Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9646/02**
Higher 2

Paper 2 Structured Questions

20 September 2013

1 hour 45 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use			
1		/	10
2		/	8
3		/	7
4		/	10
5		/	9
6		/	16
7		/	12
Total		/	72

This document consists of **21** printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
	$= (1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{{x_0}^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas,	$E = \frac{3}{2}kT$
resistors in series,	$R = R_1 + R_2 + ...$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T = \exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 In a nuclear reactor, a fast moving neutron with initial speed u_1 makes a head-on elastic collision with a stationary nucleus of carbon-12 which has a mass 12 times that of the neutron. The speeds of the neutron and the carbon nucleus after the collision are v_1 and v_2 respectively.

(a) What is meant by a *head-on elastic collision*?

....

....

....

.... [2]

(b) (i) State the *principle of conservation of linear momentum*.

....

....

.... [1]

(ii) Determine the ratio of the final speed of the neutron v_1 to its initial speed u_1.

ratio = ... [3]

(c) Hence determine the fraction of the kinetic energy of the neutron that is transferred to the carbon nucleus.

fraction = ... [2]

(d) In nuclear engineering, a neutron moderator is a medium that reduces the speed of fast neutrons. Explain which would make a better neutron moderator, carbon-12 or neutron.

....

.... [2]

2 **(a)** Starting from the definition of work, deduce the change in the gravitational potential energy of a mass m, when moved a distance h upwards against a gravitational field of field strength g.

[3]

(b) A catapult consists of two strands of rubber that obeys Hooke's law. Each strand has original length of 0.200 m and each will stretch by 0.100 m when under a tension of 50 N. A mass of 0.060 kg is projected vertically upwards from the catapult after each strand has been extended to a length of 0.350 m.

(i) Calculate the energy stored in the stretched catapult.

energy stored = ... J [3]

(ii) Determine the maximum height attained by the stone if air resistance is negligible.

maximum height = ... m [2]

3 A vertical peg is fixed to the rim of a horizontal turntable of radius r = 15.0 cm, rotating with a constant angular speed ω = 4.0 rad s^{-1}, as shown in Fig. 3.1.

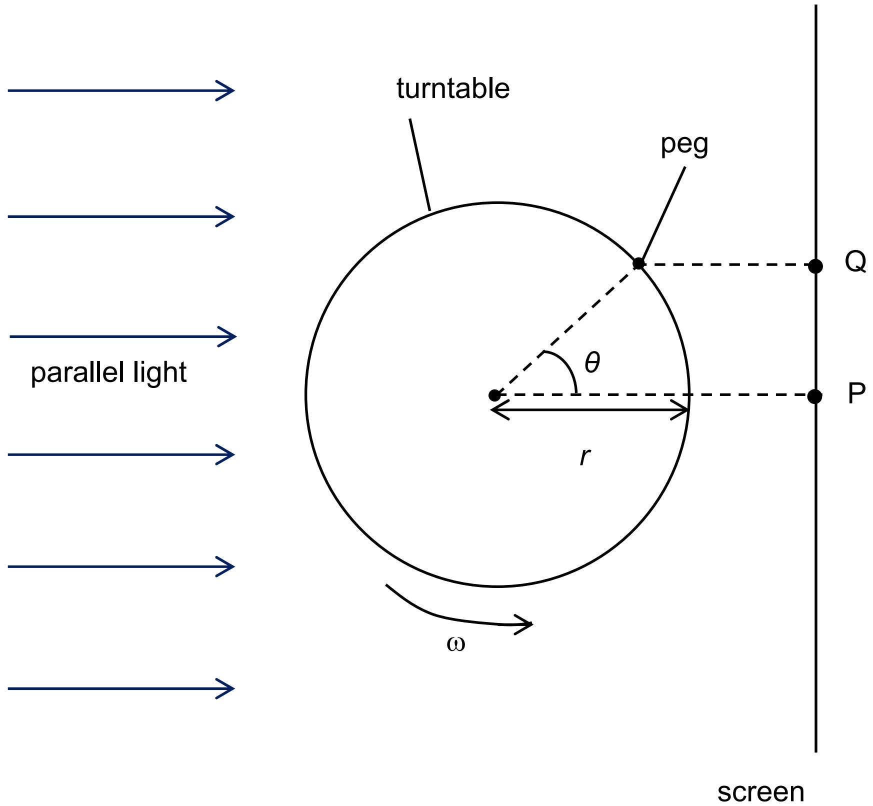

Fig. 3.1

Parallel light is incident on the turntable so that the shadow of the peg is observed on a screen, which is normal to the incident light. At time t = 0, θ = 0 and the shadow of the peg is seen at P.

