UNIT 28 SCIENCE AND TECHNOLOGIES AND EXPANSION OF KNOWLEDGE

Structure

28.1 INTRODUCTION

Throughout the long span of history most views of the world were of spiritual and mythological kind. However, the human beings also began developing tools to master the nature around them. The development of modern science was of tremendous long-term significance. In earlier civilisations, people developed practical tools, systems and technologies for managing civilisation they had built. The last years of the 15th century and the early years of the 16th century laid the foundation of the modern worldview. There was an intellectual shift when ideas about nature and society underwent a radical transformation. The men of science were charting unknown shores. This period coincided with phenomenal advances in geographical knowledge and technology. While scientists were challenging many established notions about the universe and human anatomy, other Europeans were making extensive reconnaissance or preliminary explorations of the whole earth. In fact, it has been argued that scientific revolution was the real origin of both the modern world and modern outlook, while Renaissance and Reformation were mere episodes, mere internal displacement of emphasis within the medieval ideology. The scientific revolution is usually taken to signify the contrast with the superstitious irrationality that is presumed to have been the cultural and intellectual signature of the Middle Ages. The seed of scientific revolution sprouted in the form of the Enlightenment, the bourgeois ideology of the age of capital, which established reason as the motor and measure of historical change. Everything was to be submitted to the rational, critical, "scientific" way of thinking. A second important Enlightenment concept was that the scientific method was capable of discovering the laws of nature as well as those of human society. This gave birth to social sciences. The third key idea that of progress, linked to the applicability of scientific thinking to human-existence, followed.

In this Unit our objective is to make you aware about the role of a new perception of universe that emerged around sixteenth and seventeenth centuries. This new perception called "scientific revolution" moulded many institutions of the period. These new perceptions mainly influenced the European society and changed its intellectual world. The Unit will focus on many of these changes in outlook and behaviours, apart from various advances in the field of knowledge during transition from medieval times to modernity. You will also learn about the beginnings of new methods of experimentation, observation and interpretation used by the men of science and how science and its methods were institutionalised. Moreover, we will also try to explore the relationship between science, technology and society in the Western World and its implications for the new world order that emerged with the advent of modernity.

28.2 SCIENTIFIC LEGACY OF EARLIER PERIOD

Many developments in astronomy and physics were at the core of scientific revolution, we can trace the legacy of this intellectual current in the traditional European ideas about the universe. Arab scientists such as Averroes played a key role in the development of science during the Middle Ages, not only through their own contributions, but also through preservation and transmission of the ancient Greek scientific tradition. In 12th and 13th centuries, the medieval scholastics in monasteries and institutions of learning throughout Europe adopted many works of Greek science from their Arabic contacts. The medieval intellectual life and universities left their imprints on the scientific revolution. By the thirteenth century, permanent universities with professors and large student bodies had been established in Western Europe. These Universities received social support because they educated and trained such professionals in diverse areas as lawyers, doctors and church leaders. The emergence of modern science was not an accident. The men of science built their paradigms upon the ideas of their predecessors. However, the Church dominated the Western World. Other ideas were brought into harmony with the official Christian doctrines. According to prevalent notion in the medieval universities, a motionless earth was fixed at the centre of the universe and ten separate, transparent, crystal spheres moved around it. The moon, the sun, the five known planets and the fixed stars were embedded in the first eight spheres. Two more spheres were added during the Middle Ages to account for slight changes in the positions of the stars over the centuries. Beyond the tenth sphere was heaven, with the throne of god and the souls of the saved.

