[94/234] 1985

SCOTTISH CERTIFICATE OF EDUCATION

PHYSICS

Higher Grade—PAPER II

Wednesday, 8th 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 $g = 10$ m s^{-2} or $g = 10$ 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.

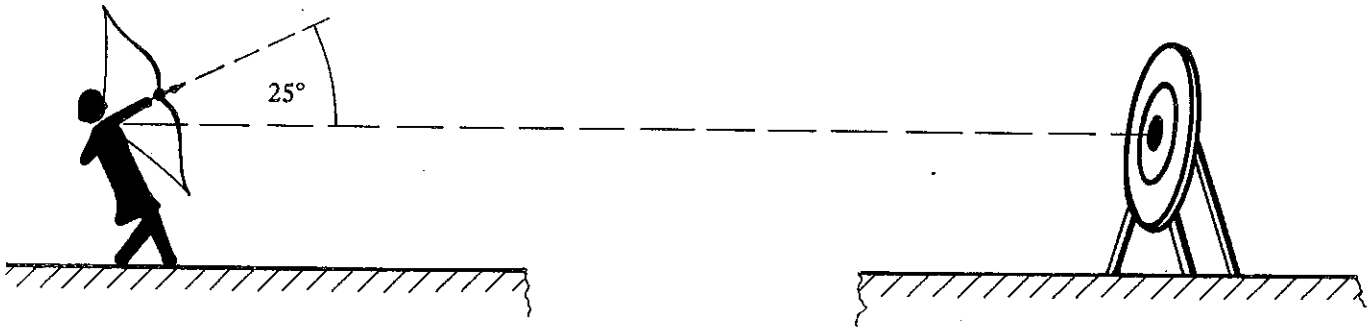
TE&S 94/234 6/6/21160

SECTION A

ALL questions in this section should be attempted.

Marks

1. An archer fires an arrow at a target 60 m distant. The arrow leaves her bow at 28 m s^{-1} at an angle of 25° to the horizontal as shown.



(*a*) What is the horizontal component of the velocity of the arrow?

(*b*) How long will it take the arrow to reach the target? **4**

2. A rocket of mass $2{\cdot}2 \times 10^6$ kg is launched vertically. The rocket engines exert a constant force of $3{\cdot}0 \times 10^7$ N.

(*a*) Calculate the resultant force on the rocket at take-off.

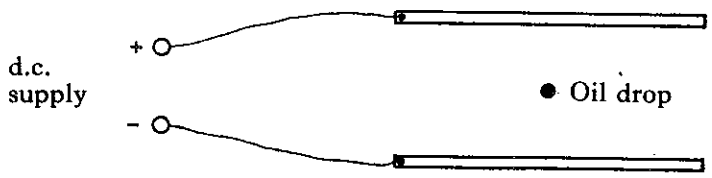
(*b*) Find the initial acceleration of the rocket as it takes off.

(*c*) The table below shows the speed of the rocket at intervals of time after the launch.

Time (s)	0	10	20	30	40
Speed (m s^{-1})	0	40	90	150	220

State what the figures in the table indicate about the acceleration of the rocket during the first 40 seconds of flight. **4**

3. An oil drop of weight $1{\cdot}44 \times 10^{-14}$ N is suspended in the electric field between a pair of charged, horizontal plates as shown.

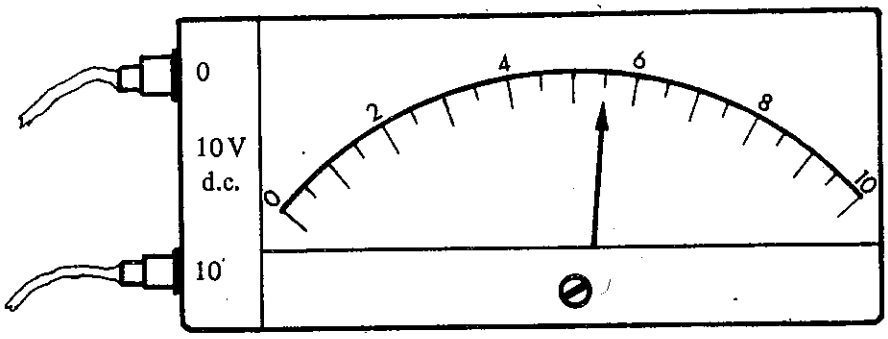


The electric field strength between the plates is $3{\cdot}00 \times 10^4$ N C^{-1}.

Calculate the size of the charge on the oil drop. **2**

Marks

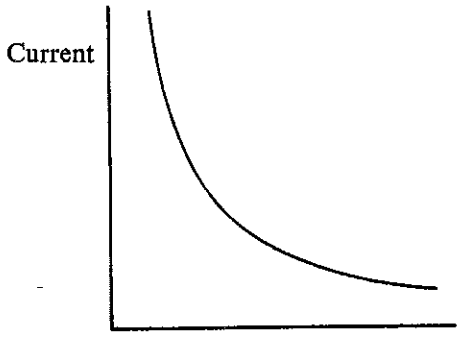
4. The diagram shows the reading obtained on a voltmeter during an experiment.



