[3220/287] 1989

SCOTTISH CERTIFICATE OF EDUCATION

PHYSICS

Higher Grade—PAPER II

Tuesday, 9th May—1.30 p.m. to 4.00 p.m.

In SECTION A answer ALL questions.

In SECTION B answer any THREE questions.

In SECTION C answer any ONE question.

Use the approximation $g = 10\,\mathrm{m\,s^{-2}}$ or $g = 10\,\mathrm{N\,kg^{-1}}$.

Any other data required will be found in the Science Data Booklet (1982 edition) provided.

Square-ruled paper (if used) should be placed inside the front cover of the answer book for return to the Examination Board.

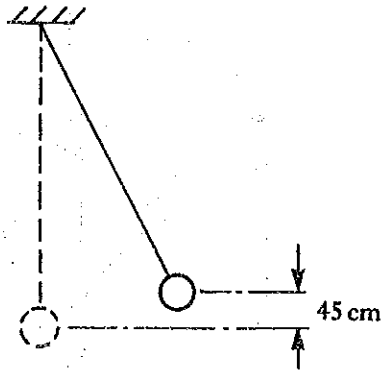
UCP 3220/287 6/3/19560

SECTION A

ALL questions in this section should be attempted.

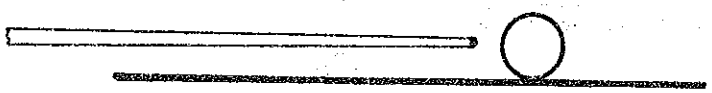
Marks

1. A pendulum is made from a long piece of string and a 2 kg mass. The mass is pulled aside so that it is 45 cm above its lowest position and is then released from rest.



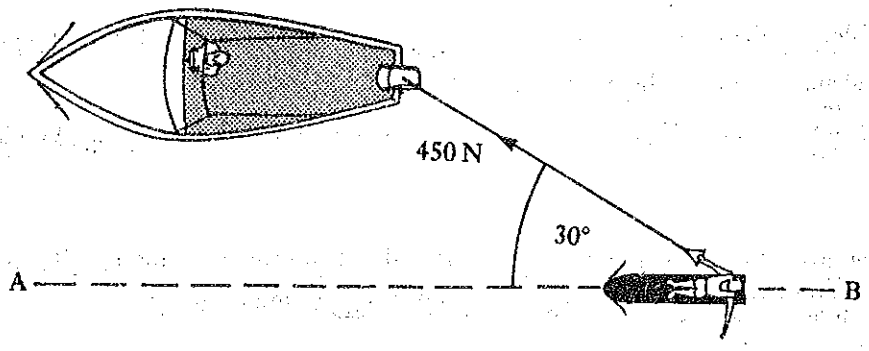
Calculate the speed of the mass as it passes through its lowest position. 3

2. A stationary snooker ball of mass 0·2 kg is hit by a cue so that the ball moves off with an initial velocity of 2 m s^{-1}. The time of contact between the cue and the ball is measured electronically to be 50 ms.



Calculate the average force exerted on the ball by the cue. 2

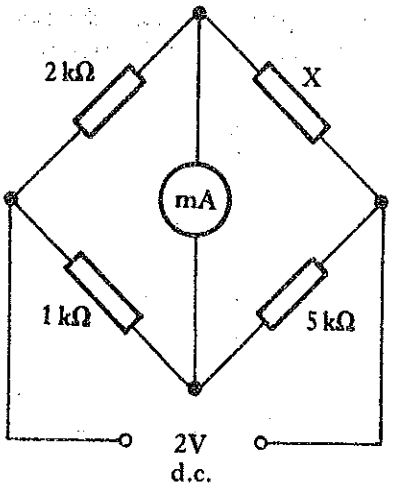
3. A water skier is being towed as shown by a boat travelling at constant speed.



If the tension in the rope is 450 N, calculate the force acting along line AB opposing the forward motion of the skier. 3

Marks

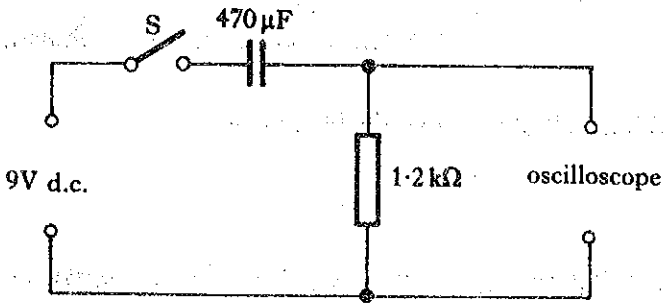
4. In the following circuit the current in the milliammeter is zero.



(*a*) Calculate the resistance X.

(*b*) Draw a circuit diagram to show how this value of resistance would be measured as accurately as possible using a suitable ammeter-voltmeter method. 4

5. The circuit shows an uncharged 470 μF capacitor in series with a 1·2 kΩ resistor. An oscilloscope is connected across the resistor.



(*a*) Calculate the initial current in the 1·2 kΩ resistor after the switch S is closed.

(*b*) Calculate the final charge stored on the capacitor.

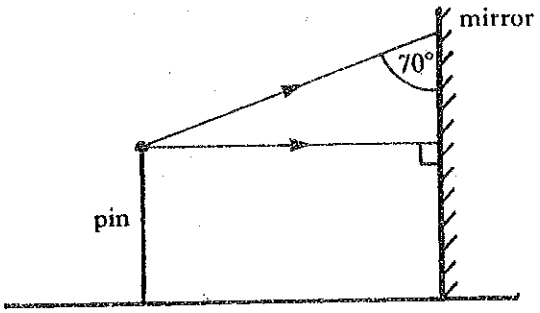
(*c*) Sketch the trace shown on a suitably adjusted oscilloscope during the charging period. 5

6. A signal generator has two outputs, one marked 3 Ω and the other marked 1000 Ω.
Which output should be used to drive a loudspeaker of impedance 8 Ω?
Explain your answer. 2

[Turn over

Marks

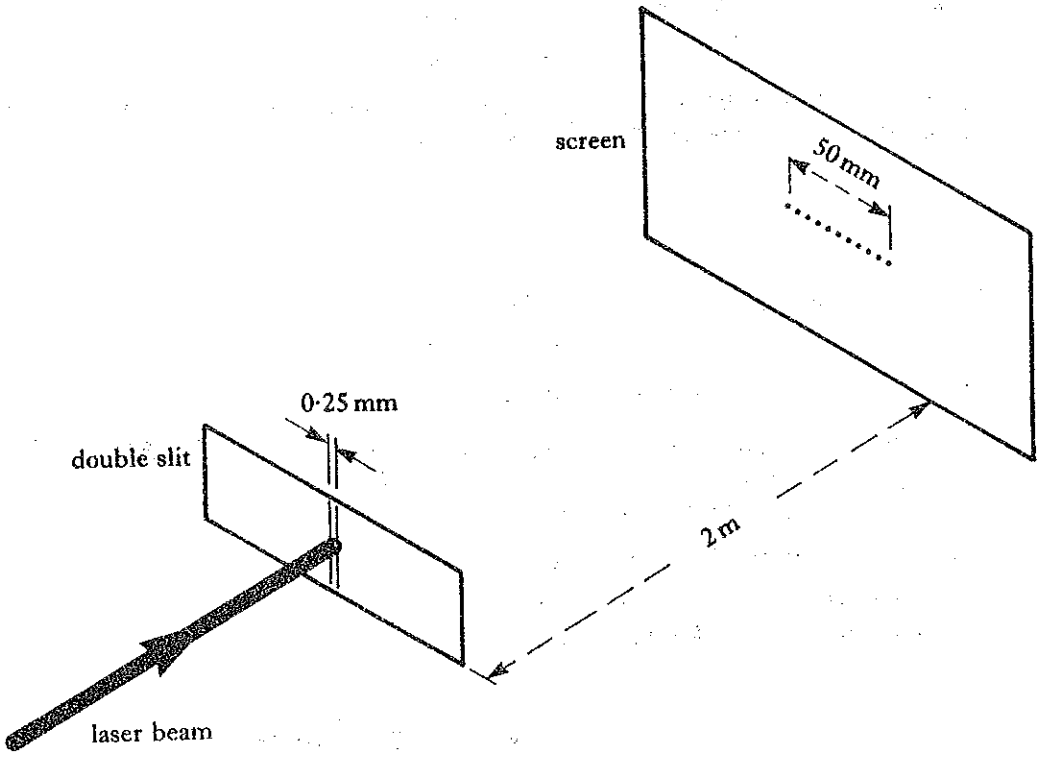
7. The diagram shows two rays of light from the head of a pin which are incident upon a plane mirror.