28.3 WORLD TURNED OUTSIDE-IN: ADVANCES IN ASTRONOMY

Copernicus, Tycho and Kepler were three learned men who introduced revolutionary changes in the way their contemporary society perceived the world. They provided new insights about the earth and the universe through their works in the area of Astronomy. Astronomy was an old science patronised because it was believed that celestial bodies influenced Kingdoms and human-life. As a result of such beliefs the study of the positions of planets and stars in the sky became an important area of study. Copernicus clung to the Aristotelian idea of crystalline spheres and the idea that the stars hung on an outer sphere. But he was not fully convinced because the observed facts failed to fit in the theory. He, therefore, tried to figure out his facts from a different perspective. He thought that the Sun, not the Earth, might be at the centre. Still the observed facts did not quite fit with his new hypothesis. But it came a lot closer than any other idea ever put forward earlier. Tycho's scheme again put the Earth back in the centre of things and he collected massive data bank of observations to prove his point. His honest and careful observations did not validate his claims but his massive data was later on utilised by Kepler. Kepler believed that the orbits of planets must be circular – the perfect harmonious creation of God. But the observed facts indicated that planets orbited the Sun in elliptical (oval) paths rather than circular ones. The work of these three men marks the beginning of modern astronomy. In the following sub-sections of the Unit we will focus on their contribution in a systematic way.

28.3.1 Contribution of Copernicus

Nicolaus Copernicus (1473-1543), the Polish clergyman and astronomer studied Church law and astronomy in various European universities such as Krakow, Bologna, Padua and Ferrara. He was bothered by many inconsistencies in the Ptolemaic (geo-centric) model of the universe. The earth-centered model of Ptolemy, the last great astronomer, who lived in Alexandria in the second century A.D, did not fit with many actual observed facts about planets and stars. It was also a complex and unwieldy system of spheres and epicycles. In order to explain the apparent retrograde motion of planets, Ptolemy explained that each planet moved in small circles around an invisible centre, which in term moved in a larger circle orbiting the Earth. This basic concept, which he called epicycles, served roughly to reconcile the differences between observation and Aristotle's earlier theory that all heavenly objects rotated around the Earth in concentric spheres, set one within the other. The great medieval scholar, William of Ockham (1285-1349) had cautioned against adopting such complicated theories. Copernicus also preferred an old Greek idea that Sun rather than earth was at the centre of the universe. Copernicus worked on this hypothesis from about 1506 to 1530. He made mathematical calculations to see the results of a heliocentric or sun-centred universe. The result of his work was published as *On the Revolutions of the Heavenly Spheres* in 1543, the year of his death.

The earth, Copernicus maintained, revolves around its own axis once every 24 hours, causing the heavens to appear overhead. The sun's distance from the earth, he believed was negligible compared to the great distance of fixed stars. The apparent motion of the sun through an annual cycle is caused by the earth revolving round the sun. Only moon, he said, revolves around the earth. And the strange, mysterious retrogressions (backward movement) of Mars, Jupiter and Saturn are caused by the fact, that they like the earth are moving around the sun–but farther away. The earth, travelling in a smaller orbit around the sun, would sometimes pass up these outer planets in their longer orbits, making them look like they were moving backward across the sky. This was a simpler and neat theory compared to complicate and messy Ptolemaic theory.

Copernicus's theory had enormous scientific and religious implications. It destroyed the main reson for believing in crystal spheres capable of moving stars around the earth, because it was simply a result of the earth's rotation. It also suggested an infinite universe as earth took one year to revolve around sun and yet the stars appeared to remain in the same place. Finally, if earth was just another planet, Copernicus destroyed the basic idea of Aristotelian model–that earthly world was quite different from heavenly one. Where were heavens and the throne of God then? The Christian clergy, including Protestant Martin Luther and Calwin declared it false as it did not fit into Christian dogmas about the universe and its nature.

