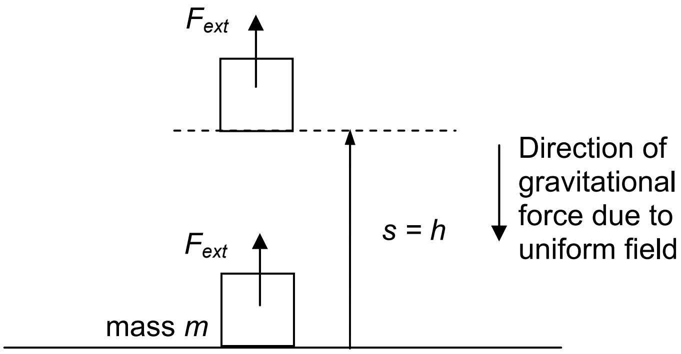
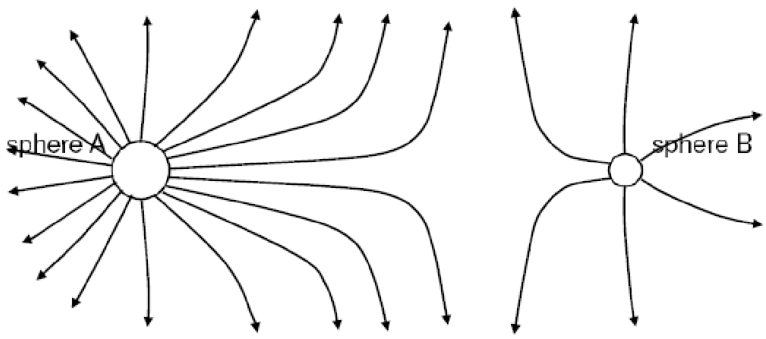
Answers to 2013 JC2 Preliminary Examination Paper 2 (H2 Physics)

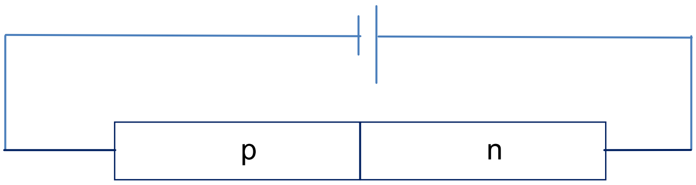
Suggested Solutions:

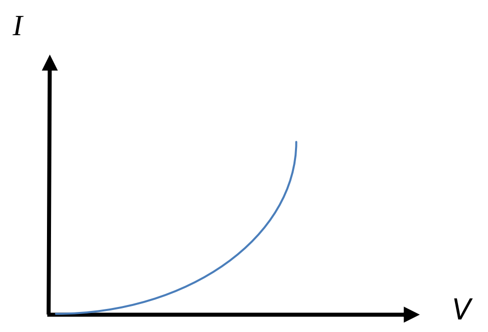
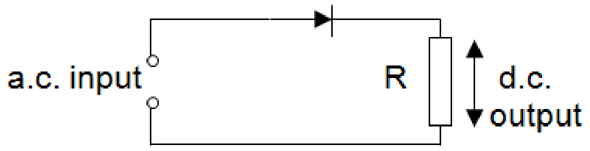
No.	**Solution**
1(a)	A head-on collision takes place along the line joining the centres of the colliding bodies. An elastic collision is one in which the kinetic energy is conserved.
1(b)(i)	The total momentum of a system is constant, provided no external resultant force acts on it.
1(b)(ii)	By conservation of linear momentum, $mu_1 = mv_1 + 12mv_2$ $\Longrightarrow u_1 - v_1 = 12v_2$ ……….(1) velocity of approach = -velocity of separation $u_1 - 0 = v_2 - v_1$ $u_1 + v_1 = v_2$ ………(2) (1) + (2) $2u_1 = 13\ v_2 \Longrightarrow v_2 = \frac{2}{13}u_1$ From (2) $v_1 = v_2 - u_1 = \frac{2}{13}u_1 - u_1 = -\frac{11}{13}u_1$ Thus ratio $\frac{v_1}{u_1} = -\frac{11}{13}$
1(c)	Required fraction $= \dfrac{\frac{1}{2}m(u_1^2 - v_1^2)}{\frac{1}{2}mu_1^2} = 1 - [\frac{v_1}{u_1}]^2$ $= 1 - [\frac{11}{13}]^2$ $= 0.28$
1(d)	Carbon-12 atom is more massive and slows down the neutrons while the neutron has the same mass and will not slow down the incoming neutron.