(*a*) Copy the diagram and complete it to show how these two rays are reflected.

(*b*) Show how these reflected rays can be used to find the position of the image of the pin formed by the mirror. 2

8. A laser beam is directed on a double slit which has a slit separation of 0·25 mm. An interference pattern is observed on a screen 2 m from the double slit as shown.



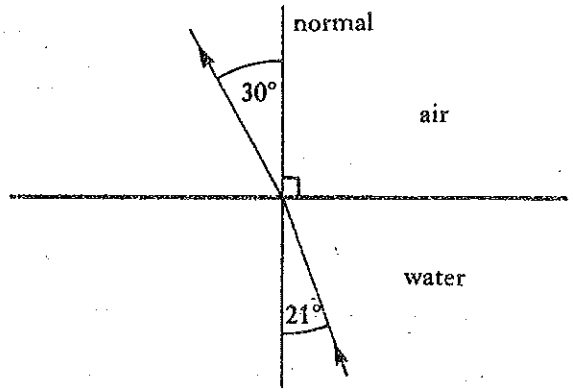
(*a*) Calculate the wavelength of the laser light used, given the relationship

$$\lambda = \frac{xd}{D}.$$

(*b*) The double slit is replaced by another with a smaller slit separation. What effect does this have on the interference pattern? 3

Marks

9. The diagram shows a ray of light leaving water.



(*a*) Calculate the refractive index of water.

(*b*) Using your answer to (*a*), and any other necessary information from the Science Data Booklet, calculate the velocity of light in water. 4

10. The kinetic model for a gas suggests the following relationship:

$$pV = \tfrac{1}{3}Nm\overline{u^2}$$

Use this relationship to show that equal volumes of two different gases under the same conditions of temperature and pressure contain the same number of molecules. 3

11. The following reaction takes place in the sun:

$$^{3}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}.$$

(*a*) State the name given to this type of reaction.

(*b*) Calculate the energy available from the above reaction, given the following information. Any other data required will be found in the Science Data Booklet.

Rest mass of $^{3}_{1}\mathrm{H} = 5{\cdot}005 \times 10^{-27}\,\mathrm{kg}$

Rest mass of $^{2}_{1}\mathrm{H} = 3{\cdot}342 \times 10^{-27}\,\mathrm{kg}$

Rest mass of $^{4}_{2}\mathrm{He} = 6{\cdot}642 \times 10^{-27}\,\mathrm{kg}$

Rest mass of $^{1}_{0}\mathrm{n} = 1{\cdot}674 \times 10^{-27}\,\mathrm{kg}$ 4

(35)

[END OF SECTION A]

[Turn over

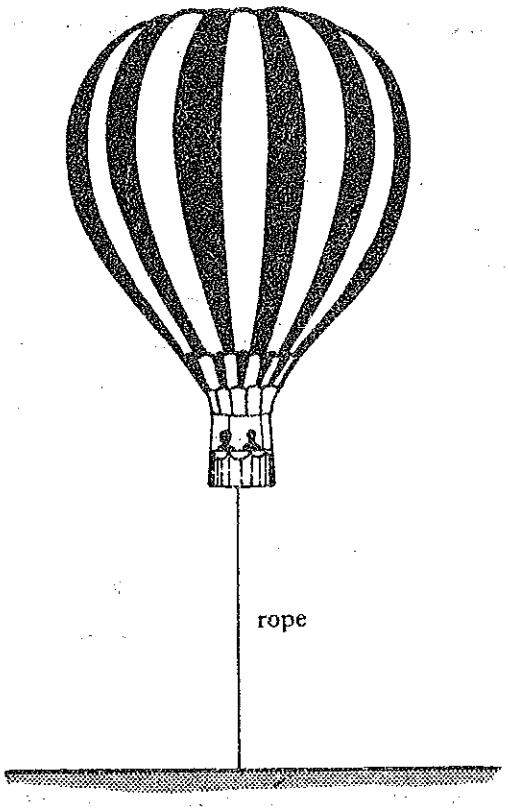
SECTION B

Answer any THREE questions. Each question carries FIFTEEN marks.

Marks

12. (*a*) On a calm day, a hot air balloon is tethered to the ground by a rope in which there is a tension of 300 N.

The total mass of the balloon is 600 kg.



(i) Draw a diagram showing **all** the forces acting on the balloon.

The balloonist releases the rope which tethers the balloon and 10 s later he accidentally drops a spanner which hits the ground in a further 4 s.

(ii) Find the acceleration of the balloon when the rope is released.

(iii) Find the velocity of the balloon 10 s after the rope is released, assuming the acceleration of the balloon is constant.

(iv) Describe the motion of the spanner relative to the earth, after the spanner is dropped.

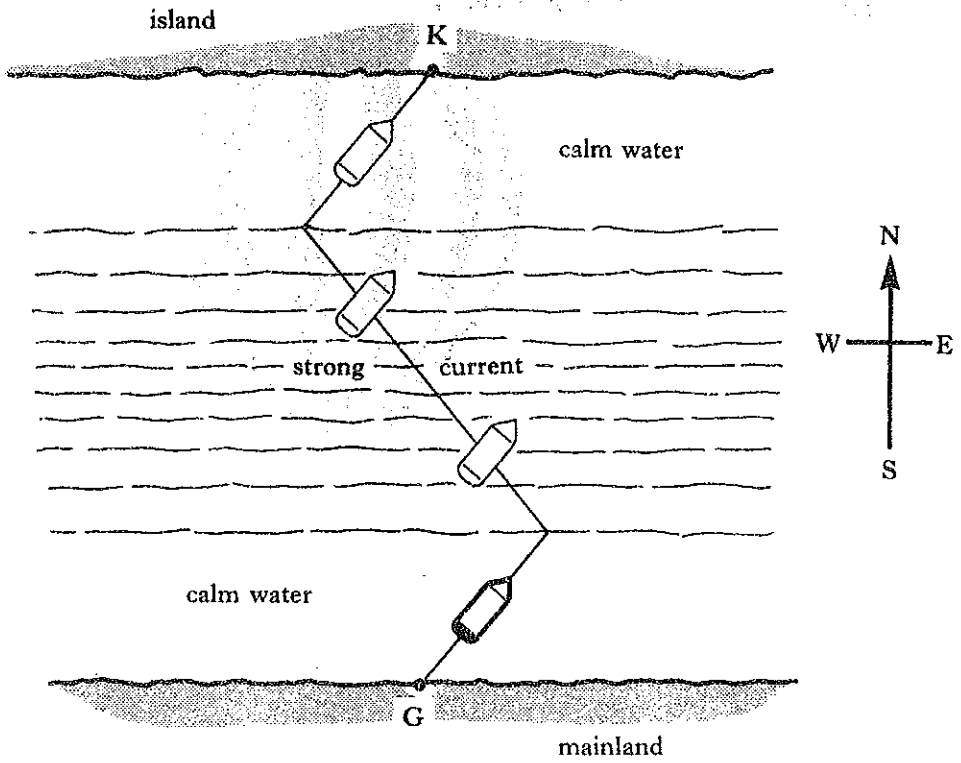
(v) Calculate the height of the balloon when the spanner is dropped. 8

(*b*) Describe how a balloonist could use a 1 kg mass and a spring balance to measure the vertical acceleration of a balloon.