28.3.2 Tycho Brahe: Observing the Stars

The greatest astronomical observer before the invention of telescope was an eccentric and colorful Danish scientist named Tycho Brahe (1546-1601). Aided by generous grants from the King of Denmark, Brahe built the most sophisticated observatory of his times. For years, he collected a mass of data by meticulously observing stars and planets with naked eyes. The Copernicus model had simplicity, regularity and consistency, and it did make better astronomical predictions, at least some of the time, but Brahe clung to idea that all planets moved around the sun but the sun and planets revolved in turn around the earth. Tycho relied on exact measurements and observations to study stars, planets and comets. In observing a comet that appeared in 1577 Tycho found the comet followed an elliptical path deep in the skies. This delivered another blow to the idea of perfection in the heavens, since in Aristotelian system only circle was perfect. Tycho's assistant Johannes Kepler subsequently made brilliant use of his masterly and accurate data.

28.3.3 Elliptical Orbit of Johannes Kepler

Johannes Kepler (1571-1630), the brilliant young German assistant of Tycho Brahe worked on his mentor's vast store of data. Observation showed that the planets travelled at variable speeds, at times slower, sometimes faster. Kepler also found that their speed increased as they drew closer to the sun. Kepler tested various hypotheses by performing voluminous calculations. After years of labour, he came to the conclusion that the orbits of planets could not be circular. In his work *Astronomia Nova* or "New Astronomy" (1609), Kepler propounded his first two laws of planetary motion. He abandoned his own platonic learning and contrary to Christian theology, he found that the planets moved in an elliptical path, a relatively imperfect oval path. Instead of having one centre, an eclipse has two foci. This was the substance of Kepler's first law. In his second law, Kepler described a planet's variations in speed during its orbit around the sun. According to it, a planet moves around the sun in such a way that if an imaginary line is drawn from the sun to the planet the planet would sweep over equal areas in equal periods of time. As a result, the closer the planet came to the sun, the shorter the imaginary line and faster the planet would have to move to cover an equal area.

Kepler published his third law of planetary motion in his book *Harmonies of the world* (1619). The square of any planet's period of revolution about the sun, he demonstrated, is proportional to the cube of its distance from the sun. Thus, Kepler, by precisely relating the time taken by a planet to make a revolution around the sun to its distance from the sun, explained only how planets moved, and not why they moved. As it turned out that Kepler's law of planetary motion holds true for celestial bodies that Kepler did not know about. For example, Galileo later observed that the four moons of Jupiter that he discovered through his telescope, moved around the planets according to the same laws.

28.4 BEGINNINGS OF THE EXPERIMENTAL METHOD

Many of early men of science did engage in it for sheer love of it. They were not professional modern scientists earning living from science. Yet they adopted new methods of observation, experimentation and classification of natural phenomenon while investigating problems. Galileo's experiments, which he carefully recorded step by step and his conclusions based on experiments, demonstrate another attribute of modern science – that the experiments could be duplicated to verify results of an earlier experiment, or by looking for errors in the experiments, results could be partially or wholly modified. However, science is more than mere observation, experimentation and classified presentation of result. The careful gathering of variable data and figures through experiments is not the sole pathway followed by the scientists. Many of them create 'theories', but ultimately such theories must be verifiable by experiment and observation. Although Galileo often gets the credit for being the first scientist to regularly employ the new methods of observation and experimentation, some others also pioneered this method. William Gilbert (1544-1603), the English Physician and Physicist, studied magnetism using a series of detailed experiments and observations. The English thinker Francis Bacon (1561-1626) rejected the Aristotelian and medieval method of using speculative reasoning to build general theories. He stressed on the value of empirical, experimental research, thus formalising the empirical method into a general theory of inductive reasoning known as empiricism. It was a process of reasoning that establishes general truths on the basis of particular instances or empirical data.

