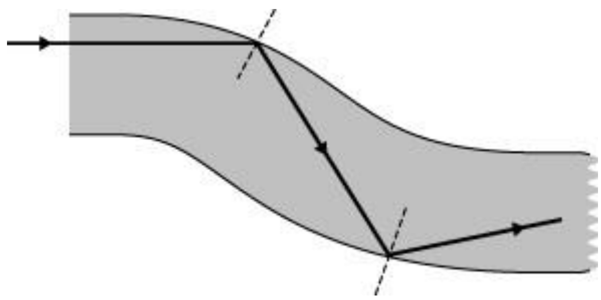
CASE STUDIES

1 THE MEDICAL ENDOSOCOPE (Textbook p151)

The medical endoscope is used to see inside the body. It consists of two bundles of optical fibres, one used to direct light into the body and the other to observe the region illuminated by the light. Each optical fibre transmits light entering at one end to the other end, regardless of how the endoscope bends along its length. The fibres are very thin so that a light ray passing along the length of a fibre undergoes total internal reflection each time it reaches the side of the fibre.

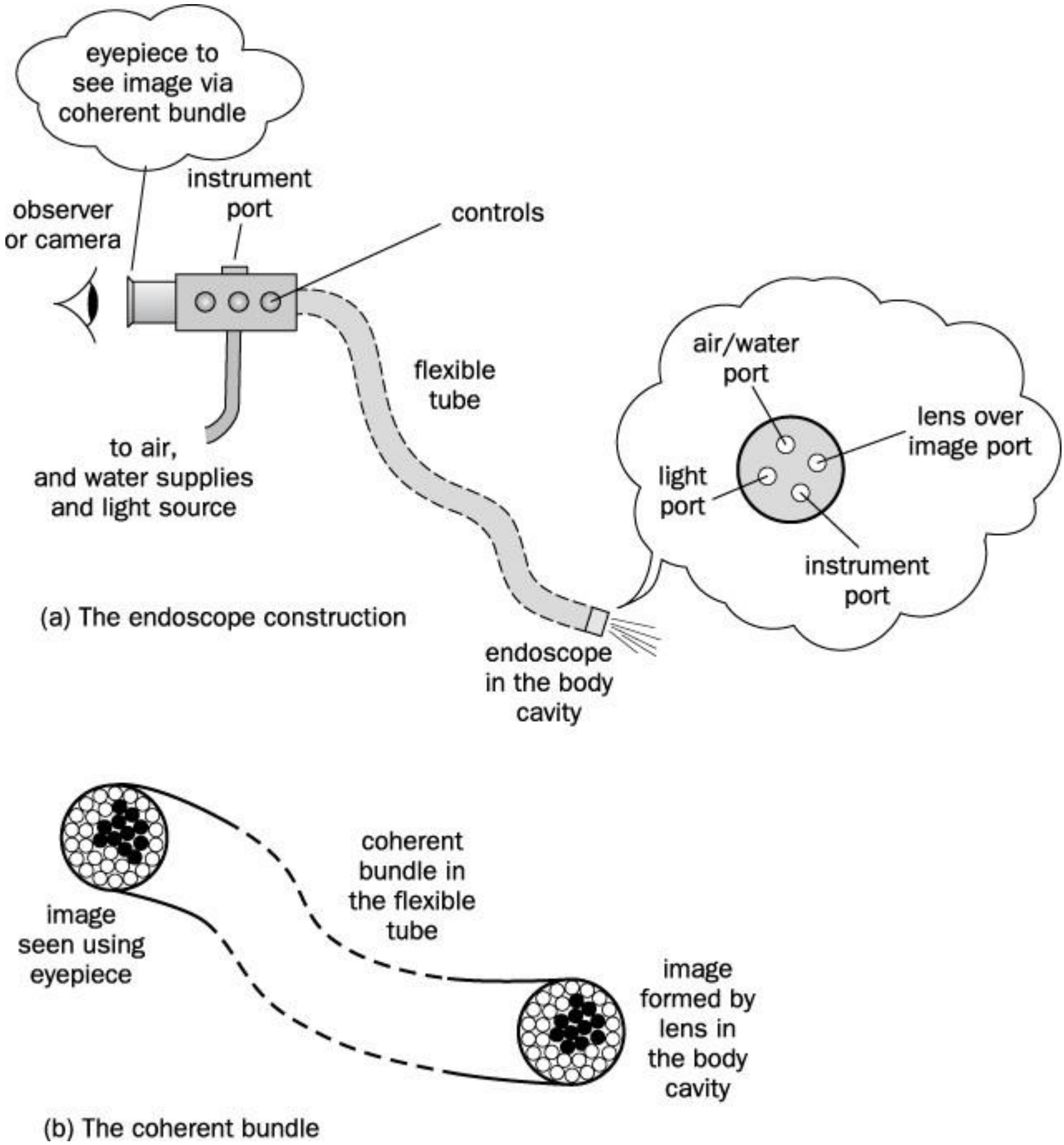
Fig 6A An optical fibre



The fibre bundle that is used to observe inside the body is constructed so that the fibres are in the same positions relative to each other at each end. A small lens over the end in the body is used to form an image of the internal organ surface on the flat ends of the fibres. Light incident on the end of a fibre is transmitted by the fibre and emerges at the other end, outside the body. Because the fibres are in the same positions relative to each other, the image is therefore seen on the end of the bundle outside the body. In effect, the image is seen as a matrix of dots illuminated by the image formed by the lens. The fibre bundle used to observe the image is referred to as a **coherent** bundle because the fibre ends are in the same positions relative to each other at each end of the bundle. This positional requirement is not necessary for the other bundle which has the function of transmitting light into the body. This bundle is therefore referred to as **incoherent.**

In addition to the two fibre bundles, the endoscope contains a port for specially-designed tools such as cutters which are inserted via the port and then operated manually. In addition, a further port is used to supply a jet of water to wash the lens surface.

