UNIT 29 MODERN DEVELOPMENTS IN SCIENCE AND TECHNOLOGY—I

Structure

29.1 INTRODUCTION

Products of modern science and technology have become a part and parcel of our daily life. Whether we are situated in farflung villages or in the hustle and bustle of cities, we come across these products everyday — in food and agriculture, in transport and communications or in various other articles we use. You have already read about some of these technologies in Unit 28. There are several modern technologies which we may not come across directly, but we do read about them in the newspapers or magazines. One day we are told about exciting developments in semiconductors, computers, robotics or artificial intelligence, another day about lasers, optical fibres or materials science and technology. Millions of us have watched Squadron Leader Rakesh Sharma and astronauts from other nations make successful trips in space — a feat made possible only due to the advances in space technology. Biotechnology is a hot topic of debate and discussion these days. So is fission technology. Fusion may replace fission as a source of nuclear energy by the beginning of the next century, if the rapid pace of development continues.

You have studied, in Unit 27, that we shall be using in the next ten or fifteen years (or even earlier) technologies that are now in the making. Hence, one of the last parts of this course tries to acquaint you with the emerging technologies. We would also like you to know and think about the likely social impact of these technologies, about the benefits their proper use might confer on us and the problems and difficulties their misuse might create for us. So that, if the need arises, you could consciously react to and influence issues relating to these technologies. What is being said about each technology is very brief. If some of you develop an interest in any of these technologies and wish to study them further, a list of books has also been provided at the end of the unit. In this unit we discuss lasers, fibre optics, space technology, fission and fusion, and biotechnology. In Unit 30, we will take up semiconductors, computer technology, robotics, artificial intelligence, and materials science and technology.

Objectives

After studying this unit you should be able to :

- list properties that make light from a laser different from sunlight or light from ordinary sources, such as fluorescent tubes, bulbs etc.,
- state what an optical fibre is,
- explain the functions of rockets, artificial satellites and space probes,
- describe nuclear fission, nuclear fusion and a nuclear reactor,
- state what biotechnology is, and explain genetic engineering and enzyme immobilisation,
- describe the applications of the technologies discussed in this unit.

29.2 LASER: PUTTING LIGHT TO WORK

LASER stands for **Light Amplification by Stimulated Emission of Radiation.** It's a fairly long string of words. Well, don't let it stop you from reading further. What we wish to bring out here is that lasers produce a very special kind of light. The light that lasers produce has several useful properties that make it different from ordinary light. It is because of these properties that laser light can be put to work in a number of ways.

Refer to Fig. 10.1 and Sec. 10.2 in Unit 10 to know what is meant by wavelength.

You may wonder what the difference between ordinary light and light from a laser is. Light from the Sun or from a lamp in your home is a mixture of many wavelengths. Each wavelength produces a different colour. These colours mix and form ordinary light. We have all seen colours in the sunlight separating out to form a rainbow in the sky after a rainy day. Moreover, light waves from an ordinary source of light are all jumbled up and uncoordinated in their movement (Fig. 29.1a).

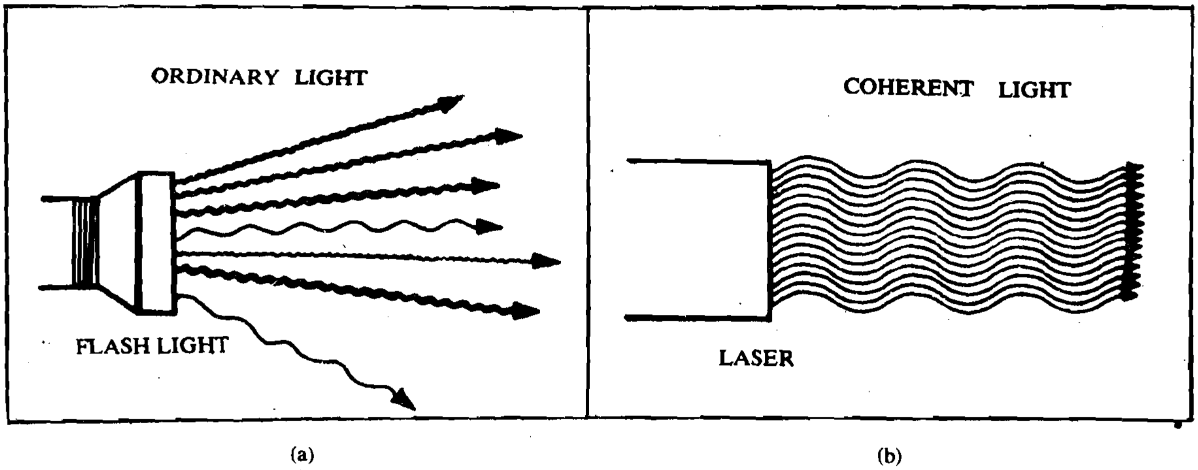

Fig. 29.1: (a) Light from an ordinary source is made up of many wavelengths and the waves move in different directions; (b) laser light is of a single wavelength and all the waves are in phase with one another, i.e. the crests (hills) and troughs (valleys) of one wav- fall on top of the crests and troughs of other waves.

Laser light is made up of waves of the same wavelength. What is more, all the waves in a laser beam are organised to proceed exactly in step (in phase) with each other (Fig. 29.1b). This property of lasers is called **coherence**. It reminds you of contingents of smartly dressed men moving in unison in the Republic Day parade. Or of the uniform movement of oars in boat races of Kerala held on Onam. Does it not? As a result of coherence, *light waves in a laser beam can travel large distances without spreading apart. Because a laser beam does not spread out, there is a large concentration of energy per unit area on the object on which the laser beam falls.*

29.2.1 Applications of Laser

Due to its properties, laser light can be put to a number of uses in industry, medicine, communications etc. We will briefly describe some of these uses. Because of the high concentration of energy, a laser beam can quickly burn tiny holes, a few millimetres wide, even in a strip of steel. Lasers have an advantage over all other traditional methods of cutting and welding. Using lasers you can cut any kind of material, such as paper, plywood, plastic or cloth, as also the hardest of metals, ceramics and glass with greater efficiency and accuracy. Lasers can, thus, make an ideal tool for metal workers, carpenters and tailors, apart from engineers.

Military Applications
Another area where the above mentioned properties of lasers are being used with a 'deadly' precision is that of military applications. Lasers have been pressed into the service of the global war machine. A whole range of laser weaponry has come into being, for use on land, on sea and in space. X-ray lasers that can carry enormous energy have been developed. Efforts are on to install deadly laser weapons in satellites. The same technology could be used to destroy factories, forests, farms and habitation. It is certainly a matter of concern to see so much human effort and wealth being used to turn the laser technology into an instrument for mankind's destruction. Every effort should be made to stop this misuse of technology.

Healing Touch of Lasers
Contrast the above application of lasers with their uses in medicine where the laser is working wonders.