28.5 INSTITUTIONALISATION OF SCIENCE

The educated middle classes of Western Europe like lawyers, doctors and members of nobility and clergy expressed their concern for scientific matters. The practitioners of the highly specialised crafts such as surveying, metallurgy, military engineering, clock-making, industrial-chemistry and instrument- making also were pre-occupied with scientific matters of their times. From mid-17th century science became more institutionalised. London Royal Society grew out of informal gatherings of scientists from 1645 onwards. In 1662 it was formally constituted for promotion of scientific knowledge. In its initial years the Royal Society was more concerned with the use of scientific discoveries for practical, utilitarian purposes such as construction of better instruments and equipments and devising of techniques suited to the commercial, manufacturing problems of the times. The French Royal Academy inspired by the French mercantilist, Colbert, became the model for many such societies established all over Europe. Astronomy still continued to be favored by scientists, although, engineering, hydraulics, navigation, medicine, chemistry, optics and physiology also assumed great significance. Bacon's *The New Atlantis* (1627) described a research institution equipped with many tools of modern sciences including laboratories, libraries and printing presses. His ideas led to a trend towards professionalisation of scientific pursuits. Others especially French writer, Bernard le Bovier de Fontenelle (1657-1757) popularised science among the ordinary people through their writings.

28.6 MAJOR SCIENTIFIC ADVANCES

The early breakthroughs made by Copernicus, Tycho and Kepler opened a window and allowed the fresh air of scientific enquiry into a long-closed and musty room. Many giants followed them–Galileo and Newton in Physics, Vesalius, the anatomist, Paracelsus, the Physician, William Harvey, the Physiologist and many others. Each of them made significant contribution in his field and further advanced the cause of scientific thinking. In three sub-sections we will discuss some of these men and their contributions.

28.6.1 Physics and Mechanics

Galileo Galilei (1564-1642), the Italian scientist stressed the need for carefully controlled experiments. He combined observation, measurement and mathematical analysis to look for cause and effect relationships among natural events. He discovered many basic principles of mechanics. In his famous acceleration experiment, he showed that a uniform force produced a uniform acceleration. He also formulated the famous law of inertia, that is, rather than rest being the natural state of objects, an object continues in motion forever unless stopped by some external force. On hearing the invention of telescope in Flanders, Galileo procured one for himself and used it to study celestial bodies. He quickly discovered the first four moons of Jupiter. He found that the Milky Way in the sky was a big cluster of innumerable stars and that surface of moon was not smooth and uniform. Galileo was employed by the Medicis of Tuscany. His work eventually aroused the ire of some theologians. After the publication of his work *Dialogue on the Two Chief Systems of the World* (1632), which lampooned the Aristotelian views and Ptolemy's astronomy and defended Copernicus, Galileo was tried for heresy by the papal Inquisition and imprisoned. Under such tremendous pressure and persecution Galileo withdrew his opinion publicly, "renouncing and cursing" his Copernican errors.

Isaac Newton (1642-1727) combined experimental and inductive approach of Bacon, Galileo and Gilbert with the quantitative approach. He applied mathematical tools to arrive at and frame experimental results. Newton used the findings of others to develop a unified view of the forces of the universe. In his *Principia* (1687) or *the Mathematical Principles of Natural Philosophy*, he formulated his famous three laws of motion as well as a law of universal gravitation. The first law of inertia merely summarised what Galileo had already said: An object at rest tends to stay at rest. An object in motion tends to continue at constant speed in a straight line. His second law of motion states that if more force is placed on an object, the more it accelerates. But the more massive it is, the more it resists acceleration. Finally, the third law that for every action there is an equal and opposite reaction. Newton used the three laws as a basis for calculating the gravitational force between the earth and the moon. He came to the conclusion that it is directly proportional to the product of the masses of two bodies and inversely proportional to the square of the distance between their centres. This law of attraction was same throughout the universe and it also explained all of Kepler's laws. Newton's study of lenses and prisms laid the foundation for the study of modern optics. Furthermore, Newton and Gottfried Wilhelm Leibniz, a German philosopher, independently developed a new system of mathematics, Calculus.

