed for determining the circumference of the earth.

Hipparchus of Nicaea (Ca.190 – 120 BC) was the greatest of quantitative astronomers of antiquity. He built an observatory in Rhodes and proceeded to chart the exact position of about 1000 stars which are normally visible in the skies over Egypt. Hipparchus is generally credited with the invention of trigonometry. He is said to have constructed a table of natural sines and is believed to have discovered the important theorems.

Claudius Ptolemy (Ca.85 – 165 AD) made astronomical observations for a long time. His best known work is *Almagest*.

MEDICAL SCIENCES IN ALEXANDRIA

Galen (Ca.129 – 199 AD) is the most prominent name in the field of medicine. He dissected both dead and living animals, though not human bodies. He is remembered for the discovery of the circulation of blood. Galen distinguished between the functions of the veins and arteries and also understood the operation of the heart valves. The crucial role of respiration in the purification of blood was recognized by him.

THE ROMAN CONTRIBUTION TO SCIENCE

The Romans did not add much to science. Their contribution lay in the field of organization, the formation of public medical service, the building of roads and aqueducts, the introduction of the Julian Calico and the formulation of Roman law to regulate their organizations.

JULIAN CALENDAR

The Romans computed, their year in terms of 12 lunar months. Their year had 355 days, starting from the 1st of March. Julius Caesar introduced a drastic calendar reform. The year was fixed as 365 days, divided into 12 months. Every fourth year, an additional day called bis-sextus was added.

MATHEMATICS

Romans developed the branch of commercial Arithmetic diligently. The Roman numerals were superior to the Greek. They also developed a useful system of finger-reckoning besides the use of the Greek abacus.

Glossary

Seafarer	-	working as a sailor
Primordial quintessence	-	essence
Cosmogony	-	origin of the universe
Deductive method	-	the method of reasoning through deduction
Ferment	-	confusion
Cardinal	-	basic
Fortuitous	-	unexpected
Concourse	-	open space
Annexation	-	capture
Legions	-	a large group of soldiers
Barbarians	-	uncivilized people
Byzantium	-	a place in Italy
Oddments	-	scraps
Treatise	-	thesis
Impiety	-	sin
Obliquity	-	something not expressed directly
Antiquity	-	olden days
Isosceles	-	having two sides equal
Intuitively	-	by instinct
Rarefaction	-	to make something less dense or solid
Contemplation	-	thought
Commune	-	be together
Octave	-	a series of eight
Excommunicated	-	officially exclude a person from the church
Equilateral triangles	-	a triangle with equal sides
Tantalizingly	-	teasingly
Sanguineous	-	confident
Phlegmatic	-	indifferent
Incandescent	-	glowing
Gratification	-	satisfaction
Erroneous	-	incorrect
Aqueducts	-	a long bridge with many arches
Empirical	-	experimental

Short Answer Questions

1. Identify the factors which distinguished the Greek science from those of Mesopotamia or Egypt
   Ans: The essential ingredient missing in Egypt or Babylonia but available in Greece was the development of the alphabetic writing and the resulting liberation of knowledge from the priesthood. Apart from that Greeks were travelers and seafarers and had a sense of adventurous temperament.

2. Explain the doctrine of the four humours
   Ans: Hippocrates of Cos developed the doctrine of the four humours. According to this, the human body contains four humours: the melancholic, the sanguineous, the choleric and the phlegmatic. Their correct proportions were indispensable for health. The excess of any of them caused illness.

3. The experiment which Eratosthenes conducted is one of the most beautiful experiments ever conducted. What did Eratosthenes do? And why is it considered as beautiful?
   Ans: Eratosthenes did experiments for determining the circumference of the earth. He is also credited with measuring the 'obliquity of the ecliptic' or the tilt of the earth's axis of rotation, which causes seasons. The experiments that Eratosthenes did were amazingly simple.

4. How is the Julian calendar superior to the earlier calendars especially those devised by Babylonians?
   Ans: The Romans computed their year in terms of 12 lunar months. Their year had 355 days, starting from the 1st of March. Julius Caesar introduced a drastic calendar reform. The year was fixed as 365 days, divided into 12 months. Every fourth year, an additional day called bis-sextus was added.

5. Explain the role of Galen in the field of medical sciences.
   Ans: Galen dissected both dead and living animals, though not human bodies. He is remembered for the discovery of the circulation of blood. Galen distinguished between the functions of the veins and arteries and also understood the operation of the heart valves.

6. What was Plato's philosophy on mind and the material world?
   Ans: According to Plato mind is the only fundamental reality and the material world is only a shadow of that reality. Only the mental forms or ideas are perfect, material objects perceived were only fleeting glimpses and imperfect representations of the perfect forms.

7. We now know that the world view presented by Ptolemy was completely wrong. How scientific was it?
   Ans: Ptolemy presented the earth-centered system according to which the Moon, the Mercury, Venus, Sun, Mars, Jupiter and Saturn revolve around it. But later the Copernican theory presents a sun-centered universe.

8. What is Pythagoras remembered for?
   Ans: Pythagoras founded a school in croton. The Pythagorean Arithmetic was much concerned about the mystical properties of integral numbers. Among many other such discoveries, Pythagoras found that two similar strings equally stretched will sound an octave apart if one is exactly twice the length of the other. Pythagoreans gave much attention to 'regular solids'

UNIT – 4

CONTRIBUTIONS OF EARLY INDIA

Objectives

After reading this unit, you should be able to:

1. Understand the scientific thoughts and ideas that are reflected in early India
2. Know India's position among other countries in the field of science
3. Know more about the great scientists of early India.

SCIENCE IN THE VEDAS

Vedas are the religious scriptures of Aryans. The life and times of the Aryans are portrayed in these works. In the Vedas, scientific thoughts have been conveyed in a spiritual background

MATHEMATICS

Arithmetic and Geometry were well developed during the Vedic period. The Vedic Sage, Medhatithi is known to have enumerated various multiples of ten including 10^{12} in a systematic way.

The complicated religious rituals of the Aryans provided the impetus for the development of Geometry as well as Astronomy in early India. The performance of religious rituals, especially the 'yagnas' required a good knowledge of Geometry and Astronomy. Thus, astronomy developed to calculate the time and geometry developed to measure lengths, areas and volumes of the altars.

VEDIC ASTRONOMY

Astronomy was a well developed science in the Vedic period. The practices of the Vedic rites called for an accurate conjunction of heavenly bodies.

The Vedic Aryans were familiar with the ecliptic path taken by the sun and the moon in the sky. They identified the 24 constellations. *Jothisha vedanga* is the earliest astronomic text consisting of the calculations of the position of the sun and moon.

The day was counted from sunrise to sunrise and the year consisted of 366 days. All months were made up to 30 days duration, and then one extra month was added every five years, to make up for the accumulated error in predicting the seasons.

VEDIC MEDICINE

The Atharva Veda mentions various human ailments and describes their treatment. Fever, cough, consumption, diarrhea, jaundice, abscesses, tumors, paralysis etc… are found frequently mentioned. The most important and vital element, as also the prime mover of life, is prana, which governs all the physiological processes.

More than 150 herbal and other medicines used by modern ayurvedic practitioners are mentioned in Vedas. There are also indications of surgery conducted by Ayurvedic surgeons.

Numerous references about the use of metals lime gold, silver, copper, tin, lead, iron and some alloys can be seen in Vedas. The vedic Aryans knew the preparation of sura or alcohol and also curds. Precious stones and jewels were refined in fire.

In all the four Vedas, several kinds of technicians like blacksmiths, smelters, builders, etc, and their tools have been mentioned.

SCIENTIFIC THOUGHTS IN THE VEDAS

Some of the Rishis believed that the earth rotated around its own axis and also that it revolved around the sun. They also knew that the Moon shone with reflected sunlight. One of the most striking features is that different types of thoughts and deliberations, sometimes contradictory, have been harmoniously included in the Vedas. Not a single Rishi seems to have been disgraced or discarded for his views.

THE ATOMIC THEORY

The earliest known references to speculative atomism in India occur in the Kanada sutras. They are:

1. The body is not composed of three or five elements and a conjunction of atoms is not denied.
2. The first actions of atoms are caused by adrishta.
3. Atoms are eternal

The commentators of Vaiseshika and Nyaya schools later developed this into the atomic theory of matter.

According to them, the external world exists independently of human cognition. Atoms are eternal, part-less and spherical. Four distinct types of atoms corresponding to the four substances – earth, water, fire and air – are thought of and each type has specific qualities with reference to odour, taste, colour and touch.

GOLDEN AGE OF INDIAN SCIENCE

The period from the fourth century BC to the sixth or seventh century AD – of about a thousand years – covering the Maurya, Saka, Kushana and the Gupta empires, was marked by free exchange of ideas with the outer world, intense cultural, political and commercial interaction with the western and eastern countries. We can also witness a kind of scientific advancement within the country during this period. India surpassed all other countries in almost all the fields.

Nalanda and Takshasila were the great centres of learning in India. They attracted students from all over the world. When the Chinese pilgrims Huan Tsang and I-Tisng visited Nalanda they found that the university had over 8500 students and more than 1500 scholars. More than fifty of the students were from other lands. Nalanda scholars were dispatched to all lands, to spread the science and philosophy of India. As a result the Indian culture took deep roots in countries like Sri Lanka, Myanmar, Tibet, Afganistan, Cambodia, Thailand, Indonesia, Japan, Korea, China etc.

MEDICAL SCIENCES

Medicines played a significant role in early Indian scientific activities. Classical Indian medical knowledge is called Ayruveda or the 'knowledge of long life'. The two chief traditions of Ayurveda are those of 'Atreya' and 'Dhanvantari'. The most important text of 'Atreya' is *Agnivesatantra*, believed to have been prepared by Agnivesa and later edited by Caraka as *Carakasamhita* The 'Dhanvantari' tradition is represented by the classical *Susruta Samhita* which was named after Dhanvantari's disciple susruta. The *Susruta Samhita* stresses surgical treatment and C*arakasamhita*, diagnosis and prognosis.

Theoretically, classical medicine consists of: 1) general surgery 2) eye, ear, nose and throat treatment 3) general therapeutics 4) science of disease – causing demons 5) child care 6) antidotes 7) strengthening or restoration of youth 8) aphrodisiacs. New methods of diagnosis and treatment were developed. There was even a branch of medicine devoted to the treatment of diseased plants, called 'Vriksha Ayruveda'.

PSYCHOLOGY AND PSYCHOSOMATIC

The most original and advanced Indian science was psychology. The analysis of the workings of the mind and the thought began in the last centuries BC. They resulted both in an idea of the importance of subconscious life and in a realization of the link between bodily and psychic functions. They argued that every conscious experience leaves a trace in the 'soul'. They are not lifeless imprint, but in turn form an 'ethereal' body. This 'ethereal' body governs the tendencies and reactions of the soul and can be reincarnated after death in a new physical body. Yoga can be used for the achievement of mastery over mind and body. Some forms of Yoga borrow ideas about marma from ayurveda. The authoritative text on Yoga is the *Yogasutra* of Patanjali.

CHEMISTRY AND METALLURGY

Chemistry in India developed mostly from medicine. A theory of chemical reactions, in connection with tastes which distinguish substances, was prescribed by Caraka. The earliest surviving text of chemistry is the *Rasarathakara* of sage Nagarjuna. Nagarjuna was also associated with the discovery of the process of distillation and calcinations.

Another chemist was Patanjali, whose field was iron and its uses. Early Indians were aware of the process of smelting and casting iron and copper. They also made brass and bronze articles. An example for their knowledge is the solid copper bolt of Rampura Asoka pillar and of the famous Iron Pillar of Delhi. It has withstood corrosion and rusting for at least 1500 years. Indians also knew mineral acids and the preparation of metallic salts.

MATHEMATICS AND ASTRONOMY

According to Aristotle the unique contribution of Indians to the world of mathematics is the system of writing decimal numbers, with place values and the use of zero.

Among the early Indian mathematicians, the most outstanding figure is Aryabhata, the author of *Aryabhatiyam.* Aryabhata stated that the earth was a sphere and rotated on its own axis. He refuted the traditional concept of Rahu. He knew that Moon was essentially dark and was illuminated by the Sun.

Aryabhata laid the foundations of algebra and was the first Indian author to give the rule for attaining square and cube roots.

Another great mathematician of India is Varahamihira who wrote *Panchasidhantika*. He too regarded that the earth is an immovable sphere, fixed at the centre of the universe, around which the sun, the Moon, and the other planets revolved.

Brahmagupta is another mathematician who was known for his enunciation of the concept of zero for the first time. He showed that zero subtracted from a negative quantity, positive quantity, or zero itself would leave the quantity unchanged. Zero multiplied by a negative, positive or zero, would also furnish zero.

Bhaskaracharya, the author of *Sidhanta Siromani,* was the finest algebraist of them all. His famous book *Lilavti* is dedicated to his daughter by that name.

Due to the repeated invasions and plunders, India was not able to continue its pursuit of science.

Glossary

Enumerated - specify
Explicitly - openly
Vortex - current
Parallelogram - four sided figure
Reckoning - estimate
Abscesses - swelling containing puss
Rudiments - basics

Coexisting - existing together
Dissolution - ending
Skepticism - doubt
Alleviation - lessening
Bile - anger
Phlegm - calm and unemotional
Decoctions - boiling down to extract some essence
Physiological - related to body
Pillage - plunder

Multiple Choice Questions

1.____________taught that everything came from water
a. Thales b.Anaximander c.Aristotle d.Plato

2.___________ said "Things are numbers"
a.Aristarchus b.Socrates c.Pythagoras d.Archimedes

3. He is considered the father of Greek Atomism.
a.Eudoxus b.Democritus c.Hippocrates d.Hipparchus

4.Stoicism is associated with ____________
a.Strato b.Plato c.Socrates d.Zeno

Short Answer Questions

1. Identify clearly the original contribution made by India in the number system and trace how it reached Europe and the world.

   Ans: The idea of decimal system was known in almost all ancient societies. The idea of it actually came from Aristotle. It was the system of writing decimal numbers, with place values and the use of zero, which was a unique Indian contribution. Then the Arabians began to use it and eventually it was passed on to the Europeans.

2. What was Aryabhata's discovery about the solar system?

   Ans: Aryabhata stated that the earth was a sphere and rotated on its own axis. He refuted the traditional concept of Rahu. He knew that Moon was essentially dark and was illuminated by the sun.

3. Outline the general approach of Ayurveda to the science of healing, and examine how it compares with the approach of modern science?

   Ans: In Ayurveda healing seeks simultaneously to cure symptoms, to abolish causes and to re-establish, by exciting or calming medicines, the normal balance of breath, bile and phlegm. For this, hygiene, correct diet and drugs are very important. Pharmaceutical preparations are powers, pastes, steepings, decoctions, infusions etc. New methods of diagnosis and treatment are developed. The examination of the pulse, for e.g, became a complicated method of interpreting disturbances of health.

4. What are the references to atomism in the *Kanada Sutras*?

   Ans: The references in the *Kanada Sutras* are that
   - i) The body is not composed of three or five elements and a conjunction of atoms is not denied.
   - ii) The first actions of atoms are caused by 'adrishta' and
   - iii) Atoms are eternal

5. What are the chief traditions of early Indian medicine?

   Ans: The two chief traditions of Ayurveda are those of 'Atreya' and 'Dhanvantari'. The most important text of the former is *Agnivesatantra*, first prepared by Agnivesa and later edited by Caraka when it became known as *Carakasamhita*. The 'Dhanvantari' tradition was revised and completed by Susruta. The *Susrutasamhita* stresses surgical treatment and *Carakasamhita*, diagnosis and prognosis.

Essay Question

1. Discuss in detail the original contributions of India in the field of Mathematics.

Vedas are the religious scriptures of Aryans. The four Vedas of Aryans – Rigveda, Atharva veda, Yajur veda and Sama veda contain scientific thoughts in a spiritual background.

Arithmetic and Geometry were well developed during the Vedic period. The Vedic sage, Medhatithi, is known to have enumerated various multiples of ten including 10^{12} in a systematic way.

The complicated religious rituals of the Aryans provided the impetus for the development of Geometry as well as Astronomy in early India. The performance of religious rituals, especially the 'yagnas', required a good knowledge of geometry and astronomy. Thus astronomy developed to calculate the time and geometry developed to measure lengths, areas and volumes of the altars.

According to Aristotle the unique contribution of Indians to the world of mathematics is the system of writing decimal numbers, with place values and the use of zero.

Among the early Indian mathematicians, the most outstanding figure is Aryabhata, the author of *Aryabhatiyam*. Aryabhata stated that the earth was a sphere and rotated on its own axis. He laid the foundations of algebra and was the first Indian author to give the rule for attaining square and cube roots.

Another great mathematician of India is Varahamihira who wrote *Panchasidhantika*. He too regarded that the earth as an immovable sphere, fixed at the centre of the universe, around which the sun, the moon, and the other planets revolved.

Brahmagupta is another mathematician who was known for his enunciation of the concept of zero for the first time.

Bhaskaracharya, the author of *Sidhanta Siromani*, was the finest algebraist of them all. His famous book *Lilavati* is dedicated to his daughter by that name.

After Bhaskaracharya science and culture faced a decline in India due to the repeated foreign invasions and plunder.

UNIT – 5

SCIENCE IN CHINA

Objectives

At the end of this unit, you will be familiar with:

1. the historical background of China
2. scientific developments that had happened in early China.

EARLY HISTORY

As we have already mentioned the most striking feature of Chinese civilization is their habit of keeping records. The documented history of China extends continuously to nearly 1600 BC up to the Shang dynasty. They used bronze, fine pottery and horse drawn chariots.

The 6th to the 3rd centuries BC, are often called the period of the 'warring states' because of the battles between empires. However it also seems to have been a period of intense intellectual activity, promoting science and philosophy. Both Confucius (Ca.551 – 479 BC) and Lao Tsu (Ca.666 BC) lived at the beginning of this period.

The Chin dynasty (221 – 206 BC) was started by Shih Huang Ti or the 'First Emperor' who destroyed books on history. However he introduced a uniform writing system and standardized weights, measures and coinage. The Emperor built a network of roads and created the Great wall by joining and extending several walls. But his dynasty lasted a very short period of 15 years. Next was the Han dynasty, founded by Liu Pan which proved to be long and vigorous one and was noted for its technical and scientific achievements.