A laser can be applied with almost perfect precision in surgery. It can burn away diseased tissue without damaging the healthy tissue nearby. The tissues are cut neatly and without any oozing of blood, and they can also be joined together. Lasers are completely sterile, because bacteria cannot survive exposure to a laser beam. Today, lasers are routinely used in eye surgery to treat detached retinas and to destroy abnormal blood vessels that form in the retinas of diabetic patients. Earlier these diseases would result in blindness. For such patients, laser is indeed a "miracle light". Lasers have become standard equipment for ear, eye and other delicate forms of surgery. From removing brain tumours, to stopping bleeding from ulcers, and treating cancer of the bladder, lasers find a wide use in medicine (Fig. 29.2).

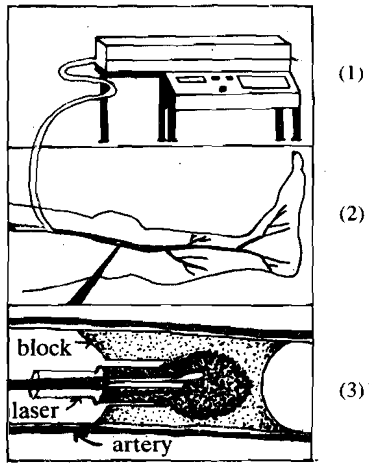

Fig. 29.2: A laser beam (1) guided by an optical fibre (2) burns the block in the leg artery (3).

Communications
Lasers have also become an important means of long distance communication. Travelling through hair-like glass fibres, laser light can be made to carry thousands of times more information than electric signals in conventional copper wire. Thousands of telephone calls can be transmitted on a single fibre.

Other Uses
Lasers may be used to measure the distance of objects like the moon from the earth. Here, time taken for a laser beam to reach the moon and be reflected back to the earth is measured. As you know, light travels at the speed of 3×10^5 km per second. Thus, the distance can be found from the simple formula : distance = speed $\times$ time.

Laser beams are also used to read and play the music or images recorded on CDs (compact disks), and read the information stored on CDROMs in computers.

Among other things, scientists use lasers to monitor small traces of chemicals polluting the atmosphere because these molecules disturb the passage of the beam and thereby reveal themselves. Efforts are being made to transmit power by means of laser beams. Laser beams are used to etch music and video pictures on records which look like ordinary gramophone records. Such records can be played back by a laser beam and, thus, they never wear out. If you happen to visit a science museum you will see **holograms** of various objects. These are life-like three dimensional images created by laser beams.

Thus, you see that lasers can be put to endless uses for the benefit of human beings. These uses seem to be limited only by the imagination of the scientists and engineers. And the best is yet to come.

SAQ 1

a) Using the words given below, fill in the blank spaces in the following statements about lasers and their properties.

   i) Lasers are sources of a special kind of .... which has several useful properties.

   ii) A laser beam can carry energy or .... over .... distances.

   iii) Lasers can direct a large .... of energy per unit .... on the object on which it falls because it does not ....out.

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light, spread, amount, signals, long, area

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b) Here are a few applications of lasers. Which of the properties of lasers mentioned in part (a) of this SAQ are being utilised for these applications? Write the appropriate numbers against each application.

i) Finding the distance between the earth and the moon. ....

ii) Drilling holes in baby bottle nipples. ....

iii) Shooting down missiles. ....

iv) Transmitting phone calls. ....

The application of lasers in communications has been made possible largely due to the advances in fibre optics. Let us know about fibre optics and its applications.

29.3 FIBRE OPTICS

Radiowaves are electromagnetic waves of long wavelength. See Sec. 10.2 in Unit 10 to refresh your memory.

The songs you hear on your transistor, or the pictures you see on your TV are carried from the studios to your home on radiowaves. Telephone calls you make, on the other hand, are transmitted by electric current flowing in copper wires. In the recent past, new technologies have appeared for transmitting various kinds of electric signals on glass fibres. This has been possible due to the advances in **fibre optics** technology.

Fibre optics is the technique of transmitting light waves through glass wires as thin as human hair.

These wires called **optical fibres** could be made of glass or transparent plastic, quartz, nylon or polystyrene. *Optical fibres are thin hair-like solid strands that carry light along their length, by a process of multiple total internal reflections* (Fig. 29.3). We will not go into the details of the process. In this process the beam of light entering at one end is transmitted along the fibre, without loss of intensity, whether the fibre is straight or bent in a curve.

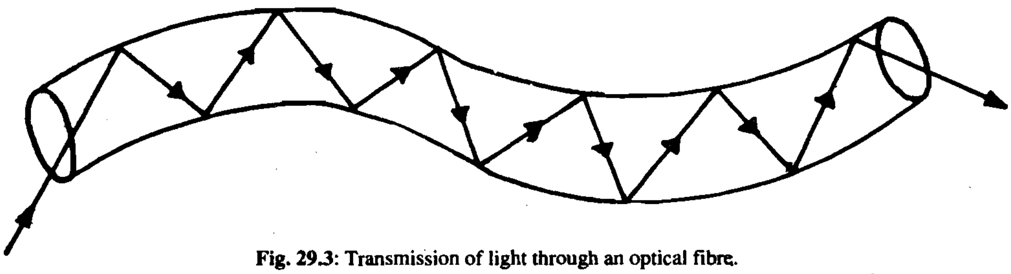


Fig. 29.3: Transmission of light through an optical fibre.

29.3.1 Applications of Optical Fibres

Fibre optics finds many applications in areas like medicine and communications which we will briefly describe. We will also discuss its advantage over traditional technologies.

Viewing inaccessible regions
Instruments made of optical fibres, called **endoscopes**, are used to see the internal organs of the human body, such as the interior of the stomach, or the bronchial tubes. Inserted into the body, some fibres of the bundle carry light so that the internal organ is lit up. Other fibres are used to return light so that the image of the interior is carried to the observer outside. Endoscopes are often connected to a camera or TV monitor. Since these fibres are very fine, they can be inserted easily in the body. The images are very useful in heart and brain surgery and in diagnosis of some other diseases.

Freeing crowded cableways
The use of optical fibres has been very advantageous in telecommunications. Signals of voice, text, computer data or picture transmissions are superimposed on laser beams. The modulated laser beams are then guided along optical fibres, to various points where they are received. At the receiving end, one is able to hear the voice, read the data or see the picture (Fig. 29.4).

The signal carrying capacity of light waves is much greater than that of radio waves or waves along copper wires. Therefore, the light waves travelling in fibres can carry thousands of different signals. For instance, a pair of glass fibres can carry 1300 telephone calls at the same time, as against 24 for copper wires.