28.6.2 Life Sciences

The same year that Nicolaus Copernicus published his helio-centric theory, Andreas Vesalius ((1514-64), a Belgian anatomist, published his tradition-breaking work, *On the Fabric of the Human body* (1543). In this work, Vesalius laid out in detail the most precise anatomical knowledge of the day, based on his observations he made while dissecting human corpses. His book gradually replaced those of Galen and Avicenna. Galen's anatomy and medicinal theories were based on dissection of animal corpses in A D.100's. Avicenna was also an influential Arab Physician of late 900's and early 1000's. Galen, the Greek Physician's work, *On Anatomical Preparations*, remained the standard text of anatomy in the European Universities. It contained many significant errors. Vesalius tried to remove Galen's errors in his path-breaking work on human-anatomy, although he retained many ideas of Galenic physiology.

How traditions continued to impose their hold on the minds of 16th century scientists can be illustrated with the example of Paracelsus (1493-1541), the Swiss Physician. He ridiculed Galen's medicinal theory that accounted for diseases in terms of some internal imbalance of imaginary humors. Instead he hinted at external sources and causes of diseases, some substances absorbed through air or by contact with skin. It was perhaps, one of the earliest versions of germ theory. However, Paracelsus was also a firm believer in alchemy, whose major objective was to transform base metals into gold and to discover the elixir of life to obtain immortality. Paracelsus was not only deeply immersed in the magic and superstition of the alchemist's art, but also believed in astrological belief that different parts of the human body were governed by the planets.

The scientific revolution also extended too many other areas. Modern physiology began in the early 1600's with the work of William Harvey (1578 – 1657), an English Doctor. Harvey performed careful experiments and used simple mathematics to show how blood circulates through the human body. He published his understanding on the circulation of blood in his masterpiece, *On the Movement of Heart and Blood in Animals* (1628).

The Dutch microscope-maker Zacharias Janssen was probably the first to use combined lenses to aid their magnifying power around 1590. Marcello Malpighi (1628-94) made microscopic study of wing membranes of bats and discovered small blood vessels, later called capillaries, connecting the smallest visible arteries to the smallest- visible veins. Robert Hooke's book, *Micrographia* (1665) contained some of the most exacting and beautiful drawing ever made of microscopic studies. It was Dutch scientist, Antony van Leeuvanhock (1632-1723), who observed a fantastic new micro-universe of protozoa and bacteria.

28.6.3 Chemistry and Others

In the mid - sixteenth century, Robert Boyle, an Irish scientist, helped establish the experimental method in chemistry. Boyle introduced many new ways of identifying the chemical composition of substances. However, it was in 1700's that modern chemistry developed. Scientists developed techniques necessary for isolating and studying gases in their pure forms. They discovered chlorine, hydrogen and carbon-dioxide. Oxygen was discovered by the Swedish chemist Carl Scheele in the early 1700's and independently by the English chemist Joseph Priestley in 1774. By 1777, Antonne Lovoisier of France had discovered the nature of combustion as a process of rapid union of burning material with oxygen. He also proved the law of conservation of matter which states that matter cannot be created or destroyed but only changes its form.

William Gilbert (1544-1603), the English Physician made a long series of carefully detailed experiments and observation on the nature of magnetism. His book, *About Magnates* (1600) was a classic of experimental science. Gilbert concluded that the Earth itself behaved like a giant magnet with its magnetic poles very near its geographical poles. Gilbert's researches into magnetism and its properties were not surpassed until well into the 18^{th} century when scientists began to investigate intensively on magnetism and electricity.