Fig 6B The endoscope



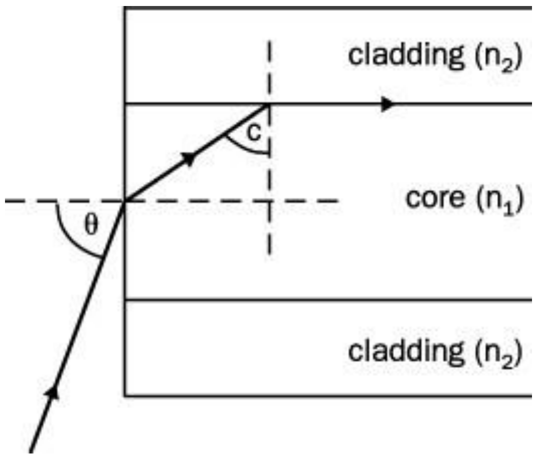
Each fibre in the coherent bundle consists of a core of flexible transparent material surrounded by a thin flexible layer of a second transparent material , referred to as **cladding**, which has a lesser refractive index than the core. Because total internal reflection takes place at the core-cladding boundary, this outer layer prevents light passing from one fibre to another at points where the fibres are in contact with each other. Without this layer, light would pass between the fibres where they were in contact and an image could not be observed. The cladding material needs to have a lesser refractive index than the core so that light can be totally internally reflected at the core-cladding boundary. However, the refractive index of the cladding needs to be as low as possible so that the critical angle at the core-cladding boundary is as small as possible and as little light as possible passes through the boundary. As explained on p 150, the critical angle , c , at the core cladding boundary is given by the formula $\mathbf{\sin c = n_2 / n_1}$, where n_2 is the refractive index of the cladding and n_1 is the refractive index of the core.

The light entering a fibre end inside the body must be inside a 'cone of viewing' if it is to be transmitted along the fibre. If the light ray is outside this cone, it passes through the core-cladding boundary because its angle of incidence at this boundary is greater than the critical angle . The **acceptance angle** , θ, of the cone of viewing, shown in Fig 6C, is given by the equation

$$\sin \theta = (n_1^2 - n_2^2)^{1/2} / n_0$$

where n_0 is the refractive index of the substance inside the body where the 'lens' end of the endoscope is located. If the acceptance angle is too small , the cone of viewing is too narrow.

Fig 6C The acceptance angle



Questions

1. (a) What is meant by a coherent bundle of fibres ?

(b) Why is it not possible to see an image using a bundle that is not coherent ?

2. (a) Why is it necessary for the core of an optical fibre in the coherent bundle to be surrounded by a cladding of lesser refractive index ?

(b) Calculate the critical angle at the core-cladding boundary for $n_1 = 1.55$ and $n_2 = 1.40$.

3. (a) With the aid of a diagram, explain what is meant by the acceptance angle of an optical fibre.

(b) Calculate the acceptance angle for $n_0 = 1.33$ (water) , $n_1 = 1.55$ and $n_2 = 1.40$.

Numerical answers

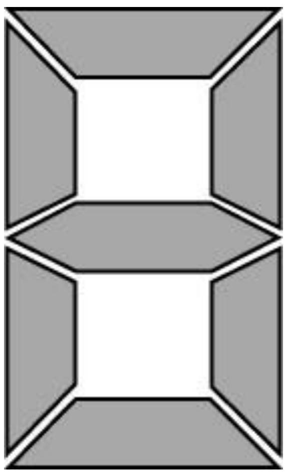
2. (b) 65^0 3 (b) 30^0

<u>2 LIQUID CRYSTAL DISPLAYS</u> (Textbook p 71)

A crystal has a well-defined shape that is characteristic of the substance which it is made from. A liquid has no shape and takes the shape of the container which it is placed in.   A liquid can flow and a crystal cannot.   The two properties of shape and flow seem to be mutually exclusive as a substance that can flow cannot possess its own characteristic shape and a substance that keeps its own shape cannot flow. However, at an atomic level, the reason for the shape of a crystal is that the atoms of a crystal are arranged in an ordered pattern of fixed positions whereas the fluidity of a liquid is because the atoms of a liquid are not in fixed positions. In a liquid crystal, the atoms and molecules possess a certain amount of order yet are capable of moving relative to each other. A liquid crystal substance has no recognisable shape like a solid crystal and it can flow yet its molecules can be aligned with each other . So it can possess a degree of order and it can flow.

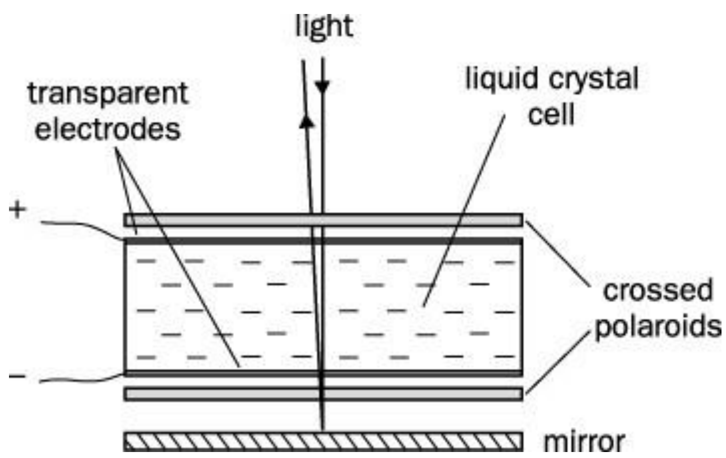
Liquid crystals are used in electronic displays. A liquid crystal display consists of a matrix of tiny cells, each cell appearing light or dark according to whether or not a voltage is applied to it. Look closely at a number on the LCD display of a calculator and you will see that there are 7 cells or 'segments' for each number displayed, as shown in Fig 6D. The number that appears depends on which segments are dark and which are bright. Number 8 appears on a 7-segment display when all the 7 segments are dark.