At some time t, the shadow is seen at Q.

(a) (i) Write down an expression for x in terms of ω, r and t, where x is the distance PQ.

[1]

(ii) Hence, prove that the shadow on the screen executes simple harmonic motion.

[2]

(b) Calculate the speed of the shadow on the screen at a displacement of 7.5 cm above P.

speed = ... m s^{-1} [2]

(c) Calculate the maximum acceleration of the shadow.

maximum acceleration = ... m s^{-2} [2]

4 Two small charged metal spheres A and B are situated in a vacuum. The distance between the centres of the spheres is 12.0 cm, as shown in Fig. 4.1.

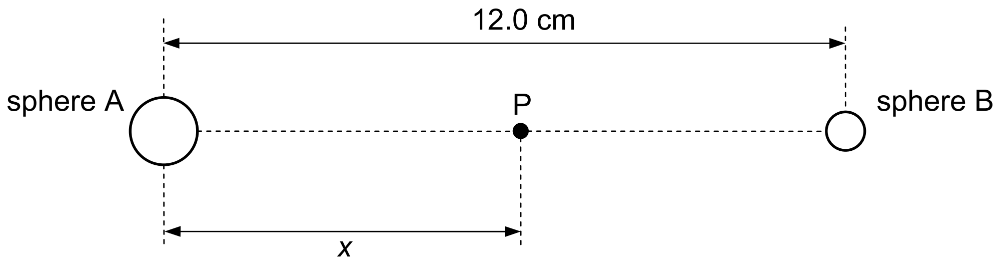

Fig. 4.1

The charge on each sphere may be assumed to be a point charge at the centre of the sphere. Point P is a movable point that lies on the line joining the centres of the spheres and is distance *x* from the centre of sphere A.

The variation with distance *x* of the electric field strength *E* at point P is shown in Fig. 4.2.