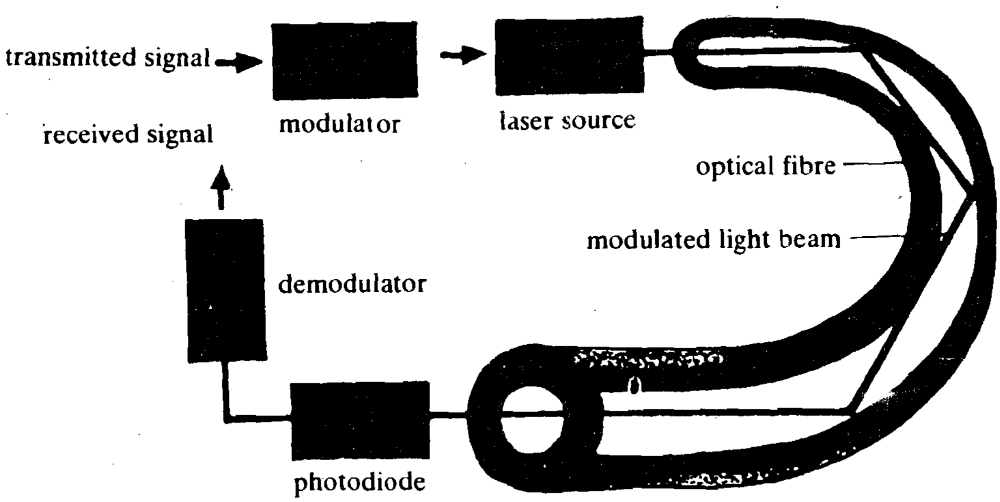


Fig. 29.4: The fibre optic link between telephone exchanges. A laser beam with the signal impressed on it, is directed at one end of the fibre. It emerges at the other end. A photodiode converts the light beam into electric current. The demodulator recovers the original signal.

The use of laser beams in optical fibres enables the transmission of signals for thousands of kilometres. Transatlantic undersea fibre–optic cables have been in use for communication between USA and UK. Instead of being broadcast from antennas, TV programmes can now be transmitted through fibre-optic cables. The cable TV can, thus, make available several channels to the viewer. Preliminary experiments on the use of fibre-optic technology in India are being done so that we can also take advantage of this technology in the coming years. Indian research laboratories have already developed the technology of producing the special glass, drawing fibres from it and giving it a special coating so that internal reflection takes place with a minimum loss. Indian industry is now manufacturing optical fibres.

The fibre optics technology has many advantages over the traditional technology. An optical fibre cable, the size of an ordinary electrical cord, can replace copper cable hundreds of times thicker. Optical fibres are light and sturdy. They are much less expensive than copper wires for the amount of information they carry. Because optical fibres carry light beams, they are free from the disturbances, such as you hear on the radio due to nearby electric disturbances. Fibre-optic communication is also advantageous for military communication because it cannot be "jammed"

It is possible to interfere with and disturb messages being sent on radio waves, by transmitting other radio waves of the same frequency at the same time. This process is called 'jamming'.

There may come a day when optical fibre cables enter many of our houses carrying not only telephone calls but also television programmes, communication from computers and electronic mail sent from person to person.

SAQ 2

a) Select from i) to vii) below the **three true** statements about optical fibres and write your answer in the space given below.

An optical fibre is:

i) a hollow hair-like thin transparent wire that carries light.

ii) a solid hair-like thin transparent wire that carries radio waves.

iii) a solid hair-like thin transparent wire that carries light.

iv) made up of a transparent material like glass, quartz or polystyrene.

v) used to carry information to nearby places.

vi) used to carry large amounts of information.

vii) more expensive than a copper cable.. .

b) The following is a summary of what you have just learnt about fibre optics. Fill in the blank spaces using the words given below:

Fibre optics is a technique that provides a way of transmitting information. It transmits information on .... Light travels in glass wires known as .... Fibre-optic cables are .... and transmit more information without loss and disturbance when compared with .... and .... Optical fibres are made from .... material.

optical fibres, electric current, lighter, cheaper, light waves, radiowaves

You have just read about lasers and fibre optics. We will now describe space technology, another major technology to have emerged in modern times.

29.4 SPACE TECHNOLOGY

In a flat dry plain called the Sea of Tranquillity on the moon, is a footprint. This footprint was left there by Neil Armstrong. He was the first human being to walk on the moon. He was a member of the 3-man crew carried to the moon by the American spacecraft Apollo 11 in July, 1969.

It was a dream come true for mankind — a dream of flying into space and visiting another body in the universe. Since then great strides have been made in space technology. The first step in this direction was the development of rockets.

Rockets or Launch Vehicles

Every flight into space begins with a rocket launching. The **rocket** can lift a satellite or spaceship carrying human beings and equipment into space. Therefore, it is also called **launch vehicle.** The rocket has been known to mankind for centuries. Rockets used as firecrackers are a common sight on festive occasions in our country. But the rockets that launch space vehicles use highly advanced technology, and, of course, they are far more powerful.

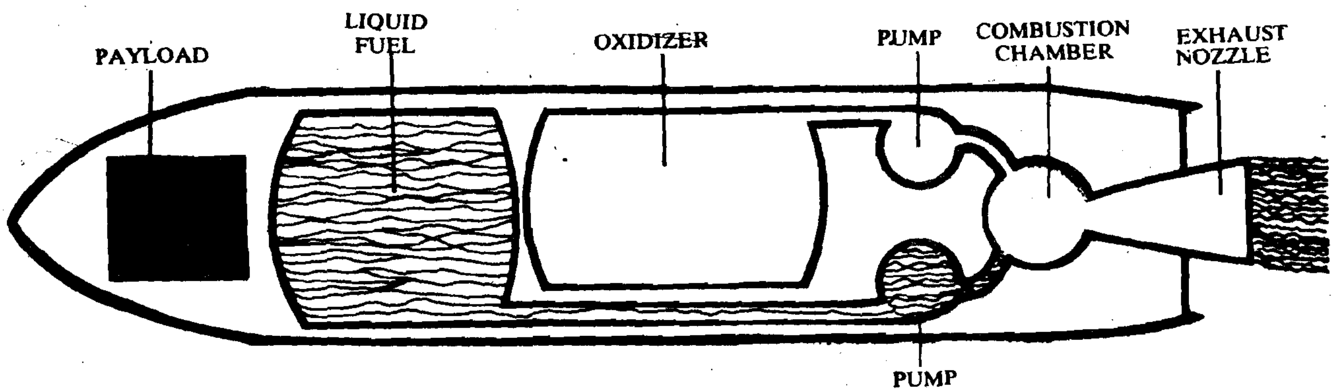


Fig. 29.5: Cutaway view of a liquid-fuel rocket. Pump drives fuel and oxidiser to combustion chamber.

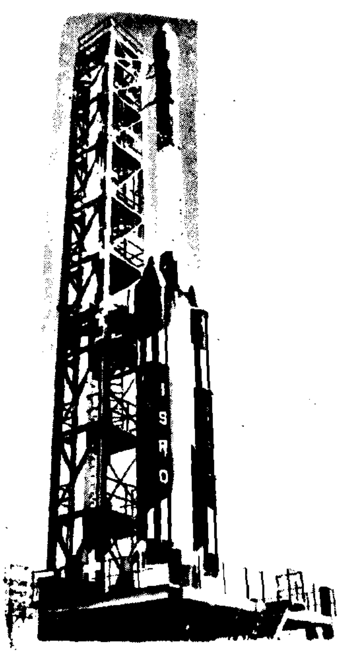


Fig. 29.6: The multi-stage Indian Rocket PSLV.