Explain clearly how the acceleration would be calculated. 3

Marks

(*c*) A ferry crosses from a point G on the mainland to a point K on a nearby island.
The ferry sets out at $2{\cdot}4\,\text{m s}^{-1}$ in the direction 40° east of north (040°).
While in the strong current flowing through the middle of the channel, the ferry is found to be moving at the same speed in the direction 40° west of north (320°), although the ferry is still pointing in the original direction as indicated in the diagram.



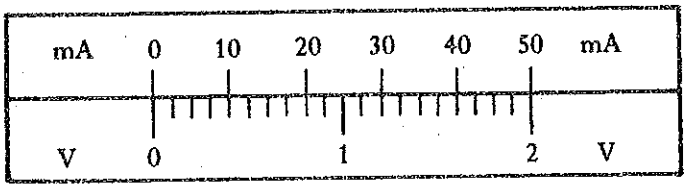
Draw an accurate vector diagram and, hence or otherwise, find the velocity of the water in the middle part of the channel. **4**

(15)

[Turn over

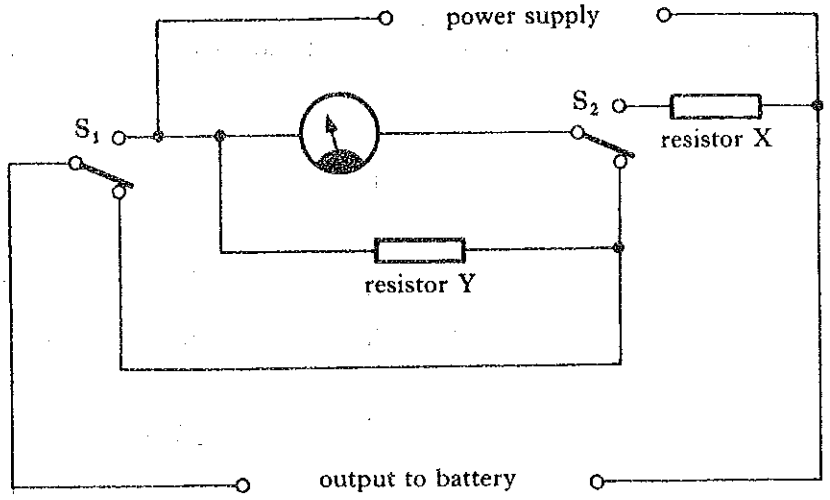
Marks

13. (*a*) (i) A meter has two scales with full scale deflections of 50 mA or 2 V as illustrated.



Calculate the resistance of the meter.

(ii) A power supply and the above meter are used to make a battery charger.
They are connected as shown in the circuit below. Switches S_1 and S_2 allow the meter to monitor either the voltage or the current.

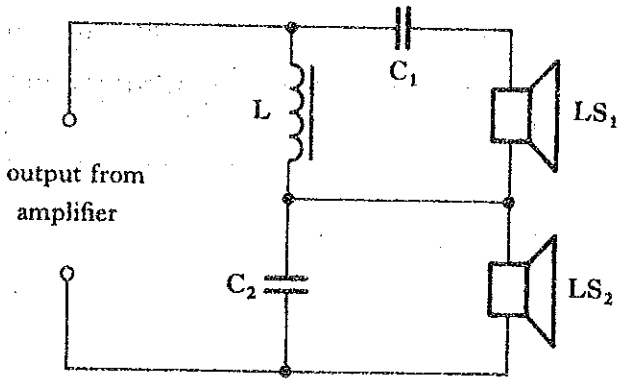


When the switches S_1 and S_2 are in the positions shown in the diagram, explain whether the meter is being used to monitor the voltage or the current.

(iii) The meter is required to show a full scale deflection with a power supply voltage of 20 V or a charging current of 5 A.
Calculate the values of the two resistors in the circuit. **8**

Marks

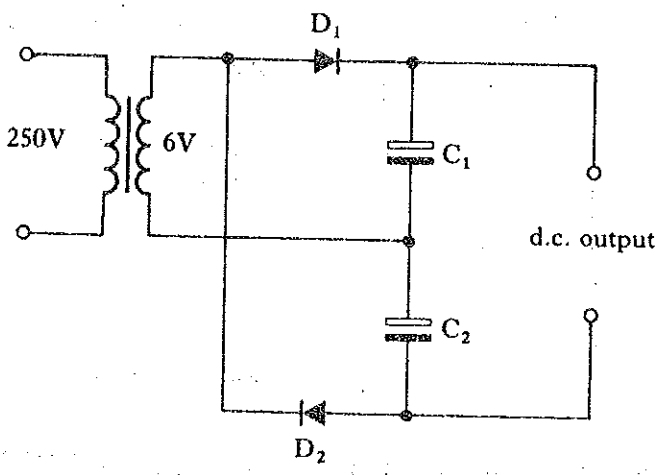
(*b*) The output from an audio amplifier contains a range of frequencies.
This output drives two loudspeakers, LS_1 and LS_2, using the circuit shown.



(i) Copy this diagram and indicate clearly on it the path taken by the current producing a low frequency sound (e.g. 300 Hz) and the current producing a high frequency sound (e.g. 8 kHz).

(ii) In the case of a high frequency sound, explain why the current takes the path which you have shown. 3

(*c*) In an electronics book, a girl finds this circuit under the heading "voltage doubler".



(i) The transformer output is 6 V, *r.m.s.*
What is the peak value of this voltage?

(ii) By considering each half cycle of the a.c. in turn, explain how this circuit works to give a d.c. output.