28.7 SOME INTERPRETATIONS OF SCIENTIFIC REVOLUTION

The origin of scientific revolution has been keenly debated by the historians of science and other scholars. One viewpoint sees development of science as autonomous creation of a few individuals' geniuses and great personalities with insight. Butterfield, for instance, stresses the role of individual genius. Other scholars relate the scientific developments to changes in societal, economic needs of the rising middle classes. They stress the lowering of social barriers between the scholars and craftsmen, the new technical needs of a dynamic society undergoing demographic change, rising productivity and commercial expansion and changes in cultural and religious spheres as factors responsible for the scientific developments. These trends, they believe led to a fusion of empiricism and rationalism (a product of Renaissance and Reformation), thus giving birth to a new kind of science based on observation and experimentation. However, it is difficult to see a direct link between a new secularised society, the technical needs of rising middle classes and the birth of science. Many of the people who contributed to 16^{th} and 17^{th} century scientific development belonged to the most divergent social groups and environments. They were professionals-university teachers, physicians, surveyors, engineers and noblemen. Many of them were steeped into medieval world of religion and magic, trying to find explanations worthy of God's perfect creation. The Medieval universities were not free from the burden of theology. The Renaissance humanism also did not make a direct contribution to the development of science, nor was it able to purge religious ideology and traditional world-view and authority of classics from universities. In a way, the works of scientific pioneers, as they refused to base their conclusions on traditions and established sources or ancient authorities, were their own creations, autonomous of social environment in which they lived.

We know that early discoveries of science were resented by the religious authorities including Protestant Martin Luther. The ideas of scientist were found to be opposite to the world-view of clergy. However, some scholars feel that experimental science, as a corollary of the Protestant ethic, was one of the most significant ideological manifestations of the Reformation. They point out the involvement of Calvinism in the development of science and scientific societies. They argue that the early Protestant ethos and scientific attitudes were similar and that there was certain congruence between the Protestant theology and notions of scientists. Christopher Hill, the renowned English historian, also tried to relate the puritan social ethic of merchant artisan classes with the intellectual development of experimental science. It is argued that the bourgeoisie encouraged science and Puritanism and adopted social attitudes conducive to scientific advance. The endeavour required active co-operation of craftsmen and practical puritan merchants. Such groups might have encouraged certain technological advancement as is symbolised by the stress on navigational techniques in the Gresham College formed by Thomas Gresham, the great London merchant and financier. This was an attempt to turn science in the service of solving vital practical problems. Such co-operation between practical puritan merchants and scientific activity, however, was rare. Resolution of certain practical technical problems did lead to better instruments such as the telescope, the barometer, the thermometer, the clock, the microscope and the air pump. These instruments were utilised for obtaining more knowledge. However, as we know from the background of many scientists of 16th and 17th century, they were trained and skilled in universities for a conceptual task far beyond the capacities of practical unschooled men.

28.8 DEVELOPMENT OF TOOLS AND METHODS: TOWARDS A BETTER MASTERY OVER NATURE

There has been a considerable debate on whether Puritanism and the merchant classes correlated in anyway to scientific development and technological changes. It appears that specific technological advances in this period were results of the skill of craftsmen while scientific revolution was product of middle class educated men. Their achievements owed little to the actual technical tools and methods of the workshops. In other words, the brilliant work of men of science was different from the world of practical and often unlearned craftsmen who made new innovative tools. Many of the discoveries of scientists of this period had no immediate practical utility. On the other hand, technology and its tools and instruments served the cause of scientific revolution.

28.8.1 Sources of Power

Many of sources of power used in the Western Europe were still the inventions of Middle Ages. For instance, the invention of horse-shoe, the paddled rigid horse collar and the stirrup transformed horse as a major source of power. Horse became more efficient draft animal due to harnessing of horse collar to the heavy plough. It could also be easily put to military use. Apart from animal power, Europe inherited from the Middle Ages use of Norse Water-Mill, using a horizontally mounted waterwheel driving a pair of grind stone directly and a modified version of Water-Mill known as Greek Mill. The Water-Mills were extensively used in grinding of grain, sawing of wood, crushing of vegetable seeds for oil and in woolen textile industry.

Wind-mills were another major source of power especially in low-lying areas where rivers could offer little energy such as Spain, the down lands of England and the fenlands and polders of the Netherlands. By 15th century, the post-mill (in which the whole body of the mill pivots on a post and can be turned to face the sails into the wind) were substituted by the tower-mill type of construction. In the latter, the body of the mill remained stationary with only the cap moving to turn the sails into the wind.