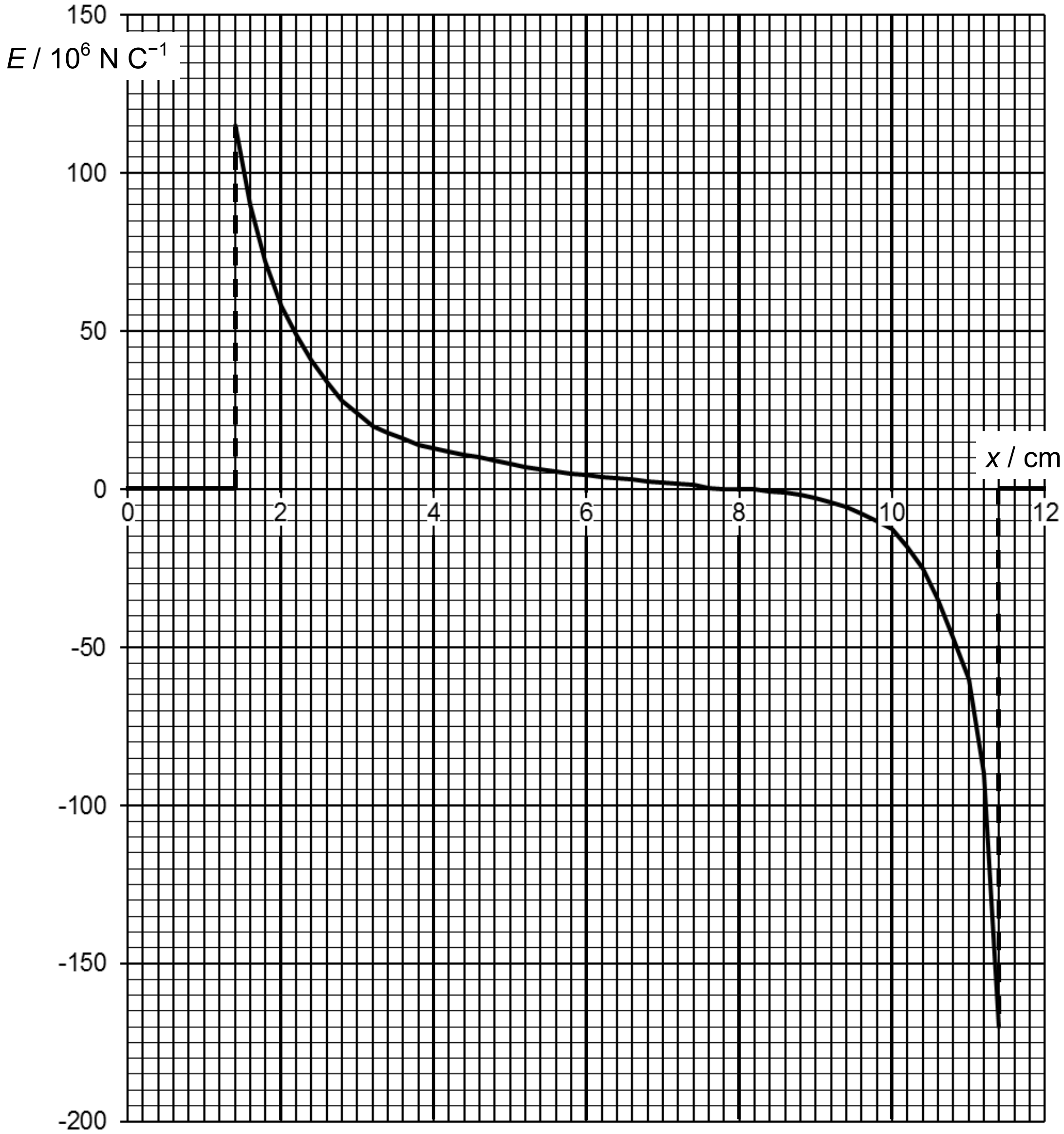

Fig. 4.2

[Turn over

(a) State the evidence provided by Fig. 4.2 that the spheres are conductors.

....

.... [1]

(b) (i) Comment, with explanation, on the polarity of the two charges.

....

....

....

.... [2]

(ii) Use Fig. 4.2 to determine the ratio $\dfrac{\text{charge on sphere A}}{\text{charge on sphere B}}$.

ratio = ... [2]

(iii) Hence, on Fig. 4.3, sketch the electric field lines due to these two charges.

Fig. 4.3

[2]

(c) (i) State the relation between electric field strength E and potential V.

.... [1]

(ii) A negative point charge of –0.20 C is moved by an external force from the point where x = 2.0 cm to the point where x = 8.0 cm, along the line joining the centres of the spheres.

Use Fig. 4.2 to determine the magnitude of the net work done by the external force in this process.

net work done = ... J [2]

5 **(a)** A junction is formed between slices of p-type and n-type semiconductor material, as shown in Fig. 5.1.

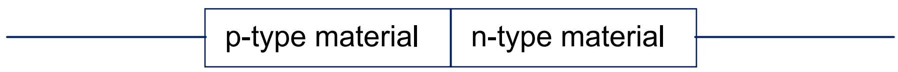

Fig. 5.1

(i) On Fig. 5.1, draw an arrow to show the direction of movement of electrons as the two slices are brought into contact. [1]

(ii) Describe the origin of the depletion region at the junction.

....

....

....

....

....

.... [3]

(iii) On Fig. 5.1, draw the symbol for a battery, connected so as to increase the width of the depletion region. [1]

(b) By reference to the band theory of conduction, explain why the electrical resistance of an intrinsic semiconductor material decrease as its temperature rises.

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.... [4]