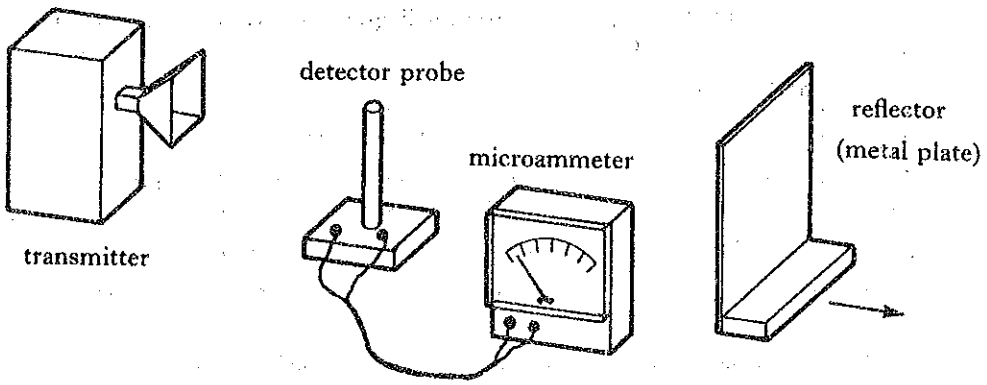
(iii) What would be the reading on a high resistance voltmeter connected across the d.c. output? 4

(15)

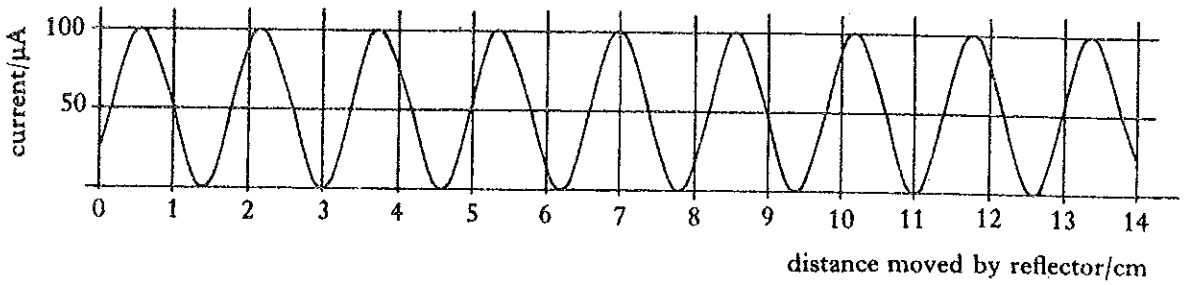
[Turn over

Marks

14. (*a*) In an experiment, microwaves from a transmitter are reflected by a metal plate. Between the transmitter and the reflector is a detector probe which is connected to a microamrneter.



The following graph shows how the microammeter reading varies as the reflector is moved to the right.

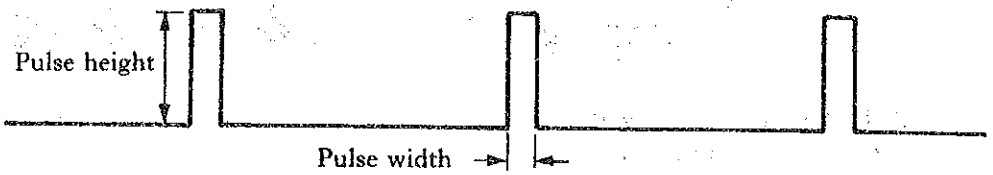


(i) Explain why movement of the reflector causes the maxima and minima shown on the graph.

(ii) What is the wavelength of the microwaves?

The reflector is then moved away at constant speed and the maxima detected by the probe are converted electronically to give pulses of a fixed amplitude and width.

Applied to a calibrated oscilloscope, these pulses have the following appearance.



(iii) If these pulses have a frequency of 275 Hz, calculate the speed of the reflector.

These pulses can also be applied to a microammeter.

Each pulse causes a charge of $1{\cdot}50 \times 10^{-6}$ C to pass through the microammeter.

(iv) Find the current in the microammeter when the frequency of the pulses is 275 Hz. **8**

Marks

(*b*) A stamp collector wishes to examine fine detail on a stamp by using a convex lens as a magnifying glass.

He uses the lens so that it gives a magnification of 5 and forms an image 25 cm from the lens.

On the square ruled paper provided, draw a diagram to show how the lens would be used, and hence, or otherwise, find

(i) the focal length of the lens,

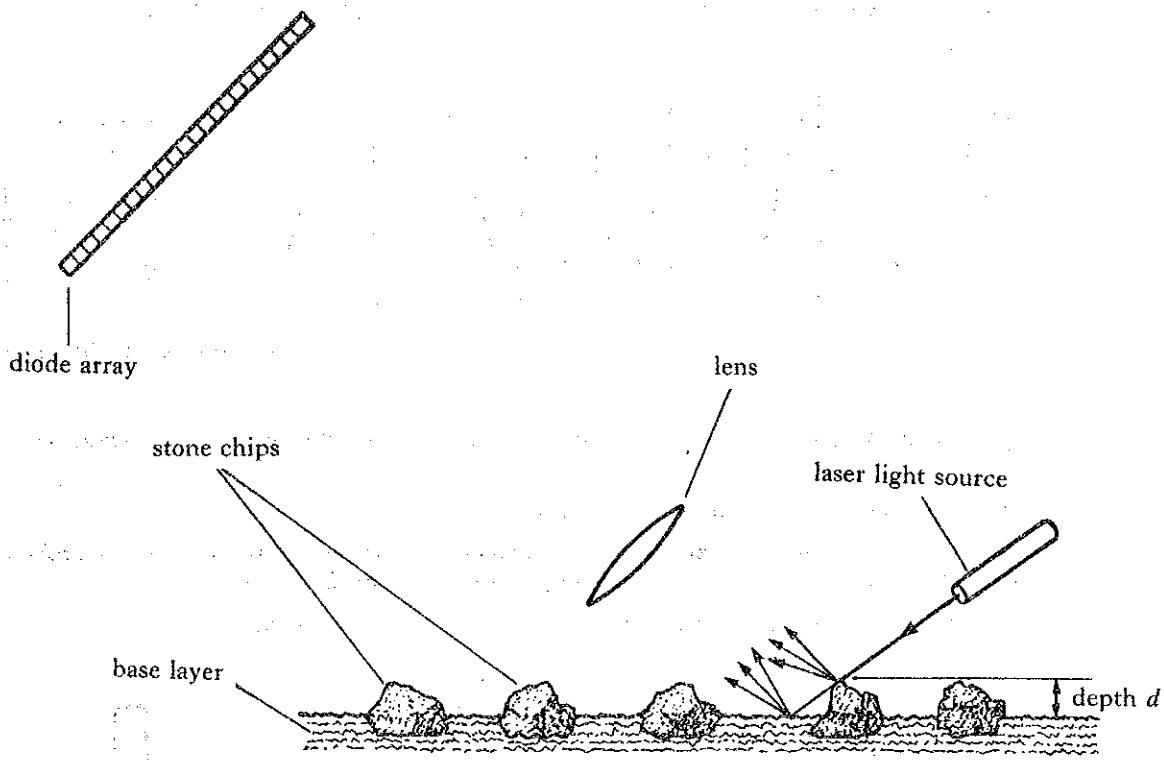
(ii) how far from the lens the stamp should be placed. 4

(*c*) A road surface consists of a base layer with stone chips embedded in it. A check is kept on the depth *d* between the top surface of the road and the base layer.

If the depth *d* is not great enough, there is a danger of skidding if the road is wet.

Equipment consisting of a laser, a lens and an array of light-sensitive diodes is used to monitor the depth *d*.

Light from the laser is directed at the road. Some of the light is scattered from the stone chips and the base layer as shown.



(i) Re-draw and complete the ray diagram to show what effect the lens has on the light scattered from the road.