2(a)	 Work done is $W = Fs$, where s is the displacement in the direction of the force. To move the mass through a vertical height h without acceleration, an external force is needed to overcome the weight of the mass. Thus, $F_{ext} = mg$ Work done = $F_{ext}\, s = mgh$ = change in gravitational potential energy.
2(b)(i)	Applying Hooke's law, $F = ke$ $\Rightarrow k = \frac{F}{e} = \frac{50}{0.100} = 500 \text{ N m}^{-1}$ Elastic potential energy stored in both strands $= 2\left(\frac{1}{2}ke^2\right) = ke^2 = (500)(0.350 - 0.200)^2 = 11.3 \text{ J}$
2(b)(ii)	From conservation of energy, gained in G.P.E. = lost in E.P.E. $mgh = 11.3$ $h = 19.1$ m
3(a)(i)	$x = r\sin\omega t$
3(a)(ii)	Differentiating x with respect to time t, we have $v = \omega r\cos\omega t$ Differentiating v with respect to time t, we have $a = -\omega^2 r\sin\omega t$ Replacing $r\sin\omega t$ by x, we have $a = -\omega^2 x$ Hence the shadow on the screen undergoes simple harmonic motion.

3(b)	$v = \omega\sqrt{[x_o^2 - x^2]}$ $= 4.0\sqrt{[0.150^2 - 0.075^2]}$ $= 0.52\ \mathrm{m\ s^{-1}}$
3(c)	$a = \omega^2 x_o$ $= 4.0^2 \times 0.15$ $= 2.4\ \mathrm{m\ s^{-2}}$
4(a)	<u>Zero electric field strengths</u> in sphere A (between x = 0 and x = 1.4 cm) and in sphere B (between x = 11.4 and x = 12.0 cm)
4(b)(i)	The charges on the spheres are <u>both positive</u> because the <u>field strength is zero at a point between the spheres</u> or the <u>electric fields are in opposite directions</u>.
4(b)(ii)	At x = 0.08 m, the electric field strength due to sphere A cancels out the electric field strength due to sphere B. Electric field strength due to sphere A $E_A = \dfrac{Q_A}{4\pi\varepsilon_o x^2}$ --- (1) Electric field strength due to sphere B $E_B = \dfrac{Q_B}{4\pi\varepsilon_o (0.12 - x)^2}$ --- (2) $E_A = E_B$ $\dfrac{Q_A}{4\pi\varepsilon_o x^2} = \dfrac{Q_B}{4\pi\varepsilon_o (0.12 - x)^2}$ $\dfrac{Q_A}{4\pi\varepsilon_o (0.08)^2} = \dfrac{Q_B}{4\pi\varepsilon_o (0.04)^2}$ $\dfrac{Q_A}{Q_B} = \left(\dfrac{0.08}{0.04}\right)^2 = 4$ Allow estimation from graph, 7.8 cm < x < 8.2 cm Alternatively: Electric field strength at surface of sphere A, $E_A = \dfrac{Q_A}{4\pi\varepsilon_o r_A^2} - \dfrac{Q_B}{4\pi\varepsilon_o (0.12 - r_A)^2}$ --- (1) Electric field strength at surface of sphere B, $E_B = \dfrac{Q_B}{4\pi\varepsilon_o r_B^2} - \dfrac{Q_A}{4\pi\varepsilon_o (0.12 - r_B)^2}$ --- (2) (1) / (2) $\dfrac{\dfrac{1}{4\pi\varepsilon_0}\left[\dfrac{Q_A}{r_A^2} - \dfrac{Q_B}{(0.12 - r_A)^2}\right]}{\dfrac{1}{4\pi\varepsilon_0}\left[\dfrac{Q_B}{r_B^2} - \dfrac{Q_A}{(0.12 - r_B)^2}\right]} = \dfrac{E_A}{E_B} = \dfrac{115}{170} \approx 0.676$