ASTRONOMY AND MATHEMATICS

Before Renaissance the Chinese were the most accurate observers of celestial phenomena. China had a feudal bureaucratic government and they kept accurate records. The most ancient verifiable eclipse was recorded by them in1361 BC. They have also listed Novae, Supernovae and Comets. The Chinese stated that the tails of comets always point away from the sun as early as 635 AD.

Even the precession of the Equinox was known to them. The most famous of their astronomers was Shih Shen who prepared a star chart of about 800 stars, and gave the rules for predicting eclipses.

The pole star was the most important of the heavenly bodies for the Chinese. The astronomical calculations of the Chinese were almost entirely algebraic like that of Indians. Decimal place-value and a blank space for zero had begun in China almost contemporarily with India. There must have been considerable contact between India and China.

MEDICINE

Medical science has enjoyed a high status in China. Even before the time of Hippocrates in Greece, the Chinese physicians had used scientific methods of diagnosis, as well as such therapeutic methods as acupuncture, gently radiant heating, counter – irritants, aqueous and alcoholic decoctions of drugs, massage, gymnastics and medical plasters. The philosophy of Chinese medicine included the division of all diseases into six classes derived from excess of one or the other of the six fundamental principles: Yin (masculine aspect of the universe), Yang (feminine aspect), wind, rain, twilight influence, and brightness of the day.

Chinese medicine was also shaped by Taoism and they advocated dietetic techniques to prolong life and cure sickness. The most interesting feature of the Chinese Medical system is its thorough organization and bureaucratic setup. An Imperial Medical College was established around 620 AD. The government had established a well organized hospital system also and they had imposed quarantine regulations during epidemics.

One particular practice of Chinese medicine that deserves special mention is acupuncture. There are more than 100 acupuncture points that lie on 11 pairs of 'meridians' called 'ching mai' throughout the body. These are regarded as conductors of vital energy. The Chinese doctors relied on four methods – looking, listening, asking and feeling the pulse. Acupuncture consisted of inserting needles at critical points along the harmful excess of body humours. Needles were formerly made of wood and bamboo, and later copper. Acupuncture has been used against paralysis, apoplexy, diabetes, cholera, rheumatism, sprains, swollen joints, tuberculosis, functional disorders and infections. Most recently acupuncture has been used as a tool for local anesthesia.

CHEMISTRY

The first reference to alchemy in world history occurs in China in 133 BC. In their quest for prolonging life, they tried several elixirs based on mineral acids.

Medical Chinese chemists had succeeded in preparing mixtures of androgens and oestrogens in a relatively purified crystalline form. The most extraordinary development in China was the preparation of sex hormones from urine.

CONCLUSION

Even though we can witness scientific advancement in medieval China, modern technology did not develop there. This may be because of the large and variable rainfall and consequent disastrous floods in China; they were faced with the necessity of making large scale irrigation and flood control work. This had two consequences. Millions of workers had to be organized and controlled for this purpose. A large body of officials also was needed. The result was the existence of a highly centralized bureaucracy. A large number of towns were developed for the emperors. This resulted in the supremacy of the civil servants. Chinese society has been called 'bureaucratic' and 'feudal'. Naturally, it was not possible for modern science and technology to gain ground.

Glossary

Fastidious	: difficult; hard to please.
Documented	: put into a document
Excavation	: reveal or extract by digging
Radiating	: burning
Contemporarily	: recently
Twilight	: nightfall
Therapeutic	: healing
Acupuncture	: treatment by pricking needles in to the skin
Decoctions	: boiling down to extract some essence
Dietetic	: nutritional
Vitality	: energy
Epidemics	: spreading diseases
Ailments	: sickness
Apoplexy	: sudden loss of consciousness
Rheumatism	: inflammation and pain in the joints
Sprains	: sudden pain in the ankle or wrist
Neuralgia	: intense pain in the nerve
Insomnia	: sleeplessness
Anesthesia	: absence of sensation artificially induced before surgery
Prejudice	: discrimination
Elixir	: supposed remedy for all ills
Immortality	: everlasting

Multiple Choice Questions

1. The Chinese records of comets go back to the __________

a .4th century AD   b.4th century BC

C. 8th century BC   d. 16th century BC

2. The name of founder of the Chin dynasty was Shih Hwang Ti. It meant ____________

a. The Greatest Emperor
b. The First Emperor
c. Descended from the Gods
d. The Eternal Emperor

3. Alchemy had its origins in the attempts to prepare secret potions which________

a. were supposed to give long life
b. were aphrodisiacs
c. could convert base metals into gold
d. could do all of these

4. What was the most important of the heavenly bodies for the Chinese?
a. Pole star b. Sun c. Moon

Short Answer Questions

1. What were some of the reforms made by Shih Huang Ti?
   Ans: Shih Huang Ti was a great Emperor who inaugurated the Chin dynasty. He destroyed books on history. However, a uniform writing system was introduced by him. Weights, measures and coinage were standardized. He built a network of roads and essentially created the Great Wall of China.

2. Why do the astronomers of today examine the old Chinese records of Novae and Supernovae?

   Ans: The most ancient verifiable eclipse in the history of any people was recorded by the Chinese as early as 1361 BC. A particularly interesting record is the list of Novae and Supernovae which appeared between 1400 BC and 1690 AD. Hence modern astronomers often refer these records.

3. What is the significance of the Pole Star in Chinese astronomy?

   Ans: The Pole Star, which appeared to remain absolutely stationary, was the most important of the heavenly bodies for the Chinese.

4. Describe the similarities and differences between the Chinese and Indian traditional systems of medicine.

   Ans: Ayurveda, considered as the traditional Indian medicine has treatment for all diseases. Ayurveda gives more care to cure symptoms and to abolish causes. But in ancient China scientific methods of diagnosis were known. Acupuncture was the chief method of treatment. Looking, listening, asking and feeling the pulse were the four methods used by the Chinese doctors.

Essay Question

1. Why did industrial revolution not take place in China?

The most striking feature of Chinese civilization is their habit of keeping records. From those records we can understand that the Chinese scientists made great progress in the fields of Astronomy, Mathematics, Medicine and Chemistry. Till the medieval period they continued their efforts. Early Chinese period seems to have been a period of intellectual activity, promoting science and philosophy. Great philosophers like Confucius and Lao Tsu lived during this period.

The most ancient verifiable eclipse was recorded by them in 1361 BC. They have also listed Novae, Supernovae and comets. The Chinese stated that the tails of comets always point away from the sun.

Even before the time of Hippocrates in Greece, the Chinese physicians had used scientific methods of diagnosis, as well as such therapeutic methods as acupuncture, gently radiant heating, counter- irritants, gymnastics etc. The philosophy of Chinese medicine included the division of all diseases into six classes derived from excess of one or the other of the six fundamental principles: Yin (masculine aspect of the universe), Yang (feminine aspect), wind, rain, twilight influence, and brightness of the day. Chinese medicine was also shaped by Taoism and they advocated dietetic techniques to prolong life and cure sickness.

One particular practice of Chinese medicine that deserves special mention is acupuncture. Acupuncture consisted of inserting needles at critical points along the harmful excess of body humours.

The first reference to alchemy in world history occurs in China in 133 BC. In their quest for prolonging life, they tried several elixirs based on mineral acids.

Even though we can witness scientific advancement in medieval China, modern technology did not develop there. This may be because of the large and variable rainfall and consequent disastrous floods in China; they were faced with the necessity of making large scale irrigation and flood control work. This had two consequences. Millions of workers had to be organized and controlled for this purpose. A large body of officials also was needed. The result was the existence of a highly centralized bureaucracy. A large number of towns were developed for the emperors. This resulted in the supremacy of the civil servants. Chinese society has been called ‘bureaucratic’ and ‘feudal’. Naturally it was not possible for modern science and technology to gain ground.

UNIT – 6
THE ROLE OF THE ARABS IN THE HISTORY OF SCIENCE

Objectives

At the end of this unit, you will be able to:

1. Understand the role of Arabs in the history of science.
2. See how scientific activities got transferred from the east to the west.

Glossary

Barbarians	:	uncivilized and violent people
Heathen	:	person having no religion
Culminating	:	ending
Hellenistic	:	the culture of ancient Greece
Servility	:	slavery
Credulity	:	willingness to believe that something is real or true
Stipulation	:	thought or idea
Trustees	:	someone with legal control of money or property that is kept for another person or firm.
Receptive	:	one who receives thoughts and ideas

HISTORICAL BACKGROUND

In 476 AD all kinds of learning and scientific advancement stopped in Rome and Athens. There was a gradual decline and decay of the creative genius of the Hellenistic peoples. The Great Library of Alexandria was destroyed in 642 AD. Just as the great cultures of China and India were emerging into a final flowering of their scientific and technical achievements, Europe was slipping into a dark age of servility, credulity and superstition. It was an age of devoid of creativity, imagination, or initiative in the areas of science.

THE RISE OF ISLAM

Muhammad, the prophet of one God, worked something like a miracle upon his people. He disciplined and united the different clashing tribes. The Islamic empire expanded with the conquest of Palestine, Iraqi, Syria, Egypt, Alexandria, Persia, Western Turkestan, parts of Western India, Northern Africa, Spain and Western Europe.

All these conquests led to increased learning. Their conquest of Egypt gave them whatever of learning was left in the empty shell of Alexandria. By their conquest of Persia they came into contact with the Nestorians. The Arabs welcomed foreign technicians, chemists and physicians. There was a great demand for manuscripts and translators.

When treaties were signed, one of the stipulations was that scientific books should be surrendered to the Arabs. Soon Baghdad became the cultural capital of the world and Arabic became the international language of culture and science.

Arabs excelled as translators, commentators and writers and the greatest contribution of the Arabs was their functioning as trustees of this great heritage, which was later passed on to a receptive Europe.

Glossary

Alchemy	:	form of chemistry studied in the Middle Ages, which was concerned with trying to discover ways to change ordinary metals into gold
Transmuted	:	changed
Arsenic	:	a very strong poison which can kill people
Equinox	:	one of the two days in the year when day and night are of equal length
Eccentricity	:	madness
Observatory	:	a building with a large telescope from which scientists study things such as the planets by watching them.
Prodigy	:	someone young who has a great natural ability for something such as music, mathematics or sport.
Pores	:	holes

ARABIC SCIENCE

The Golden Age of Arab science is from about 900 AD to 1100 AD. It was a period of creativity and the most characteristic Arabic scientific developments were made in Chemistry, Astronomy, Mathematics, Physics and Medicine. Not many of the scholars were Arabs and some were not even Muslims, but were mostly Syrians, Persians and Jews with Arab names.

CHEMISTRY OR ALCHEMY

Alchemy arose in Islam during the ninth century with Jabir Ibn Hayyan (721-815) and he is called 'the father of Arabic Alchemy'. Arabs formulated the doctrine that all things, and in particular metals, were formed by the interaction of the principles of Mercury and Sulphur. They also suggested that a metal could be transmuted into another metal by quantitatively changing its elementary constitution. They used the balance and studied chemical operations and knew how to prepare Arsenic and Antimony, how to refine metals and how to dye cloth and leather.

PHYSICS

Abu Ali Hasan Ibn al-Haitham (965 – 1038) who is known to the west as Alhazen, is noted for his work on Optics. Ancient thinkers like Euclid, Ptolemy and others believed that the eye sends out rays of light to view objects. But Alhazen opposed this theory and said that rays of light came from the object, as the light spread out spherically from any source. Also, Alhazen's experimental study of magnifying glasses brought him very near to the modern theory of convex lenses. The Arabs are said to have prepared extensive tables of the specific gravities of metals and other materials.

MATHEMATICS

The Arabs borrowed heavily from the Indian mathematical traditions. The Indian scholar, Kanaka, traveled to Baghdad during the time of Caliph-al-Mansur. Kanaka used the Brahma Sphuta Sidhanta to explain the Hindu system of Mathematics and astronomy. All these theories were translated into Arabic by Al-Fazari and this work later came to be known among Arab astronomers as the *Great Sindhind*.

Muhammed Ibn Musa Al-khwarizmi (780 – 850) is credited with 'inventing' algebra. His masterpiece is titled *al jabr wa'I mugabala*.

Al-khwarizmi is another mathematician who has written two subsequent works – one based on Indian Astronomy and the other on Arithmetic.

Omar Khayyam was a renowned Mathematician and a great poet. He dealt with cubic equations.

ASTRONOMY

Caliph Al-Mamun established an astronomical observatory at Baghdad in 829 AD. Al-Battani (858 – 929) obtained values for the obliquity of the ecliptic and the precession of the equinox.

Around 1000 AD, Ibn-Yunus (950 – 1009), the greatest of the Arab astronomers, made valuable observations on solar and lunar eclipse. About this time, astronomer Arzachel (1080) made the revolutionary suggestion that the planets moved around the sun in ellipses.

Hulago Khan, the grandson of Gengis Khan, founded an observatory in Azerbaidjan. Ulugh Begh, the grandson of Tamerlans, founded another observatory at Samarkhand.

MEDICINE

Arabs were mostly interested in medicine. About 8000 AD, Caliph Harun al-Raschid founded a hospital at Baghdad. The existence of 34 more hospitals has been recorded. Apart from several original writings, there were many translations also.

The first original Arabic writer on medical matters was Abu Bekr Muhammed. His fame among the Arabs was mainly grounded upon a huge encyclopaedia of the medical knowledge of his days, called the *Comprehensive Book*.

The next great Arab physician, Avicenna, was influenced by the Chinese traditions also. The most notable contribution to the field of medicine in this period came from Ibn al-Nafis. He was bold enough to challenge Galen's description of the circulation of blood. Galen had claimed that blood passed from the right chambers of the heart to the left chambers, through pores in the partition wall, but Ibn al-Nafis refuted this.

Glossary

Ripe	:	mature
Suspicious	:	doubtful
Liberal	:	free
Patronage	:	support given by someone to a person or group
Vitality	:	strength or energy
Compendium	:	a short but detailed collection of information, usually in a Book
Notation	:	a set of written symbols
Peninsula	:	a piece of land that is almost completely surrounded by Water
Seaborne	:	actions that take place on the sea in ships
Conceivable	:	believable
Munition	:	military equipments like bombs, shells and guns

THE HISTORICAL ROLE OF THE ARABS

Arabs recovered, translated, preserved and returned to Europe the considerable wisdom of the Hellenistic scientists and philosophers. As traders and empire builders they came into contact with Spain, Europe, China, India and other civilized world. Thus they provided a medium for transmitting the generally more advanced science and technology of the east to the comparatively underdeveloped west.

THE SHIFT IN ISLAMIC LIBERALISM FROM EAST TO THE WEST

Towards the end of the eleventh century, the Great Islamic Empire began to break up. Simultaneously, the Orthodox religious pundits became suspicious of science and began to attack it. The Muslims of the east started opposing science.

However, Islam continued its liberal patronage of the sciences in the western empire, and provided it with a new vitality, particularly in the two Spanish centres, Cordoba and Toledo. Gradually through these cities, an interest in Arabic ideas and an appreciation of Arabic learning spread over Western Europe. Pope Sylvester II introduced an Arabic form of the old Roman abacus, while another priest, Herman the Cripple wrote books on Mathematics and Astronomy, based on the Arab works.

An Englishman, Adelard of Bath wrote a compendium of Arabic science under the title *Natural Questions*. He introduced the Indian numerals through his translation of Algebra into Latin. Leonardo of Pisa(Fibonacci) asserted the superiority of Indian numeral system over the commonly used Roman system in his work *Liber Abaci* as also John de Hollywood.

ARAB TRADERS AND THE TRANSFER OF TECHNOLGY

The inhabitants of Arabia have been great seafarers even from the days of Solomon. The goods that the Arab ships brought from India were handed over here to the Jewish merchants, who took them over land routes to Egypt, Greece and other centres farther west. The ports of South India had received not only Arab ships but also ships from China. This helped transfer of technology to the west. There were also routes over the landmass of Asia used for transporting paper, printing and gun powder. Paper and printing were from China, but gun powder was the contribution of Mongols.

Glossary

Pursuit	:	attempts made to achieve something
Elite	:	powerful and rich group of people
Spurious	:	something that seems genuine, but false
Abbey	:	monastery
Optician	:	someone who makes glasses and contact lenses
Vague	:	not clear
Propelled	:	rotated

EUROPEAN SCIENCE IN THE MIDDLE AGES

Education and the pursuit of knowledge remained the privilege of the elite during the Middle Ages. Alchemy, astrology and magic were the subjects of common interest.

NEW BEGINNINGS

In 787, Charles the Great resolved to encourage learning in his empire. Similarly, in the tenth century, two of the Byzantine Emperors, Leo VI and Constantine VII showed an enthusiasm for astronomy.

Frederick II was a great patron of sciences and Leonardo of Pisa or Fibonacci deserves a special place in the history of western science. He was an original mathematician and gave the earliest instance of what has come to be known as the Fibonacci series. It was the age when the great medieval universities were coming into being. The first of them was at Paris (1200), followed by Oxford (1214) and Cambridge (1231). The universities were established in Italy, one at Padua (1222) and the other at Naples (1224).

SCIENCE AND MONASTIC ORDERS

Franciscans and Dominicans were the two monastic orders that were founded around 1209 and 1215 AD. At first both were engaged in religious activities. But soon they realized the need for acquiring knowledge. Thus Franciscans produced scientists, while Dominicans gave birth to men of thought.

Roger Bacon (1204 – 1294) wrote Opus Majus, a sort of compendium of scientific ideas and knowledge of the period. He made his own experiments with mirrors and lenses, and anticipated great discoveries. His knowledge was based on the works of Al-Haithan. Even though his original contributions were in optics, he also described how mechanically propelled carriages, ships and flying machines might be constructed, and discussed possible uses of gun powder and burning–glasses.

Glossary

Timidly	:	shyly
Cardinal	:	a high ranking priest
Prerogative	:	preference
Soothed	:	comforted
Presage	:	warning or sign
Rivulets	:	small streams
Torrent	:	water flowing rapidly

CONCLUSION – THE SIGNS OF COMING DAWN

There happened various conflicts between the Christian, the Jewish and Islamic cultures. Thus the Middle Ages represented an era of transition and compromise. But these conflicts helped different cultures come into contact with one another and resulted in much give and take. A sign of intellectual independence began to appear. The first branch that developed was Astronomy. The one who took the initiative was Oresme, Bishop of Lisieux, advisor to the Kings Charles V and VI. Then it was taken up by Nicholas of Cusa. He rejected the traditional Astronomy He maintained that the earth moves as do the other planets.