(ii) Explain how the array of light-sensitive diodes will be used to detect variations in depth *d*. 3

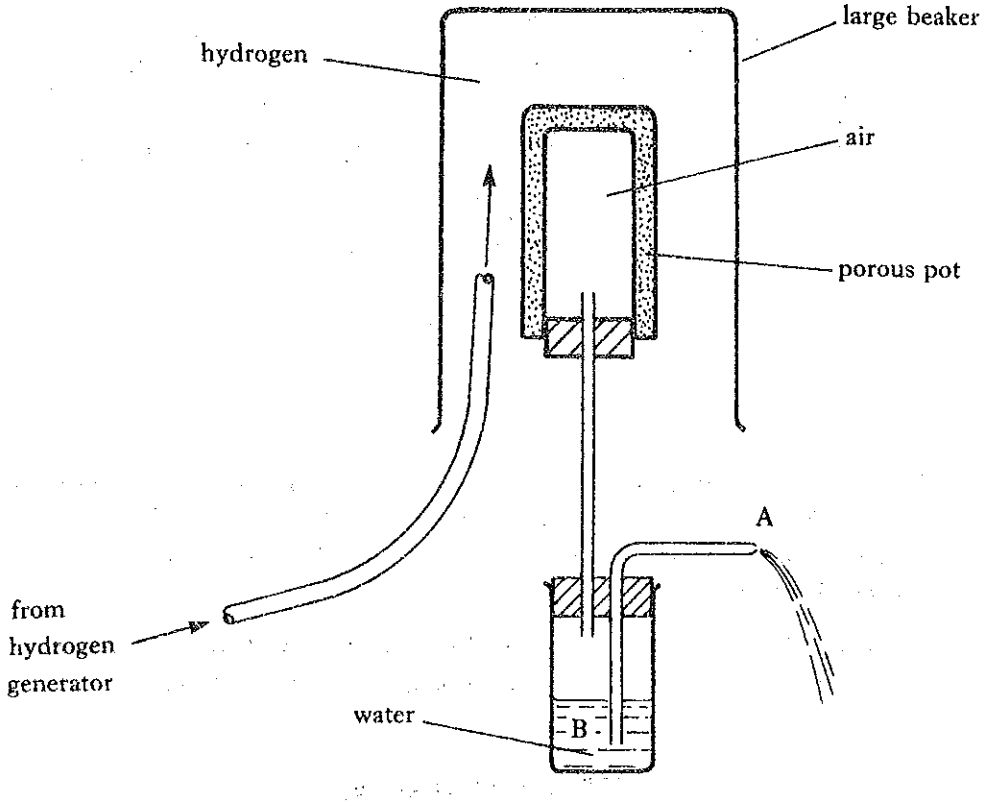
(15)

[Turn over

Marks

15. (*a*) Using information from the Science Data Booklet, calculate the *r.m.s.* speed of hydrogen molecules at standard temperature and pressure. 3

(*b*) The porous pot used in the following experiment is made of unglazed porcelain, a material through which gases can diffuse.



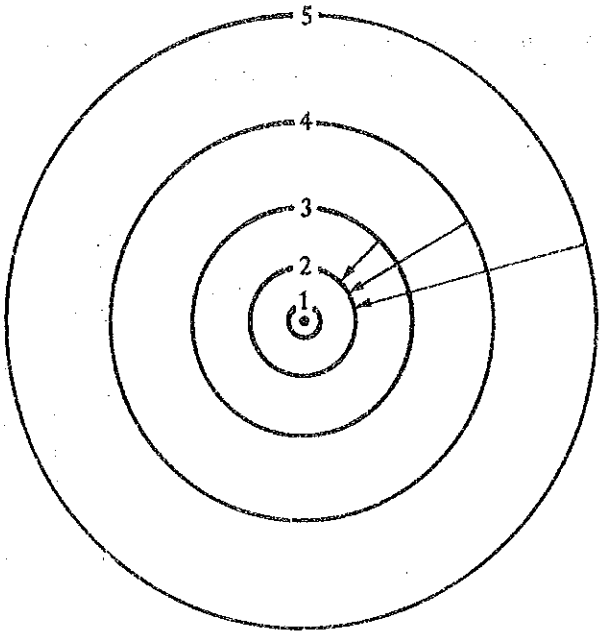
(i) Explain fully why, after a few minutes, water comes out from the tube at A.

(ii) After a further few minutes, the large beaker and the hydrogen generator are removed. State and explain what will then happen. 5

Marks

(*c*) The table below gives the energy associated with the energy levels available to the orbital electron in a hydrogen atom.

Energy level	*Energy/J*
1	$2{\cdot}185 \times 10^{-18}$
2	$3{\cdot}821 \times 10^{-18}$
3	$4{\cdot}124 \times 10^{-18}$
4	$4{\cdot}230 \times 10^{-18}$
5	$4{\cdot}279 \times 10^{-18}$



One series of lines in the hydrogen spectrum involves electrons, which have been excited into higher energy levels shown in the diagram, falling back to energy level 2.

(i) Which transition in this series gives rise to the line of longest wavelength?

(ii) Calculate the wavelength of this line.

In another series of lines, similarly excited electrons return to energy level 1.

(iii) Show that none of the lines in this series is in the visible spectrum. **7**

(15)

[END OF SECTION B]

[Turn over

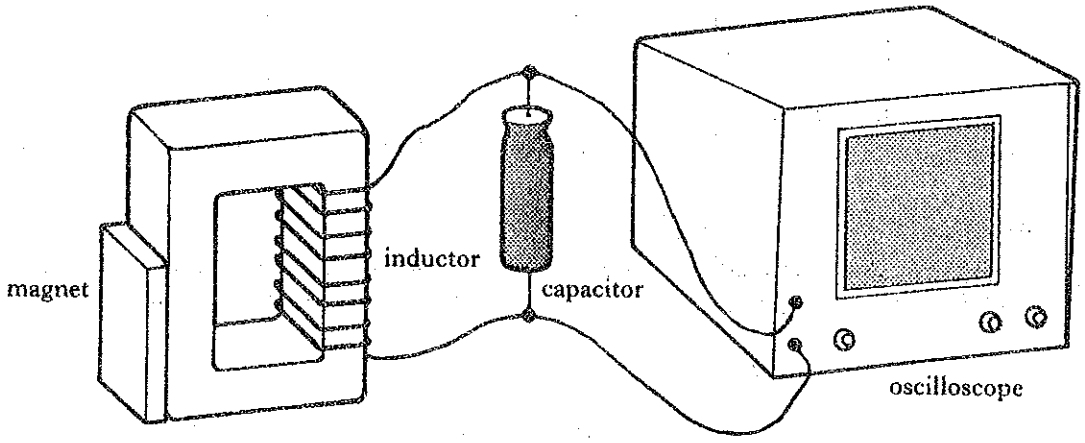
SECTION C—SPECIAL TOPICS

Answer any ONE question. Each question carries TWENTY marks.

Marks

16. *RADIO COMMUNICATION*

(*a*) The following apparatus is used to investigate electrical oscillations. The oscilloscope is set to show several complete oscillations. Initially the magnet is attached to the core of the coil as shown.



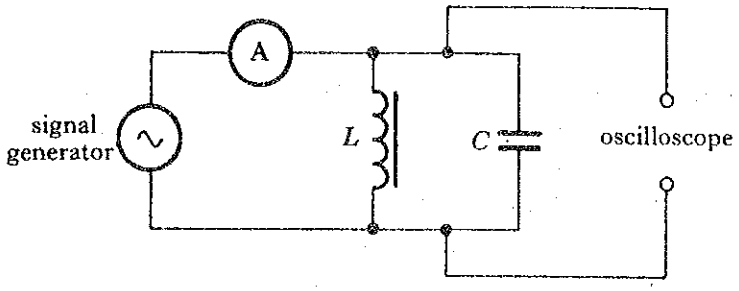
The magnet is removed suddenly.

(i) Sketch the trace which appears on the oscilloscope. Use the square-ruled paper provided.

(ii) Explain why removing the magnet starts the oscillation.