	$\frac{Q_A}{r_A^2} - \frac{Q_B}{(0.12 - r_A)^2} = 0.676\left[\frac{Q_B}{r_B^2} - \frac{Q_A}{(0.12 - r_B)^2}\right]$ $Q_A\left[\frac{1}{r_A^2} + \frac{0.676}{(0.12 - r_B)^2}\right] = Q_B\left[\frac{0.676}{r_B^2} + \frac{1}{(0.12 - r_B)^2}\right]$ $\frac{Q_A}{Q_B} = \frac{\frac{0.676}{r_B^2} + \frac{1}{(0.12 - r_B)^2}}{\frac{1}{r_A^2} + \frac{0.676}{(0.12 - r_B)^2}} = \frac{\frac{0.676}{(0.6)^2} + \frac{1}{(12 - 1.4)^2}}{\frac{1}{(1.4)^2} + \frac{0.676}{(12 - 0.6)^2}} \approx 3.66$
4(b)(iii)	Diagram  Deduct 1 mark if any of the following is not shown. • Correct field line direction and shape. • At least more field lines radiating out of sphere A than sphere B. • Location of neutral point nearer to sphere B.
4(c)(i)	The field strength is negative of the potential gradient, i.e. $E = -\frac{dV}{dx}$ (not $\frac{V}{x}$).
4(c)(ii)	$V = -\int_{x=2cm}^{x=8cm} E\,dx$ Hence, change in potential from x = 2.0 cm to x = 8.0 cm, ΔV = area under E−x graph (from x = 2.0 cm to x = 8.0 cm) Counting the number of squares, estimated about 3 (1 cm × 25 × 10^6 N C^{-1}) squares or 75 (2 mm × 5 × 10^6 N C^{-1}) squares $\Delta V = 3 \times (0.01 \times 25 \times 10^6) = 7.5 \times 10^5$ V (accept any logical estimation of area under E−x graph) Magnitude of W.D. by external force, W = $q \times \Delta V$ W.D. = 0.20 × 7.5 x 10^5 = 1.5 × 10^5 J (accept ± 10 % deviation)

5(a)(i)	 **Fig. 5.1**
5(a)(ii)	When p-type and n-type materials are placed together, free electrons, from n-type material, diffuse across junction to fill up holes in the p-type material producing negative ions in p-type material leaving positively charges ions in n-type material. This process continues until an electric field is set up to prevent any further diffusion of electron through the p-n junction. This leads to the formation of a layer depleted of any mobile charges at the junction and this layer is called the depletion region.
5(a)(iii)	 **Fig. 5.1**
5(b)	The energy between valence band and conduction band is narrow at 1 eV. At 0K, there are no electrons in the conduction band and the valence band is fully filled. At temperatures > 0K, a significant number of electrons become thermally excited and move into the conduction band, leaving holes behind in the valence band. As temperature rises, more electrons-holes pairs are produced resulting in more charge carriers and thus reducing the resistance.
6(a)(i)	$R = Ae^{\frac{B}{T}}$ $\ln R = \ln A + \frac{B}{T}$ Taking temperatures at $50^{o}\mathrm{C}(323.15\mathrm{K})$ and $80^{o}\mathrm{C}(353.15\mathrm{K})$, R= 110 Ω and 50 Ω respectively.

	$\ln 110 = \ln A + \dfrac{B}{323.15}$ ... (1) $\ln 50 = \ln A + \dfrac{B}{353.15}$ ... (2) (1) − (2), $\ln 110 - \ln 50 = \dfrac{B}{323.15} - \dfrac{B}{353.15}$ $B \approx 3.0 \times 10^3\ \text{K}$ $A \approx 1.02 \times 10^{-2}\ \Omega$
6(a)(ii)	
6(b)(i)	At 30.0 °C, the resistance of *X* is approximately 188 Ω. By potential divider principle, $V = \dfrac{40}{40+188} \times 6 = 1.05\ \text{V}$
6(b)(ii)	The voltmeter reading should increase. From Fig. 6.1, as the temperature of the water is raised, the resistance of Device X decreases. Using the <u>potential divider principle</u>, the p.d. across the 40 Ω will increase.
6(c)(i)	 On the positive cycle, the diode is forward biased. The diode conducts. On the negative cycle, the diode is reversed biased. The diode does not conduct. Hence, the AC input is

	half-wave rectified.
6(c)(ii)	$V_{rms} = \sqrt{6^2 \times \frac{1}{2} \times \frac{T}{2} \times \frac{1}{T}} = 3\text{ V}$
6(c)(iii)	1. LED_1 will be flashing but appears lighted up throughout due to the high frequency of flashing. 2. The LEDs will light up alternately, but the human eye will not be able to differentiate the rapid flashing, resulting in both LEDs being seemed to be lighted up at the same time. 3. Neither LED will light up.