6 The resistance R of a small semiconductor device X varies with temperature θ / °C as shown in Fig. 6.1.

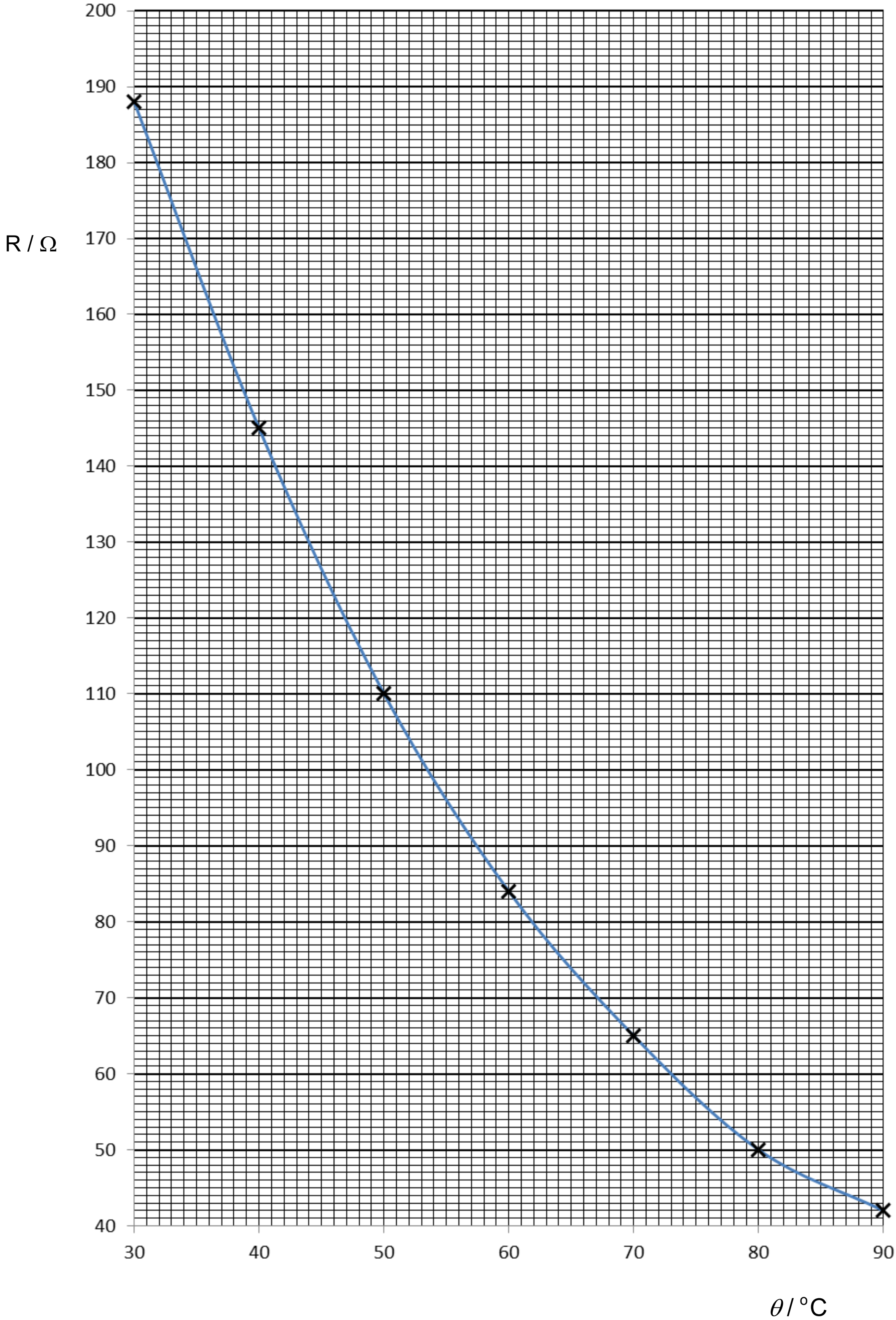

Fig. 6.1

(a) (i) The resistance and temperature of device X are related by the expression

$$R = Ae^{\frac{B}{T}}$$

where A and B are constants and T represents the thermodynamic temperature.

Determine the values for A and B. Express the answers in the appropriate units.

A = ... [2]

B = ... [2]

(ii) On Fig. 6.2, sketch a graph of the variation of the current I with the potential difference V through device X.

Fig. 6.2

[1]

(b) Device X is now connected to a fixed resistor of resistance 40.0 Ω as shown in Fig. 6.3.

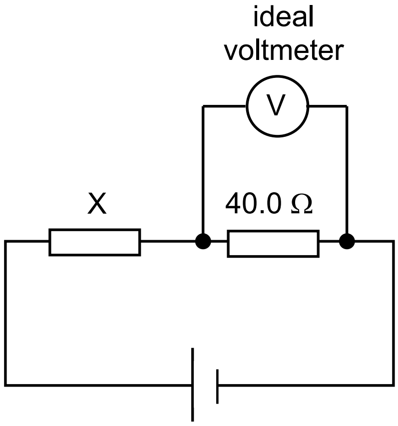

Fig. 6.3

(i) Calculate an estimated value for the voltmeter reading when device X is immersed in water at temperature 30.0 °C.

V = ... V [2]

(ii) If the temperature of the water is raised, would the voltmeter reading increase or decrease? Explain.

....

....

.... [2]

(c) Another common semiconductor device is a diode. A diode conducts a significant amount of current in one direction only and it is commonly used to rectify an a.c. voltage.

(i) Fig. 6.4 shows a simple half-wave rectifier circuit. Briefly explain how your circuit works, assuming that the diode is ideal.