(iii) Explain the resulting oscillation in terms of the movement of electrons and of energy stored in magnetic and electric fields. **6**

(*b*) The following circuit is used to investigate maintained oscillations in an LC circuit.



The reading on the ammeter is kept constant throughout the experiment.

The peak voltage shown on the oscilloscope is noted at different frequencies.

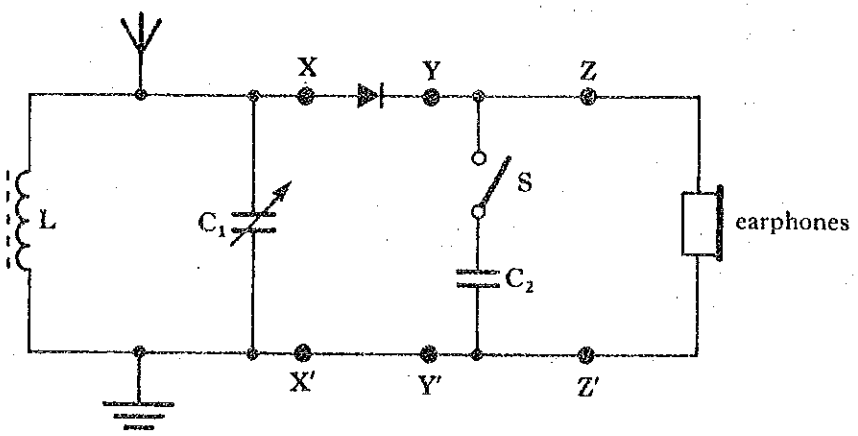
The following table shows the results.

Frequency/Hz	*Peak Voltage/V*
100	0·8
200	1·5
300	5·0
400	5·1
500	2·4
600	1·6
700	1·1

(i) Plot a graph of peak voltage against frequency and hence find the resonant frequency of the circuit.

(ii) The capacitance of C is $0{\cdot}22\,\mu F$. Calculate the inductance of L. 7

(c) A student sets up the following simple radio receiver which is tuned to a station transmitting a signal which, by amplitude modulation, carries a constant frequency test tone.



(i) The signal received is examined at various points using an oscilloscope.
Sketch the trace obtained when the oscilloscope is connected across

(A) XX′

(B) YY′ with switch S open

(C) ZZ′ with switch S closed.

(ii) State the function of capacitor C_1 in the tuned circuit.

(iii) State the function of capacitor C_2.

(iv) The above receiver operates on a.m. With the aid of sketches, describe the difference between a.m. and f.m. 7

(20)

[Turn over

Marks

17. *OPTICAL INSTRUMENTS*

(*a*) Chromatic aberration is one of the defects which can occur when using a simple camera with a single lens.

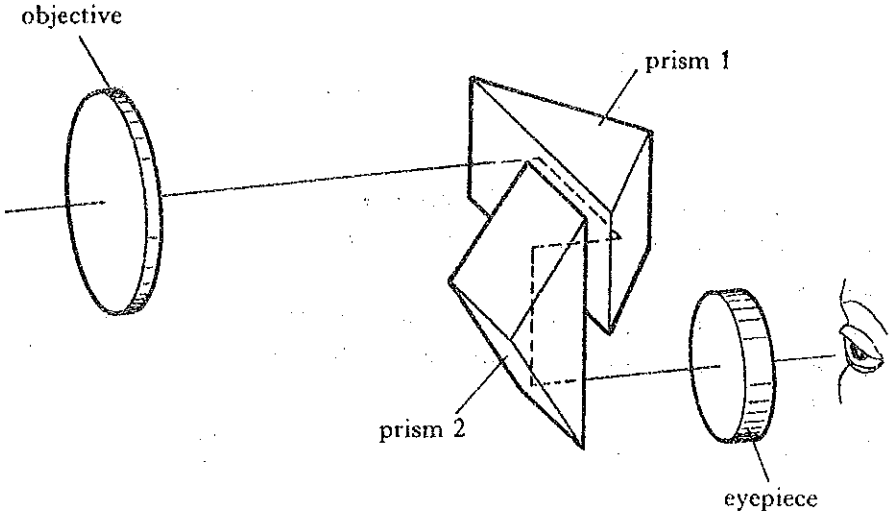
(i) Explain what this defect is and why it occurs.

(ii) Describe briefly how chromatic aberration is reduced in better quality camera lenses. 4

(*b*) (i) Distinguish between linear magnification and angular magnification.

(ii) Show that, for a telescope at normal adjustment, the angular magnification equals the ratio of the focal lengths of the objective and the eyepiece. 5

(*c*) (i) Prismatic binoculars contain right-angled prisms as shown below.



State the effect which each of these prisms has on the image.

(ii) Zoom lenses can be used in binoculars in order to provide a range of magnifications.

The numerical specification of such a pair of binoculars ranges from 8 × 50 to 25 × 50.

Find the diameter of the exit pupil in each case.

(iii) Hence state and explain under what conditions it would be suitable to use the 25 × magnification. 6

(*d*) The power of a normal eye is approximately +40 D and it has an accommodation of +4 D.

(i) From these figures, calculate the effective length of the eyeball.

(ii) Hence find, by accurate diagram or by calculation, the nearest point of distinct vision for a normal eye.

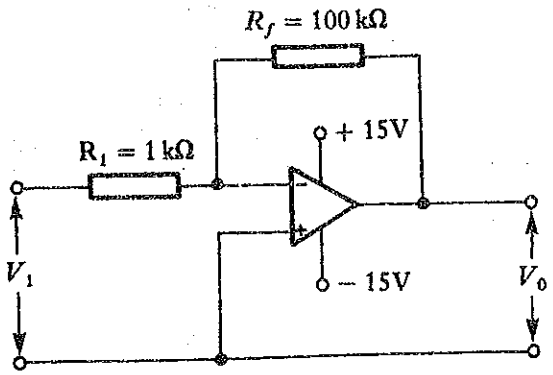
Show all your working. 5

(20)

Marks

18. *ANALOGUE ELECTRONICS*

(*a*) An operational amplifier is used with negative feedback as shown.



Circuit 1

(i) State what is meant by negative feedback.

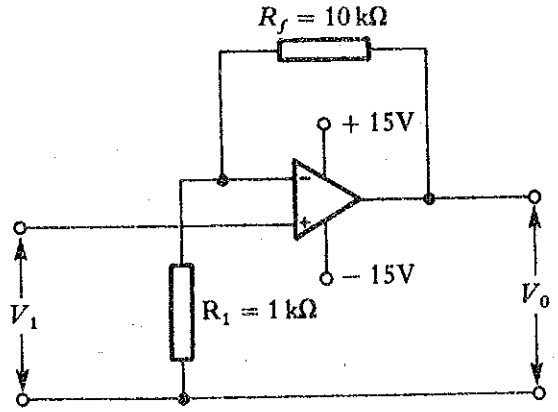
(ii) Give **two** effects of using negative feedback.

(iii) Calculate the gain of the circuit shown.

(iv) Calculate the output voltage V_0 for an input voltage V_1 of 15 mV.

(v) What happens to the gain and bandwidth of the circuit if the feedback resistance is reduced? **8**

(*b*) The same operational amplifier is used in the non-inverting mode.