7. Suggested solution:

Diagram (equipment to be used is shown in the diagram)

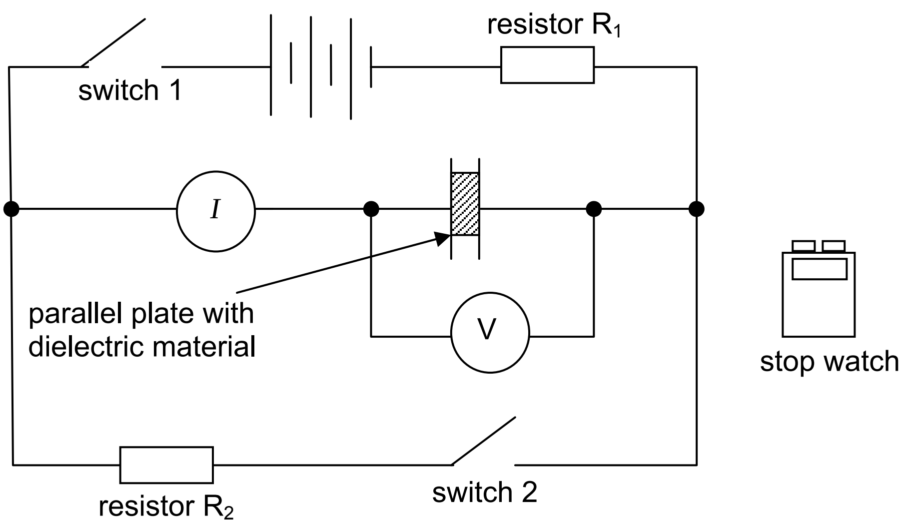


Fig. 7.1

Aim: To investigate the relationship between the thickness of the dielectric material in a capacitor and the amount of charge stored.

Independent variable: thickness of the dielectric material

Dependent variable: amount of charge stored in the capacitor, by determining the area under the current-time graph as the capacitor discharges.

Controlled variables : - the e.m.f. of the battery used to charge the capacitors,
- type of dielectric material

Procedure:

(a) Select a capacitor with a certain dielectric material of thickness *t* and connect the capacitor to the circuit shown in Fig. 7.1.
(b) Close switch 1, leaving switch 2 open to charge the capacitor. The capacitor is fully charged when the voltmeter connected across the capacitor reaches a maximum reading.
(c) With the circuit connected, record the p.d. *V* of the fully charged capacitor.
(d) After the capacitor is fully charged, open switch 1 to disconnect the fully charged capacitor from the battery.
(e) Close switch 2 and immediately start the stop watch. The capacitor is discharged through the circuit containing resistor R_2.
(f) Take readings of the current flowing in the circuit every 5 s interval.
(g) Continue to obtain the value of current as the capacitor discharges until the current reduces to a very low value (near to zero).
(h) Plot the graph of current against time and determine the area below the curve, *A* and record the reading.
(i) Replace the capacitor with another dielectric thickness and repeat steps (a) to (h).
(j) Plot a graph of the area *A* against the thickness *t* of dielectric material.

Suggested Marks Allocation

Listing the equipment and the diagram		[3]
battery connected in series to charge the capacitor		
voltmeter connected across the capacitor so that the potential difference across the capacitor be measured.		
another circuit connected to discharge the capacitor		
procedure		[2]
Able to provide instructions for charging and discharging the capacitor (either separate circuit or same circuit with switches)		
Repeat readings with capacitor of different dielectric thickness		
how the amount of charge stored in the capacitor can be measured		[2]
measuring the current flowing from the capacitor during discharging (to obtain the current vs time curve)		
Integral of discharge current vs time curve to obtain the amount of charge stored in capacitor		
Identifying and control of the variables		[3]
- thickness of the dielectric material (independent variable) - amount of charge stored in the capacitor (dependent variable) - the e.m.f. of the battery used to charge the capacitors are to be kept constant, - resistance of resistor R_1 and R_2 in the circuit to be kept constant,		
precautions that would improve the accuracy		[2]
Allow sufficient time during charging of the capacitor so that the capacitor is fully charged before disconnecting from the battery.		
The resistor R_1 and R_2 may get too hot after a while and its resistance may vary with increasing temperature.		
Handle the capacitor with insulating gloves as static charge could discharge the stored charges easily or short circuit the capacitor.		