The church was tolerant towards science. It was believed that science was found to support and confirm orthodoxy. This was the view propagated by the scholastic school, of which St.Thomas Aquinas was the chief proponant. There was enough freedom of thought and it was the greatest period of creativity in human history, from Greece, Alexandria, India and China.

Now everything was favourable for a period of scientific activity which can be seen in the sixteenth and seventeenth centuries.

Short Answer Questions

1. Trace the line of transmission of Indian numerals to Europe
   Ans: Muhammed al-khwarizmi was a great Arabian Mathematician who wrote two subsequent works on Indian Astronomy and Arithmetics. He borrowed a lot from Indian mathematical traditions. After that the Indian place-value system was introduced to Europe through Latin translations.

2. Identify the original contributions of Arabs to science.
   Ans: It was the Arabs who found that metals were formed by the interaction of the principles of mercury and sulphur. Arabs gave their contribution to Optics also. They believed that the rays of light come from the object as the light spread out spherically from any source. This was in opposition to the view of Euclid and Ptolemy. They also prepared extensive tables of the specific gravities of metals and other materials.

3. Critically examine the relation between the political fortunes of an empire and its attitude to science in the context of the Arabic conquests.
   Ans: Towards the end of the eleventh century, the Great Islamic Empire began to break up. Simultaneously, the Orthodox religious pundits became suspicious of science and began to attack it. However, Islam continued its liberal patronage of the sciences in the western empire.

4. Examine critically the role played by the church and the Monastic orders, in the progress of science in Europe.
   Ans: Before the Orthodox Muslims, the Christian church started opposing science. Pope Sylvester II introduced an Arabic form of the old Roman abacus, while another priest wrote books on Mathematics and Astronomy, based on the Arab works. For the next two centuries the two monastic orders, Franciscans and the Dominicans produced most of the scientists and men of thought.

Essay Question

1. Write an essay on the "Non-European Origins of Science"
   In 476 AD all kinds of learning and scientific advancement stopped in Rome and Athens. There was a gradual decline and decay of the creative genius of the Hellenistic peoples. The Great Library of Alexandria was destroyed in 642 AD. Just as the great cultures of China and India were emerging into a final flowering of their scientific and technical achievements, Europe was slipping into a dark age of servility, credulity and superstition. It was an age devoid of creativity, imagination or initiative in the areas of science.

Muhammad, the prophet of one God, worked something like a miracle upon his people. He disciplined and united the different clashing tribes. The Islamic empire expanded with the conquest of Palestine, Iraq, Syria, Egypt, Alexandria, Persia, parts of India, Northern Africa, Spain and Western Europe.

All these conquests led to increased learning. Their conquest of Egypt gave them whatever of learning was left in the empty shell of Alexandria. By their conquest of Persia they came into contact with the Nestorians. The Arabs welcomed foreign technicians, chemists and physicians.

Arabs excelled as translators, commentators and writers and the greatest contribution of the Arabs was their functioning as trustees of this great heritage. All these later passed on to a receptive Europe.

Thus science originated in Greece, China, India and the Arab world. And as time passed by all those got transferred into Europe and flowered.

MODULE 2

UNIT – 7
SCIENCE IN THE MIDDLE AGES

Objectives

At the end of the unit, you will get an outline of:

1. how science flourished during the Middle Ages
2. the contributions of some great scientists
3. how Aristotelian universe collapsed and the scientific method emerged

Glossary

Renaissance - rebirth
Exposure - contact
Paraded - marched
Magnates - wealthy and influential persons
Exhausted - tired
Discerned - understood clearly
Ventilation - exposure to air
Epitomized - exemplified perfectly
Illegitimate - unlawful
Utilitarian - useful
Anatomical - related to the bodily structures
Blinkers - a vehicle's turn indicators
Persecuted - victimized or ill treated
Heretical - unorthodox

EUROPE (1450-1550)

The cultural and scientific Renaissance in Europe during the middle ages was the result of their contact with the Arabs and orient and also due to the socio-economic changes which took place in Europe. At first these was a blind faith in all. Then it had the backing of the church and gradually resulted in a true spirit of inquiry and fearless pursuit of knowledge.

Urban society was dominated by financiers, merchants and craftsmen. Their wealth was dependent upon trade, crafts and application of technology. So they had a keen interest in improving the technical process underlying manufacture and trade.

The Europeans tried to translate various Greek philosophical and literary works. When they were exhausted with ancient philosophy and literature, they turned to

Mathematics and Science. The commercial instincts towards increasing their wealth led them to support the study of ancient science.

The inhabitants of the Italian ports became interested in navigation and the building of ships. The increased demand for silver and other metals gave a big stimulus for the development of mining in Europe. The mines raised severe problems of flooding and ventilation. These, in truth, caused the engineers to improve pumps and to study their mode of operation. As a result of these efforts we can find the emergence of the study of fluids in motion and the science of mechanics.

The most important man was Leonardo da Vinci (1452-1519) the great universal engineer, scientist and artist. Apart from being a great artist, he was also an outstanding engineer and scientist. In fact, many hail him as the first scientist to disentangle his thought from all the confused and erroneous ideas of the Middle Ages to approach the study of nature in a truly modern spirit.

His best contribution is the explanation of the dim illumination which appears over the dark part of the moon, as due to "earth shine" –sunlight reflected from the earth. He also did some experimental work in optics, mechanics and hydraulics. He made plans and designed models for flying machines, helicopters, parachutes and quick-firing and breach-loading guns. His 750 anatomical drawings put him in the front rank of the anatomists of the world.

Leonardo da Vinci's general views on scientific methods are similar to what Roger Bacon had expressed a century earlier. But Bacon's views had been restricted by the powerful influence of theology, whereas Leonardo's mind worked perfectly freely.

Unfortunately, he could not exert much influence on the development of science in Europe.

Glossary

Geocentric	- earth centred
Dissent	- disagree
Clerics	- member of the clergy
Conviction	- idea
Jugglery	- the trick of tossing objects in the air
Heliocentric	- regarding the sun as centre
Flung	- threw
Prodigy	- genius
Discrepancies	- differences
Unsurpassable	- that cannot be passed beyond
Prematurely	- too early
Impaired	- damaged
Infallibility	- unfailing

THE FALL OF THE ARISTOTELEAN UNIVERSE:

BRUNO, COPERNICUS AND GALILEO

For about two thousand years human thought was dominated by the geocentric world view, propounded by Aristotle. During Renaissance, in Europe, many free thinking philosophers and some clerics raised their dissent openly. Among them the important names are Nicolaus Copernicus, Johannes Kepler, and Galileo Galilei.

Mikolaj koppernigk [Latinized as Nicolaus Copernicus, (1473-1543)] was, by profession, a physician as well as a theologian. But he devoted much time to pursue his astronomical studies. He depended mainly on secondary data. On examining the Ptolemaic system closely, he found that many errors had accumulated, over time, in the predictions according to the original mathematical modal. Thus he analyzed alternative models, with the sun at the centre and the planets as well as the Earth revolving around it. He attempted to calculate the results of a planetary system with interrelated circular orbits around the Sun, instead of the Earth. At last he published his findings.

Strangely enough, he did not have much of an immediate impact. The main reason for this was that Copernicus was still using epicycles to describe the planetary orbits. Secondly, in spite of his new model, Copernicus could not considerably improve upon the accuracy of the Ptolemaic system. Thirdly, the objections against the heliocentric theory were still substantial, from a purely rational point of view.

Tycho Brahe (1546-1601) is a scientist who got interested in astronomy when he happened to witness an eclipse of the sun in 1560.

Johannes Kepler (1571-1630) earned his reputation as a superb mathematician and astronomer. After studying minutely all the observations made by Tycho Brahe and others, he prepared the Rudolphian Tables. Kepler used this data to make a thorough study of the motion of Mars. After many steps he found out that the paths of the planets around the Sun are ellipses. This became Kepler’s First Law.

Kepler then propounded his Second Law. The planets move so that their radius vectors sweep out equal areas in equal times. In other words, the planets travel more rapidly when they are near the Sun than when they are away from it.

Kepler was obsessed with the idea of order and regularity in the universe and was constantly looking for some clue, some pattern, among the configurations of the planets. Finally discovered his third Law - the ratio between the square of the time required by a planet to make a complete revolution around the Sun, and the cube of its average distance from the Sun, is a constant for all the planets.

GIORDANO BRUNO – THE MARTYR

Giordano Bruno (1547-1600) was a man who contributed more to the development of science by his death, than he probably would have ever achieved by living a long life. A young man of independent mind, and aggressive, intolerant and turbulent spirit, he was a cause of considerable concern to his monastic superiors.

If Copernicus had displaced the Earth from the centre of the universe, Bruno displaced the sun also from such an exalted position. He said there was no centre, for the universe is infinite. These doctrines of Bruno struck at the very vitals of the Orthodox beliefs - the idea of infinite worlds, the identity of the Creator and his creation, the insignificance of man and the Earth - all this was anathema to the Church.

GALILEO-THE FATHER OF MODERN SCIENCE

Galileo Galelei (1564-1642), at first a mathematician, was also interested in geometry, mechanics and astronomy. He made significant discoveries in kinematics of motion, astronomy and strength of materials. He is widely regarded as the father o modern science.

Galileo did not invent the telescope, but was the first to use it to view the heavens, and what he saw was enough to shatter the whole of the Aristotelian picture of that serene element. He saw that the moon was not a perfect sphere but was covered with seas and mountains. He saw that Venus showed phases like the Moon, while Saturn seemed to be divided into three. Most important of all, he found that Jupiter had four Moons orbiting around it. In March 1610, Galileo published his tale of the satellites and of his other discoveries in a small pamphlet called"Siderius Nuncius" (meaning Messenger from the Stars), which shook the intellectual world.

The telescope also revealed that the solar system itself contained more bodies than were known to the ancients, that the stars were far more distant than the planets. Other planets were also inert and non-luminous like the Moon or Earth, and shone only by reflected sunlight.

Galileo wrote a book called *Dialogue Concerning the Two Chief Systems of the World* in 1632.

Glossary

Dissections	- cutting animals and plants to examine
Stagnation	- state of existing in the same position
Arteries	- blood vessels carrying oxygen from the heart
Capillaries	- small blood vessels
Curative	- that can be cured

MEDICAL SCIENCES

During the Middle Ages theory and practice did not go together in medicine. The medical students would not do dissection. Thus there was a stagnation and deterioration in medical science. But during the sixteenth century, the barrier between the theory and practice began to break down and there came the end of the period of stagnation.

Andrea Vesalius, Professor of Medicine, published his major, work, *Concerning the Fabric of the Human Body* in 1543. Michael Servetus suggested that the blood circulated from the right to the left chamber of the heart through the lungs, where the contact with life-giving air purified it. Renaldus Columbus, Professor of Anatomy repeated the same theory. William Harvey published his masterpiece *An Anatomical Exercise on the Motion of the Heart and Blood in Animals* in 1628. This book not only explained blood circulation, but also gave details of the various aspects of the circulatory system.

MEDICAL CHEMISTRY

Paracelsus was the first true chemist who was mainly interested in the curative uses of chemistry. He tried the effects of various chemicals, some of them poisonous, on the bodies of unsuspecting patients. He was the first person to name strong spirits of wine as 'alcohol'. He prepared ether and discovered its anaesthetic properties. Chicken, he found, could be put to sleep with it and awakened uninjured after a moderately long time. The doctrines of Paracelsus were further developed by John Baptist Van Helmont.

Glossary

Tedious - making tired
Arc - a curve
Transcendental - not based on experience
Penetration - diffusion
Bibliography - list of books referred to
Catalogue - ordered list of items

ADVANCEMENT IN INDIA

While Europe was at its peak, ie, going through renaissance in science, India was almost in a dormant state. The only exception was an active tradition in Mathematics and Astronomy, which flourished in a remote corner, in South-West India, in what is now called Central Kerala. It is a fact that most number of translations and commentaries of 'Aryabhatiyam' have been recovered from Kerala. When the glory of Indian Mathematics started waning from most parts of India, an active and creative school of Mathematics and Astronomy flourished in some parts of Kerala, for about four hundred years. Madhava, who must have lived in the period 1340-1425 and Parameswara, who made some corrections in the traditional method of calculating the planetary positions were great thinkers of this period. The next great name is Nilakantha Somayaji who, we know, was the disciple of Damodara, the son of Parameswara.

Madhava's discoveries include the Taylor series for the sine, cosine, tangent, and arc-tangent functions. He correctly computed the value of ∏ to 13 decimal places.

The Kerala School usually expressed their results in concise form, without giving proof. The students have to learn that from the mouth of the teacher, or to work out themselves. The notable exception is *Yuktibhasha*, which gives the derivations and proofs also, just like in modern texts.

One interesting feature of the Kerala school of Mathematics is their use of a system for expressing numbers using the letters of the Alphabet, which was different from the one advocated by Aryabhata. The letters. Ka, ta, pa, and ya stood for I, and the succeeding letters stood for 2, 3 etc.., in the alphabetical order. Hence this system was known as ka-ta-pa-ya-adi, and was very powerful in expressing very large numbers in a convenient form.

THE SPREAD OF INDIAN SCIENCE

Indian sciences very probably had links with Greek science in the latter's early stages. Various points of Babylonian astronomy link to that of Vedic Indians. In Astronomy the calendar durations decided upon by Heraclitus and others correspond to the Indian values. The deep penetration of Indian religion into the neighbouring countries of Tibet, China, Japan, Indochina and Indonesia brought with it considerable scientific exchange also. In later centuries, Indian Medicine, Astronomy and Mathematics were carried by the Arab traders and scholars, and were transmitted to the west.

Ali al-Tabari, who lived at Baghdad wrote his great medical work *Firdaus al-Hikma* and he quoted from Caraka, Susruta and Vagbhata. The great Al-khwarismi introduced the Indian numerical system to the west. Al-Biruni wrote an admirable work called *Tarikh al-Hind* which consists of a profound examination of all the sciences of India.

Glossary

Waning - fading

Reliance - dependence

Craft lore - wisdom

Empirical - experimental

MODERN SCIENTIFIC OUTLOOK

By the first half of the 17th century, there developed a new reliance on experience and especially on planned experimentation, as a way to acquire knowledge.

GILBERT, BACON, AND THE EXPERIMENTAL METHOD

1600 was the year in which William of Gilbert of Colchester (1544-1603) published his book *Concerning the Magnet*. Gilbert took over and extended the experimental work of the sixteenth century compass maker Robert Norman and also the thirteenth century writer Pierre de Maricourt. Norman floated a magnet on water, supported by cork, and found that the magnet only turned to the North – South direction, but did not move either to the North or the South. From this, he concluded that magnetism was only an orienting force and not a motive force. Gilbert, repeated these studies and concluded that the earth was a giant magnet and gravity was a form of magnetism.

Francis Bacon (1561-1626), Lord Chancellor of England, through his work the *Great Instauration of Learning*, contributed much to science. Bacon tried out various hypotheses as to the nature of heat, and reached the conclusion that the essence of heat was motion. It was the 'motion of the smaller particles of bodies' taking place beneath the surface of the phenomena that produced the sensible effect of heat. Bacon held that behind the visible world of nature, there were structures and processes that were hidden from us by the nature of our sense organs which he called the 'Latent configurations' and the 'Latent processes' of nature.

Bacon's view of scientific method was essentially experimental, qualitative, and inductive.

Glossary

Immortal - everlasting

DESCARTES (1596 – 1650)

Descartes is probably best remembered for his immortal saying, 'Cogito ergo sum' - 'I think, therefore, I am'. He was a great philosopher as well as a mathematician. Descartes prepared a thesis, *Le Monde*, which contained a complete theory of the origins and working of the solar system. It followed the Copernican hypothesis that the earth moves annually about the sun.

Descartes thought that Bacon had started his inquiries from the wrong end. He had started with the empirical facts of the natural world, rather than the general principles, which provided a basis for deductive inquiry. So Descartes did not give undue importance to experiments. He relied more on his intuition.

CONCLUSION

The emergence of physical sciences is the result of the collapse of the Aristotelian universe and the emergence of the scientific method. Even though, Descartes underlined the importance of the mathematical method, it had to be strengthened. This challenge was taken up by Issac Newton. Newton created his own mathematics. This led to a grand synthesis, which influenced the growth of physical sciences for the next two centuries.

Short Answer Questions

1. Why is Leonardo da Vinci depicted as personifying Renaissance in Europe?

   Ans: Renaissance means a kind of re-birth of new ideas and thoughts in every field. Leonardo da Vinci personified Renaissance in Europe. He made experiments of a practical kind in optics, mechanics and hydraulics. He made plans and designed models for flying machines, helicopters, parachutes and quick-firing and breach-loading guns.

2. Galileo is often referred to as the 'Father of Modern Science'. Critically examine this statement.

   Ans: Galileo made significant discoveries in kinematics of motion, astronomy, and strength of materials. Thus he is widely and quite correctly regarded as the father of modern science.

3. How does the methodology of modern science differ from that of the ancient?

   Ans: Theory and practice go together in modern times. But in ancient times it was entirely different. Medical students would not do any dissections and the barber-surgeons would not know anything about the theoretical treatises written in scholarly Latin.

4. Discuss the role played by Bacon and Descartes in modernizing science.

   Ans: Francis Bacon contributed much to science. Bacon tried out various hypotheses as to the nature of heat and reached the conclusion that the essence of heat was motion. His unfinished work *Great Instauration of Learning* contained a large amount of facts relating to a particular topic. It was the 'motion of the smaller particles of bodies' taking place beneath the surface of the phenomena that produced the sensible effect of heat.

   Descartes is remembered mostly for his saying 'cogito ergo sum', I think, therefore, I am'. He was a mathematician and a philosopher. His thesis *Le Monde* contained a complete theory of the origins and working of the solar system. Through his mathematical method he deduced all the salient features of the natural world.

Essay Question

1. Describe the process by which the Aristotelian world view was overturned.

   Aristotle's theory of geocentric world view was supported by the church. During the time of renaissance in Europe, many thinkers, scientists and philosophers expressed their dissent freely. They tried to contradict the old concept. Nicalaus Copernicus, Johannes Kepler and Galileo Galelei were the most prominent among them.