When the fuel in the rocket is set to fire, a stream of hot gases is expelled at a high speed from its rear end (Fig. 29.5). *As a reaction to the thrust of the gases, the rocket moves in the opposite direction. As long as the fuel in the rocket burns, shooting out gases, the rocket continues to accelerate forward, and acquires great speed.*

No single rocket fired from the earth can attain in one go the high speeds needed to orbit the earth, or to escape its pull. Higher speeds are reached by using big and small rockets, in stages, in the launch vehicle. As the large rocket soars into space and uses up its fuel, it is separated from the smaller rocket and drops off. The smaller rocket already going at high speed is then fired to accelerate it to an even higher speed. Three-stage rockets are usually able to achieve speeds suitable for most purposes in space (Fig. 29.6). The final stage of the launch vehicle carries the payload.

Activity

Verify the principle of rocket motion by releasing an inflated balloon with its neck open.

The different kinds of payloads that rockets carry into space include artificial satellites and space probes to nearby heavenly bodies. The satellites and probes themselves carry communication and research equipment.

Artificial Satellites—Tireless Servants in the Sky

The space crafts that move in an orbit around the earth are called **artificial satellites.** Most satellites go around the earth once in about 90 minutes at a height of a few hundred kilometres. But it is possible to launch satellites with a proper speed at greater heights (around 36,000 kms). They would then move around the earth once in 24 hours and hence appear to be stationary. Such satellites are called **geostationary** satellites.

As you have read in Unit 26, our own INSAT series of satellites are geostationary satellites. Every night, towards the end of TV news on any channel, we are shown pictures of clouds over India. These pictures are taken by INSAT satellites and televised to the earth. Apart from monitoring the weather, INSAT satellites are used to receive and retransmit telephone calls. Television programmes are also relayed via these satellites.

Satellites carry equipment to survey the earth's natural resources and monitor weather. India's satellite programme has also provided useful information on agricultural land and prospecting for ores and minerals. Recently, the satellite IRS 2D in the IRS (Indian Remote Sensing Satellite) series has been launched to survey India's natural resources by remote sensing methods.

The effect of living in space on plants and animals is also studied in satellites. At present, Russia has a space station called Mir going round the earth as a satellite. Crew members and supplies are regularly sent to this station where three or more persons work at time, for periods as long as a year. Satellites can pinpoint sources of pollution, spot forest fires and locate areas of disease in crops and forests. Weather conditions can be monitored by satellites enabling us to predict storms and prevent damage. Satellites also help in locating and guiding ships. But the maximum use of satellites is made for communications.

Space Probes—Journeying to Neighbouring Worlds

If a spacecraft is directed to move out in space, away from the earth, it is called a **space probe**. As you read in Unit 11, several unmanned space probes have either passed by or landed on the planets Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune. They have sent back valuable data and photographs of all these planets. So we have come to know what these planets look like from near, what they are made up of, and what physical conditions prevail near them.

SAQ 3

a) INSAT–2D is a geostationary satellite. Which **two** of the following statements about INSAT–2D are true? Write T against the appropriate choices.

i) It circles around the earth at a height of 400 kilometres. ....

ii) It completes two orbits around the moon in 24 hours. ....

iii) It can be used to give advance warning of cyclones and prevent loss of life and property. ....

iv) Experiments on plants are being done aboard INSAT-2D ....

v) It has sent valuable data about the neighbouring planets to the earth. ....

vi) It circles the earth once in every 24 hours. ....

b) Write in the space given, which of the following spacecraft is a rocket, an artificial satellite or a spaceprobe?

i) Intelsat can bring home to us on TV any event occurring in the world. ....

ii) The spacecraft Pioneer sent the first photographs of Jupiter to the earth ....

iii) Saturn-5 put the manned Apollo spacecraft in its orbit around the moon. ....

29.4.1 Dividends from Space

When the space programme began, its primary aims were research, adventure and national prestige. As it expanded, the investment in it also grew. It is now a highly expensive undertaking. A natural question to ask is, how does it benefit humankind.

There have been many benefits from space programme. In meeting the challenge of space travel, scientists and engineers have come out with a stream of innovations. These are equally useful on the earth. Some examples are—new materials for use in industry, e.g., light but strong alloys, better steel, plastics and adhesives. Highly reliable and tiny electronic components made for spacecraft are now used in TV and other electronic goods. Computers have become compact. Medical instruments made for astronauts are used in hospitals. New technology for food preservation saves energy. Ultra sensitive fire alarms and fireproof fabrics have been developed. The list is very long.

If you add to it the benefits derived from a satellite, like weather forecasting, prospecting or communication, it becomes truly remarkable. As you have read in Unit 26, the satellites are being used in a big way not only for news and information but also for education.

Programmes initiated from a few places can reach people situated in distant and inaccessible locations. Most parts of our country can now be reached through satellite supported television.

As it is with all scientific endeavors, space can also be misused. Either bombs, laser machines or other kinds of weapons can be stationed there. There is a world-wide and strong opinion to prevent the use of space for war-like purposes.

Perhaps the futility of war-mongering is realised most if one looks at space travel from another view. Travelling in space has given man an entirely new view of his home, his planet Earth. It has shown the earth as a beautiful planet, rich in colour, movement and life. Our planet is a "closed system", dependent only on the sun for energy, with limited resources that cannot be replaced. It is a spaceship itself, fragile and isolated in the vast universe—a flicker of life very precious. Certainly, the planet Earth demands preservation as a single environment. We have only one world. We must protect it from those who because of their greed or ignorance would use science and technology to destroy it.

Nuclear fission and fusion technology is another such technology which can be put to destructive use. However, strong public opinion around the world has served to curb its destructive use to some extent. Let us now examine this technology and various issues related to its use.

29.5 FISSION AND FUSION ENERGY

'The Italian navigator has arrived in the new world'

This coded message announced the beginning of the atomic age on 2nd December, 1942. The 'navigator' was the Italian-American physicist Enrico Fermi. That afternoon, in a squash court under the stadium of Chicago University of USA, Fermi and his team of scientists succeeded in taming the atom for the first time. In the heart of the first atomic furnace, atoms were made to split, under strict control, to produce energy. Fermi had indeed ushered in a new world. Today, in the giant atomic power stations around the world, or in nuclear weapons, we can see how far this discovery has taken us.

29.5.1 Nuclear Fission: Splitting the Atom

You know that atoms are made up of a nucleus and electrons moving around the nucleus, and the nucleus is made up of protons and neutrons. The principal actor in the fission drama is the uranium atom. The nucleus of the Uranium 238 atom has 92 protons and 146 neutrons. About one atom in 140 atoms of uranium has 143 neutrons in its nucleus. It is called Uranium 235. It is the Uranium 235 that is mostly used to provide fuel for nuclear furnaces.