Write down the voltmeter reading and its uncertainty. State how you arrived at your value for the uncertainty. **2**

5. A pupil is given a box of electrical components which includes a resistor, a capacitor and an inductor and is asked to investigate how the alternating current in each component varies with the frequency of the supply.

One of the graphs obtained is shown below.



(*a*) Name the component used in this case.

(*b*) Describe how such a graph could be obtained experimentally.
Your description should include a circuit diagram of the apparatus used. **5**

6. A microwave oven, used to cook a steak, produces microwaves of frequency 2450 MHz.

(*a*) Find the wavelength of these microwaves in a vacuum.

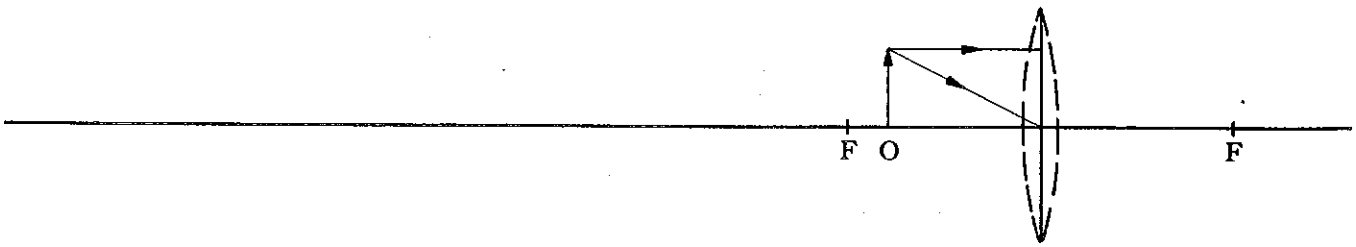
(*b*) State how the wavelength will be affected when the microwaves enter the steak. **2**

[Turn over

Marks

7. An object of height 2 cm is placed at O in front of a convex lens of focal length 25 cm. The ray diagram started by a pupil to investigate the type of image produced by the lens is shown below.

horizontal scale 1 cm : 10 cm
vertical scale 1 cm : 2 cm



(*a*) Find the type, position and size of the image produced by the lens.
(You may choose to complete the diagram in the space provided on this question paper but you are **not** required to return it with your answer book.)

(*b*) State where the object would have to be placed to form a real, inverted image equal in size to the object. **4**

8. The relationship below is one which can be derived when considering the kinetic theory of gases.

$$p = \tfrac{1}{3}\rho\overline{u^2}$$

(*a*) State the usual meaning of the symbols p, ρ and $\overline{u^2}$ in this equation.

(*b*) Find the root mean square speed of oxygen molecules at a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^5$ Pa. **5**

Marks

9. The table lists the energy required to remove an electron from the surface of a number of different metals.

Metal	copper	sodium	potassium	aluminium
Energy (J)	$7{\cdot}1 \times 10^{-19}$	$3{\cdot}6 \times 10^{-19}$	$3{\cdot}5 \times 10^{-19}$	$6{\cdot}7 \times 10^{-19}$

The energy of a photon of electromagnetic radiation is related to its frequency by the equation $E = hf$.

(*a*) Light is shone on to these four metals. The wavelength of the light is gradually increased until only one metal shows the photoelectric effect. Name this metal.

(*b*) Calculate the minimum frequency of light which will eject an electron from sodium. **3**

10. An investigation of solid metallic elements suggests that the following approximate relationship holds:

(relative atomic mass) × (specific heat capacity) = constant.

Construct a table as shown below.

Metal	*Rel. At. Mass*	*Sp. Ht. Capacity*	*Constant*

Using data obtained from your data book for **three** solid metallic elements, complete the table and find the approximate value of the constant in the above relationship. **4**

(35)

[END OF SECTION A]

[Turn over

SECTION B

Answer any THREE questions. Each question carries FIFTEEN marks.

Marks

11. (*a*) The passenger cars on a roller-coaster at a fun-fair are pulled up to point A and released (figure 1).

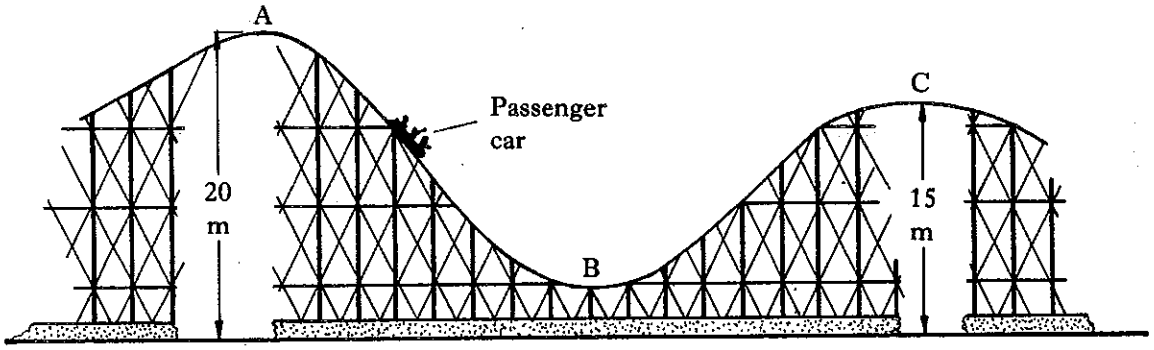


figure 1

A safety officer requires to measure experimentally the speed of the cars as they pass the lowest point B on the track.