Copernicus studied the classics, Mathematics, Astronomy, Medicine, Law, Economics and Theology. His teacher in Astronomy, Domenico Novara was the one who questioned the Ptolemaic ideas of the universe. Domenico Novara, Bishop Oresme and Cardinal Nicolas shared the same view, namely, that the sun is at the centre and the earth and other planets revolved round it. Copernicus tried to calculate the results of a planetary system with interrelated circular orbits around the sun, instead of the earth. The book of Copernicus did not have much of an immediate impact in Europe. The church did not ban the book because it did not threaten their power. The elegance and beauty of his central concept was lost among the maze of mathematical jugglery.

The Danish astronomer Tycho Brahe observed the skies and soon realized that there were serious discrepancies, between the observed positions of planets and those calculated from the tables of Ptolemy and Copernicus. Kepler, a German astronomer, identified elliptic paths of the planets moving around the sun. This was Kepler's first law. The second law was that the planets travel more rapidly when they are near the sun. The third law says that the ratio between the square of the time required by a planet to make a complete revolution around the sun, and the cube of its average distance from the sun, is a constant for all planets.

Bruno said that the sun does not occupy the centre of the universe. According to him, the universe has no centre, but it is infinite. Galileo observed the skies through a telescope and what he saw was enough to shatter the whole Aristotelian picture. He said that there were countless more stars in the heavens than Aristotle had dreamed of; that even the solar system itself contained more bodies than were known to the ancients. He published his ideas in his book *Dialogue Concerning the Two Chief* Systems *of the World.* Thus the Aristotelian world view was overturned.

Some Extra Questions

Short Essays

1. Trace the growth of modern science in Europe
2. Describe the development of Medical science during the Renaissance period.

Essay

1. Trace the development of chemistry from 'Alchemy' to 'Modern Chemistry'

MODULE III
MODERN SCIENCE

UNIT -8
NEWTON AND AFTER

OBJECTIVES

At the end of this unit, you should be able to:

i) understand why 17th century in Europe was considered to be a century of Europe.
ii) know and appreciate the contributions made by Newton and his great contemporaries.
iii) Know the impact of Industrial Revolution on science.

SUMMARY

8.1 A Century of Genius

In the domain of science, the 17th century in Europe was a period of genius. Several factors contributed to the development and growth of science. The complacency that everything that needed to be known, had been told by ancient scholars like Aristotle, had evaporated. The physical sciences, especially, was proving to be an exciting field. Experiment and observation replaced faith in authority. The invention of the telescope and the microscope amplified the human capability for observation. The discovery of logarithms greatly reduced the drudgery of calculations. The spirit of Renaissance had freed men's thoughts from their traditional shackles, giving them a wider vision. A new development was the conquest of America, and the resulting commercial prosperity of the seafaring nations facing the Atlantic. Another important development was the founding of scientific academies in all European countries. The *Academia Secretorum Naturae* was founded in Naples. *Accademia Dei Lincei* existed in Rome from 1603 to 1630. *Accademia del Cemento* functioned in Florence from 1657 to 1667. In England, largely due to the influence of Francis Bacon, Charles II founded the 'Royal Society for the Improvement of Natural Knowledge' in 1662.The *Academie des Sciences* was founded by Louis XIV, in Paris, in 1666. The Elector Frederick of Prussia founded the Berlin Academy in 1700. All these societies widely contributed to the development of the style of presentation of scientific materials, and thus, the form of scientific communication became standardized.

Glossary

Epithet	:	an adjectival expression
Domain	:	field of influence
Complacency	:	self satisfaction
Amplify	:	enlarge
Drudgery	:	boring or unpleasant task
Shackle	:	manacle; fetter
Inquisition	:	official investigation
Constraint	:	limitation imposed on

8.2 The Newtonian Synthesis

Copernican hypothesis faced two enormous difficulties: (i) What power was at work to keep this heavy and sluggish Earth, as well as the heavenly bodies, in constant motion? (ii) What was the explanation of gravity? The work of Galileo, Tycho Brahe, and Kepler had helped to solve only some of the details of the problem. They were solved finally by the Grand Synthesis produced by Isaac Newton in his *Principia* in 1687. He proved that the whole physical universe is subject to the same law of gravitation and the same laws of motion, so that all physical objects or events in one part of the universe, exercise some influence upon all others, and this together, constitute one cosmic system of interconnected parts.

Isaac Newton (1642-1727) was professor of Mathematics in Trinity College, Cambridge. He resumed his interrupted researches in optics. He built his reflecting telescopes during this period and also discovered the opposite nature of sunlight. Newton's attention had been attracted to the problem of gravitation, from time to time, by conversations and correspondence with scientific friends. Then he conducted an intensive research in theoretical mechanics, which culminated in the publication of his *Principia* in 1687.

Glossary

Sluggish	:	slack; lazy; slothful
Vocation	:	occupation
Speculations	:	conjecture

8.3 The Great Contemporaries of Newton

The 17th century in Europe was blessed with many intellectual giants who were contemporaries of Newton. They were Kepler, Galileo, William Harvey, Huygens, Halley, Hooke, Boyle, Wren, Casssini, Roemer, Picard and Leibniz.

Observational Astronomy

At the command of Louis XIV, the great scientific architect **Claude Perrault** built the first state observatory of modern times in Paris. It was intended to provide facilities for men of science, whatever their country. **Jean Picard** is remembered for his measurement of the dimensions of the earth. Newton made use of these measurements in his discovery. **Christian Huygens** improved the telescope and also showed that the changes in the appearance of Saturn were due to a ring inclined at 28 degrees to the ecliptic. The micrometer, a telescopic device for measuring small angular distances, was effectively introduced by him. He also made discoveries in dynamics. His work *Horologium Oscillatorium* explains the principles of the pendulum clock and composition of forces in circular motion. **Ole Christensen Romer** was the first to show that light has a finite velocity. G.D.Cassini became famous for his work on comets and on the rotation periods of Jupiter, Mars and Venus. He also demonstrated the flattening of the earth at the poles. He measured the distances of Mars and the Sun within an error of 7%.

Physical Optics

Willebrord Snell discovered the correct law of refraction. Kepler described light as the 'sensation of a stimulation of the retina' and said that the crystalline lens of the eye forms an image of the object of vision upon the retina. He thought that the retina contained a subtle spirit, the 'spiritus visivus' which was decomposed when light fell on it through the crystalline lens. He explained short-sightedness and long-sightedness correctly. The posthumous work of Francesco Grimaldi, *Physicomathesis de lumine coloribus et iride*, contained the first description of the phenomenon of 'diffraction'- the phenomenon in which light rays behave as a wave, in the most demonstrable way. **Robert Hooke** in his book, *Micrographia* argued that ordinary white light was produced by rapid vibration of particles in the luminous body. It was Newton who explained the meaning of colours by saying that different colours meant different degrees of diffraction. He also demonstrated that the colours, which separated out when white light passed through a prism, retained their identities, when made to undergo further refractions. He was also able to explain how chromatic aberration occurs in telescopes. He also gave a simple explanation of the rainbow. **Christian Huygens** came up with a proposition that light was completely an undulatory phenomenon. He too, like Descartes, Newton and others of the period, believed in the aether theory. They imagined that the whole of space was filled with a 'very subtle and elastic medium' through which the light waves were propagated.

The Structure of Matter

Atoms were recognized as the fundamental unit of which all matter was composed. The French philosopher **Pierre Gassendi** thought that all matter was composed of atoms, which were absolutely rigid and indestructible. They were similar in substance, but varied in size and form, and moved about in all directions through empty space. He also identified the three states of matter- solid, liquid and gas. **Robert Boyle**, who is considered as the father of Chemistry, published his book *The Skeptical Chemist* in 1661. He corrected all the earlier theories of atom. He stated that all matter is made up of solid particles, each with its own determinate shape and these particles came to be called atoms. Boyle also said that atoms can combine with one another to form molecules.

Glossary

Refraction	:	change of direction of rays
Stimulation	:	incitement; investigation
Luminous	:	shining
Aberration	:	deviation from the natural state
Deviation	:	divergence
Undulate	:	rise and fall in waves
Revive	:	refresh; recover
Combustion	:	burning
Isolate	:	place apart or alone; segregate

8.4 Mathematics

It was in the 17th century that Applied Mathematics came into existence and pure mathematics fell back into second place. Analytical geometry had already been created by Rene Descartes and Pierre de Fermat. **Blaise Pascal** (1623-1662) helped the development of two new disciplines: projective geometry and probability. The latter strongly influenced the development of modern Economics and Social Science. Pascal also studied fluids and explained the concept of pressure and vacuum. The next great creation of the seventeenth century Mathematics was the calculus of the infinitesimals. It may be described as a method of applying mathematics to continuous changes. Kepler had used a rather primitive form of the technique as far back as 1604, but it was first clearly stated by the Italian mathematician **Bonaventura Cavalieri** in a book published in 1635. John Wallis had again used the technique in his *Arithmatica Infinitorum* (1656), to show that the area enclosed by the curve $y=x^m$ (wher *m* is an integar), is 1/(*m*+1) times the product of base and height. **Gottfreid Wilhem Leibniz** developed an infinitesimal calculus which was substantially identical with that of Newton, but was expressed in a simpler and far more convenient form. Two other great mathematicians who made great contribution to the study of calculus were the brothers **James Bernoulli** and **John Bernoulli**.

Glossary

Tackle	:	close or shut in; envelope
Prior	:	preceding; earlier

8.5 The Century After Newton

The century after Newton was an era of steady and sound progress. Outstanding mathematicians like Euler, Lagrange and Laplace and competent experimentalists like Cavendish, Young and Priestly dominated this period.

Mechanics

Newton's laws of motion were applicable only to particles and needed to be extended to rigid bodies. The rules for effecting this transformation were obtained by **Leonard Euler**. He is famous for familiar notations and important theorems. He made important contributions in differential geometry and also the calculus of variations. From Newton's laws for the motion of a particle, he added general laws for the motion of a rigid body and produced satisfactory explanations of the movements of gyroscopes, spinning tops, of the flight of a spinning cricket ball, of the procession of the Earth, and variety of similar motions. **Joseph Louis Lagrange** further transformed them to suit all systems of bodies.

Astronomy

The principal figure in the field of astronomy was Pierre Simon Laplace, who has been hailed as the French Newton. The contribution of Laplace in the field of mechanics was a continuation and the extension of the work of Newton. Laplace explained the problems connected with the tides of the oceans, the flattened shapes of the earth and other planets, and a variety of problems resulting from the gravitational pull of the planets on one another. He hypothesized that the solar system had started out as a nebulous mass of hot gas in a state of rotation. This gradually cooled, and as it cooled it shrank. As it shrank, it had to rotate even faster, to conserve the angular momentum. As it rotated faster, it would have become flatter and flatter, until it assumed a disc-like shape. Then it could flatten no further, but broke into pieces by shedding ring after ring of matter, which condensed and eventually formed the present planets. These too, starting off as masses of hot rotating gas clouds, would in turn have given rise to their own satellites. All these condensed bodies would finally have their angular momentum in the same original direction in which the original solar nebula was rotating. This Nebular hypothesis was widely accepted as a plausible scenario for a long time. But a detailed study has revealed a couple of serious mathematical flaws in it. So the Nebular hypothesis, at least as originally propounded by Laplace, is no longer in favour.

The Structure of Matter

The traditional four-element theory of matter had been modified by **Paracelsus**, to the effect that all chemical substances contained three essences or principles; Sulphur, the principle of inflammability, Mercury, the principle of fluidity, or volatility; and Salt, the principle of fixity or inertness. In 1703, **George Ernst Stahl** (1660-1734) introduced the concept of 'phlogiston'. This was supposed to be the 'motion of heat', or 'the motion of five', as well as the sulphurous principle. In general, phlogiston was the essential element of all combustible bodies, like oils, fats, wood, charcoal and other fuels. The phlogiston escaped when those bodies were burnt. **Joseph Black** (1728-1799) proved the existence of a gas, different from air, which he called 'fixed-air', because it could be fixed by combination with other substances. This was nothing but Carbon-dioxide. **Henry Cavendish** (1731-1810) is best remembered for the discovery of hydrogen. **Joseph Priestly** (1733-1804) discovered 'soda water', which was, of course, carbon-dioxide dissolved in water, under pressure. His most important contribution was the discovery of Oxygen. He was also responsible for the discovery that water is not an element but a compound of Hydrogen and Oxygen. **Antoine Laurent Lavoisier** (1743-1794) introduced the idea of mass as something permanent and indestructible. **Benjamin Thompson** (1753-1814) disproved the hypothesis which explained heat as the flow of an invisible fluid called caloric. He argued that heat was 'a kind of motion'. He tried to test his conjecture experimentally. Since ice needs a lot of heat to be melted into water, he argued that the gain of caloric should produce an increase in mass. So it was argued that caloric was a weightless fluid. Later, it was **James Prescott Joule** (1818-1889) who gave the concept of heat as a form of energy.

Glossary

Era	:	system of chronology starting from some particular point of time
Breakthrough	:	important development or achievement

Dominate	:	have commanding influence over
Prodigious	:	enormous; huge
Unabate	:	continue without any reduction in intensity or amount
Deduce	:	deduct; infer
Precession	:	act of going before or moving forward
Hailed	:	called
Allegiance	:	loyalty
Shrank	:	contracted; shrivelled
Condense	:	make denser
Plausible	:	apparently right
Flaws	:	defects
Rapidly	:	quickly
Eject	:	cast out; expel
Propound	:	offer for consideration; propose
Inflammable	:	easily kindled
Erroneous	:	incorrect; wrong
Concrete	:	after one thing to another

8.6 Industrial Revolution and its Impact on Science

Industrial Revolution made a radical change in the method of production from cottage-based to factory-based. One practical impact that the Industrial Revolution had on scientific work, was the realization that the products of scientific research could aid the production of wealth. The mine owners found that knowledge of chemistry was critical in evaluating mineral ores for their quality and potential for commercial exploitation. The efforts to improve the efficiency of the steam engine created the science of thermodynamics. The breakthroughs in optics gave rise to the entirely new industry of lens making. Thus the linkage between science, technology and industry became well established. The Industrial Revolution and the rise of capitalism gave a big boost to scientific activity. **Georges Bufffon** (1707-1788) challenged the Biblical idea that the Earth was only about six thousand years old. **Charles Lyell** (1791-1875) reiterated that only the geological forces presently at work should be used to explain the past history of the Earth. It was the study of geology that led **Charles Darwin** to the theory of evolution of species. Darwin came to the conclusion that different species had originated due to natural selection from among naturally occurring variations. **Alfred Russel Wallace** (1823-1913) confirmed Darwin's theory. Charles Darwin published his *On the Origin of Species* in 1859.

Glossary

Impact	:	strong effect; influence
Linkage	:	connection
Reiterate	:	repeat again and again

8.7 The Mechanistic Universe and Scientific Determinism

From the second half of the 17th century to the end of the 19th century, people lived in a world whose material framework had been laid by Isaac Newton. For Newton, the universe was a machine, and there was nothing evolutionary about it. But the world view advocated by Descartes or the primordial nebula of Laplace, had fashioned the universe according to the eternal laws of mechanics, until it reached the present configuration. Newton started the idea of determinism. Determinism is the proposition that everything is predetermined. Some deterministic philosophers hold that this is totally opposed to the concept of free will. They think that free will is an illusion. They are called Hard determinists or Incombatibilists. Soft determinists or Combatibilists, believe that the two ideas can be reconciled. Casual determinism argues that future events are determined by past and present events, together with the laws of nature. Laplace conjectured an entity, which is called 'Laplace's Demon'. This Demon knows every single detail about all past and present events, and also all the laws of nature. This 'dogma' is referred to as Scientific determinism. Logical determinism argues that all propositions, either about the past, present or future, are either true or false. Environmental determinism says that physical environment, rather than social conditions determines culture. Biological determinism is the theory that all behavior, belief and desire are governed by our genetic make up.

Glossary

Configuration	:	outline; shape
Primordial	:	existing from the beginning
Culminate	:	reach the highest point
Reconcile	:	reunite after estrangement
Conjectured	:	guessed

8.8 The French Revolution – The Idea of Progress

We saw that the Newtonian approach gave rise to a mechanical model of the universe. In this mechanical world, nothing had developed historically. All the creatures of the earth had existed in their present form from the very beginning. During this period, it was argued that societies and races were predetermined to certain inescapable destinies by their environment, history and geography. In such a world, neither the progress of mankind nor the evolution of the species could have any meaning. But the extension of the mechanistic viewpoint to psychology, helped to generate the idea of progress. **John Locke** (1632 - 1704), **Claude Helvetius** (1715 – 1771), **Voltaire** (1694 – 1778) and **Rousseau** (1712 – 1778) argued that the mind of a person was determined by external conditioning forces, such as education. Thus during the 18th century there was a great emphasis, in France, on the importance of education legislation and other social reforms as instruments to bring about a true egalitarian society.

Science and the French Revolution

The new regime was very much pro-science. The first track was the reform of weights and measures and the establishment of the metric system. The second was the creation of modern scientific education. This was achieved in the face of stiff opposition from the old Universities. The foundation of the Ecole Normal Superieure, the Ecole de Medicine, and the Ecole Polytechnique gave models for the institutions for science teaching and research, of the future.

Glossary

Reform	:	rebuild; remodel
Ascribed	:	attributed
Egalitarian	:	equalitarian
Enlighten	:	elevate by knowledge
Despise	:	look down upon: scorn

Multiple Choice Questions

1. The ‘Academies’ started in Europe during the 16th and 17th centuries served an important role in the development of sciences. Which among the following was their major contribution?
   A. They standardized a method of reporting scientific information, with emphasis on experimental findings.
   B. They helped to separate scientific pursuit from religious and state interferences.
   C. They helped to make available industrial funding for scientific projects.
   D. They provided an opportunity for young researchers to present their findings.

2. Who among the following was not a contemporary of Newton?
   A. Robert Hooke B. Leibniz C. Huygens D. Galileo

3. When Newton published the *Principia*, he was forced to acknowledge that one of the results obtained by him had also been independently obtained by this person. Who was this person?
   A. Kepler B. Leibniz C. Hooke D. Wren

4. The controversy between Newton and Huygens was related to ……………….
   A. whether light consisted of waves or particles
   B. the authorship of the discovery of laws of diffraction.
   C. which of them had invented calculus.
   D. mere personal rivalry.