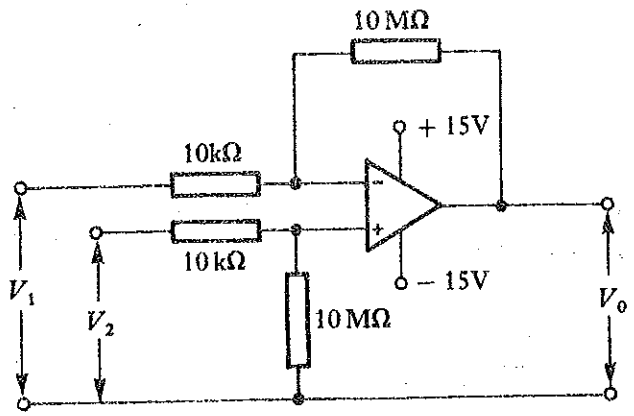
Circuit 2

(i) Calculate the output voltage V_0 when $V_1 = 0{\cdot}5$ V.

(ii) Give values for R_f and R_1 so that an output voltage V_0 of 5 V may be obtained for an input voltage V_1 of 49·5 mV. **4**

[Turn over

(*c*) Circuit 3 shows an operational amplifier used in the differential mode.



Circuit 3

(i) Explain what is meant by the term "differential mode".

(ii) Calculate the output voltage V_0 when $V_1 = 500\,\text{mV}$ and $V_2 = 510\,\text{mV}$. 4

(*d*) Electrical signals from the heart produce pulses of potential difference of the order of 1 mV between the hands. The body also picks up 50 Hz signals from the mains supply. This mains signal is of the order of 20 mV with respect to earth at both hands and makes the small 1 mV heart signal undetectable. A biological amplifier may be used to reject the mains signal and amplify the heart signal only.

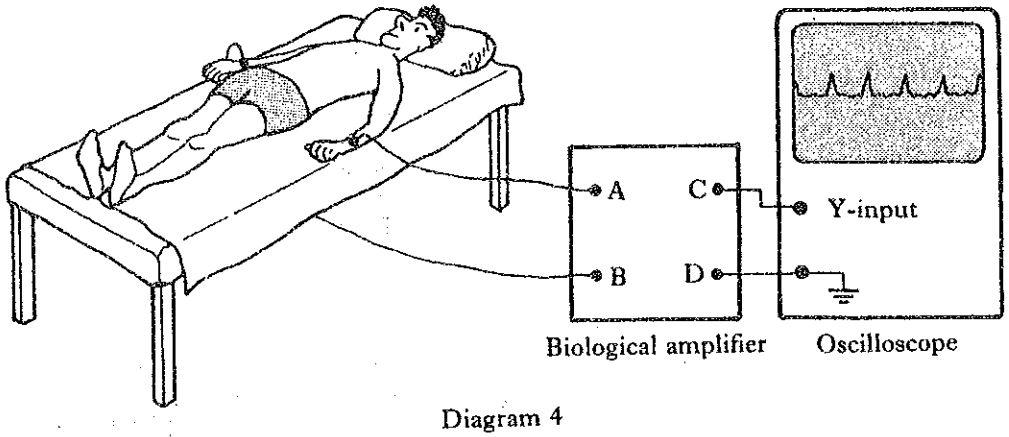


Diagram 4

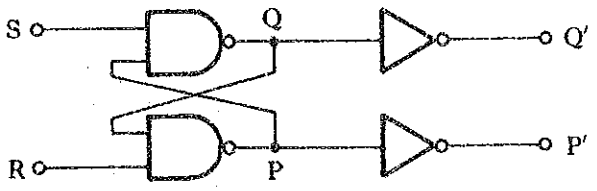
(i) Show how the differential amplifier in Circuit 3 could be connected to A, B, C and D to amplify the heart signals only.

(ii) Explain how your circuit works. 4

(20)

19. *DIGITAL ELECTRONICS*

(*a*) Two NAND gates are connected in the following way.



(i) What is another name for two NAND gates cross-coupled in this way?

(ii) Copy and complete the following two truth tables for this combination of gates.

Table A

S	R	Q	P	Q′	P′
0	0	1	1	0	0
1	0				
1	1				

Table B

S	R	Q	P	Q′	P′
0	0	1	1	0	0
0	1				
1	1				

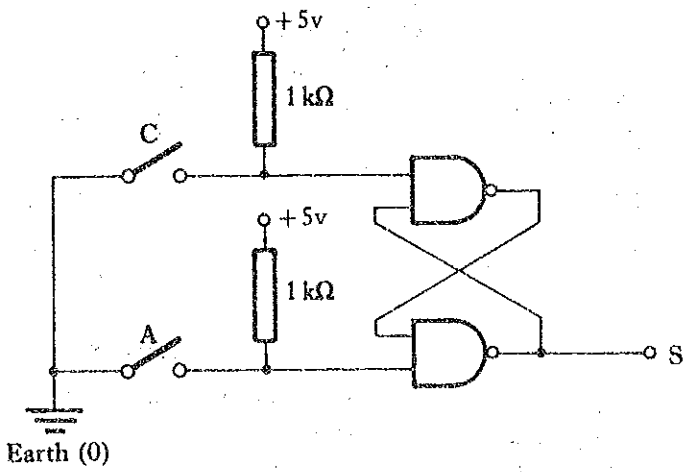
(iii) In a quiz game, the above circuit determines which of two contestants is first to press his answer switch.

Depending on which contestant's switch is pressed first, either S or R will go to logic 1.

That contestant's light comes on, indicated by Q′ or P′ going to logic 1, and the other contestant's light is prevented from coming on.

How does the sequence of the logic of part (ii) satisfy the requirements of the quiz game?

To avoid "contact bounce", each contestant's switch requires to be connected to S or R in the following way.



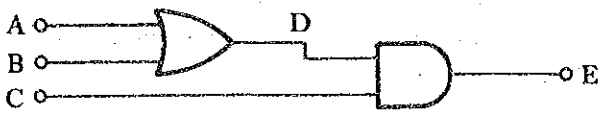
(iv) How does this arrangement avoid "contact bounce" for contestant A using switch A?

(v) How would the system be reset ready for the next question in the quiz? **7**

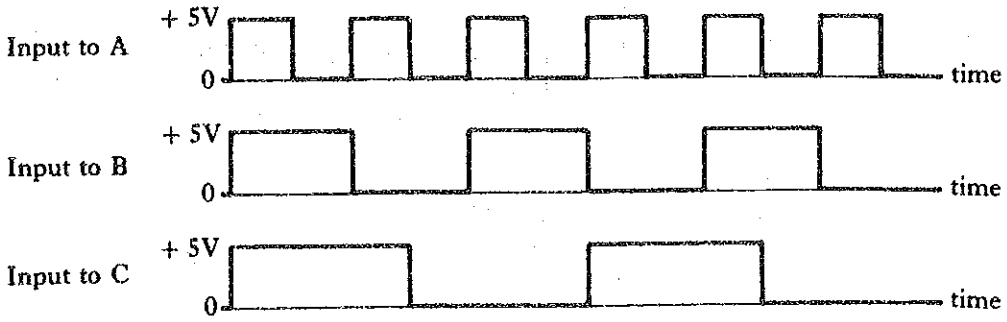
[Turn over

Marks

(*b*) Two logic gates are connected together in the following way.



Input pulses are applied to A, B and C respectively at frequencies of 6 Hz, 3 Hz and 2 Hz.