Fig 6D A 7 segment display



A liquid crystal cell in an LCD display is sandwiched between 2 crossed polaroids with a mirror under the lower polaroid, as shown in Fig 6E. The cell consists of the liquid crystal substance between two transparent electrodes, each made of a very thin metallic film which light can pass through. When there is no voltage between the electrodes, the cell appears grey because light enters it through the upper polaroid and is reflected back out by the mirror. When a voltage is applied between the electrodes, light enters through the upper polaroid but is absorbed by the lower polaroid and therefore cannot be reflected back out.

Fig 6E Inside a liquid crystal display



The voltage applied between the electrodes makes the molecules of the liquid crystal substance line up with each other. The two polaroids are aligned at right angles to each other so light passing through one polaroid is polarised and cannot pass through the second Polaroid. The voltage lines the liquid crystal molecules up with each other so they do not affect the polarised light . However, when the voltage is zero, the molecules rotate the direction of polarisation of light passing through the cell by exactly 90^{o} so the polarised light from the first polaroid can pass through the second polaroid and therefore be reflected back out by the mirror.

The reason why the molecules have this effect on light is that the surface of the top piece of the cell in contact with the liquid is marked with fine parallel lines. In the absence of a voltage, the liquid crystal molecules align with these lines at the top. The surface of the bottom piece of the cell in contact with the liquid is also marked with fine parallel lines at right angles to the upper set of lines. The liquid molecules at the bottom of the cell align with this lower set of lines in the absence of a voltage. The alignment of liquid crystal molecules between the top and bottom of the cell progressively turns through 90^{o} from the top to the bottom in the absence of a voltage. The effect of this twisted alignment is to rotate the direction of polarisation of the polarised light entering through the top polaroid through exactly 90^{o} in the absence of a voltage, thus allowing light entering the cell to pass through both polaroids and be reflected back out. When a voltage is applied to the electrodes, this twisted alignment is disrupted by the electric field between the electrodes and polarised light cannot pass through the lower polaroid.

Questions

1. (a) Describe the differences between a liquid and a solid crystal in terms of shape and flow.

(b) Explain these differences in terms of the arrangement and movement of atoms.

2. (a) Explain why light cannot normally pass through two polaroids that are 'crossed' at 90^{o} to each other.

(b) Explain why light can pass through two polaroids at 90^{o} to each other if the direction of polarisation of the light from the first polaroid is rotated through 90^{o} between the two polaroids .

3. Explain why a liquid crystal cell appears

(a) dark when a voltage is applied between its electrodes.

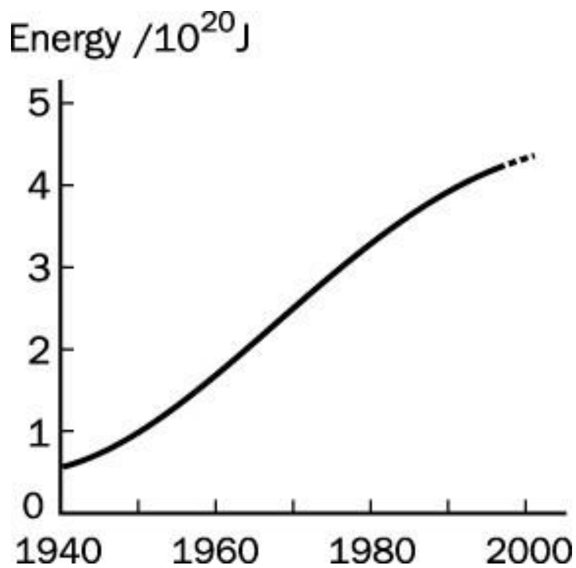
(b) light when no voltage is applied between its electrodes.

4. Observe a liquid crystal display through a polaroid. Turn the polaroid and describe how the display changes. Explain your observations.

3. ENERGY RESOURCES (Textbook p 63)

Energy cannot be created or destroyed so why should we be concerned about not having sufficient energy to meet our future needs? The energy we use is referred to as useful energy. When a machine is used to do work, some of the energy supplied to it is transferred to the surroundings by frictional forces between the moving parts. So the amount of useful energy is less than the total energy supplied to it. The difference is the energy transferred to the surroundings. Each human being uses about 1500 joules of energy every second , taking account of all activities and needs.   The current world energy usage for the entire human population of about 6 billion people amounts to about 1500 million million million joules every year. Global energy usage will probably double over the next half-century as poorer countries become richer and energy usage per person   in such countries rises from 1500 joules per second closer to the 'first world'   average of about 8000 joules per second.

Fig 6F World energy demand (see also Fig 4.13, p61 in textbook)



To meet the increasing demand for energy, alternative sources to traditional fuels like coal, oil and gas will need to be developed on a very large scale. World reserves of these fossil fuels will probably be exhausted within a century, probably sooner for oil and gas. In addition, global warming is thought to be caused by burning fossil fuels and such warming needs to be stopped and reversed as it could melt the polar ice caps and cause flooding of low lying countries due to rising sea levels. The World's supplies of uranium for nuclear reactors is likely to be in short supply within a century if it continues to be used at the present rate. In addition, the problems of safe storage of vast amounts of radioactive waste remains the cause of great concern in many countries. Huge energy savings can be made by improving the efficiency of machines and installing better thermal insulation in our homes. However, even if energy usage in 'first world countries' is reduced, the increased demand from poorer countries is likely to outstrip reductions elsewhere. Thus world energy demand is likely to increase and world fuel reserves are likely to decrease . Unless alternative energy sources are developed very significantly, conflicts between countries could occur as scarce energy supplies become even scarcer.

What developments could occur to meet the growing demand for energy without adding to global warming or radioactive waste problems ? The Sun radiates energy at a colossal rate . Just 1% of 1% of the energy received by the Earth from the Sun would meet the World's present energy needs. Solar radiation heats the oceans, causing ocean currents and winds. Wind turbines and wave generators could contribute significantly to our energy needs . For example, 5000 wind turbines each generating 1 MW of electricity or wave power from a 100 kilometre stretch of coast line could provide the same amount of electrical power as a nuclear power station. Hydroelectric power stations in mountainous regions, tidal power stations in estuaries and geothermal power stations in certain regions could provide significant amounts of electrical power. However, there would need to be thousands and thousands of such renewable power stations to meet the total global demand for energy. The capital costs would be enormous, probably beyond the reach of poorer countries. In addition, transport would need to run from electric power, either battery operated vehicles or connected vehicles such as trams and electric trains.