5. Flamsteed was asked to set up an observatory in Greenwich because ……….
   A. England wanted to build the best observatory in the world.
   B. Flamsteed was the most celebrated astronomer in Europe.

C. a very accurate star chart was needed to be prepared for navigation.
D. there was a great deal of popular interest in astronomy in England at that time.

6. Instead of the traditional description of the world based on 'fundamental elements' or 'principles', the modern concept of elements was set forth in the book 'The Skeptical Chemist". It was written by …………………
   A. Joseph Black
   B. Joseph Priestly
   C. Lavoisier
   D. Robert Boyle

7. The important feature of Industrial Revolution was ……………………
   A. the switch from cottage mode of production to factory mode of production.
   B. division of labour and mechanization.
   C. the use of steam power.
   D. All of the above.
8. It has been said that the French Revolution was inspired by philosophers. Who among the following philosophers does not belong to this group?
   A. Rousseau B. Voltaire C. Helvetius D. Descartes

9. Those who believe in 'scientific determinism' argue that ……………….
   A. everything is predetermined by fate.
   B. science gives us the determination to decide our future.
   C. everything has a cause, so whatever happens now is determined by earlier events, and we have no choice in the matter.
   D. when science has progressed enough, we will be able to predict the future.

Answers

1. A 2.D 3.B 4.A 5.C 6.D 7.D 8.D 9.A

Short Answer Questions

1. Explain the significance of the term 'Newtonian Synthesis'. What is the role of the proverbial apple in it?
   Ans. Newton produced the theory of the Grand Synthesis in his *Principia* in 1687. This theory states the whole physical universe is subject to the same law of gravitation and the same laws of motion. As a result of this, all physical objects or events in one part of the universe, exercise some influence upon all others, and constitute one cosmic system of interconnected parts.

2. 'Thus by the time he was 24 years old, and before he had finished his university education, Newton had made good progress towards solving many of the most pressing scientific problems of the day.' Elucidate.
   Ans. Newton resumed his researches in optics. He built his reflecting telescopes during this period, and also discovered the composite nature of sunlight. His attention was attracted to the problem of gravitation.

3. What happened to Lavoisier?
   Ans. Lavoisier was a typical French scientist and he is another contender to the title 'Father of Modern Chemistry'. He introduced the idea of mass as something permanent and indestructible. He was guillotined in the French Revolution.

4. Explain why the French Revolution is said to have been inspired by philosophers.
   Ans. The French Revolution is said to have been inspired by philosophers. It was argued by some thinkers that the mind of a person was determined by external conditional forces, such as education, so that progress can be achieved if education were reformed. This trend was pioneered by John Locke and later by the French philosopher Claude Helvetius. Helvetius said that the inequality of minds was due to the difference of education. Voltaire and Rousseau were influenced by their thoughts. Their teachings inspired the French Revolution.

Essay-type Questions

1. Describe the socio- political climate of England at the time of Newton, and examine their interplay with the developments in science.
   Ans. The 17th century in Europe was indeed a century of genius. It is obvious that in the 17th century, several factors combined to produce an exceptionally active and fertile era for science in Europe. Experiment and observation were replacing faith in authority. The spirit of Renaissance had freed men's thoughts from their traditional shackles and gave them a wider vision. The protestant countries gave greater encouragement and support to the study of science. But in catholic countries the dreaded Inquisition prevented progressive thinking. A new development during this period was the conquest of America, and the resulting commercial prosperity of the seafaring nations facing the Atlantic.

   Another important development which helped the growth of science was the founding of scientific academies. Many of them were national in their character and even enjoyed royal patronage. The medieval universities, which were often controlled by the church, did not encourage the growth of science. As a result, there was revolt against authority and they needed some sort of meeting place where scientific investigations could proceed free from religious constraints.

   Thus a number of academies were formed. *Accademia Secretorum Naturae* was founded in Naples, in 1560. *Accademia Dei Lincei* existed in Rome from 1603 to 1630 and *Accademia del Cemento* in Florence, from 1657 to 1667. In England, largely due to the influence of Francis Bacon, Charles II founded the 'Royal Society for the Improvement of Natural Knowledge' in 1662. The *Accademie des Sciences* was founded by Louis XIV, in Paris, in 1666.The Elector Frederick of Prussia from the *Berlin Academy* in 1700. These societies were all started with the same aim of increasing natural knowledge by means of free discussion. All these societies widely contributed to the development of the style of presentation of scientific materials, and thus, the form of scientific communication became standardized.

The work of Galileo, Tycho Brahe, and Kepler helped Newton in discovering the gravitational theory. In 1687, Newton produced his Grand Synthesis in his *Principia*.

2. Explain how Newtonian Synthesis contributed to the deterministic phase in science.

The Universal Law of Gravitation, which was enunciated by Isaac Newton states that 'every particle of matter in the universe attracts every other particle, with a force inversely proportional to the square of the distance between the two particles'. This showed that not only the planets and the Sun and the satellites, but probably even the stars were governed by one comparatively simple and universal law.

The big question as to what was the force which kept such huge bodies like the Earth in motion greatly puzzled the scientists. Galileo's experiments had showed that an external force is required only to alter a body's uniform motion in a straight line. No force is required to keep it moving in a straight line. This meant that the astronomers had to explain, not why the planets fail to move in exact circles, but why they resolve around the Sun in closed curves at all, and do not travel in straight lines into outer space.

Newton found that gravitational attraction varying as the inverse square of the distance gives the law of planetary motion. Then he made a test of this law by comparing the acceleration of the Moon towards the Earth, with the acceleration of falling bodies at the surface of the Earth. It was already known that the distance between the Moon and the Earth's center is about 60 times the radius of the earth. Newton did the following things: (1) He found out the law, according to which the force of gravity fell off, with increase of distance from the Earth. (2) He calculated from this law, what acceleration will be produced by gravity, on the Moon. (3) He calculated the actual acceleration of the Moon, assuming its orbit to be a circle (4) He checked whether the accelerations calculated under(2) and (3) are reasonably equal, and so, could be regarded as arising from the operation of one and the same force.

Newton's *Principia* is often described as the greatest work in the history of science. It formed the basis of all astronomical and cosmological thought. It was a stupendous achievement to demonstrate in detail, how the same principle of gravitation and the same laws of motion, apply to the falling of an insignificant apple on Earth and to the largest celestial bodies, to phenomena of obvious regularity, and also to such seemingly irregular happenings as the tidal waves of the seas and the wayward appearance of comets. The success of Newtonian mechanics influenced psychology, economics, and sociology. Thus Newton's contributions gave rise to a 'deterministic era' in science and philosophy.

UNIT -9

THE ADVANCING FRONTIERS: MODERN MEDICINE TO NANOTECHNOLOGY

OBJECTIVES

At the end of this unit, you should be able to:

i) know about the emergence of modern medicine.
ii) get a picture of the new frontiers in biology.
iii) know about the development of nuclear physics.
iv) get a clear idea about the frontier technologies.

SUMMARY

9.1 The Emergence of Modern Medicine

The advances in Information Technology, Biotechnology, and Nanotechnology had given exciting possibilities as well as some anxieties also. We are closer than ever to finding out the basic structure of matter as well as the basic processes of life. Concepts like dark matter and dark energy challenge some of the fundamental understanding which we had developed so far.

Advances in Anatomy and Surgery

The art of healing had a continuous development in all societies. On the one hand, there were families of traditional physicians. We find that in the 18th century, the theory of medicine had not advanced significantly from where it had been at the time of the Greeks or Romans. European physicians continued to practice on the basis of the Greek theory of the four humours. Vesalius, Servetus, Harvey and others had enriched the knowledge of human anatomy. **John Hunter** (1728-1793), a Scottish Surgeon who rose to become the Surgeon General of the British Army made a beginning in modernizing the surgical practices. He made a complete study of the development of the foetus and proved that the maternal and foetal blood supplies were separate. He also made contributions in dentistry and studied inflammations. **Ignaz Semmelweis** (1818-1865), a young obstetrician in the Vienna Hospital, reduced child-mortality rate considerably. **Joseph Lister** (1827-1865) introduced aseptic practices into surgery, and thereby produced post surgical mortality dramatically. He explained wound infections in terms of bad chemicals in the air, or a 'stinking miasma'. In 1867, he tried and confirmed the use of carbolic acid as an antiseptic. The germ theory got established.

Impact of Modern Science on Healing

The first true microscope was probably made in the Netherlands, around 1595. It was **Antonie van Leeuwenhock** (1632-1723), who thought of using it for inspecting very small life forms. So, he can rightly be called the father of Microbiology. The first person to report seeing microbes under the microscope was Robert Hooke. With a crude compound microscope, he saw and sketched the cell structure of a plant and some fungi. Smallpox was one of the scourges of mankind. There was an ancient practice, prevalent in China and India, of rubbing the material from the dried scab of a mildly infected person to the skin of a healthy person, which was supposed to give him resistance to the disease. Such practices were also prevalent in England. It was **Edward Jenner** (1749-1823) who invented a remedy for smallpox by injecting cowpox. This was one of the greatest achievements of immunology and it was officially announced by the WHO in 1980.

Germ Theory and the Birth of Microbiology

Louis Pasteur (1822-1895) was one of the founders of modern immunology. **Robert Koch** (1843-1910) became famous for isolating the bacteria which cause anthrax. With the help of new techniques and meticulous studies, he managed to isolate and identify the germs causing anthrax, smallpox, cholera, and tuberculosis. He was awarded for his work on tuberculosis and is best remembered for formulating his famous postulates. These state that in order to establish that a disease is caused by a microbe, it must be: (1) found in all the cases where the disease is examined, (2) prepared and maintained in a pure culture, (3) capable of producing the original infection, even after several generations in culture, and (4) retrievable from an inoculated animal and cultured again. With the work of Pasteur and Koch, the Germ Theory of Disease became established. **Ronald Ross** (1857-1932) identified the malaria-causing parasite and became the first Nobel laureate from India. *Homeopathy* had been founded by a German physician Samuel Hahnemann, in1796. He formulated a new principle. He theorized, partly based on his own experience with cinchona bark that all effective drugs would produce symptoms in healthy people, similar to the ones that they can cure. This is the 'Law of similars' which is the basis of the system of Homeopathy. The word *homeo*, in Greek, means similar or alike. Hahnemann gave the name *allopathy* to the mainstream medicine.

The New Frontiers in Medicine

With the help of technological advancement, beginning with the X-rays, and progressing to ECG, EEG, ultrasound, NMR imaging, and of course in computer technology, new methods of investigation and diagnosis have begun to dominate medical practice. At the same time, new diseases like HIV, SAARS, etc., began to pose a serious challenge to humanity. So it became essential to develop a better understanding of the human biology.

Glossary

Discern	:	make out; distinguish
Enriched	:	enhanced
Purge	:	purify
Laxative	:	Purgative medicine
Antagonize	:	make hostile
Tribulation	:	severe affliction; distress
Miasma	:	infectious emanation

Scourge	:	something that causes a lot of trouble or suffering to a group of people.
Scab	:	crust over a sore
Maggot	:	worm
Relent	:	soften
Inoculate	:	vaccinate

9.2. Frontiers in Biology

Linnaeus and Scientific Taxonomy

It was **Carolus Linnaeus** (1707-1778) who came up with his brilliant suggestion for a scientific classification for all living beings. He published his *Systema Naturae* in 1735. This system had many evident flaws and discrepancies. **George Cuvier** (1769-1832) made some changes to make it more 'natural' and also to emphasize the relationships.

Biology after Darwin

Gregor Mendel (1822-1884) discovered the principles of heredity. In 1900, **Hugo de Vries** (1848-1935) discovered that sudden mutations might appear in plants and could get transmitted to future generations. Based on Medal's work, **William Bateson** (1861-1926) discovered that not all traits are inherited independently**.** **Walther Flemming** (1843-1905) discovered Chromosomes. **Thomas Hunt Morgan** (1866-1945) chose the fruit fly for his experiments and succeeded in perpetuating a natural mutation. **Theodosius Dobzhansky** (1900-1975) in his book Genetics and the Origin of species, showed that mutations are, quite common and are often very viable and useful.

The Architecture of life

Friedrich Miescher (1844-1895) discovered the presence of nucleic acids in the cell nuclei. Chromosomes and proteins had also been discovered. **James B. Sumner** (1887-1955) showed that the enzyme *urease* was a protein. The first protein to be sequenced was insulin. James Watson and Francis Crick discovered the structure of the DNA. In 1956, **Mahlon Hoagland** discovered the role of *transfer* RNAs. Soon the messenger RNAs were identified. The genetic codes for all the 20 amino acids were also discovered.

The Human Genome Project: The Book of Life

The international project conducted in the National Institute of Health (NIH) USA, under the leadership of James Watson proved that the complete human genome consisted of about 25,000 genes. The genetic defects owing to particular errors in gene sequence can be clearly identified. This is of great use in identifying genetic disorders and many psychological conditions.

Biotechnology

The discovery of the structure of DNA, the success in decoding it, and the ability to 'cut and paste' sections of different segments from different sources, have given birth to the new branch of science known as Genetic Engineering. Transfer of DNA segments from one organism to another has opened up unimaginable possibilities. **Paul Berg**, a biochemist from Stranford University was one of the first to develop the recombinant DNA technology. He joined the DNA strand from the monkey virus SV40 to the DNA strand of another antibacterial agent known as bacteriophage lambda. Then he wanted to insert this modified genetic material into the laboratory strain of the *E.Coli bacterium*, which is found in the human intestine, in abundance. The SV40 was a known carcinogen (and so many scientists discouraged this experiment.) and so the recombinant DNA experiments had come to a standstill in the face of the confusion and forebodings regarding the consequences. The potential of genetic engineering, through which the genes from one organism are transplanted into another, with a view to combine the beneficial characteristics of both, is already manifest in agriculture. This has already been done in Bt cotton, and Bt brinjal.

Support to Evolution from Genetics

The advances in genetics strongly supported the Darwinian theory of evolution. The evidences supporting the Darwinian theory of evolution came from palaeontology and observations of the living world. The very fact that the entire living kingdom share the same DNA-based life architecture, underlines the unity of life. **Niles Eldredge** and **Stephen J. Gould** suggested a model called *Punctuated Equilibrium*, which says that the speed with which changes occur in the organism vary from very slow to comparatively fast, during geological periods.

The Secret of Life

While we have a fairly good idea about how life evolved on the planet, we have much less knowledge about how life began. **Stanley Lloyd Miller** and **H. C. Urey** went a long way with their researches and found out that the building blocks of life could have evolved, given the atmospheric and environmental conditions prevailing on the earth during the primordial period and with sufficient passage of time. Amino acid and nucleotides could have formed in countless numbers and again, given sufficient length of time, they could have developed into nucleic acids capable of replicating themselves. **Cyril Ponnamperuma**, an exobiologist, reported that he had identified traces of five amino acids in a meteorite that landed in Australia. These are the first signs of extraterrestrial constituents of life ever found.

Glossary

Resort	:	turn for aid
Discrepancy	:	inconsistency between facts
Transmitted	:	passed on; conveyed
Mutation	:	a change in genetic structure

Stumble	:	take a false step
Stunned	:	bewildered
Perpetuate	:	cause to last for ever
Viable	:	capable of sustaining independent life
Unravel	:	unknit; disentangle
Unerring	:	making no error

9.3 A Paradigm Shift in Physical Sciences

The Breakdown of Classical Physics

The Michelson-Morley experiment revealed that something was fundamentally wrong with the classical structure of physics. This experiment was designed to measure the speed at which Earth moved through it. It failed to observe any 'ether drag'. Then **Hendrik Antoon Lorentz** (1853-1928) and **George Franics Fitzgerald** (1851-1901) proposed an ingenious explanation that the motion of an object caused it to shrink in the direction of its motion, but not in a perpendicular direction. Such shrinkage could never be detected by direct measurement, since every measuring instrument would shrink as much as the object it was measuring. **Albert Einstein** (1879-1955) explained the Michelson-Morley paradox by the hypothesis that 'it is impossible to determine the speed of motion of an object through space by any experiment whatever'. His *Special Theory of Relativity* says that all the phenomenon of nature must be the same for a person moving with one constant speed as for a person moving with another constant speed. The other aspect of this theory was the relation between the mass and velocity of a body. The famous equation of mass energy equivalence ($E=mc^2$) followed mathematically from this theory. Einstein was able to predict that the apparent position of the stars near the sun will shift, due to the bending of their rays as they travel through the curved space near the sun. In 1919, Sir Arthur Eddington verified the phenomenon of bending of starlight due to the presence of the sun, during a solar eclipse. The theory of relativity showed that just as there was no absolute concept of mass or velocity, there was no absolute measure of energy or force.

Electron and the Atom

Sir William Crooks (1832-1919) observed a luminous glow stretching from the negative end, the cathode, of a highly evacuated discharge tube. **Johnstone Story** (1826-1911) called the cathode rays *electrons* in 1894. **Jean Perrin** (1870-1942) showed that they carried a negative charge and **J.J. Thomson** (1856-1940) measured their speed. **Konrad Von Rontgen** (1845-1923) observed something outside the cathode-ray discharge tube that made fluorescent screens shine in the dark and that could fog photographic plates through black paper-rays that could pass through opaque bodies. And he called it the 'X-ray'. In 1896, Professor **Henri Becquerel** (1852-1909) found that a certain compound of Uranium emitted a stream of radiation, which resembled X-radiation in its deep penetration of matter, in affecting photographic plates, in exciting phosphorescence, and in turning gases through which it passed into conductors of electricity. **Pierre Curie** (1859-1906) and his Polish Wife **Marie** (1867-1934) had found sources much stronger than the original Uranium. They isolated elements of a new kind such as Polonium and Radium, the latter so powerful that it shone by itself in the dark and could inflict serious and ultimately fatal injuries on people who went near it.