Describe how the safety officer could carry out the experiment. Your description should include:

(i) a sketch of the apparatus used;

(ii) the procedure carried out and the measurements taken;

(iii) an indication of how the final result would be obtained. **4**

(*b*) During one run, a car and passengers of mass 800 kg are released from rest at point A, a height of 20 m above the ground. The car travels a distance of 120 m along the track until it reaches point C, a height of 15 m above the ground. A constant frictional force of 250 N acts between the car and the track as the car moves from A to C.

(i) State the energy changes which occur as the car moves from A to C.

(ii) Calculate the work done against friction in moving the car from A to C.

(iii) Find the kinetic energy of the car on reaching point C. **7**

Marks

(*c*) At the fair, a boy and a girl are seen bouncing on separate trampolines as shown in figure 2.

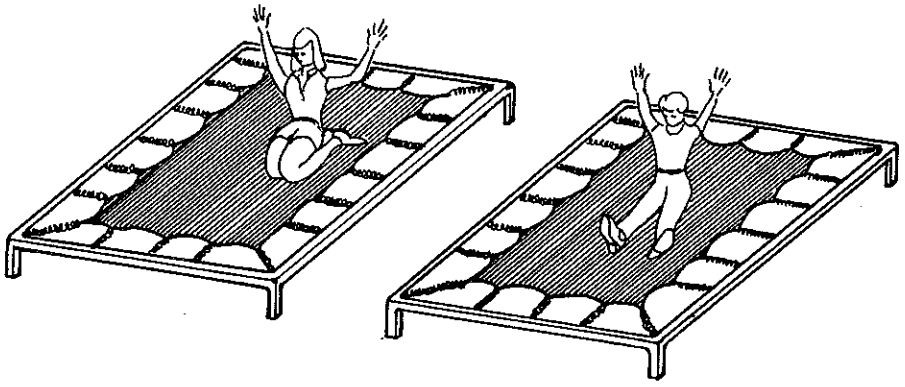


figure 2

The graphs in figure 3 show how the forces exerted by the trampolines on the children vary with time. Graph A represents the force on the girl and graph B the force on the boy.

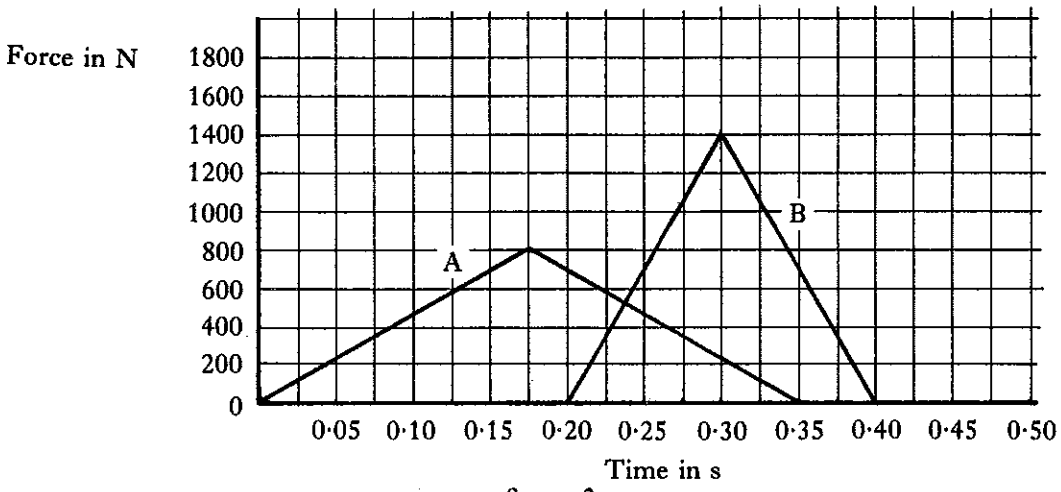


figure 3

(i) "Each child undergoes the same change in momentum during one bounce."
Justify this statement.

(ii) The boy has a greater mass than the girl. Both children drop from the same height on to their trampolines.
Which child will rebound from the trampoline with the greater speed?
Explain your answer. **4**

(15)

[Turn over

Marks

12. Using modern technology, many electrical components are produced by depositing very thin films of material on insulating bases.

(*a*) A capacitor is constructed by depositing tiny gold plates on either side of a thin layer of insulating material.

(i) State how the capacitance of the capacitor will be affected as the thickness of the layer between the plates is increased.

(ii) A capacitor produced by the above method has a capacitance of 220 pF. A potential difference of 5·0 V is applied to the plates.

(A) What will be the charge on the capacitor?