Solar cells provide power without requiring huge constructions such as power stations. Solar heating panels fitted to the roofs of buildings can supply hot water and therefore reduce fuel bills. Such heating panels are being fitted on buildings in many countries and they are cost-effective in the sense that the installation costs are recovered through savings on fuel bills. Panels of solar cells provide electricity directly but they need to cover large areas to generate useful amounts of electrical power as they are not efficient energy converters. Further research could lead to more efficient solar cells. Large installations could be used to produce hydrogen gas for use as a transport fuel by passing electricity directly through tanks of sea water. Less than 0.02% of the World's surface, equivalent to a total land area less than the Sahara desert, could meet the global demand for energy if covered with solar panels. **Q1** (a) What are fossil fuels and why are they unlikely to contribute to global energy supplies in the next century ?

(b) State one advantage and one disadvantage of a nuclear power station compared with a gas-fired power station.

Q2 (a) Describe one measure that would reduce energy usage in homes and buildings .

(b) Why is global energy usage likely to rise not fall in the near future ?

Q3 (a) Explain what is meant by 'renewable energy' and list as many different sources of renewable energy as possible .

(b) How many 1 MW wind turbines would need to be built to meet the national electricity demand of 55 000 MW ?

(c) List two advantages and two disadvantages of solar power .

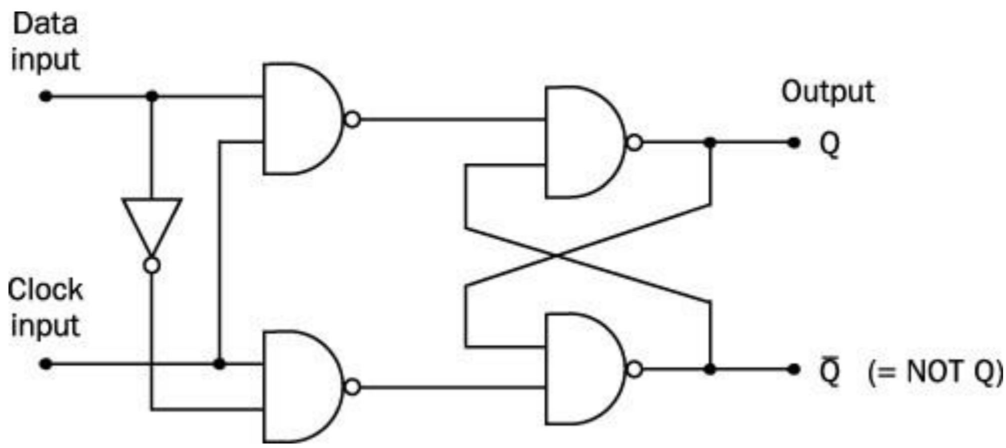
4 ELECTRONIC MEMORY (Textbook p243)

Information is stored electronically in 'bits' , each bit being either a '0' or a '1' in a digital circuit or on a computer disc. A string of bits such as 1101 is referred to as a byte, in this case a 4-bit byte. Different bytes are used to represent different symbols, letter and numbers in accordance with an agreed convention. A computer disc with a capacity of 10 Mb is capable of storing 10 million bytes. To store a page of text comprising 400 words, about 4000 bytes of storage capacity would be needed. A computer 'floppy' disc with a storage capacity of 1.4 Mb (= 14 00 000 bytes) could therefore store about 70 pages of text. The disc on the hard drive of a computer has a much greater storage capacity. A computer with a 1 Gb hard drive has a storage capacity of about 1000 million bytes. A CD Rom disc has a similar storage capacity.

A computer storage disc has a thin layer of material that can be magnetised on its surface. A small electromagnet or 'head' is used to 'write' data in the form of 0's and 1's on the disc. Each time a voltage pulse (ie. a '1') is applied to the electromagnet, a tiny part of the disc surface next to the electromagnet is magnetised . The disc is rotated so it scans across the 'head', enabling bits to be written onto the disc. To read the data, the same 'head' is used to scan the disc ; each time the magnetisation of the surface changes between a 1 and a 0 , a voltage pulse is generated in the head. Thus the 1's and 0's stored magnetically on the disc generate a corresponding sequence of voltage changes in the 'head'.

A CD Rom is a computer disc that works by reflecting light from a tiny source onto a light detector. The reflective surface of the disc is made up of tiny 'pits' arranged on a spiral track . The disc is rotated so that the reflected light is broken into a sequence of pulses by the sequence of pits along the track. The detector thus produces a corresponding sequence of voltage pulses. In ordinary CD Roms, the data is recorded permanently on the disc surface at the manufacturing stage so the disc is 'read only' . The size of a pit is of the order of micrometers so a disc of diameter about 100 millimeters would have 100 000 pits across its diameter and about 10 000 million pits on its surface, corresponding to a storage capacity of about 10 Gb. A computer circuit that stores data is a memory circuit as it keeps the bits in store after the logic state of each input terminal has changed. Such circuits store the routine instructions necessary for a microcomputer to work. A RAM or 'Random Access Memory' chip contains millions of electronic latches, each latch capable of storing a bit of electronic data. Each data byte is stored in a set of latches , accessed by using an 'address' byte to open certain logic gates in the chip , thus allowing the data byte to reach the latches. Thus a 32-bit memory chip is capable of storing 32-bit bytes applied to the data input terminals at addresses accessed by applying 32 bit bytes to the address input terminals. A memory chip with a capacity of 64 Mb would therefore be capable of storing 64 million bytes.