Rutherford and Radioactive Transformations

Ernest Rutherford (1871-1937) showed that there were two distinct kinds of radiations called 'alpha rays' and 'beta-rays' in 1899. In 1990, **Paul Villard** found that Radium emitted a still more penetrating kind of radiation, which he called the *gamma-radiation.* Later, it was found that elements were not always alike or homogeneous, that each element could contain a number of atoms, alike chemically but breaking up physically in different ways. These were called the *isotopes.*

Planck and the Early Quantum Theory

Max Planck (1858-1947) suggested that the energy of atoms could not be given off continuously, but in chunks. There was thus a constant quantum (the product of energy and time) the *Planck's constant* ($h=6.6x10^{-27}$ erg seconds), that controlled the quantity of all energy exchanges of atomic systems. Einstein applied this new concept to explain that light consisted of 'packets' of energy or photons, of frequency v, the energy the photon being given by $E=h.v$, where h was Planck's constant. In a sense, he supported the old idea of Newton that light consisted of particles.

The Rutherford – Bohr Atom

Rutherford and his co-workers **Geiger** and **Marsden** passed a fusillade of alpha particles through a layer of gas. Most of the projectiles passed right through, showing that the atoms were full of empty spaces. But a few of the particles were deflected from their courses through very large angles. This meant that they were hitting something very hard. Thus, the idea of the atomic nucleus, the counterpart of the electron, was born. One of Rutherford's colleagues, **Niels Bohr** (1885-1962) succeeded in combining the four separate strands - the hard nucleus of the scattering experiment, the simple laws discovered by Balmer regarding the frequencies in the hydrogen spectrum, the regularity of the wavelengths of the X-rays from different elements, and Planck's theory of the quanta - which would serve to link them together. And he showed that the atom was miniature solar system, in which each electron had its own particular orbit, and the light or X-rays were produced only when an electron moved from one orbit of high energy to another of low energy.

Glossary

Ingenious	:	skilful in invention
Contrive	:	devise
Imponderable	:	very light
Corroborate	:	confirm by evidence
Edifice	:	large building; structure

Luminous	:	shining
Evacuate	:	withdraw; clear out people
Opaque	:	observe; not trasparent
Emit	:	send out; give out
Chunk	:	thick piece of anything

9.4 The New Quantum Theory

Bohr's quantum theory of the atom failed to explain the energy levels of the slightly more complicated, diatomic molecules.

Wave Mechanics

The *Raman Effect* discovered by **Chandrasekhara Venkata Raman** gave further proof of the quantum nature of light. For this, Raman got the Nobel Prize. **Louis-Victor-Pierre-Raymond** conjectured that electrons might be waves, just as light waves might be particles. Erwin **Rudolf Josef Alexander Schrodinger** (1887-1961) applied these ideas to the motion of the electron inside the atom. This theory permitted the electron to move only in certain orbits in the atom, and Schrodinger showed that the permitted orbits were those which just contained integral number of complete waves, so that the wave pattern joined up neatly to complete the cycle. In this way he gave a mathematical specification and a physical picture to explain the quantum theory. **Werner Heisenberg** (1901-1971), by the use of matrices and **P.A.M. Dirac** (1902-1984), by a new algebra, provided equally good formal solutions to the problems of physics.

The Uncertainly Principle

The instruments we use in research themselves share the atomicity, (i.e., discontinuity) of the universe, so that we can never make perfect predictions. The smallest mass we can command is that of the electron, the smallest energy we can liberate is that of a complete quantum. Heisenberg showed that it is impossible to fix both the position and the speed of an electron beyond a certain degree of precision.

Glossary

Scion	:	a young member of a family
Postulate	:	necessary assumption

9.5 Development of Nuclear Physics

The Mechanical Models

Ernest Rutherford and his brilliant team concentrated on studying the interiors of the atomic nucleus. In 1919, they discovered that the nitrogen nucleus can be broken up by a direct hit from an alpha particle. Then it became clear that the nuclear processes could be controlled if suitable projectiles, with which they can be bombarded, could be found.

Nuclear Fission

James Chadwick (1891-1974) discovered neutron. Soon afterwards, **Carl D. Anderson** (1905-1991) discovered another fundamental particle, the positive electron or positron, whose existence had been theoretically predicted by Paul Dirac in 1928. This supplied a needed symmetry between positive and negative in the relations of particles. **Irene** and **Frederic Joliot-Curie** discovered that nearly all atoms bombarded with neutrons became themselves radioactive. **Enrico Fermi** (1901-1954) bombarded very heavy elements with neutrons and claimed that he had produced a number of elements heavier than any that were found in nature. **Otto Hahn** (1879-1968) and his colleagues, **Fritz Strassman** (1902-1980) and **Lise Meitner** discovered that some of the products produced by bombarding Uranium with neutrons were of an altogether lower atomic mass, almost half that of the Uranium atom. This led them to the discovery that atoms could be split.

Glossary

Rugged	:	rough; hard
Crucial	:	decisive; critical
Ejection	:	expulsion

9.6 IT, BT, and NT-The Frontier Technologies

Information Technology

Information Technology is as old as human civilization itself. There are four different stages in its development: (1) Pre-mechanical (2) Mechanical (3) Electromechanical, and (4) Electronic. The first stage was characterized by writing, the use of paper and pen, establishment of the great libraries, the invention of the number system, and the use of rudimentary calculating devices like the abacus. The mechanical age started with the introduction of movable type printing by Johann Guttenberg. The slide rule was invented by William Oughtred. The calculating machine, Difference Engine, Analytical Engine and the programmable computing machine were the other inventions of this period. The Electromechanical era was characterized by the Telegraph, Telephone (**Alexander Graham Bell**, 1876), and the Radio (**Marconi**, 1894). The first 'Electrical Tabulating System' was patented by **Hermann Hollerith** in 1889. The first High Speed, General-Purpose Electronic Computer using vacuum tubes was ENIAC (Electronic Numerical Integrator and Calculator) which was developed by **Mauchly** and **Eckert** in 1946. The first binary, stored programme computer was EDVAC (Electronic Discrete Variable Automatic Computer). This was soon followed by UNIVAC (Universal Automatic Computer), which became the world's first commercial computer. The release of Apple II in 1977, by **Stephen Wozniak** and **Steven Jobs** was really a significant achievement.

Nanotechnology

The term nanotechnology was first coined by **Norio Taniguchi**. He defined nanotechnology as 'consisting of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule'. Two events have helped in the development of Nanotechnology - (1) Development of cluster science, and (2) invention of Scanning Tunneling Microscope (STM) followed by the Atomic Force Microscope. The nanoscale is of the order of 10^{-9}m. The epithet *nano* is applied to all operations at the scale of less than 100nm. Apart from size, the big difference with nanomaterials is that when the substances are reduced to the molecular sizes, their physical, chemical and electrical properties change drastically. Many materials which are normally inert begin to exhibit new catalytic properties at the nanoscale. These phenomenal changes in properties of materials open up exciting possibilities in nano technology.

Cosmic Rays and Fundamental Particles

The study of cosmic radiation (radiation reaching the earth from outer space) has provided a powerful means for understanding the structure of matter. **Homi J. Bhabha** (1909-1966) was one among the pioneers of this study. In addition to the electron, proton and the neutron, more elementary particles or nucleons were identified. There are several intermediate elementary particles called *mesons*. These fundamental particles are always accompanied by corresponding antiparticles and when they meet, they both disappear by mutual annihilation and their energy is transformed into a pair of photons. The smallest and strangest of the fundamental particles are the massless, chargeless, weakly interacting *neutrions* which were first predicted by **Wolfgang Pauli.** **Cockroft** and **Walton** built a high-tension tube through which protons could be accelerated with about one or two million volts, and demonstrated that such particles could break up the nuclei of a number of light atoms. A new principle, introduced by **Ernest Lawrence**, in the cyclotron, of building up the velocity of the particle in successive impulses, opened the way to ever more powerful betatrons, synchrotrons, and synchro-cyclotrons giving the equivalent of tens of billions of volts. In 1936, **Carl Anderson** found a new particle called *μ-meson* or *muon*. Later new particles like *pi-meson,* K-mesons and hyperons were also detected. **Murray Gell-Mann** came to the conclusion that these were indeed the same particles characterized by a new property, which he called 'multiplicity'. The force that holds the nucleus together is termed *strong interaction.* The force that causes radioactivity is rather weak and is called the *weak interaction.* These two forces, together with the electromagnetic force and gravity, constitute the four fundamental forces of nature.

From the Very small to the Very Large

The 200 inch Hale telescope was erected in Mount Palomer, California, in 1949. Then came the 400 inch Keck telescope in Mauna Key, Hawaii, built in 1991. These revealed millions of galaxies beyond our Milky Way. The sound waves seem compressed when they approach, and stretched when they recede. The same kind of distortion happened to the light waves also. This is called the Doppler Effect. Using this phenomenon, **Edwin**

Hubble (1889-1953) calculated that the far away galaxies were flying apart, the farther the faster. This is called the Hubble's law. Radio telescopes and the satelite-mounted telescopes reveal that the kind of matter we see around us accounts for only 4% of the total matter in the Universe. Of the remaining 96%, about 22% consists of "dark matter" and the balance 74% is yet to be accounted for.

Glossary

Consolidate	:	make firm: unite
Manipulate	:	manage craftly
Annihilation	:	complete destruction
Deflection	:	deviation
Compress	:	press together; make smaller in size

Multiple choice Questions

1. John Hunter, Ignas Semmelweis and Joseph Lister had much in common:
   A. All of them were reputed surgeons.
   B. All of them tried to introduce the principles of 'asepsis' into surgical practices.
   C. All of them faced stiff opposition from their colleagues.
   D. And one of them was so persecuted that he died in a mental hospital.

2. Who was this 'martyr'?
   A. Hunter B. Semmelweis C. Lister D. None of them

3. The credit for discovering the microscope is usually shared by the Hansens, Leeuwenhoek, and Robert Hooke. But only one of them managed to see any micro-organisms through his magnifying glass, and to produce reasonable sketches. Thus was done by................................
   A. Robert Hooke B. Hans Jansen
   C. Sakharias Jansen D. Leeuwenhoek

4. Louis Pasteur, Edward Jenner, Robert Koch and Ronald Ross were associated with the establishment of the Germ Theory. Which one of them was born in India?
   A. Pasteur B. Jenner C. Koch D. Ross

5. The number of genes in the human body is..........................
   A. between 20 and 25000 B. about 1 million
   C. Close to 5 million D. above 1 billion

6. Among the fundamental particles, the first to be discovered was.............
   A. Proton B. Electron C. Neutron D. Positron

7. In the light of modern developments in physics, state whether the following well known laws are true or false.
   A. The law of conservation of mass
   B. The law of conservation of energy
   C. The law of immutability of elements
   D. The law of conservation of momentum

8. Which of the following 'strange' facts are 'scientifically' proven?
   A. The universe is expanding, the farthest galaxies are moving away at the fastest race.
   B. Of the total matter in the Universe, only 4% is accounted for.
   C. There is a black hole at the centre of our galaxy.
   D. All the above.

9. The terms Nanotechnology' refers to................
   A. extreme miniaturization
   B. operations involving particles of one nanometer or less
   C. operations in the scale 100 nano meter or less
   D. anything which is done at molecular level.

Answers

1.D 2.B 3.D 4.D 5.A 6.A 7.A & B are true and C & D are false 8. B 9.D

Short Answer Questions

1. Explain how the developments in science contributed to the evolution of 'modern medicine'. How is it that one particular branch of medicine is known by this epithet?
   Ans. The birth of Microbiology contributed to the development of medicine. Robert Hooke saw microbes through the microscope. The germs causing anthrax, smallpox, cholera, and tuberculosis were identified with the help of new techniques. Samuel Hahnemann founded Homeopathy. He gave the name allopathy to the mainstream medicine, but its practitioners call it 'modern medicine'.

2. Trace how the 'germ theory' came to be generally accepted?
   Ans. Edward Jenner, a country practitioner conducted an experiment by injecting the puss from cowpox into a healthy boy. After eight weeks, he injected the actual puss of small pox into the boy. The boy showed no serious reaction. That was the first step in the invention of immunology. Later Louis Pasteur and Robert Koch conducted some experiments and with their work, the Germ Theory of Disease became established.

3. Why is the contribution of Linnaeus considered to be seminal in the modernization of biology?

   Ans. Linnaeus had an abiding interest in plants. He spent his time on his favorite pursuit and produced a paper on plant stamens and pistils. After many years of observations, he came up with his brilliant suggestion for a scientific classification for all living beings.

4. What are the corroborative evidences for Darwin's Theory of Evolution, which modern science has added?

   Ans. Gregor Mendel through his systematic experiments derived the revolutionary principles of heredity. Then Hugo de Vries discovered that sudden mutations might appear in plants and could get transmitted to future generations. This cleared some of the ideas of the Darwinian Theory. William Bateson discovered that not all traits are inherited independently. Walther Flemming discovered chromosomes. Thomas Hunt Morgan succeeded in perpetuating a natural mutation. Theodosius Dobzhansky showed that mutations are quite common and are often very viable and useful.

5. Explain Einstein's *Special Theory of Relativity.*

   Ans. According to Einstein's *Special Theory of Relativity*, all the phenomena of nature must be the same for a person moving with one constant speed as for a person moving with another constant speed.

Short Essay Questions

1. Promise and Perils of nanotechnology

   Ans. The term nanotechnology was first coined by Norio Taniguchi in 1974. He defined nanotechnology as 'consisting of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule'. Eric Dexler popularised this new field through his famous books *Engines of Creation: The coming Era of Nanotechnology* and *Nanosystems: Molecular Machinery, Manufacturing, and Computation.* The nanoscale is of the order of 10^{-9}m. The epithet *nano* is applied to all operations at the scale of less than 100nm.

   All the materials we need are composed of atoms and molecules. Nanotechnology can work at the intricate level, atom by atom, molecule by molecule. When the substances are reduced to the molecular sizes, their properties change drastically. Gold, for example, becomes a liquid at room temperature, Aluminium becomes combustible and Copper becomes transparent. Many materials which are normally inert begin to exhibit new catalytic properties at the nanoscale. These phenomenal changes in properties of materials open up exciting possibilities.

Nanotechnology has side-effects and misuse. Scientists are concerned about the health effects of nanoparticles. It is said that carbon nanotubes could be as dangerous as asbestos, if inhaled in sufficient quantities.

2. Genetically modified food: boon or bane?

Ans. The potential of genetic engineering, through which the genes from one organism are transplanted into another, with a view to combine the beneficial characteristics of both, is already been done in Bt cotton, and Bt brinjal. Bt rice is said to be ready, and has been called the *golden rice.* It is supposed to supplement the natural nutrients of rice with extra vitamins, so that vitamin deficiency can be corrected. This has been pointed out as a clear example of misplaced science. Vitamin deficiencies occur among poor children due to insufficient intake of food and vegetables. Vegetables serve other food functions also, besides providing vitamins. What these children need is adequate intake of balanced diet, and not golden rice, enriched with vitamins. This is what happens when research agenda is set by profit-oriented corporations.

3. The search for the fundamental building block of matter.

Ans. The study of cosmic radiation has provided a powerful means for understanding the structure of matter. In addition to the electron, proton and the neutron, more elementary particles or nucleons were indentified. Besides, there are several intermediate elementary particles also, called *mesons.* Some of them are extremely short-lived. These fundamental particles are always accompanied by corresponding antiparticles.

The smallest and strangest of the fundamental particles are the massless, chargeless, weakly interacting *neutrions* which were first predicted by Wolfgang Pauli. Scientists like Cockroft, Walton and Ernest Lawrence built very powerful accelerators like 'cyclotrons', 'betatrons', 'synchrotrons' and 'synchro-cyclotrones' to bombard atoms. Later some new particles like muon, pion, K-mesons and hyperons were also detected. The only difference among these particles was in the matter of charge and mass. Murray Gell-Mann conjectured that these were indeed the same particles characterized by a new property called 'multiplicity'. The force that holds the nucleus together is termed strong interaction. The force that causes radioactivity is rather weak and is called the weak interaction. These two forces, together with the electromagnetic force and gravity, constitute the four, fundamental forces of nature. With the help of large telescopes, Edwin Hubble calculated that the far away galaxies were flying apart, the farther the faster. It has been proved that the kind of matter we see around us, accounts for only 4% of the total matter in the Universe. 22% is dark matter and the remaining 74%, is yet to be known.

Essay Question

1. Explain the advances in Information Technology and Nanotechnology

Ans. Information Technology is as old as human civilization. There are four different stages in its development, depending upon the principal technology used to solve the input, processing, output and communication needs of the time. These are: (1) Pre-mechanical (2) Mechanical (3) Electromechanical, and (4) Electronic.

The first stage was characterized by writing, the use of paper and pen, establishment of the great libraries, the invention of the number system, and the use of rudimentary calculating devices like the abacus. The mechanical age started with the introduction of movable type printing by Johann Guttenberg. The slide Rule was invented by William Oughtred and this made engineering calculations manageable. Wilhelm Schickard was the first person to build a calculating machine. Charles Babbage designed a 'Difference Engine' which could supposedly calculate polynomial functions.

The Electromechanical era was facilitated by the Telegraph, Telephone, and the Radio. The first 'Electrical Tabulating System' was patented by Hermann Hollerith in 1889. The first High Speed, General-Purpose Electronic Computer using vacuum tubes, was ENIAC, which was developed by Mauchly and Eckert in 1946. This was soon followed by UUNIVAC, which became the world's first commercial computer.

The First Generation Computers used vacuum tubes and punched cards. The Fourth Generation, starting 1979, is marked by the use of Large Scale and Very Large Scale Integrated Circuits and microprocessors, which made personal computers possible. The release of Apple II in 1977, by Stephen Wozniak and Steven Jobs marked a watershed in IT history. The first Graphical User Interface came with Apple Macintosh in 1984. This made PCs tremendously popular.

The term nanotechnology was first coined by Norio Taniguchi and he defined nanotechnology as 'consisting of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule'. Two events have helped in the development of nanotechnology: - (1) Development of cluster science, and (2) invention of Scanning Tunnelling Microscope (STM) followed by the Atomic Force Microscope, which has become the foremost tool for imaging, measuring and manipulating atoms at the nanoscale.

The nanoscale is of the order of 10^{-9}m. The epithet 'nano' is applied to all operations at the scale of less than 100nm. Our present manufacturing techniques also involve the reordering of molecules and nanotechnology allows us to work at the intricate level, atom by atom, molecule by molecule.