(B) How much energy will be stored in the capacitor?

(1 picofarad = 1×10^{-12} farad) **5**

(*b*) Certain resistors are constructed by depositing a thin film of conducting material on top of an insulating base. Connection to the film is made with gold pads at each end of the film as shown in figure 1.

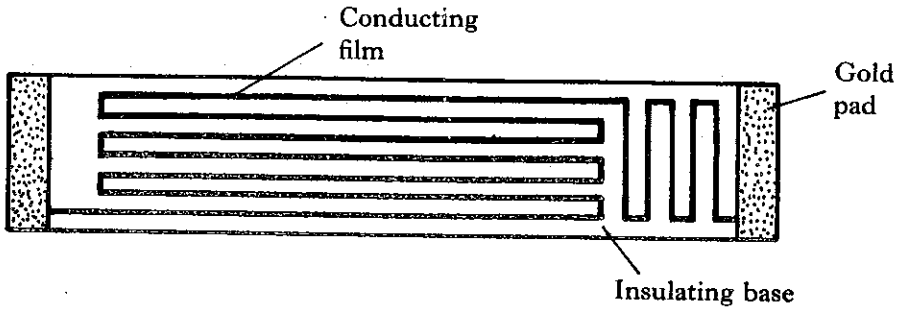


figure 1

The resistance between the end gold connectors depends on the breadth of the conducting film. The results below show the resistance for various breadths of film of the same length and thickness.

Breadth (μm)	150	87	67	60	55
Resistance (Ω)	80	140	180	200	220

Find the relationship between the resistance and the breadth of the conducting film. You must show how the data were used to arrive at the relationship. **4**

Draw graph.

Marks

(*c*) A platinum-film resistor is to be used to indicate changes in temperature.

To find the resistance at room temperature the resistor is placed in one of the arms of a Wheatstone bridge. A variable resistor and fixed resistors of 6·00 kΩ and 4·00 kΩ are placed in the other arms.

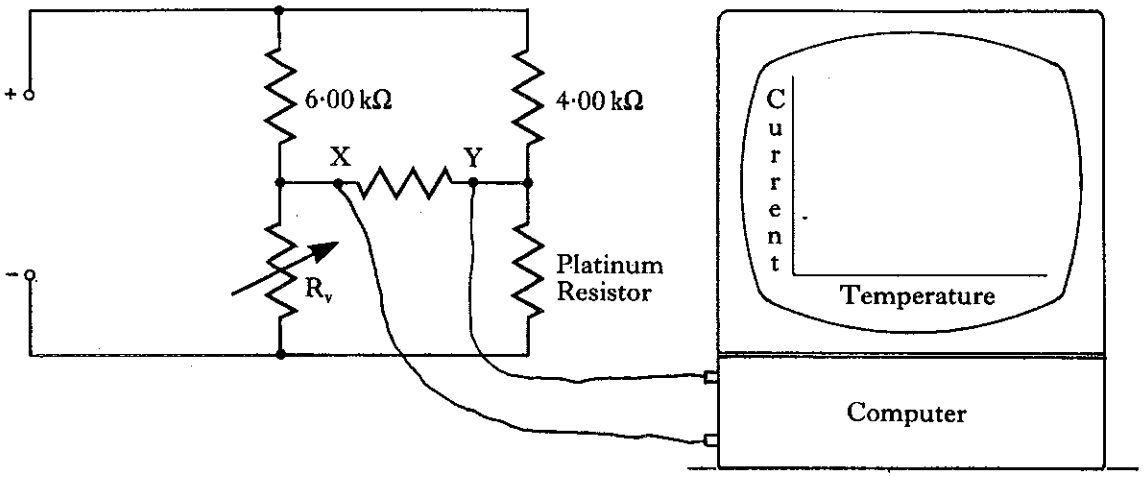


figure 2

A computer is connected across XY and programmed to read the current between X and Y (figure 2).

(i) The computer shows that the current between X and Y is zero when the variable resistor is set at 162 Ω. Calculate the resistance of the platinum-film resistor at room temperature.

(ii) The computer is now programmed to plot a graph of the current in XY against the temperature of the platinum-film resistor. Suggest and explain the shape of graph you would expect as the temperature of the platinum-film resistor is increased. **6**

(15)

[Turn over

Marks

13. (*a*) A pupil allows two narrow beams of red light, P and Q, to enter a semi-circular glass block as shown (figure 1). **Three** beams are observed by the pupil after the light strikes the glass-air boundary. Assume the critical angle for the glass is 42°.