Before the Second World War, two German scientists discovered that if neutrons were shot at the nuclei of Uranium 235, the nuclei split into two and produced other neutrons to repeat the process. This is called **nuclear fission** (Fig. 29.7a).

Nuclear fission is the splitting of a large nucleus into two smaller nuclei.

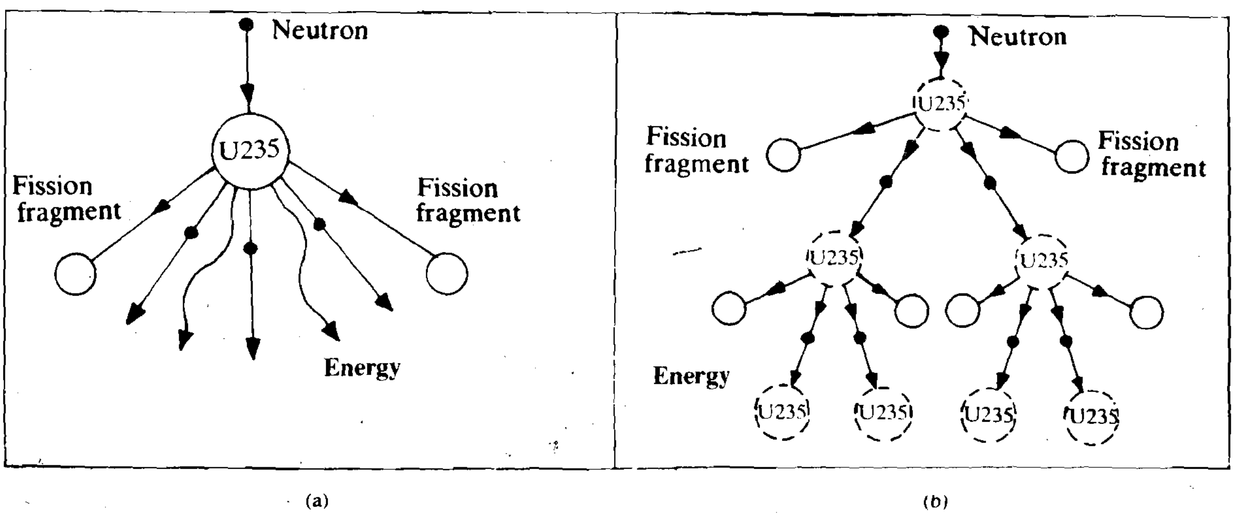


Fig. 29.7: (a) Nuclear fission; (b) chain reaction.

Release of Energy

When the atom splits, the masses of the fragments and the neutrons produced do not add up to the mass of the original. A tiny amount of matter disappears. This lost matter turns into energy. The amount of energy 'E' generated by the lost matter of mass 'm' is given by the famous equation due to Einstein:

$E = mc^2$, where c is the speed of light.

c is large (about 300 million metres/sec) and c^2 is enormous (about 90,000 trillion m^2/sec^2). Thus, a small amount of lost matter would get converted into very very large amounts of energy.

Chain Reaction

When the atomic nucleus splits, it not only gives off energy, but also throws out two or three more neutrons. These new neutrons can, in turn, split two or three other atoms. This way they release more energy and more neutrons, which will split more atoms. In other words, once the splitting of the nuclei starts, it becomes self-sustaining. This whole process is called a **chain reaction** (Fig. 29.7b). If the chain reaction is allowed to go on, it would lead to an explosive release of energy. Control it by absorbing the extra neutrons and you have the slow, smouldering reaction of the "nuclear reactor". This serves as a source of energy much like a thermal power station. We will now describe the nuclear reactor. But how about trying an SAQ first!

SAQ 4

a) State in the boxes given, which of the following statements about nuclear fission are true (T) or false (F).

i) Nuclear fission is the process in which two light nuclei are formed when a heavy nucleus splits. ☐

ii) The sum of the masses of the resulting nuclei is exactly equal to the mass of the parent nucleus. ☐

iii) When an atomic nucleus splits, it only gives off energy and nothing else. ☐

iv) In nuclear fission a small amount of matter disappears and is converted into energy. ☐

v) The amount of energy released is huge because it depends on the square of the speed of light. ☐

b) In the space given below draw the next step of the chain reaction shown in Fig. 29.7 (b).

29.5.2 Nuclear Reactor

Nuclear fission can be maintained as a controlled chain reaction in a nuclear reactor to produce energy.

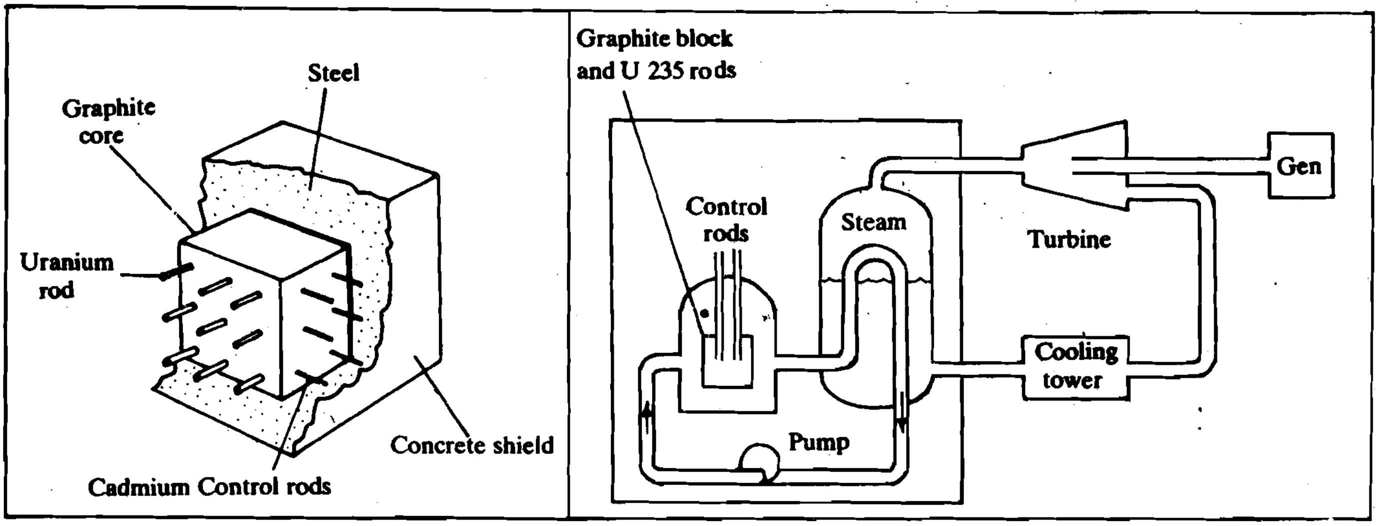
The black 'lead' used in pencils is, in fact, made of graphite and not lead, as it is mistakenly called.