When the substances are reduced to the molecular sizes, their properties change drastically. Gold, for example, becomes a liquid in room temperature, Aluminium becomes combustible and Copper becomes transparent. Many materials which are normally inert begin to exhibit new catalytic properties at the nanoscale. Much of the interest in nanotechnology is due to these phenomenal changes in properties of materials, which open up exciting possibilities.

MODULE IV

UNIT -10

BASIC CONCEPTS IN THE PHILOSOPHY OF SCIENCE

OBJECTIVES

At the end of this unit, you should be able to:

i) distinguish science from other disciplines.
ii) understand the components of science.
iii) know the concept of unity of science.

SUMMARY

10.1. Introduction

The word philosophy is derived from the two Greek words, *philo* (to love) and *sophia* (wisdom). So, Philosophy means, love of wisdom. Wisdom consists of an in-depth understanding of facts and events, their interrelations and interconnections, and also their consequences and implications. This calls for the knowledge of the 'what', 'how' and 'why' of things. Philosophy deals with three fields of inquiry: metaphysics, epistemology, and axiology. Metaphysics is the study of reality. Epistemology is the study of knowledge. Axiology is the study of values.

Glossary

Implication	:	suggestion
Acquire	:	gain something which is more or less permanent

10.2 Some fundamental Questions

The history of science deals with the development of ideas. The philosophy of science deals with the logic of ideas.

What is Science?

Science is a systematic study of nature, or the world around us. Science helps us to understand, explain, and predict the natural phenomena. The distinguishing feature about science is the particular method that scientists use to arrive at these results or predictions. Experiments, formulation of hypothesis, making predictions based on them, and their verification are the distinct features of science.

Science and Pseudo-Science

Science provides verification, but other systems do not provide for any verification. There are no unchallengeable authorities in science. All the theories of science are liable to be challenged. If needed, the theory will have to be modified or discarded. It is this openness that distinguishes a science from a pseudo –science.

Glossary

Verify	:	prove to be true
Liable	:	legally bound; subject to an obligation
Modify	:	change the form or quality of
Discard	:	throw away; give up

10.3 Scientific Reasoning

Deduction and Induction

Deductive arguments are those which start with some self evident truths. They can be taken as axioms. Then we use logic and reason to deduce some other propositions from these axioms. As long as our axioms are correct, and provided our logic is perfect, our results will always hold good. The following is a classical example.

All humans are mortal.

Socrates is human.

Therefore, Socrates is mortal.

The first two statements are called premises. And when deductive logic is applied on these two premises, the conclusion follows, logically and irrefutably. Whether the conclusion is true or false depends on the truthfulness of the premises. The inductive logic was introduced by Francis Bacon and others. Inductive logic begins by gathering as much information as possible, about the subject of study, through systematic and careful observations. From these observations or data, a hypothesis is formed. This has to be tested. For this, we need to make some predictions, which are testable. This process of testing is called experimentation. It should be capable of yielding an unambiguous conclusion, either proving or disproving the hypothesis. If the result is positive, then the hypothesis survives.

Probability and Induction

We normally assume that if something has survived several tests then it is quite probable that it will always be true. But this is not acceptable to the philosopher. Just because it has not been disproved in the few tests conducted, it does not follow that it will always be true. Just like the problem of induction, there is a problem of deduction too. Unless one takes refuge in revelations or gospels, the initial axiom or premises can come only from observations, through induction. Even in the case of seemingly 'proven' scientific theories, there may be many underlying assumptions. We construct models of theories based on our observations and findings. Even if the theory is validated by experiments, it is no guarantee that is represents the 'real' phenomenon. That is why we keep the doors of scientific inquiry open, and are willing to consider new evidence whenever it is brought in.

Inference

There are other types of 'non inductive' reasons also, for making inferences. During the waxing and waning of the Moon, we find that the whole of the lunar disc is not shining. In the ancient days people had explained this phenomenon as the curse of some God. It was Leonardo da Vinci who opined that this is due to the reflected light from the Earth. The bright side is shining due to light it receives from the sun. No sunshine is falling on the other half, and hence it is dark. But, the Earth will be reflecting some sunlight on to that side also and hence that portion appears to be faintly lighted. This certainly appears to be a sound explanation for the phenomenon. Such reasoning is called *Inference to the Best Explanation* or IBS.

Glossary

Abide	:	remain firm
Mortal	:	subject to death
Irrefutably	:	undeniable; indisputable
Quagmire	:	difficult situation
Bestow	:	deposit; confer

10.4 Scientific explanation

The typical function of science is to give credible explanations of the physical phenomena that we see around us. We shall examine what constitutes a scientific explanation.

Models of Explanations

It was Carl Hempel who gave scientific explanation to a theoretical structure. He called it the *Covering Law Model.* This structure has a fact or event which needs explanation. This is called the *explanandum.* The condition responsible for this event is called *explanans.* The most basic question regarding scientific explanation is whether science can explain everything. Some believe so. Some philosophers think that it is logically impossible.

Glossary

Resurrect	:	restore to life; revive
Credible	:	believable; worthy of belief
Irrefutable	:	undeniable; indisputable

10.5 The Components of Science

The essential components of the scientific method are observation and measurements, data analysis and hypothesis formation, and experimental verification.

Observation and Measurement

All science begins with observation and measurement. There are some philosophical concerns regarding observations and measurement. Some of these concerns are metaphysical in nature (about the *what* of observation and measurement). Some are epistemological in character (the *how* of it). There are axiological (value based, or *why*) objections also. This forms the very basis of the scientific method.

Experimentation

The purpose of some experiments might be to improve some particular technique. Other experiments may be heuristic in nature that they open up new lines of inquiry. Many experiments are of a fact-finding type and some experiments involve the creation of new entities. A good experimental design may have the following features:

* Replicability
* Accuracy
* Precision
* Generalizability
* Simplicity
* Focus
* Absence of systematic error
* Consistency
* Utility

Interpretation and Theory

Pierre Duhem argued that just like observation and measurement, experimentation also is theory laden. No experiment is complete until its results or observations are interpreted.

Glossary

Sacrosanct	:	sacred and inviolable
Innocuous	:	harmless; safe
Discernible	:	distinguishable

10.6 Realism and Anti Realism

Philosophy asserts that there is no such thing as objective reality, and reality is what we construct in our minds. Some philosophers conceded that where direct observations are available, scientific theories might represent reality. Almost all scientists believe that the purpose of science is to discover the real world and to explain it. Science proceeds from incomplete theories to more complete theories. *Scientific realism* argues that science is gradually moving towards a better understanding of the reality even though there is no guarantee that it will eventually succeed in unraveling all the mysteries of the universe. The philosophical school of *Idealism* argues that there is nothing like independent reality, and it is all in the mind of the beholder. *Phenomenalism* argues that we can only perceive the phenomena as we experience them, and that is the only reality we can talk about. Some others hold the view that scientific theories and models are only instruments to make sense of such phenomenon that we encounter. It is clear that all these schools do not agree with *realism.* Science works because it is able to explain how the world works and it also enables us to predict how it will work in a given situation. As science progresses, more and more evidences open up. The errors are removed and we move closer and closer to reality. Arthur Fine introduced a new approach to resolve the perpetual dispute between realists and anti realists and it is called "*Natural Ontological Attitude*" or *NOA.* According to Fine, the NOA is an outer mediate position, which accepts that scientists account for actual entities of the world.

Theories and Models

Theory may be defined as 'a formulation of underlying principles of certain observed phenomena, which has been verified to some degree'. Theories and laws are different. Theories deal with the general system and laws deal with specific behaviour. Laws are definitive and allow for no exceptions, unless it is accommodated within the theory. Theories are not facts. There is still an element of uncertainty about them. A theory should cover a whole class of phenomena. Theories make predictions which can be verified. There is what is called the plasticity of a theory. This refers to its ability to accommodate new developments, which were not foreseen when the theory was originally formulated. Consistency or coherence is another quality of a good theory. This means that the various components of the system do not contradict each other. Elegance or simplicity is another sign of a good theory.

Glossary

Ingenious	:	skilful in invention
Wrath	:	intense anger; fury
Concede	:	admit or allow; yield or give up
Unravel	:	unknit; disentangle
Notion	:	a concept in mind; idea
Resolve	:	determine; analyse
Perpetual	:	everlasting; endless
Elegance	:	grace; refinement
Override	:	supersede

10.7 Reductionism and Unity of Science

Unity of Science

Humans had a strong desire to reduce everything to 'fundamentals' so as to unravel the 'unity of nature'. The implicit assumption is that the world is orderly and can be explained by a small number of natural laws. E.O. Wilson thinks that biology and culture interact across all societies to create the commonalities of human nature. According to him the world is one, and the phenomena are what they are. So, there is unity of phenomena, or *ontological unity.* Science has a grand role in explaining this unity. This unit of explanation is termed *epistemological unity.* Another aspect of this unity is the belief that the values of science, like its aims and goals, are also unified. This is *axiological unity.*

Reductionism

Some philosophers say that all sciences can be shown to be the manifestations of a single science. This reduction can also apply to all branches of knowledge. The notion that the various concepts, models, theories, etc. that scientists use to explore and explain the phenomena can themselves be reduced to the concepts, models, and theories of a more basic science, is known as epistemological reduction. Since all scientific disciplines deal with the different aspects of animate and inanimate matters, and physics is the fundamental science dealing with matter, some use these arguments to claim that all the other sciences can be reduced to physics, ultimately. There are also those who oppose the very concept of the unity of science. They hold that the various sciences differ in content, methods, and goals. Quite a few philosophers and scientists accept the concept of reduction in principle, but not in practice. Reductionists claim that we will achieve better understanding of the phenomena using a reductionist approach, but critics disagree.

One word Answer Questions

1. ....is the study of reality.
   Metaphysics

2. Axiology is the study of.........................
   Values

3. Inductivism was introduced by..................
   Francis Bacon

4. Epistemology is the study of.....................
   Knowledge

5. NOA was introduced by............................
   Arthur Fine

6. The unity of phenomena is called.......................
   ontological unity

Short Answer Questions

1. What are the main components of the 'scientific method'?

   Ans. The essential components of the scientific method are observation and measurements, data analysis and hypothesis formation, and experimental verification.

2. Why is 'observation' alleged to be 'theory laden'?

   Ans. Some philosophers argue that our observations are influenced by our expectations, our previous experiences, and even our vested interests. So they say that observations are theory laden.

3. What is the basic proposition of 'scientific realism'? What are its major critiques?
   Ans. The notion that science is gradually moving towards a better understanding of the 'reality out there' is the predominant feature of scientific realism. Idealism argues that there is nothing like independent reality, and it is all in the mind of the beholder. Phenomenalism argues that we can only perceive the phenomena as we experience them, and that is the only reality we can talk about.

4. What is the basic difference between the deductive and inductive reasoning methods?

   Ans. Deductive reasoning starts with some self evident truths. This can be taken as axioms. Then logic and reason are used to deduce some other propositions from these axioms. As long as our axioms are correct, and our logic is perfect, our results will always hold good. The inductive logic was introduced by Francis Bacon. Here, we begin by gathering as much information as we can, about the subject of study, through systematic and careful observations. Based on these observations or data, some generalization is made.

5. Why do some philosophers insist that you can never prove anything by induction?

   Ans. We normally assume if something has survived several tests then it is quite probable that it will always be true. But some philosophers argue that just because it has not been disproved in the few tests conducted, it does not follow that it will always be true.

6. How does science 'explain' something?

   Ans. In science experiments are conducted and based on these experiments, hypothesis or theories are formulated. Predictions are made on their basis. Then these are verified through experiments. These are the features of the scientific method.

Short Essay Question

1. Science and pseudo-science

   Ans. Science is a systematic study of nature, or the world around us. Science helps us to understand, explain, and predict the natural phenomena. The distinguishing feature about science is the particular method that scientists use to arrive at these results or predictions. Science makes use of experiments. Formulation of hypothesis or theories, making predictions based on them, and their verification by experiments or planned observations, are very distinct features of science. There are other methods also to know about the world. But these methods do not provide for any verification. There are no unchallengeable authorities in science. All the theories of science are liable to be challenged. If any observation arises contrary to the existing theory, then it has to be modified or discarded. It is this openness that distinguishes science from pseudo-science.

Essay type Questions

1. Distinguish between science, non-science, and pseudo-science.

   Ans. The history of science deals with the development of ideas, but the philosophy of science deals with the logic of ideas. Science is a systematic study of nature, or the world around us. Science helps us to understand, explain, and predict the natural phenomena.

   Religion also tells us many things about the world. Astrologers also make predictions. But religion and astrology are not sciences. The distinguishing feature about science is the particular method that scientists use to arrive at these results or predictions. A very clear example is the use of experiments. Formulation of hypothesis or theories, making predictions based on them, and their verification by experiments or planned observations, are very distinct features of science.

   Science is not the only means of knowing about the world. It was not easy to distinguish science from the other disciplines, which seek to understand the world, or to make predictions about the future. But those other systems do not provide for any verification. There are no unchallengeable authorities in science. All the theories of science are liable to be challenged. If any observation arises, which is contrary to the explanation provided by the existing theory, then the theory will have to be modified or discarded. It is this openness which distinguishes a science from a pseudo-science.

2. What does 'reductionism' imply in science? How is it related to the 'Unity of Science'?

   Ans. Some philosophers argue that all sciences can be shown to be the manifestations of a single science. This idea is known as the unity of science. Johannes kepler had formulated three laws to explain the planetary motions. Later, when Newton discovered the Laws of Motion, the planetary orbits came out as a special case of the Newtonian laws. So, Kepler's theory or laws can be derived from Newton's equations but not vice versa. Hence it can be said that Newton's laws reduce Kepler's laws. This kind of reduction can apply to all branches of knowledge.

The notion that the various concepts, models, theories etc. that scientists use to explore and explain the phenomena can themselves be reduced to the concepts, models and theories of a more basic science, is known as epistemological reduction. All of the sciences can be reduced to a few basic sciences, or perhaps to physics itself. Since all scientific disciplines deal with the different aspects of animate and inanimate matter, and physics is the fundamental science dealing with matter, some use this argument to claim that all the other sciences can be reduced to physics, ultimately.

Some philosophers oppose the very unity of science. They hold that the various sciences differ in content, methods, and goals. For example, in biology the nature of explanation is often in terms of functions. The role of explanation is different in physics. So, even if there may be unity of phenomena, there can never be a single unified science. It has to be conceded that none of them can violate the laws of physics, since they are fundamental to all matter.

Quite a few philosophers and scientists accept the concept of reduction in principle, but not in practice. Reductionists claim that we will achieve better understanding of the phenomena using a reductionist approach.

UNIT – 11

SOME ISSUES IN THE PHILOSOPHY OF SCIENCE

OBJECTIVES

At the end of this unit, you should be able to:

i) develop familiarity with the current challenges facing science and scientific temper.

SUMMARY

11.1 Scientific Change and Scientific Revolutions

The rate of progress in the field of technology is tremendous. Science is different from technologies. Even in the field of science, the sheer volume of information explosion is mind boggling. The knowledge about the existence of Dark Matter and Dark Energy is entirely due to information gathered during the last ten or twenty years. It is even true that, for a great number, the actual conditions of life have deteriorated during this very period of phenomenal 'progress'. A large number of persons have become 'developmental refugees' as a result of projects launched in the name of 'progress'. Science definitely gives us more knowledge, and when it is translated into technology, it vastly enhances our power for both good and evil. Unless this power is combined with the 'good sense' to use it for the common benefit, it will certainly spell disaster.

Inductivism

Though the seeds of intuitivism were sown by Francis Bacon, the modern versions owe much to the works of **John Stuart Mill** (1806-1873). The so-called 'Mill's Methods' have now been widely adopted as standard practices in establishing casual relationships. The first of them is the *Method of Agreement,* which enumerates positive instances of co-occurrence. A limitation of this model is that mere co-occurrence of two events need not by themselves indicate a cause and effect relationship, unless reinforced by other factors. Mill suggested what has been called the *Method of Difference.* It is important to know when the two events occur together, but also whether one is invariably absent when the other is also absent. This combination is a useful pointer to a cause and effect relationship between the two. But there could be other causes also, which have not been ruled out in this study. Another method of casual inference prescribed by Mill is the *Method of Residues.* Here we have to isolate one cause by eliminating other possible causal agents. Thus the real causal agent is left as the residual cause.

Critique of Inductivism

Karl Popper (1902-1994) objected the very foundation of inductive reasoning. He introduced an alternate view of inductivism. Popper rejects the arguments based on the high degree of reliability or probability, which the defenders of inductivism usually put forward. At some point, they also try to universalize from limited observations. Popper then suggests a method for critically testing theories. This is falsification. According to this theory, the maximum that we can say about the truthfulness of any theory is that, it has not been shown to be false so far. It is an inherent limitation of inductive method. This has been criticized by John Gray. According to him this would have killed the theories of Darwin and Einstein at birth. It is known that science is always ready to accept any contrary proof, at any point of time. If a theory has the possibility of being proved wrong at any point of time in future, it just shows that is has not been proved conclusively, and its claim to truth cannot be accepted.

Glossary

Tremendous	:	awe-inspiring; huge
Deteriorate	:	make worse; grow worse
Enhance	:	increase; intensify
Discern	:	make out; distinguish
Enumerate	:	count the number of
Propound	:	offer for consideration; propose
Refute	:	disprove; repel
Impediment	:	obstacle; hindrance

11.2 Paradigms and Research Programmes

Paradigms

Thomas Kuhn challenged the very idea that scientific progress was a steady, linear, cumulative, and rational process. According to him changes occurred in paradigm shifts. He cited the transition from Ptolemic to Copernican, and from Newtonian to Einsteinan world views, and also the Darwinian revolution in biology to prove his point about paradigm shift. Kuhn introduced a new concept called incommensurability to show that the old and new paradigms were radically different. Kuhn questioned the objectivity of observations. He attacked the notion that all kinds of evidence, irrespective of whether they supported or refuted currently held views, were accepted by the scientific world with impartiality. He challenged the notion that scientific changes took place in a rational and objective manner, free of any type of extraneous influence. Kuhn did not mean to undermine the rationality of science, but only wanted to offer a more realistic and historically accurate picture of how science actually develops. His main was to highlight the social context in which scientific activities take place

.

Research Programme Approach

Imre Lakatos (1922-74) proposed a new method to resolve the contradiction between the two approaches given by Kuhn and Popper respectively. It is known as *Methodology of Research Programmes.* He explained that some series of scientific theories may be marked by a certain continuity, which connected their members. It is this continuity which made it a Research Programme, and provided it with methodological rules: what paths of research to avoid and what to pursue.