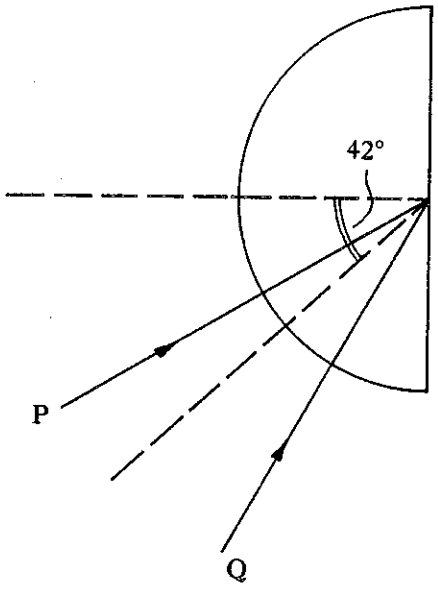


figure 1

Sketch and complete the diagram to show the paths of the beams after striking the glass-air boundary. **3**

(*b*) A narrow beam of light strikes a rectangular block of transparent plastic at an angle of 53° as shown in figure 2. Assume the refractive index of the plastic is 1·6 and its critical angle is 39°.

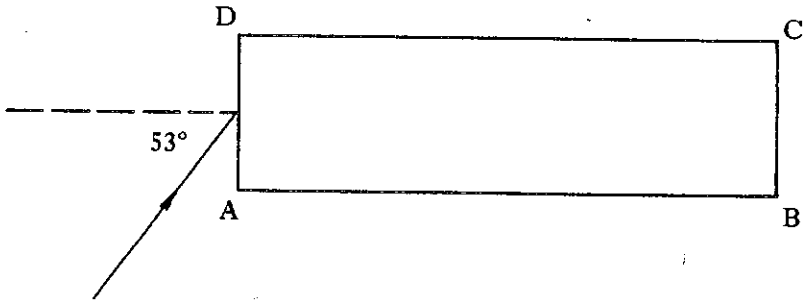


figure 2

Sketch a rectangle 7 cm by 2 cm to represent the block. On your sketch show the passage of the light beam through the plastic until it emerges from the block.

All the values of the angles at the points where the beam strikes the boundary between the block and the air must be clearly marked on your sketch. **5**

Marks

(*c*) A source of monochromatic light is placed behind two narrow slits separated by 0·25 mm. A light detector, 2·5 m in front of the slits, is moved from X to Y as shown in figure 3.

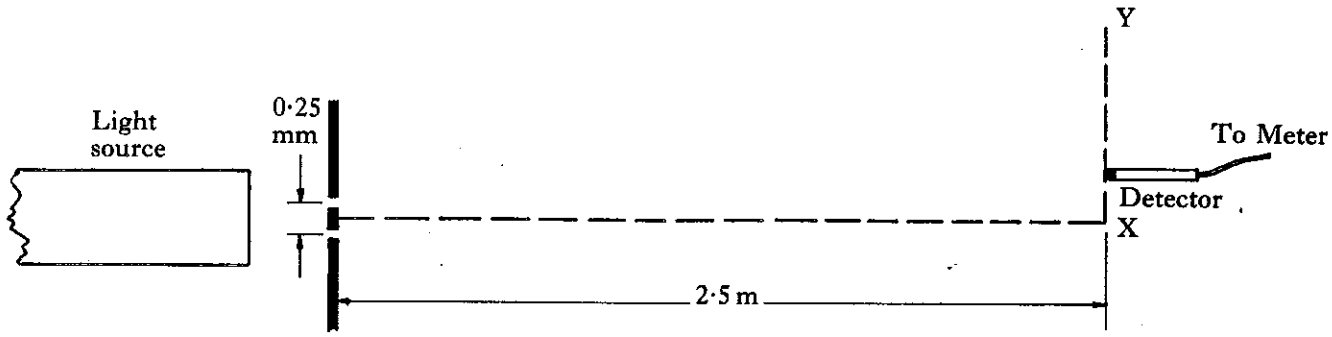


figure 3

As the detector moves from X to Y, a series of maximum and minimum readings is observed. The distance of the detector from X for each maximum reading is recorded in Table I.

Table I

Maximum reading	0th	1st	2nd	3rd	4th	5th
Distance from X (mm)	0	6·9	14·1	21·0	27·9	35·0

(i) Explain how the maximum readings on the detector are produced.

(ii) Calculate the wavelength of the light used in the experiment.

You may use the relationship $x = \frac{\lambda D}{d}$

(iii) The experiment is repeated using a different colour of light and the results are shown in Table II.

Table II

Maximum reading	0th	1st	2nd	3rd	4th	5th
Distance from X (mm)	0	6·0	12·0	17·9	24·0	30·1

(A) State how the wavelength of this light compares with that used in the original experiment.

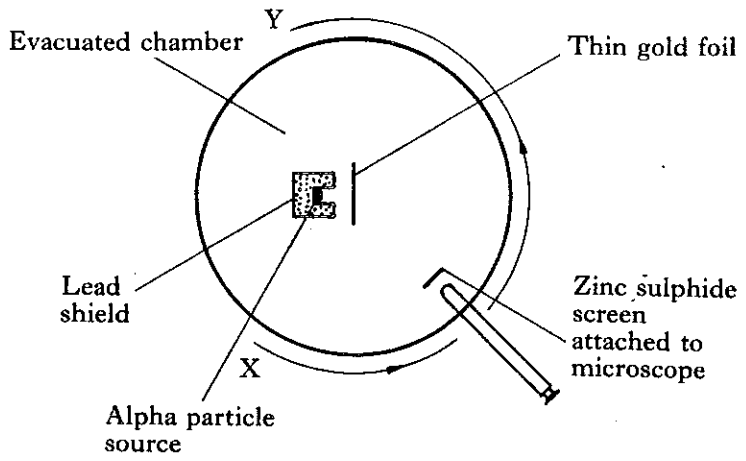
(B) Suggest one way in which the experimental arrangement could be changed so that the separation of the maximum readings returned to those in Table I. **7**

(15)

[Turn over

Marks

14. (*a*) Rutherford directed Geiger and Marsden in an investigation into the structure of the atom using the apparatus shown.