Mineral coal partly replaced wood and charcoal as the source of heat in the 16th and 17th centuries. It was used in several industries in Western Europe such as production of metals, bricks, glass, salt, soap and textiles.

28.8.2 Transport and Navigation

In the field of land transport, some improvements were achieved in road-making. There were also experiments in bridge-building and construction of canals. Canal du Midi (1692) between the Mediterranean and the Bay of Biscay stretching over 241 kms was a marvel of civil-engineering feat. The canal had a hundred locks, a tunnel and three aqueducts, many culverts and a large summit reservoir.

However, major breakthroughs came in the field of navigation which saw building of ocean-going ships dependent entirely on wind power. The European ships combined traditional square sail with Arab triangular Lanteen sail, an innovation that allowed ships so equipped to sail close to the wind. The adoption of stern-post rudder increased the maneuverability of ships. Introduction of magnetic compass provided a means of checking direction on the open sea in any weather. Other fifteenth century developments also helped in the conquest of seas. The astrolabe, an instrument Arabs had invented as early as twelfth century, could be used to determine the altitude of sun and other celestial bodies. It permitted marines to plot their latitude or position in relation to equator. Better navigational charts, maps and manuals further assisted this conquest. The substitution of wind power for manpower, and mounting of cannons on ships gave Europeans advantage over other people. Cipola aptly remarked about the opening of China to the West “While Buddha came to China on white elephants; Christ was borne on cannon balls.”

28.8.3 Printing Technology

The invention of printing in the mid-1400 by Johannes Gutenberg of Germany combined several existing technical practices such as ink, movable type, paper and the press. Printing proved to be a cost-effective and easier way of disseminating information and knowledge. Pi Sheng, a Chinese alchemist, had conceived of movable type made of an amalgam of clay and glue by baking around 1041-48. He composed texts by placing the types side by side on an iron plate coated with a mixture of resin, wax, and paper ash. Gently heating this plate and then letting the plate cool solidified the type. Once the impression had been made, the type could be detached by re-heating the plate. By 12th century, paper had been diffused as an invention through trade routes by Arabs to the European lands. Paper-mills were built in Italy, France and Germany in 13th and the 14th centuries using these techniques. Similarly, the knowledge of typographic process was spread by Ulighars, a nomadic people on the border of Mongolia and Turkistan.

Johannes Gutenberg combined the process of typography with the concept of printing press. He used association of die, matrix and lead in the production of durable typefaces in large number and with each letter strictly identical. He made type-pieces with alloy of lead, tin and antimony. Tin was used because lead would have oxidised rapidly and casting would have deteriorated the lead mould matrices. Antimony was used because lead and tin alone would have lacked durability. The printing press itself, vital for securing a firm and uniform print over the whole page, was an adoption of the screw press already familiar in the wine press and other applications. The printing press with a lower level fixed surface and a movable level upper surface moved vertically by means of a small bar on a worm screw. The composed type, after being locked by screwed tight into a right metal frame, was inked, covered with a sheet of paper to be printed, and then the whole was pressed between two surfaces.

The first major workshop, using this technique, was established at Mainz (1455-56). Soon many such work-shops were established in commercial centres of Germany, Italy and France. The printing technology was introduced in England by William Caxton in the last quarter of 15th century. Soon the revolutionary potential of this new technology was realised. It became an essential medium of commercial, social, religious and scientific communication. By 1500, about 40,000 recorded editions of books were printed in European countries.