Fig 6G

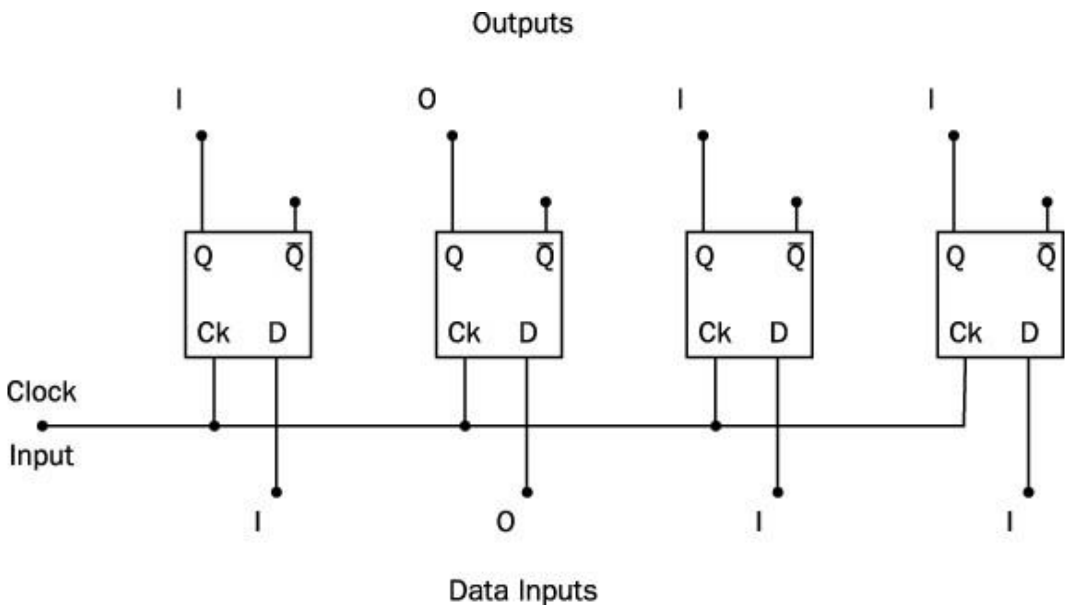


The data stored in a memory chip is 'read out' by applying an address byte to the chip and a 'read out' pulse to it. The data stored at this address is then 'read out' at the data output terminals. In a microcomputer , data is shifted between the various parts of the system on connecting wires in parallel with each other. A continuous stream of 'clock' pulses is used to shift the data and address bytes round the system, each clock pulse causing a byte transfer from one part to a different part.

The electronic latch used to store each data bit is a bistable circuit , sometimes referred to as a 'flip flop' , and it has two stable output states, namely a 0 and a 1. When a bit is applied to the data input of the bistable circuit , the bit is stored when a clock pulse is applied to the circuit. Fig 6G shows a bistable circuit made from 2 NAND gates.

The frequency of the clock pulses determines how fast a mircocomputer works.   A 1 GHz microcomputer   has a clock pulse generator that sends out pulses at a rate of 1000 million each second.   Such fast access is essential in circuits where memory chips with a storage capacity of 100 Mb or more are used.

Fig 6H



Questions

Q1 (a) Describe how data is stored on a magnetic computer disc .

(b) Describe how data is read from a computer disc .

Q2 (a) Describe in terms of data storage, the main differences between a CD Rom and a magnetic computer disc .

(b) Why does a CD Rom store more data than a magnetic computer disc of the same diameter ?

Q3 (a) Explain why the circuit in Fig 6G stores a 1 when a 1 is applied at its data input and a clock pulse is applied.

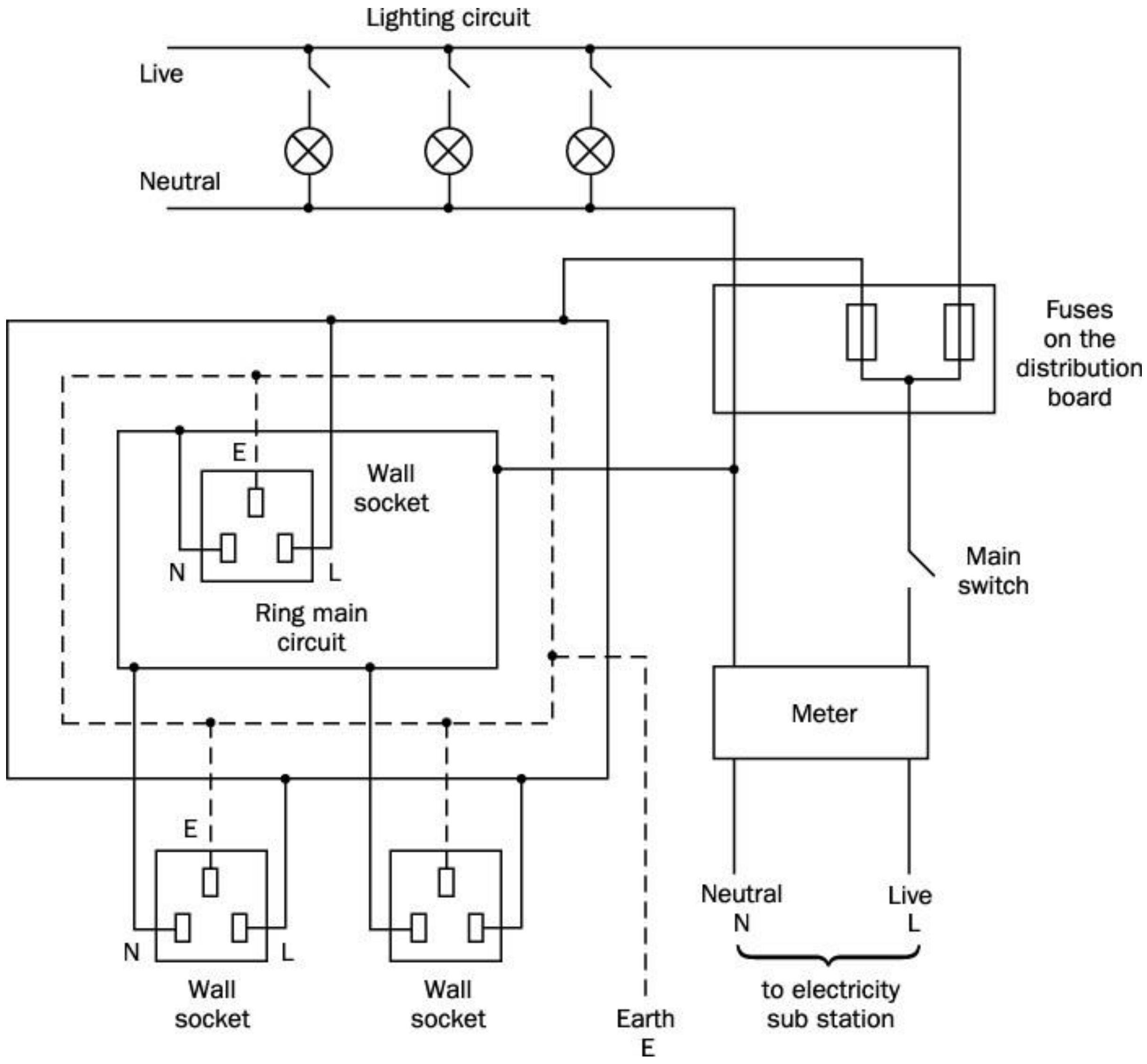
(b) Draw a circuit diagram showing how a 2-bit byte can be stored by 2 flip flops when a clock pulse is applied simultaneously to **both** flip flops.