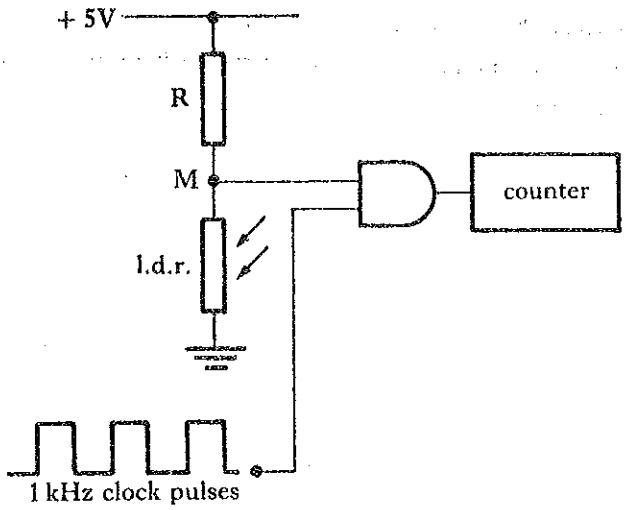
On the square ruled paper provided, copy the waveform of input A and below that draw the waveforms corresponding to

(i) the logic level at D,

(ii) the logic level of the output at E. 4

(*c*) In the circuit shown below, the resistance of the light dependent resistor (l.d.r.) is high when it is in the dark, and is low when light is shining on it.

The light beam shining on the l.d.r. can be interrupted by a passing vehicle (e.g. a dynamics trolley).

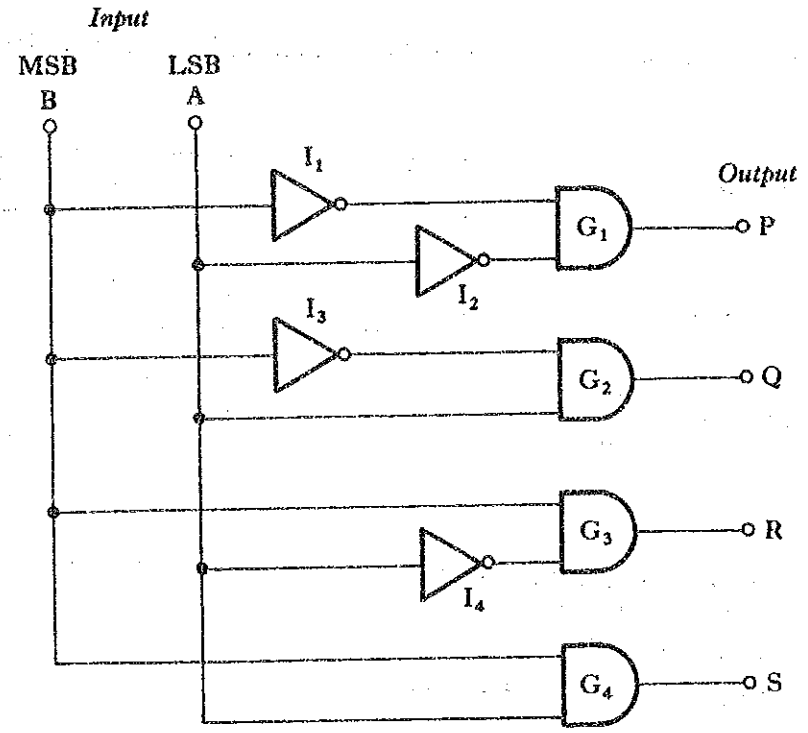


Explain how the circuit enables measurement to be made of the time taken by the vehicle to pass through the light beam. 3

(*d*) This circuit represents a 2-bit binary decoder.

An input representing a 2-bit binary number is applied at A and B.

Each binary number opens only one of the four gates G_1, G_2, G_3 or G_4, and produces logic 1 at one of the four outputs P, Q, R or S.



The binary number 10 is applied at the input.

(i) How do the labels, MSB and LSB in the diagram, determine to which of the inputs, A or B, the binary digit 1 is applied and to which of the inputs, A or B, the binary digit 0 is applied?

(ii) Explain how this input affects all four gates.

(iii) State which output therefore corresponds to the binary number 10 and state its decimal equivalent. **6**

(20)

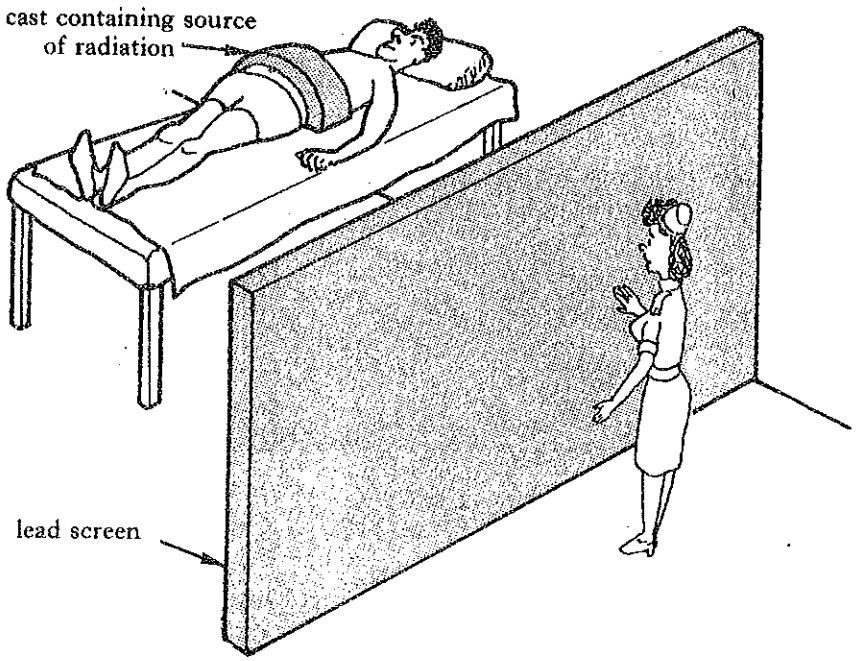
[Turn over

Marks

20. *NUCLEAR REACTORS*

(*a*) Describe an experiment to show how the intensity of gamma radiation transmitted through a lead absorber varies with the thickness of the lead. **4**

(*b*) The sketch shows a patient receiving radiation treatment. The source of radiation is built into the cast moulded to his body. During the treatment a nurse remains behind a lead screen.



The following information is available about the source and screen:

Quality factor of radiation 1

Half-value thickness of lead 1·2 cm

Without the screen in position, the absorbed dose at the position of the nurse is 480 μGy.

(i) What thickness of lead would be required to make the absorbed dose at the position of the nurse 7·5 μGy?

(ii) Calculate the dose equivalent for the nurse if the thickness of the lead screen is 2·4 cm.

(iii) How could this dose equivalent received by the nurse from the source be reduced other than by increasing the thickness of the lead screen? **5**

(*c*) Describe the function of the following components in an advanced gas cooled reactor:

(i) moderator;

(ii) control rods;

(iii) shield. **3**

Marks

(*d*) One reaction which takes place in the core of a nuclear reactor is represented by:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{58}Ce + ^{94}_{40}Zr + 2^{1}_{0}n + 6\,_{-1}^{0}e$$

Calculate the energy, in joules, available from this reaction given the following information:

Rest mass of $^{235}_{92}U$ = 235·044 u

Rest mass of $^{140}_{58}Ce$ = 139·905 u

Rest mass of $^{94}_{40}Zr$ = 93·906 u

Rest mass of $^{1}_{0}n$ = 1·009 u

1u (atomic mass unit) = $1{\cdot}660 \times 10^{-27}$ kg **4**

(*e*) After several years, fuel elements are removed from a reactor core for reprocessing.

(i) Explain why reprocessing is necessary.

(ii) Describe the steps in reprocessing a fuel element. **4**

(20)

[END OF QUESTION PAPER]