28.8.4 Some Other Major Technological Changes

Mechanical clock was another significant technical device manufactured during 14th and 15th centuries. By mid-15th century, clocks driven by springs were constructed. It led to the development of more compact mechanism and opened the way for portable clocks. The problem of diminishing power of clock's spring as it unwound was solved by simple compensating mechanism of the fusse – a conical drum on the shaft that permitted to exert an increasing momentum as its power declined. It is difficult to say whether this invention was due to importance of time-keeping in business or simply a product of a new sense of inquiry into the possibilities and practical uses of mechanical devices.

The soap-making was probably a Teutonic invention of The Middle Ages that became important in this period. The process consisted of decomposing animal or vegetable fats by boiling them with a strong alkali.

The iron industry developed as a result of two inventions-bellows driven by powerful water wheels and harnessing of water-power to work the hammers which forged iron into bar form. There were also important technological changes in brass manufacturing. Brass was produced by heating copper with charcoal and calamine, an oxide of zinc and was worked up by hammering, annealing (a heating process to soften the material) and wire drawing.

28.9 IMPACT ON SOCIEITY

The rise of modern science and the spirit of enquiry affected the society in many ways. Firstly, it went hand in hand with the emergence of a new and expanding community of professional scientists. The institutionalisation of science linked members of this community in learned societies, common interests and shared values. Expansion of scientific knowledge was the primary goal of this community.

Secondly, the scientific revolution inaugurated the modern scientific method. This new method of acquiring knowledge about nature was highly critical, and based on experimentation and observation. It refused to base its results on the authority of traditions and sacred texts.

Thirdly, the scientific revolution did not affect the economic life and the living standards of masses to any great extent until the late eighteenth century. Although changes in navigational techniques facilitated over seas trade and enriched leading merchant houses, it had relatively few practical economic applications for the common men. The scientific revolution was, at this stage, more of an intellectual revolution. It created a new world-view of Enlightenment, which is often associated with the idea of modernity. This world-view, which played a significant role in the shaping of modern mind, was based on a rich amalgam of ideas. The idea of reason that applied the methods of natural science to understand all aspects of social life, however, was central to this intellectual revolution.

28.10 SUMMARY

In this Unit we have provided a brief survey of new advances and developments in the area of science and technology. These developments in many ways signal a transition from the medieval period. One of the important advancement in our knowledge was in the area of astronomy. The works of many astronomers and especially of Copernicus, Tycho Brahe and Johannes Kepler presented new knowledge about the universe and celestial bodies. Their findings, based on keen observation and study of planets, challenged many of the myths and traditional ways of understanding the subject. Many of these new findings were criticised by the church as they contradicted the religious explanations about the universe and its mechanism. We notice that now for the first time the experimental methods get established for explaining laws of nature. The science as a whole comes to occupy the space of tradition, rationality and logic tend to overtake traditional wisdom and methods of experiments get further refined. Institutionalisation of science is one of the major achievements of this process of transformation.

Apart from Astronomy a number of scientific advances were made in the area of Physics, Mechanics, Chemistry and Life Sciences. The researches of Galileo and Newton were significant in the area of Physics. While the former involved the study of celestial bodies the latter formulated his laws of motion. The researches of Vesalius helped in a big way in understanding the human anatomy and diseases which affect the body. Scientists like Boyle, Priestley and Lovaisier helped in establishing the experimental methods in Chemistry.

The new scientific knowledge and methods led to the development of technological devices, improved instruments and tools and application of knowledge of one branch of science to others. The establishment of watermills and wind-mills provided new sources of energy. Improvement of navigational tools contributed in a big way in exploration of seas and long distance voyages. Printing technology completely transformed the method of communication and helped in the expansion of knowledge across regions and societies.

28.11 EXERCISES

1) What was the contribution of Copernicus in the field of astronomy?
2) How did Galileo contribute to the development of experimental method in science?
3) What do you understand by institutionalisation of science?
4) Describe Vesalius' role in development of modern anatomy.
5) Was scientific revolution a creation of talented scientists or product of social forces?
6) How did new technology introduce changes in the area of navigation?
7) How did printing influence society?