Fermi had found from experiment that *slower moving neutrons were more effective in causing nuclear fission.* But most neutrons produced by the splitting of the nuclei are quite fast. A way was required to slow them down. It was found that certain materials slow down the neutrons. Graphite, a pure form of carbon, is one such material. Such materials are called **moderators.**

There was still the problem of controlling the chain reaction so created, that is, to stop the reaction or allow it to proceed at will. Materials which absorb neutrons would serve to control the reaction. The neutrons absorbed by such materials would be removed and would no longer split atomic nuclei. And the reaction would be controlled. The material usually chosen as an **absorber** of neutrons, is cadmium or boron steel.

In a nuclear reactor (see Fig. 29.8a), rod-like containers of Uranium-235 are inserted in holes made in a huge block of graphite. The graphite block slows down neutrons to enhance the chain reaction. Control rods of cadmium are also inserted into the graphite block. When pushed out, they absorb fewer neutrons and the reaction is speeded up.

The problem, then, is to remove the heat and use it to generate electrical energy. This is achieved by circulating water, or liquid sodium to absorb the heat generated in the graphite block. This heat may generate steam, which can turn a turbine (a wheel with slanting blades) and the connected electrical generator (Fig. 29.8b).



(a) (b)

Fig. 29.8: (a) A schematic diagram of a nuclear reactor; (b) heat generated in nuclear fission is used to convert water into steam in most of the reactors. The steam drives a turbine which is connected to an electric generator. The steam is cooled and reused.

1 Megawatt = 10^6 watts. Watt is the unit of power, which is the amount of energy used per second.

Today we have reactors capable of yielding power upto 500 Megawatts. Smaller reactors which give 1 to 5 Megawatt power are mostly used for research work. The large ones are used for producing electricity, and driving submarines, or ships. From the uranium rods used in the reactor, another fissionable material like Plutonium 239 may be obtained. Thus, a reactor set up to generate energy can become a source for obtaining material for making a bomb. India is committed to the use of nuclear energy for peaceful purposes.

SAQ 5

Give short answers in the space provided.

a) What purpose does the huge block of graphite serve in a nuclear reactor?

....

....

b) How is the speed of a nuclear reaction controlled?

....

....

Hazards of a Nuclear World

The picture painted above seems rosy. Yet, it does have a few shades of grey. There are many risks associated with the use of nuclear fission energy. These risks have caused world-wide debate, controversy and at times fear. Accidents have happened in nuclear power plants everywhere in the world.

In 1986, there was a major nuclear accident at the Chernobyl Nuclear Power Plant in the then USSR. Rare as they are, such accidents raise demands for a complete ban on nuclear power plants. However, an unbiased assessment of the past accidents indicates that this is not the answer. A better solution lies in the need to reassess plant safety, devise improved methods of avoiding or containing the extent of mishaps. In India, there has been heated discussion on this issue, but on the basis of several precautions and safety measures, it has been decided to go ahead with the programme of generating about 4000 Megawatt power by this method, by the year 2000 A.D.

Another major problem is the disposal of radio-active waste material from the spent uranium rods of the nuclear reactors. Several alternatives are being tried out everywhere in the world, for example, burying it thousands of feet deep in the earth or in the ocean bed. Some western countries were recently reported to be dumping the highly injurious radio-active waste in African or South American countries.

From mining of the ore, to nuclear waste disposal, each step in the nuclear fuel cycle carries risks. The risks and benefits of each step depend largely on a strict watch over malfunction and human error. The challenge is to eliminate the risks and to increase the benefits.

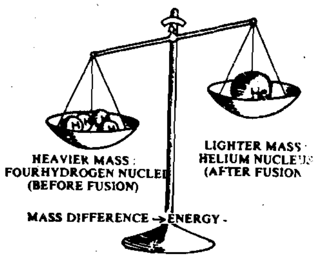


Fig. 29.9: An imaginary sketch showing a typical nuclear fusion reaction.

29.5.3 Nuclear Fusion: The Ultimate Source of Energy

An energy hungry world views with envy the glowing power of the sun and the stars, which is based on a slightly different nuclear process called **nuclear fusion**.

Nuclear fusion takes place when two light atomic nuclei join or fuse together to form one nucleus.

Fig. 29.9 shows one of the simplest fusion reactions. Two nuclei of heavy hydrogen (deuterium) also fuse to give a nucleus of helium, a neutron and energy. In this process a tremendous amount of energy is released. Half a kilo of deuterium gas would yield as much energy as 1300 tons of coal. What is more, we can get deuterium from sea water. There's about 40 million tons of deuterium in sea water. This could provide us energy for many thousand million years.

Heavy hydrogen or deuterium is an isotope of hydrogen, i.e., its atom has the same number of electrons, but its nucleus has 1 proton and 1 neutron. Hydrogen is the lightest element. Its atom is made up of one electron moving around one proton.

Well then, what stops us from tapping this source of energy? The reason is that high temperature, equivalent of millions of degrees centrigrade, is required to start fusion. And once the gas has been heated, it must be prevented from expanding; it must be contained. But no container walls can withstand such temperatures. Hence, entirely new techniques have to be developed. Much activity is going around the world to generate power through nuclear fusion. The development of fusion power has proved to be, perhaps, the most difficult task ever tackled. Nevertheless, if fusion reactors come into being, humankind would never again face an energy shortage.

29.5.4 The Other Side of the Coin

The atomic nucleus, on the one hand, holds promise for unlimited energy. On the other hand, it also poses a threat to the very existence of the living as well as the non-living world.

Mankind still rues the fateful days of August 6 and 9, 1945 when two atom bombs, which were given the nicknames, the Little Boy and the Fat Man were dropped by America on Hiroshima and Nagasaki in Japan. In a flash, the cities crumbled to dust. Hundreds of thousands of people died or were fatally injured within a few minutes. Many more thousands of survivors and their descendants are still paying the price for what may be called an unpardonable crime committed against humanity. They are not only suffering themselves but also they often give birth to deformed or mentally retarded babies. The horrifying spectre of the mushroom cloud which was observed over the two cities haunts us to this day.

The first bombs led to the manufacture of more bombs. America was soon joined by the erstwhile USSR, and an arms race commenced with stockpiling of even more deadly weapons. Hydrogen bombs based on fusion, inter-continental ballistic missiles (each one carrying many bombs), and neutron bombs have been added to the nuclear arsenal. It is estimated that more than 50,000 nuclear weapons have been deployed around the world. Situated in silos, mobile trains or trucks on land, in ships and submarines under the sea, in bombers riding the sky, they are capable of destroying the world many times over.

And look at what we lose in the bargain.

The world spends more than 1 trillion dollars (in rupee terms more than Rs. 15 lakh crore) in a year on making arms. The USA alone accounts for more than one third of this amount. Much of this expenditure is incurred by the developing countries like ours. Every one seems to be arming and buying from the few big sellers in the world. If money were not used for arms we could feed and clothe the entire world population, change our hovels to proper houses and remove illiteracy of our people.