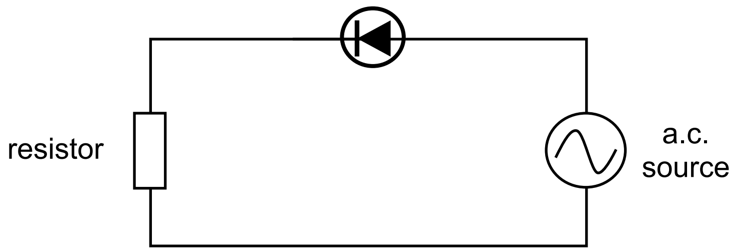

Fig. 6.4

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....

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.... [2]

(ii) The half-wave rectifier circuit in **(c)(i)** is used to rectify an a.c. source that has a peak voltage of 6 V. Calculate the r.m.s. voltage of the rectified a.c. source.

r.m.s. voltage = ... V [2]

(iii) Fig. 6.5 shows a diode testing circuit.

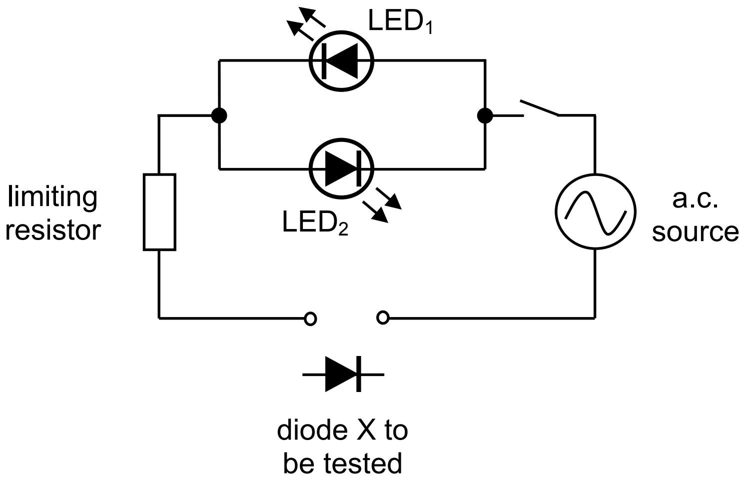


Fig. 6.5

The switch is closed.

State which of the two light-emitting diodes (LEDs) will light up when the diode X to be tested

1. is working,

.... [1]

2. fails due to a short-circuit in X,

.... [1]

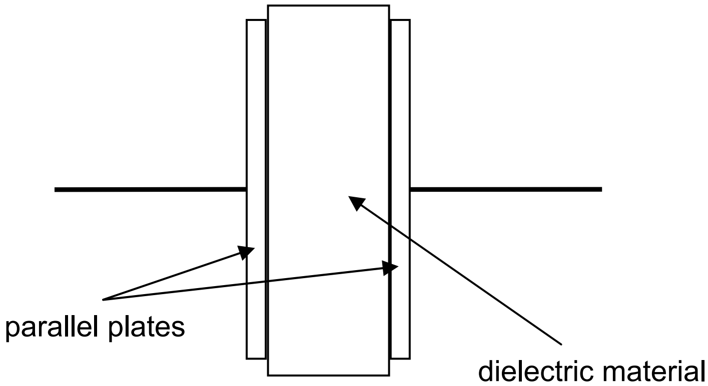
3. fails due to an open-circuit in X.

.... [1]

7 Capacitors are devices that are able to store charges, similar in a way to batteries. They store electric energy and release it when necessary. Once connected to a battery, the capacitor will be charged to the **same potential** as the e.m.f. of the battery. One plate accumulates positive charge and the other plate accumulates negative charge.

A fully charged capacitor connected to a closed circuit will discharge the charges that it stored previously. As the charges flow, the current in the circuit decreases as the amount of charges stored decreases.

A simple capacitor consist of two metallic plates brought in close proximity and isolated from one another with a dielectric substance, such as air, paper, mica, and other insulators. The type of material used as dielectric depends on the application.



A company wishes to install a new dielectric material in its capacitors. Design an experiment to determine the relationship between the amount of charges stored in a capacitor and the thickness of the dielectric material used in the capacitor.

The following equipment are available: connecting wires, resistors, voltmeter, milliammeter, batteries, galvanometer, cathode ray oscilloscope and any other equipment normally available in a school laboratory.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use for the investigation,

(c) the procedure to be followed,

(d) how the amount of charges stored in the capacitor would be determined,

(e) any precautions that you would take to improve the accuracy and safety of the experiment.

Diagram

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[12]

End of paper