Glossary

Paradigm	:	type; model
Exhaust	:	use the whole strength of
Extraneous	:	foreign; not essential
Veritable	:	real
Adhere	:	stick; cling
Persist	:	persevere; insist

11.3 Research Traditions (or Problem-Solving) Model

Larry Laudan faulted all the earlier philosophers of science for trying to assess the progress of science in terms of some abstract concepts like truth-seeking and rationality. He maintained that whatever helps to make progress is rational. And progress consists of solving particular problems. This is called the *Problem Solving Approach* to scientific progress. It is also known as the *Research Tradition Model.* According to Laudan, progress in science is to be measured by its ability to solve more problems, with the succession of theories.

Glossary

Assess	:	fix the value of; estimate
Ensure	:	make sure

11.4 Technologism

Joseph Pitt is a philosopher of science and also Philosopher of technology. His views on scientific progress gave predominance to the role played by technology, and hence may be called Technologism. Pitt defined technological infrastructure as a historically determined set of mutually supporting artifacts and structures that enable human activity, and provide the means for its development. According to Pitt, technology is not just a tool, but it is the driving force of scientific progress. Pitt based his explanation for scientific change on material grounds and not in some abstract ideas.

Science and Technology

Science and technology are becoming more and more inseparable. Their aims, objectives, and methods are quite different. Technology is a form of knowledge. Even though it is related to intelligence, it does not mean that is confined to humans. Many animals also use technology. They not only use tools, but even make them. Technology refers to the practical implementation of that intelligence. It is goal- oriented. The Greeks distinguished between three types of knowledge: *theoria, praxis,* and *techne.* Theoretical knowledge is concerned with knowing. Praxis is concerned with doing, and techne is concerned with making or manufacturing. The first deals with Pure Science, the second with Applied Science, and the third with Technology. Technology need not be science-based. Many technologies have flowed from science, but many had independent history. Some of the most significant achievements of technology, of the early period, were made without the benefit of science: like fire, the wheel, the pump, the water wheel, the wind mill and even the steam engine. The relation between applied science and technology has been changing with time. Applied science looks for opportunities for using or applying science, whereas technology may or may not use science at all. Technology also develops laws, which are likely to be empirical.

11.5 Philosophical Problems in Physics, Biology and Psychology

Some Philosophical Problems in Physics

Philosophy of physics has emerged as a special subject within the gamut of philosophy. It deals with the fundamental issues underlying physics, like what is time and what is space, what is nature of matter and energy, the concept of causality, the nature of the physical laws, etc. The absolute nature of time and space is fundamental to the physics of Newton. But Leibniz thought that space was the interval between objects. If there were no objects, there was no space. Leibniz invoked a philosophical concept called *The Principle of the Identity of the Indiscernible* or PII and it states that if two objects are absolutely identical in every respect, they are one and the same. Newton countered this with the demonstration of the validity of acceleration in absolute space.

Some Philosophical Problems in Biology

Philosophy of biology has emerged as a distinct discipline only in the 1960s and 70s. It is concerned with issues like: What is life and how do we classify different life forms? How do we differentiate one species from another? Is there a 'collective consciousness' among social organisms? How does 'natural selection' operate? Is there an editing agent for the genome? How do physicians explain disease? Should a terminally ill patient be told about his actual condition? What is the impact of reductionism in the practice of healing? And so on. It was Linnaeus who ventured to conceive of a hierarchical system even before the emergence of evolutionary hypothesis.

Some Philosophical Problems in Psychology

Some of the fundamental problems of psychology are: what would be an approximate method for the study of psychology? How closely cane the methods of natural sciences be adopted to psychological studies? Can first person experiences like emotions, desires, beliefs, etc., be measured? What is the nature of mind, brain, and consciousness? Is there something like 'extra-cerebral consciousnesses'? Is our mind modular in nature? Philosophy of psychology also closely monitors the current work in cognitive neurosciences, evolutionary psychology, and artificial intelligence.

11.6 Science and Values

There is a general belief that science is supposed to be value free. That is, its pursuit and product should be solely concerned with truth. Values become bad for science, when they influence the findings, their interpretations, or conclusions.

Values About Science and Within Science

When we consider the values of science some relevant questions arise. What are the areas that sciences should investigate? What should be the area of scientific study taken up by a society of scientists and by an individual scientist? Should funding agencies decide the area and nature of scientific investigation? Should moral and ideological considerations also decide the nature of research? Then, there can be questions about science itself, as a social institution. Does it deserve so much funding and support compared to other priorities? What is its importance compared to the other social institutions, like the arts or culture, or religion? There are several issues within science also. Is the pursuit and practice of science itself totally value free? How can we expect their scientific work to be uncontaminated?

Scientism and Scientific Temper

The words 'science' and 'scientific' have a special import in the modern society. Some people believe that science has a monopoly on all knowledge worth knowing. 'Scientism' is science worship and it is used in a bad sense by philosophers. It is the 'over-reverential attitude towards science seen in many intellectual circles'. While scientism is a bad word, *scientific temper* seems to be a better term and it is important for a nation like India. Scientific temper represents creativity, openness, and tolerance that are inherent to science. Many people think that is essential to develop a scientific temper among all the citizens. The challenge before any society, which wants its citizens to develop a scientific temper, is two-fold. One, to have a wide debate and arrive at an acceptable understanding of what scientific temper means. Secondly, to reform the education system, so that it inculcates the appropriate desirable traits among the citizens of tomorrow.

Glossary

Predominant	:	important
Grandiose	:	imposing; bombasting
Megalomania	:	the delusion that one is great and powerful
Revulsion	:	sudden violent change of feeling
Antagonism	:	active opposition
Pursuit	:	the act of pursuing
Pejorative	:	depreciatory word

11.7 Science and Religion

The tension between science and religion is very old. Religion believes in a supernatural being, often called God, who is omnipotent, omnipresent and omniscient. A common feature of all religions is that they are all anthropocentric. On the other hand, scientific world view does not admit of any supernatural being or influence in the affairs of the world. The world behaves according to natural laws and the task of science is to find out these laws, and through them, to know how the world works. Another difference between them is that while science seeks the efficient cause of phenomena, religion is concerned with the ultimate cause. Science asks the question ‘why’ or ‘how’ and expects an answer in terms of the process underlying the phenomenon. Religion answers the ‘why’ question, in terms of a divine plan. Religion is also a social institution, and sometimes a political institution too. If religion would give up this socio-political role, and would content to be a matter of personal belief and solace for individuals, only then the conflict between religion and science will end.

Glossary

Anthropocentric	:	man-centered
Anathema	:	denunciation; excommunication

11.8 Science and Society

It was **C.P. Snow**, the English Physicist and novelist, who talked about the ‘two cultures’ to indicate the widening gap between the worlds of science and humanities. Snow observed that both these groups viewed the other with indifference, suspicion, and even distrust. This is an unfortunate situation, and harmful to the role of science in society.

Science as Sexist

Feminists argue that science is sexist in terms of what gets investigated (metaphysically), how it gets investigated (epistemologically), and why it gets investigated (axiologically). The choice of subjects of inquiry rarely reflects women’s priorities or concerns. It often reflects men’s points of view and perspectives. They also argue that science adopts a masculine approach to knowledge gathering. The research aims and objectives tend to promote existing social structures, which are male-dominating and hence anti-women.

Science as Just One Narrative

Some social scientists argued that science is not the only means of explaining the natural phenomena. They also question the objectivity of science. They insist that science is a social institution, operated by individuals, who are shaped and influenced by various social forces. They argue that scientists’ investigations are directed not really towards natural phenomena, but towards providing a coherent account of them. **Paul Feyerabend** holds that science is a dangerous activity, and intends to defend society and inhabitants from it. He agrees that science was once responsible for liberating mankind from authoritarianism and superstitions. But that does not mean that it will always be like this.

People’s Science

Bill Zimmerman argues that science is inevitably political. He points out that scientific knowledge and products are marketed for profits. They are not distributed equally. They become the prerogative of the middle and upper classes and often increasing the disadvantages of those sectors of the population that are already most oppressed.

Response to Criticisms

Practicing scientists are often criticized. They know that there is some substance in these. Good science consists of constant vigil, both on the part of the individual researcher as well as the scientific community. Errors and mistakes are quoted as if they are the rules. The very strength of science is that there is a self-correcting mechanism built into the methodology of science.

Glossary

Gadget	:	a small device
Debunk	:	discredit
Scarcity	:	dearth; want
Prerogative	:	peculiar privilege

11.9 Conclusion

Science is an imposing human, societal enterprise. It has been responsible for all the *material knowledge* that we have been able to gather about the world out there. But this knowledge is provisional and liable to revision. The objectivity of science is also subject to so many assumptions and conditions, and needs to be continuously monitored. Scientists should have a certain humility and openness so that many prejudices of society can be removed. This will ensure great benefits to the whole humanity.

Glossary

Liable	:	legally bound

One word Answer Questions

1. The modern versions of inductivism owe much to...............

   John Stuart Mill

2. Popper uses the term..................instead of verification.

   Falsification

3. The new approach introduced by Lakatos to resolve the contradiction between Kuhn's and Popper's approaches is known as...............

   Methodology of Research Programme

4. The over-reverential attitude towards science is called.................

   Scientism

5. ....argues that science is inevitably political

   Bill Zimmerman

Short Answer Questions

1. Explain 'Mills Methods' in induction.

   Ans. The modern versions of inductivism owe much to the works of John Stuart Mill. The so-called 'Mill's Methods' have been widely accepted as standard practices in establishing causal relationships. The first of them is the 'Method of Agreement', which enumerates positive instances of co-occurrence. Another one is called the 'Method of Difference'. According to this, two events occur together, but when one of them is absent, the other one also is invariably absent. Another method prescribed by Mill is the 'Method of Residues'. According to this method, we have to isolate one cause by eliminating other possible causal agents.

2. Why did Popper insist that falsifiability is the true mark of a scientific hypothesis?

   Ans. Popper objected to the very foundation of inductive reasoning. He recommended an alternative approach for testing scientific theories. This is called falsification. When we put a theory to test, we are testing whether the results are as per the predictions of the theory. If they do not agree, the theory is false. But even if they do agree, Popper will only concede that the theory has not been proved to be false. Because, there is always the possibility that in another experiments, designed in a different way, the result may turn out to be negative. So, Popper insisted that the maximum that we can say about the truthfulness of any theory is that, it has not been shown to be false so far.

3. Illustrate Kuhn's concept of a 'paradigm shift', taking the overthrow of the Aristotelian Universe or the Newtonian System, as an example.

   Ans. Thomas Kuhn challenged the very idea that scientific progress was a steady, linear, cumulative, and rational process. He argued that it tended to follow set patterns long after their validity had been exhausted. It was unwilling to consider evidence contrary to the prevailing world views. And, finally, when change came, it came in an avalanche in a process more akin to a religious 'conversion', resulting in a complete 'paradigm shift'. He cited the transition from Ptolemic to Copernican, and from Newtonian to Einsteinian world views, and also the Darwinian revolution in biology to prove his point about paradigm shift.

4. Explain low Kuhn stressed the historicity of sciences.

   Ans. According to Kuhn, scientific revolutions came, not a result of rational thinking, but on account of socio-political factors. He wanted to offer a more realistic and historically accurate picture of how science actually develops. Just like the positivists, he also regarded modern science as a hugely impressive intellectual achievement. He wanted to present a more accurate picture of the real rationality of science.

5. What are some of the alternative approaches to explain scientific progress?

   Ans. Imre Lakatos suggested a new approach called Methodology of Research Programmes. Instead of the concept of paradigms, he thought that scientific research should always go on in the form of competing Research Programmes. Larry Laudan says that whatever helps to make progress is rational. And progress consists of solving particular problems. This is called the problem solving approach or Research Tradition Model.

6. Examine the interrelation between science and technology with examples.

   Ans. Science and technology are becoming more and more inseparable. Their aims, objectives, and methods are quite different. Technology is a form of knowledge. Even though it is related to intelligence, it does not mean that it is confined to humans. Many animals also use technology. It refers to the practical implementation of intelligence. It is goal-oriented. Even though many technologies have flowed from science, many had independent history. The making of copper, bronze and iron implements by early man is an example. The relation between applied science and technology also has been changing with time. Applied science looks for opportunities for using or applying science, whereas technology may or may not use science.

7. What is meant by scientific temper and what are its implications?

   Ans. 'Scientific temper' is a peculiarly Indian coinage. Prime Minister Nehru emphasized the importance of 'scientific temper' for India. By this he meant a society that exhibits the creativity, openness, and tolerance that are inherent to science. He thought that it was a requirement for the development of a diverse nation. Some may mistake it as adopting a scientific methodology for solving all the problems of the society. Some others think that this is totally absurd. Some interpret this as a call to campaign against all superstitions, irrational religious practices and pseudo-sciences like astrology.

Short Essay Questions

1. Inductivism

   Ans. Inductivism was first introduced by Francis Bacon. In this method, scientists begin by careful observation and gathering of data, related to the phenomenon in question. Both positive and negative instances will be studied. The next step is to discern a pattern among the occurrences, which might give a clue to the cause and effect relations underlying the phenomenon. This will be followed by the generation of some hypothesis which will give a logical explanation for the occurrence of this phenomenon. This is essentially a process of generalization from our limited observations. It is this generalization which gives practical value to our effort. This offers a chance to make predictions, which can be verified through experiments.

The modern versions of inductivism owe much to the works of John Stuart Mill. The so-called 'Mill's Methods' have now been widely adopted as standard practices in establishing causal relationships. The 'Method of Agreement' enumerates positive instances of co-occurrence. 'Method of Difference' states that it is important to know when the two events occur together, but also whether one is invariably absent when the other is also absent. According to the 'Method of Residues' we have to isolate one cause by eliminating other possible causal agents.

2. Falsification

Ans. Karl Popper's refutation of inductivism was not an argument against the validity of the scientific method. On the contrary, he was trying to put the scientific method on a logically sound footing. This is clear from the alternative approach he recommends for testing scientific theories. He sees the method of scientific practice as the production of conjectures and then subjecting them to rigorous testing. Science progresses from this cycle of conjectures and refutations. It the conjecture is proved to be valid, it becomes accepted. Popper says that when we put a theory to test, we are testing whether the results are as per the predictions of the theory. If they do not agree, the theory is false. But even if they do agree, Popper will not say that the theory is true, he will only concede that the theory has not been proved to be false. Because, there is always the possibility that in another experiment, designed in a different way, with respect to another prediction of the same theory, the result may turn out to be negative. So, the maximum that we can say about the truthfulness of any theory is that, it has not been shown to be false so far.

According to John Gray this would have killed the theories of Darwin and Einstein at birth. Popper's claim that any hypothesis can be tested in a straight forward way also has been challenged. It has been pointed out that we often test theories or hypotheses as a package, and a negative result does not necessarily require the discarding of that hypothesis. If scientists are forced to abandon their revolutionary ideas, on the face of such negative results, it will be a great impediment to scientific progress.

3. Technologism

Ans. Joseph Pitt's views on scientific progress gave predominance to the role played by technology, and hence may be called Technologism. Pitt defines technological infrastructure as a historically determined set of mutually supporting artifacts and structures that enable human activity, and provide the means for its development. According to Pitt, technology is the driving force of scientific progress. Most of the scientific activity not only uses technology, but their goal and content are dictated by technology. Most philosophers admit the important role that technology plays in today's science. The major departure is that Pitt based his explanation for scientific change on material grounds and not in some abstract ideas. A second objection is that Pitt also did not lay down any new standards of progress. Observations by themselves do not constitute scientific progress in the absence of appropriate theories. Pitt seemed to underestimate that.

4. Reductionism

Ans. Some philosophers interpret the concept of unity of science to the extent that all sciences can be shown to be the manifestations of a single science. Johannes Kepler had formulated three laws to explain the planetary motions. Later, when Newton discovered the laws of motion, the planetary orbits came out as a special case of the Newtonian laws. So, Kepler's theory or laws can be derived from Newton's equations, but not vice versa. Hence it can be said that Newtan's Laws reduce Kepler's laws. This kind of reduction can apply to all branches of knowledge also.

The notion that the various concepts, models, theories, etc. that scientists use to explore and explain the phenomena can themselves be reduced to the concepts, models, and theories of a more basic science, is known as epistemological reduction. Since all scientific disciplines deal with the different aspects of animate and inanimate matter, and physics is the fundamental science dealing with matter, some use this argument to claim that all the other sciences can be reduced to physics, ultimately.

There are also those who oppose the very concept of the unity of science. They hold that the various sciences differ in content, methods, and goals. Quite a few philosophers and scientists accept the concept of reduction in principle, but not in practice. Reductionists claim that we will achieve better understanding of the phenomena using a reductionist approach, but critics disagree.

Essay- type Question

1. Why should there be conflict between science and religion? Discuss.

Ans. The conflict between science and religion is very old. Both have their own world views, which are quite different. Religion believes in a supernatural being, often called God, who is omnipotent, omnipresent and omniscient. A common feature of all religions is that they are all anthropocentric. On the other hand, the essential feature of the scientific world view is that it does not admit of any supernatural being or influence in the affairs of the world. The world behaves according to natural laws, which are evident and predictable. The task of science is to find out these laws, and through them, to know how the world works.

Another difference between them is that while science seeks the efficient cause of phenomena, religion is concerned with the ultimate cause. When science asks the question 'why' or 'how', it expects an answer in terms of the processes underlying the phenomenon. But religions answers the 'why' question, in terms of a divine plan. This is not acceptable to science, but science has no quarrel with this, since it lies beyond the realm of science. But if religion answers the 'how' question in terms of definite processes or events, then it trespasses into the realm of science, and science may have something to say about it.

Religion has another role in society, and it is this role which often brings it into conflict with science. Religion is a social institution, and sometimes, a political institution too. In both these capacities, it wants to control the lives of its adherents, regulate their behaviour and influence their actions and even their thought processes. The values associated with scientific inquiry, like a healthy skepticism, habit of questioning, demanding proof, willingness to examine alternate points of view, the critical approach to problems, etc. are anathema to such a socio-political institution. The conflict between science and religion will end only if religion gives up the socio-political role and contents to be a matter of personal belief and solace for individuals.