5 MAINS ELECTRICITY (Textbook p305)

Mains electricity is supplied from the local substation to buildings via an underground cable, the so-called main cable. This cable consists of two insulated wires, the live wire and the neutral wire. The neutral wire is earthed at the sub-station. Branches from the main cable connect to the distribution board in each building .A master switch in the live wire just before the distribution board is used to disconnect the distribution board from the main cable whenever necessary.

Different circuits in the building are connected in parallel to the distribution board. A fuse in the live wire of each circuit at the distribution board prevents each circuit being overloaded. An appliance is connected to a distribution board circuit via a socket which is wired to the circuit permanently. Each appliance connected to a distribution board circuit is in parallel with any other appliance connected to the same circuit. Each connection socket is in series with a switch on the 'live' side of the socket. If too many appliances are connected to a distribution board circuit, the current in the circuit will be much larger than it should be and the circuit wires will overheat and possibly cause a fire. A correct fuse in the distribution board will prevent overloading as it is designed to melt and cut the current off if the current exceeds the fuse rating.

Fig 6I   Mains circuits



The voltage of the live wire alternates from $+V_0$ to $-V_0$ and back every cycle, where V_0 is the peak voltage. The rms voltage of the mains supply is equal to $V_0 / \sqrt{2}$ (see p304) . For example, mains electricity supplied at an rms voltage of 230 V corresponds to a peak voltage of 325V. The voltage of the live wire therefore alternates between +325 V and - 325 V.

The ring main circuit in a house consists of the live wire, the neutral wire and a third wire, the earth wire. Both ends of each wire are connected to the distribution board so the circuit connects the sockets wired to it in a ring. The earth wire is a vital safety feature as it is earthed at the premises at the distribution board. The earth wire is used to 'earth' the metal case of any mains appliance with a metal case, thus preventing the case becoming live should the live wire break off at the terminal block in the appliance and touch the case. If the case was not earthed, anyone touching it would suffer a lethal electric shock due to an electric current passing through the body between the live case and the floor. A current of no more than about 20 mA passing through the body is sufficient to deliver a lethal shock. Such a small current would not make the fuse in the appliance plug 'blow.' .Earthing the case therefore ensures there is zero voltage between the case and earth thus making it safe to touch, provided the earth wire connection to the case does not break.

A high power mains appliance such as an electric cooker or a shower heater cannot be plugged in to the ring main circuit as it would overload the circuit. Such appliances are permanently connected to the distribution board via a switch in the live wire . The connecting cable consists of copper wire much thicker than the ring main cable. This is because a thinner cable would heat up due to the very large electric current needed to power the appliance. In addition, the voltage at the appliance would be significantly less than it should be because there would be a significant voltage drop along the cable. For example, the voltage drop along a cable of resistance 0.4 Ω would be 12 V for a current of 30 A so the voltage at the appliance would be 218 V (= 230 - 12 V) not 230 V .

Electrical safety regulations require that the voltage to an appliance should not drop by more than 6 V between the distribution board and any socket which the distribution board serves. This regulation is designed to ensure the connecting wires between the distribution board and its sockets cannot overheat and become a hazard. An appliance connected to a socket of a ring main is supplied with current from the distribution board from two 'directions'. This has the effect of reducing the voltage drop between the distribution board and the appliance.

Questions

Q1 (a) Explain why a socket switch in a mains circuit is always on the live side of the socket.

(b) What is the purpose of a fuse?

Q2 (a) State two features of a ring main circuit that distinguish it from a lighting circuit .

(b) What is the purpose of the earth wire in a ring main circuit?

Q3 (a) Why is an electric cooker connected to the distribution board with its own connecting cable instead of a cable that also connects other appliances to the distribution board?

(b) The voltage drop along a connecting cable should not exceed 6 volts.

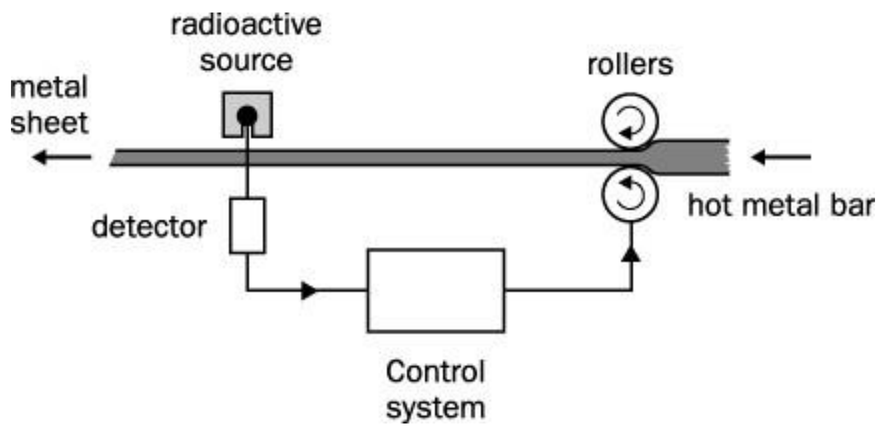
(i) Calculate the power dissipated in the cable when the voltage drop is 6 volts and the current is 25A.