(i) Describe what the experimenters observed as the microscope was moved from X to Y and explain the results they obtained.

(ii) Geiger and Marsden investigated the effect of using elements other than gold.

By imagining the passage of a single alpha-particle near to the nucleus of an atom with an atomic number less than gold, suggest how the deflection might compare with an alpha-particle passing at the same distance from the nucleus of a gold atom. Explain your answer. **6**

(*b*) The equation for a nuclear fusion reaction involving the release of energy is given below.

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} = {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H}$$

(i) State the structure of each of the nuclides in the equation.

(ii) A table of nucleon and nuclide masses is reproduced below.

Nuclide/nucleon	*Mass in* kg × 10^{-27}	*Nuclide/nucleon*	*Mass in* kg × 10^{-27}
$^{1}_{0}\mathrm{n}$	1·674	$^{3}_{1}\mathrm{H}$	5·005
$^{1}_{1}\mathrm{H}$	1·672	$^{3}_{2}\mathrm{He}$	5·004
$^{2}_{1}\mathrm{H}$	3·342	$^{4}_{2}\mathrm{He}$	6·642

(A) Calculate the loss in mass which occurs when the reaction takes place.

(B) Find the energy released in the reaction given the equation $E = mc^2$ **7**

(*c*) Astrophysicists believe that the mass of the sun is decreasing at a rate of four million tonnes per second.

Give an explanation. **2**

(15)

[END OF SECTION B]

SECTION C—SPECIAL TOPICS

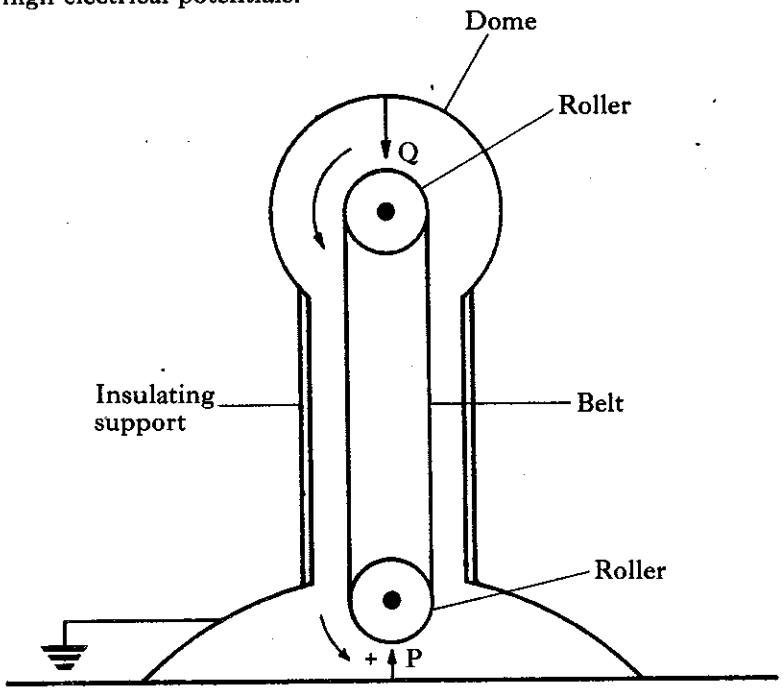
Answer any ONE question. Each question carries TWENTY marks.

Marks

15. *ELECTROSTATICS*

(*a*) Describe what is meant by corona discharge. **3**

(*b*) The diagram shows the main features of one type of Van de Graaff electrostatic generator used to provide high electrical potentials.



Explain how the dome of this generator becomes charged. **4**

(*c*) The Van de Graaff generator is switched on. After a few seconds the dome is connected to earth through a microammeter in series with a resistor of high resistance.

The reading on the meter is 15 microamperes. The dome is at a potential of 2·0 megavolts above earth potential.

(i) At what rate is charge being transferred to the dome?

(ii) Calculate the power required to maintain this rate of transfer of charge to the dome.

(iii) What power would the electric motor have to supply if 20% of the energy supplied is "lost" through such factors as friction? **6**

(*d*) Describe what is meant by a spark discharge. **2**

(*e*) Explain why aircraft tyres are made slightly conductive. **2**

(*f*) Difficulties arise due to unwanted charge in the handling of solid state devices and in the flow of liquids through pipes.