The arms race causes a whole lot of economic problems in all countries, because this is unproductive. The public all over the world is worried and agitated about the threat to its existence, and the grave economic difficulties faced by it. Only during the last 3 or 4 years, a ray of hope has been seen. Through a series of treaties, the USA and Russia have agreed to dismantle some nuclear missiles. Negotiations are going on to bring about nuclear disarmament on a bigger scale. India and the then USSR had given a call in 1986 for the creation of a nuclear weapons-free and non-violent world. With such devastating arms, countries have to learn to settle their disputes by negotiation, and have patience and mutual trust to do so.

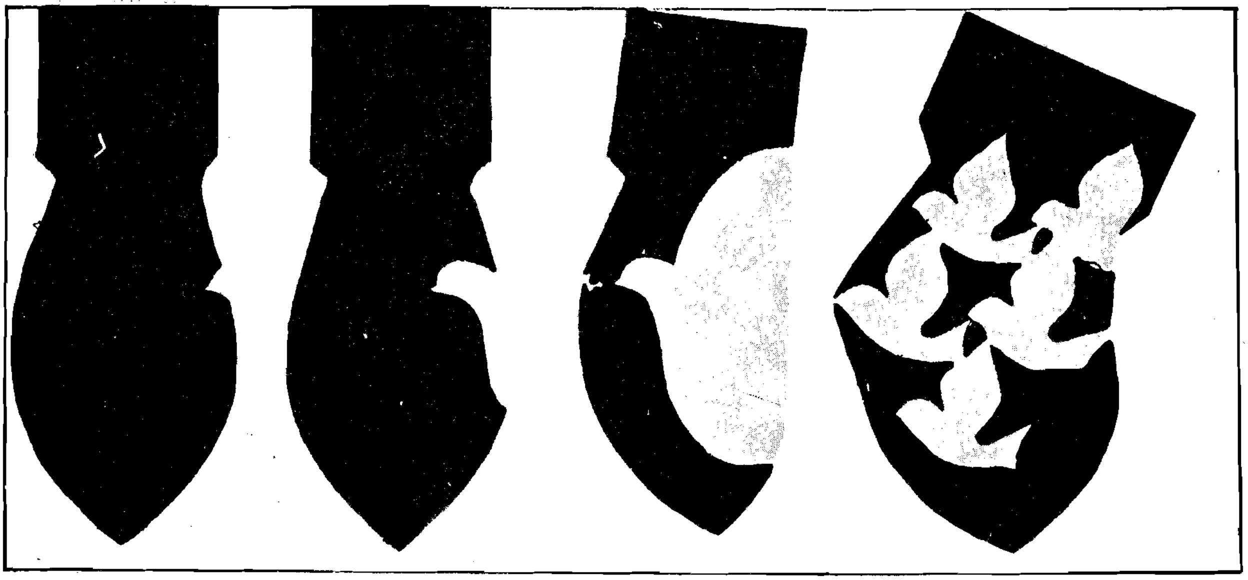


Fig. 29.10: A nuclear missile being transformed into doves, the symbols of peace—a reflection of people's desire for peace and nuclear disarmament.

Biotechnology is another emerging technology which holds promise of unlimited benefits if utilised properly. Let us see what this technology is.

29.6 WHAT IS BIOTECHNOLOGY

Biotechnology is, perhaps, best defined as the industrial utilisation of biological systems or processes. In a sense, therefore, biotechnology has existed for thousands of years. The most ancient biotechnological art is fermentation. Living micro-organisms have been used for centuries to make curds, condiments, cheese and vinegar, to prepare dough for bread or bhaturas, and to brew alcohol. But today we know much more about these simple processes. With the help of powerful microscopes and carefully done experiments in the laboratory, we have come to understand that the tiny microbes involved in these processes are small biochemical factories. And they can be used for a variety of purposes, related to health, medicine, food, pollution control etc.

The ability to control and manipulate microbes and use them for various applications has resulted in the current biotechnology. We will describe two main techniques of the new biotechnology, namely genetic engineering and enzyme immobilisation.

29.6.1 Genetic Engineering

The modern biotechnology revolution is based on the understanding and manipulation of the structure of DNA. DNA is a complex organic molecule that directs the synthesis of proteins in all living organisms. Thus, it controls the physical structure, growth, reproduction and function of all living beings. The programme for controlling protein synthesis is coded in the chemical structure of DNA. The discovery of the code, and the synthesis of DNA in test tubes, were important milestones in genetic engineering. However, the foundation of genetic engineering was laid by the discovery, that DNA supplied from outside is accepted by micro-organisms. DNA thus inserted into the cell taken from a micro-organism, enables the cells to make the proteins specified in the codes of the inserted DNA. These new cells can be cultivated or cloned, until a significant number of cells are available to produce specific, desired protein molecules.

However, this is not so easily done. When a foreign DNA molecule enters a cell, special enzymes, called restriction enzymes, rapidly destroy it This problem was solved by the discovery of the fact that small rings of DNA other than the main DNA strands exist in the cells of bacteria. These circular DNA molecules are called **plasmids** (see Fig. 29.11). A technique was developed to insert foreign DNA fragments into plasmids taken out of the cells. This is known as **gene splicing** and plasmid becomes a vehicle or a vector. Once the foreign DNA is joined to the plasmids, and inserted back in the host cell, the restriction enzymes fail to destroy it. When the cell reproduces, the foreign DNA is also replicated. When the cell carries on its normal functions, the synthetic DNA in the plasmid directs the manufacture of the protein coded in it.

Thus, through genetic engineering techniques, it is possible to introduce a foreign DNA into a host cell and synthesise any desired protein. Large quantities of scarce biologically significant proteins which are not easily available from natural sources can be manufactured in this manner. For example, insulin needed by diabetic patients can now be produced on a large scale using this technique. Just as cattle are bred for specific functions like high milk yield, or pulling heavy loads, now-a-days scientists breed bacteria for carrying out special functions. By selecting suitable bacteria, and using genetic engineering techniques, new varieties of bacteria which can eat man-made artificial products like plastics are being developed. Otherwise plastic materials, discarded and thrown in garbage, are hard to get rid off. These special bacteria are affectionately called 'Bugs'.

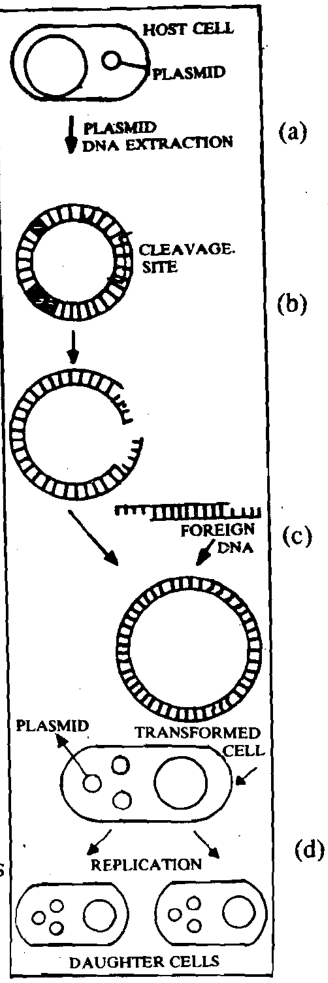


Fig. 29.11: An illustration of the genetic engineering technique; a) plasmid DNA is extracted from the host cell; b) it is cut at the cleavage site by special techniques; c) foreign DNA is then inserted into the plasmid; d) the transformed plasmid is inserted back into the host cell. When the transformed cell multiplies, the foreign DNA is also replicated.