(ii) Describe a problem that would occur if the voltage drop along a cable exceeded 6 volts.

6 APPLICATIONS OF RADIOACTIVITY (Textbook p362)

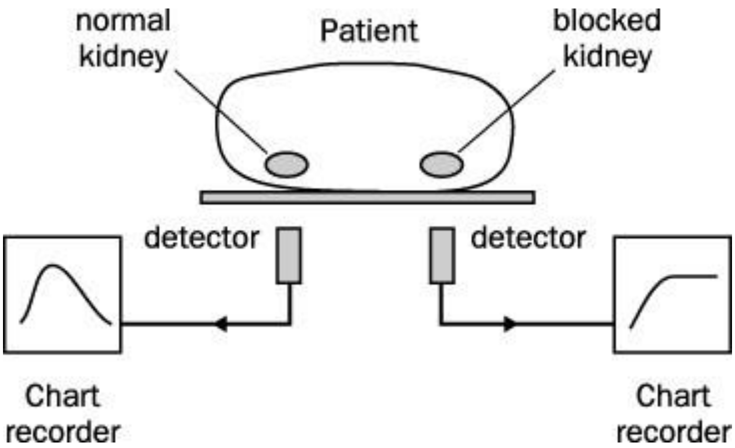
Radioactivity is used for monitoring processes where a variable quantity affects the passage of ionising radiation from a radioactive source. For example, in the process of manufacturing thin metal sheets, hot metal bars are forced between rollers which make the bars progressively thinner until they emerge as thin metal sheets. The thickness of a metal sheet depends on the pressure of the rollers. The greater the pressure, the thinner the sheets. The thickness of the metal sheet emerging from this process can be monitored by detecting β or γ radiation from a suitable radioactive source after the radiation has passed through the metal sheet. Fig 6J shows the idea. The detector signal is used to control the pressure of the rollers. If the sheet becomes too thin, the detector signal increases because more radiation passes through the metal sheet when it becomes thinner. The increase of the detector signal is then used to reduce the pressure of the rollers so the metal sheet becomes thicker . If the sheet becomes too thick, the detector signal decreases because less radiation passes through the metal sheet when it becomes thicker. The decrease of the detector signal is then used to increase the pressure of the rollers so the metal sheet becomes thinner. The radioactive source has a very long half life so its activity does not decrease during the monitoring process.

Fig 6J Monitoring thickness



Radioactivity is used as a tracer in environmental science and in medicine. For example, a leak in an underground gas pipe can be pinpointed by introducing a small quantity of a radioactive gas into the flow stream at the entrance to the pipe. Gas leaking out would be detected by a geiger counter at ground level above the leak. An example in medicine is the diagnosis of a blocked kidney. The patient is given a drink of water containing a very small quantity of radioactive iodine. The water enters the blood stream and passes through normal kidney but not through the blocked kidney. A geiger counter over each kidney would show an increase then a decrease for a normal kidney as the radioactive water passed through but it would register an increase only for a blocked kidney as the radioactive water would not pass through.

Fig 6K   Radioactivity in medicine



Gamma radiation kills bacteria as a result of its ionising effect and therefore it can be used to sterilise medical instruments in sealed wrappers   and to kill bacteria in certain foods which would otherwise be spoiled by the bacteria.

All the above applications require β or γ radiation not α radiation because the radiation must penetrate through materials to reach the detector. The radioactive source needs to have a sufficiently long half life to remain active during usage although not too long in the case of tracer applications for safety reasons.

Radioactive dating is an important tool used by archaeologists and scientists to date ancient objects. Naturally-occuring radioactive isotopes have a wide range of half lives from billions of years to fractions of a second. If an ancient object contains a radioactive isotope, the age of the object can be determined by measuring the activity of a small sample from the object and

1. the amount of the decay product in the sample , or

2. the activity of an equal sample from a similar recent object

In both cases, the half life of the radioactive isotope being used must be comparable with the age of the sample. For example, wood contains the radioactive isotope carbon 14 which has a half life of 5700 years. This isotope can therefore be used to date dead wood up to several tens of thousands of years old   but it would be no use for dating samples much older than that as it would have decayed to negligible proportions by now.

An example of 1. above is argon dating which is the dating of ancient rocks which contain argon gas consisting of the argon isotope Ar-40 formed and trapped in the rock from the decay of the potassium isotope K-40 . This isotope has a half life of 1250 million years. K-40 also decays to form the calcium isotope Ca-40 in a process which is 8 times more like than the decay leading to the formation of Ar-40 when the rock solidified. Suppose a rock is found to contain 1 atom of Ar-40 for every 3 atoms of K-40. For every Ar-40 atom, there must be 8 Ca-40 atoms in the rock and therefore there would have been 12 K-40 atoms present in the rock when it solidified. Since 25% (= $^3/_{12}$) of these K-40 atoms remain, the age of the sample must be 2500 million years as this is 2 half lives of K-40 .

An example of 2. above is carbon dating which is the dating of dead wood by measuring the amount of the radioactive carbon isotope C-14 it contains. Plants absorb carbon dioxide gas from the atmosphere and a tiny fraction of the carbon is C-14 not the stable isotope C-12. When the plant dies, the dead material no longer absorbs carbon dioxide so the number of carbon-14 atoms it contains decreases due to radioactive decay. By comparing the activity of equal masses of a sample of ancient wood and living wood, the age of the sameple can be determined. For example, if the activity of a sample of ancient wood is 1.5 Bq and the activity of a living sample of equal mass is 3.0 Bq, the age of the ancient sample must be equal to the half life of C-14 which is 5700 years.

Questions

Q1 In the production of aluminium foil , a radioactive source and detector are used to monitor the thickness of the foil as it is produced.