Choose **one** of these examples and

(i) describe how this unwanted charge is produced;

(ii) explain why the charge creates a difficulty;

(iii) state how the difficulty is overcome. **3**

(20)

[Turn over

Marks

16. *OPTICAL INSTRUMENTS*

(*a*) Describe an experiment to measure the focal length of a **diverging** lens. **4**

(*b*) A short-sighted person has difficulty seeing objects which are distant from his eyes but can see them clearly if he is able to bring them close to his eyes.

Explain, with the aid of diagrams. **4**

(*c*) A school photographic club has a camera with a "standard" lens of focal length 50 mm. The maximum aperture setting is labelled f/2.

(i) What is the corresponding area through which light enters the camera?

(ii) What aperture setting will allow only half as much light to enter in a given time? **4**

(*d*) (i) What is meant by "stopping down" a camera?

(ii) Under certain conditions, an exposure time of 1/500 second at f/4 is required. Under the same conditions, what should the exposure time be if the camera is stopped down to f/16?

(iii) How does stopping down a camera affect the depth of field? **6**

(*e*) A birdwatcher buys a pair of 8 × 30 binoculars. State what the numbers mean. **2**

(20)

Marks

17. *ANALOGUE ELECTRONICS*

(*a*) State **two** effects of applying negative feedback to an operational amplifier (op amp). **2**

(*b*) Figure 1 shows an op amp circuit which uses a ± 15 V supply (not shown).

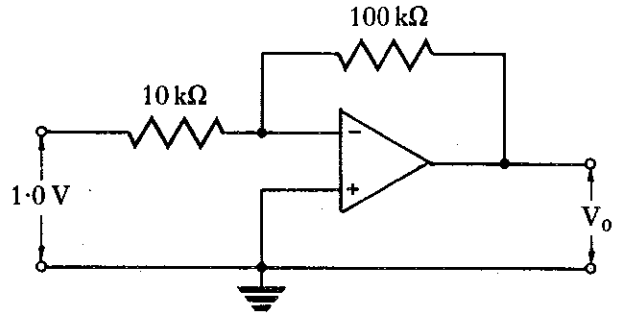


figure 1

(i) For the input of 1·0 V as shown, calculate the output voltage V_0.

(ii) What would be the measured value of V_0 if the 10 kΩ resistor were replaced by a 1 kΩ resistor? **4**

(*c*) (i) Draw the circuit diagram of an op amp operating in the **non-inverting mode** which will amplify an input voltage of 0·20 volt to an output voltage of 3·2 volts.

(ii) Calculate the values of the components required and indicate these values on your circuit diagram. **4**

(*d*) An engineer designs the circuit shown in figure 2 to cause an alarm bell to sound when the temperature in a furnace exceeds a set value. The resistance of resistor X decreases with increasing temperature. It is placed in or near the furnace.

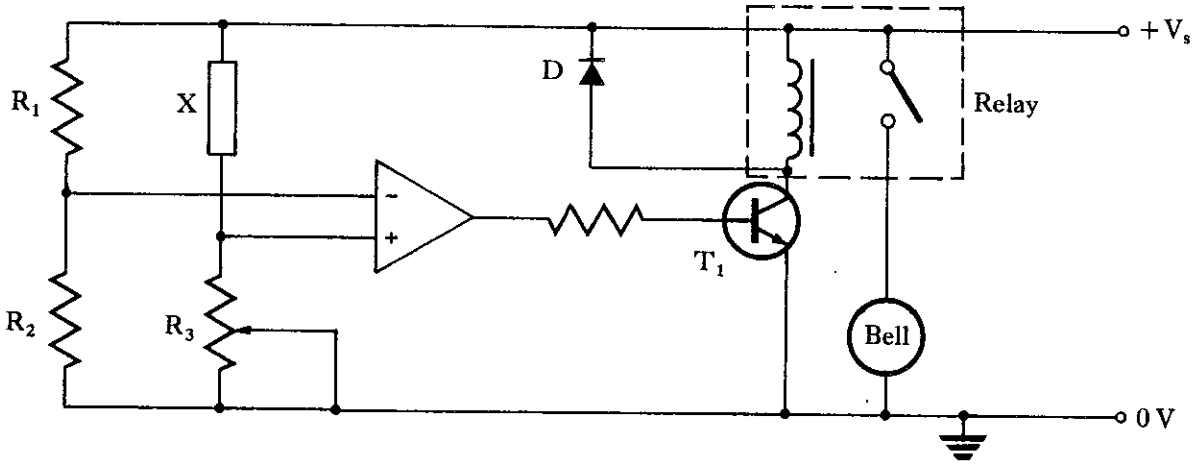


figure 2

The supply voltage to the op amp is not shown.

(i) In what mode is the op amp connected?

(ii) Is the voltage at the non-inverting input to the op amp greater when the temperature of X is low or high? Explain your answer.

(iii) In order to "switch on" transistor T_1, must the output from the op amp be positive or negative with respect to "earth"?

(iv) Explain why the transistor is necessary.

(v) Explain what may happen if the diode D is removed from the circuit.