29.6.2 Enzyme Immobilisation

The use of enzymes as catalysts is well known in a number of industries, such as baking or wine making. But purified enzymes are soluble in water. It is, therefore, not easy to remove them from the final product. Further, it is difficult to re-use them. Thus, enzyme activity is lost in one cycle of the chemical reaction. These difficulties led to the development in the late 1960s of immobilised enzymes. The trick is to link an enzyme chemically to a large molecule, such as gelatin. It can then be used as a catalyst, and it can be extracted with the large molecule, for use once again. Immobilised enzymes have been successfully used in the production of semi-synthetic penicillin and in the large scale production of fructose from maize. Fructose is sweeter than glucose, yet it has the same calorific value and is used as a low calorie sweetener.

A catalyst is a substance which aids chemical change in other substances without itself undergoing change. Enzymes are proteins that control the biochemical processes in living organisms.

SAQ 6

Explain in about three lines each what is meant by genetic engineering and enzyme immobilisation.

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Nuclear transfer is another technique of genetic engineering where the nucleus of the egg cell is replaced by the nucleus from the cell of a donor organism, in order to create a clone. The most famous example has been of 'Dolly', the first cloned sheep in Scotland. This cloning technique has raised a whole lot of ethical issues as the future holds the possibilities of cloning human beings.

Biotechnology may be dominated by microbial and enzyme technology, but it is not synonymous with them. Both animal and plant cells have their due share in its development. Biotechnological exploitation of animal cells lies behind the commercial production of viral vaccines and several proteins of high therapeutic value. Similarly, the culture of cells, tissues and organs of plants, as also breeding of improved plants are some of the areas where biotechnology is being applied. Work is also being done on the problem of nitrogen fixation by the help of bacteria found in the roots of leguminous plants, such as peas, beans, dals etc. Thus, developments in biotechnology, agriculture and medicine are likely to undergo vast changes in the years to come.

In the same measure as biotechnology can be useful, it, too, can be misused for developing Harmful vaccines, chemical agents to defoliate (i.e., get rid of leaves) crops and forests, or new breeds of rodents which could cause much destruction. Humanity has to be watchful in the case of all new advances that they truly help solve human problems rather than compound them and be a threat to human existence.

29.7 SUMMARY

- In this unit, you have briefly studied what the five modern technologies, namely laser, fibre optics, space technology, nuclear fission of fusion, and biotechnology are. We have also discussed some of their applications, advantages and dangers.
- Laser is a special kind of light with several useful properties.
- Fibre optics is a technique in which hair-like glass fibres called the optical fibres can be used to carry light even along curved paths.
- Advances in space technology have helped human beings to explore the Solar System. Artificial satellites have proved very useful in many areas.
- Fission and fusion technologies are responsible for producing energy from the atom. Fission is the process of splitting heavy atomic nuclei into light nuclei. When light atomic nuclei fuse together to form heavier atomic nuclei, the process is called fusion. In both the processes, the mass of the final products is less than the mass of the initial nuclei. This mass difference produces huge amounts of energy.
- Biotechnology is based on the control and manipulation of micro-organisms, enzymes, cells etc.

29.8 TERMINAL QUESTIONS

1) List in a Table given below four differences between light coming from a laser and an electric bulb.

Laser Light	Ordinary Light

2) List the three main advantages that optical fibre cables have for telephone communications in comparison to copper cables.

....

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3) State four ways in which we have benefited from our artificial satellite programme.

....

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4) What are the risks associated with the use of fission energy?

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....

5) We are listing below a few statements giving applications of the technologies described in this unit. State against each statement, which technology corresponds to the particular application.

a) Our natural resources can be explored, TV programmes broadcast from anywhere in the world can be relayed to any other desired place. ....

b) Large amounts of energy can be provided. ....

c) Brain tumours and blocks in arteries can be removed. ....

d) Viral vaccines and bacteria for removing pollution can be engineered. ....

e) Telephonic communications and TV programmes can be carried to large distances. ....

29.9 ANSWERS

Self Assessment Questions:

1) a) i) light
ii) signals, long
iii) amount, area, spread

b) (i)-(ii); (ii)-(iii); (iii)-(ii), (iii); (iv)-(ii).

2) a) (iii), (iv), (vi).

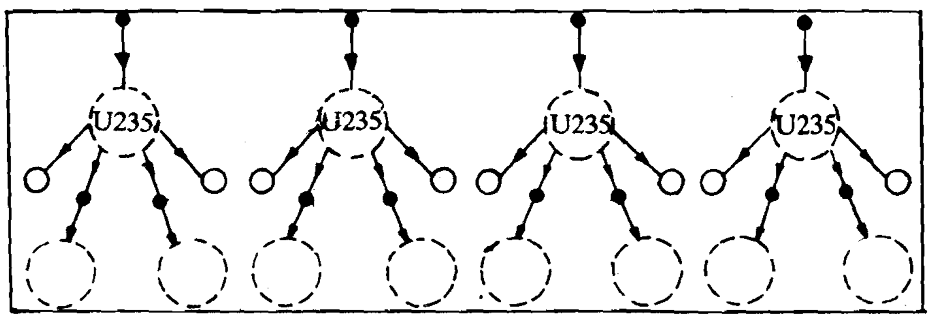
b) light waves, optical fibres, lighter, electric current, radiowaves, cheaper.

3) a) (iii), (vi).

b) (i) artificial satellite (ii) space probe (iii) rocket.

4) a) (i) T (ii) F (iii) F (iv) T (v) T

b)



5) a) The graphite block slows down the neutrons.

b) It is controlled by using absorbers, such as cadmium rods. You can explain further how it is done.

6) Genetic engineering is the technique of introducing foreign DNA fragments into host cells so that certain functions specific to the foreign DNA can be carried out within them. Enzyme immobilisation is a technique which is used to chemically bind enzymes to certain substances so that they are not lost in a single chemical reaction but can be extracted and re-used.

Terminal Questions

Laser Light	Ordinary Light
1) single wavelength,	many wave lengths,
2) coherent,	incoherent,
3) beam can travel large distance without spreading,	beam spreads apart,
4) carries large concentration of energy per unit area.	energy concentration at a distance from the source is low.

2) Optical fibres are lighter and cheaper. Further, they can carry much more information.

3) Communication, resource mapping, meteorology, education.

4) Nuclear accidents, waste disposal.

5) a) Space technology; b) Fission and fusion; c) Lasers; d) Biotechnology; e) Optical fibres.