(a) Explain why a source of β radiation must be used , not α or γ radiation .

(b) Why is it important that the source and the detector are no further apart than about 0.50 m

Q2 The radioactive isotope of iodine, I-131, is used to measure the uptake of iodine by the thyroid gland. Iodine 131 is a γ-emitter with a half life of 8 days . This gland absorbs iodine to maintain its function of producing a hormone. The patient is given a drink of water containing sodium iodide in which there is a very small quantity of I-131. The count rate due to the thyroid and the count rate of an identical amount of I-131 prepared at the same time is measured 24 hours later. The percentage uptake of the thyroid is calculated from (the count rate due to the thyroid / the count rate due to the identical amount) x 100 %.

(a) (i) Why is it necessary that (i) the radioactive isotope is a γ−emitting isotope?

(ii) Explain what is meant by a percentage uptake of 50 % .

(b) Explain why the comparison must be made with an identical amount of I-131.

Q3 (a) (i) In argon dating, why does the argon gas formed in the rock remain in the rock ?

(ii) An ancient rock contains 1 atom of Ar-40 for every 9 atoms of K-40. Show that the age of the rock is 1250 years.

(b) (i) Why does the percentage of C-14 in a tree decrease gradually after the tree dies.

(ii) Carbon dating assumes that the ratio of C-14 to C-12 in the atmosphere has not changed. If it had increased significantly over the past 10 000 years, what effect would this make to the estimate of the age of an ancient sample of wood.

7. ELECTRICITY FOR THE FUTURE (textbookp377)

The global demand for energy is increasing rapidly as people around the world strive to improve their living standards by buying more cars and other devices that will make their lives easier. The energy we all use comes mostly from fossil fuels. However, global warming is taking place and most scientists now believe that the increased burning of fossil fuels is the cause. Such burning releases carbon dioxide and other greenhouse gases into the Earth's atmosphere is the cause. Greenhouse gas emissions need to be cut back drastically to prevent global warming becoming catastrophic . Such emissions could possibly be captured before entering the atmosphere and then stored in underground caverns. The necessary technology to do this has not yet been fully developed and it would need to be implemented on a large scale in all major industrial countries to make a big difference.

International agreements on reducing fossil fuel usage could make a big difference if measures such as improved energy efficiency , increased renewable energy resources and/or more nuclear power stations are implemented on a much larger scale than at present. For example, improved home insulation in every home and office building and improved public transport could make a significant difference to energy efficiency.

Renewable electricity from wind turbines and from hydroelectric, tidal and geothermal power stations and from solar power installations would need to cover large areas to contribute significantly to the growing demand for electricity. For example, assuming solar panels in a hot climate receive at least 500 W of solar energy per square metre during daylight hours, at least 10 square metres of ground per person would need to be covered with solar panels to gather enough solar energy to provide a large community with 5 kW of electrical power per person.

Current international agreements to reduce fossil fuel usage are limited in ambition. The overall target in terms of 1990 levels agreed for 2030 (2020 previously agreed targets in brackets) by European Union member states is for a 40% (20%) reduction in fossil fuel usage, a 27% (20%) improvement in energy efficiency and a 27% (20%) target for renewable electricity. At the same time, the demand for energy from people in developing countries is increasing. Even with tougher agreements in place, energy efficiency improvements and renewable energy resources are unlikely to be developed within the next twenty years on a sufficiently large enough scale worldwide to enable global fossil fuel usage to be reduced drastically in that time. Could more nuclear power stations meet the growing demand for electricity? The Earth's reserves of natural uranium used at the current rate may last until the next century although a large increase in the number of nuclear reactors will increase the demand for uranium significantly. Nuclear power stations in operation do not produce greenhouse gases as they use enriched uranium as fuel. However, many nuclear reactors built in the 20th century need to be replaced within the next decade. Their replacement by new reactors has been a contentious issue in many countries due to public concern about their safety and about the long-term storage of the radioactive waste they produce. In addition, as the waste products from uranium reactors contain plutonium which can be used to make a nuclear bomb, concerns are being raised about nuclear proliferation, namely nuclear power stations being built in countries where unstable regimes threaten international security.

Reactors that use thorium rather than enriched uranium have been successfully built in several countries as prototypes. If successfully developed, such reactors could make a very significant contribution to worldwide energy supplies. The thorium isotope, thorium-232 is stable and can be turned into a fissile isotope of uranium by exposure to neutrons. The fissile isotope produced, uranium-233, releases about 50% more energy than uranium 235 does. A blanket of thorium surrounding the core of a uranium reactor would therefore generate more fuel in the form of uranium-233 which can then be used later. Thorium reactors produce much less radioactive waste and much less plutonium than uranium reactors produce. Large-scale development of such reactors together with a large increase in renewable energy resources could meet the growing worldwide demand for electricity in the long term. More significantly, greenhouse gas emissions would be drastically reduced.

Questions

1. Explain what is meant by carbon capture and storage.

2. a) List the following renewable energy resources in two groups according to whether each resource is likely to make a major contribution to world energy supplies.

geothermal energy,	hydroelectricity,	tidal energy,
solar energy,	wave energy,	wind energy

b) (i) Calculate the number of 1.5 MW wind turbines that would give the same output power as a 2000 MW power station.

(ii) If a single 1.5 MW wind turbine covers an area of 2500 m^2, estimate the total area that would be covered by the number of wind turbines calculated in a).

3. a) Complete the following equations that represent the changes that take place when a thorium 232 nucleus becomes a uranium 233 nucleus.

$$^{232}_{90}\mathrm{Th} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{\ldots}_{\ldots}\mathrm{Th} \rightarrow {}^{233}_{\ldots}\mathrm{Pa} + {}^{0}_{-1}\beta + \nu$$

$$^{233}_{\ldots}\mathrm{Pa} \rightarrow {}^{\ldots}_{\ldots 92 \ldots}\mathrm{U} + {}^{0}_{-1}\beta + \nu$$

b) State **two** advantages of a thorium reactor compared with a uranium reactor.