(vi) What is the function of R_3? **10**

(20)

Marks

18. *DIGITAL ELECTRONICS*

(*a*) The diagram shows a circuit constructed from two gates (figure 1).

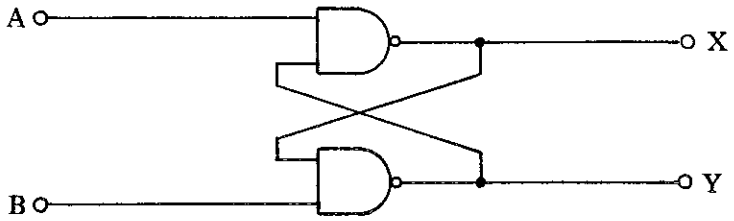


figure 1

(i) Name the gates in this circuit.

Both inputs are set to logic 1.

(ii) What is the most that can be said about the logic states of the outputs X and Y?

(iii) If A changes to logic 0 while B remains at 1, what must the logic values of X and Y become? **3**

(*b*) The diagram shows a circuit in which information is fed into a register in the form of voltage pulses (figure 2).

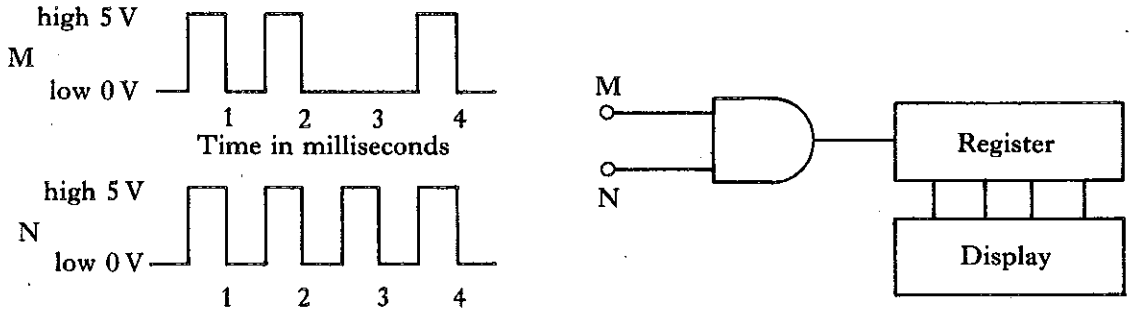


figure 2

(i) Make a labelled sketch on graph paper of the signal to the register when the inputs to M and N are as shown.

(ii) State what type of device stores the digital information in the register. **3**

Marks

(*c*) The diagram in figure 3 is a representation by means of switches of a three-input system where the state of the input is determined by the switches.

Logic 1 is the code for a closed switch.

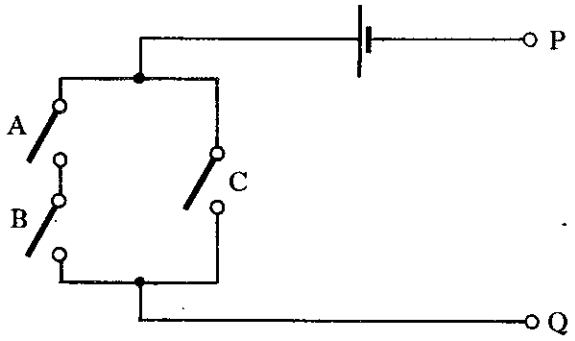


figure 3

(i) Name a suitable output display to be connected between PQ.

(ii) Suggest a suitable logic coding for the output.

Construct a truth table for the system. **6**

(*d*) Using **two** gates only, construct the corresponding logic diagram for the system shown in figure 3. **4**

(*e*) How could a circuit based on the logic diagram in (*d*) be used to check that the correct postage of 26p has been paid for a package if the only stamps available are 12p (which is coloured green), 14p (blue) and 26p (red)? **4**

(20)

[Turn over

Marks

19. *NUCLEAR REACTORS*

(*a*) In a nuclear reactor the following processes occur:

nuclear fission; controlled chain reactions.

Explain what is meant by each process.

It may be helpful to draw diagrams to illustrate your answers. **6**

(*b*) Describe how the energy released in the core of a nuclear reactor is transferred and converted to mechanical energy. **4**

(*c*) Each fuel element in an Advanced Gas-cooled Reactor (AGR) contains 36 fuel pins, each made up from uranium dioxide fuel pellets stacked inside stainless steel cans.

(i) State **two** purposes of these fuel cans.

(ii) Suggest **two** important reasons why stainless steel has been chosen as a suitable material for the fuel cans in an AGR.

(iii) Describe briefly the sequence of operations to recover unused uranium from a fuel element which has exhausted its useful life in the reactor core. **5**

(*d*) When one ^{235}U nucleus undergoes fission, $3{\cdot}2 \times 10^{-11}$ J of energy are released. Assuming the uranium dioxide pellets used in the fuel of an AGR contain $5{\cdot}9 \times 10^{22}$ nuclei of ^{235}U in each kilogram, calculate the rate at which the fuel is "used up" to generate 1200 MW of heat. **5**

(20)

[*END OF QUESTION PAPER*]