Marks

7. (a) S = supporting force

(i) $S = mg = 60 \times 10 = 600$ N — 1

(ii) $S - mg = ma \rightarrow S = mg + ma$

$= 600 + 60 \times 100$

$= 6\ 600$ N — 1

As the supporting force is very large, the astronaut should lie down in a bed-shaped seat to reduce the pressure by increasing the contact area.
(or to avoid the lack of blood flowing to the brain) — 1

(b) (i) Gravitational P.E. $= -\dfrac{GM_E m}{r}$ — 1

Equation of circular motion : $\dfrac{GM_E m}{r^2} = \dfrac{mv^2}{r}$ (v = speed of spacecraft)

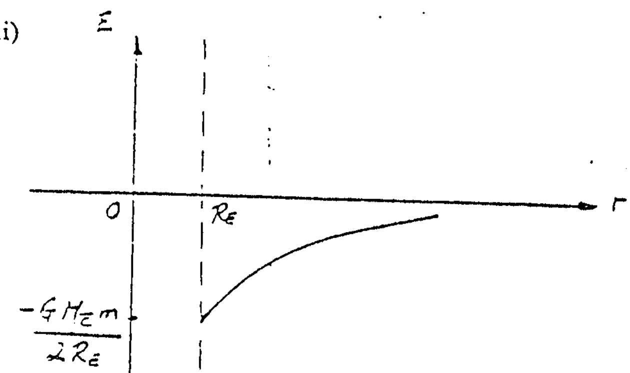
$\therefore$ K.E. $= \dfrac{GM_E m}{2r} = \dfrac{1}{2}mv^2$ — 1

Total M.E. = P.E. + K.E.

$$E = -\frac{GM_E m}{r} + \frac{GM_E m}{2r}$$

$$E = -\frac{GM_E m}{2r}$$ — 1

(ii)



shape of curve correct — 1

curve takes a finite negative value at $r = R_E$ — 1

(iii) At infinity, $E_\infty = 0$ — 1

Energy required $= E_\infty - E_r$

$= 0 - \left(-\dfrac{GM_E m}{2r}\right)$

$= \dfrac{GM_E m}{2r}$ — 1

(c) No. At a point in an orbit of radius r,

acceleration due to gravity $= \dfrac{GM_E}{r^2} \neq 0$, — 1

weight of the astronaut $= \dfrac{GM_E m'}{r^2} \neq 0$ (m' = mass of the astronaut) — 1

The astronaut is 'weightless' because his weight (gravitational force) is completely used for centripetal acceleration, thus there is no supporting force (i.e. the sensation of weight). — 1

Marking Scheme

Marks

8\. (a) violet (or blue) 1

(b) $\lambda' = \frac{\lambda}{n} = \frac{4.20 \times 10^{-7}}{1.4}$ 1

$= 3.0 \times 10^{-7}$ m

(c) (i) path difference $= 2 \times 3 \times 10^{-5}$ 1

$= 6.0 \times 10^{-5}$ m 1

(or optical path difference $= 2 \times 1.4 \times 3.0 \times 10^{-5}$

$= 8.4 \times 10^{-5}$ m)

(ii) $\because$ path difference $= \frac{6.0 \times 10^{-5}}{3.0 \times 10^{-7}} \lambda' = 200\lambda'$ 1

(or optical path difference $= \frac{8.4 \times 10^{-5}}{4.2 \times 10^{-7}} = 200\lambda$)

$\therefore$ constructive interference occurs 1

(d) Central bright spot is due to constructive interference. 1

Circular rings are due to slight variation in (optical) path difference which depends on the angle of viewing. 1

(e)

1

(f) In (d), the reflected ray has a phase change of π (i.e. p.d. $= \lambda/2$) when reflected from the coating-glass boundary. 1

In (e), the reflected ray has no phase change when reflected from the coating-block boundary. 1

Hence a phase change of π is introduced due to reflection, dark area in (d) becomes bright area in (e) and vice versa.

Marks

9. (a) b represents the 'effective' volume of the gas molecules (or a constant related to the volume of the gas molecules) — 1

(b) The attractive intermolecular force is negligible. — 1
The repulsive intermolecular force cannot be neglected. (The equation indicates a reduction in the volume in which the molecules can move.) — 1

(c) (i) $5.0 \times 10^5 (V_A - 1 \times 3.0 \times 10^{-5}) = 1 \times 8.31 \times 350$ — 1
$V_A = 5.817 \times 10^{-3} + 3.0 \times 10^{-5}$
$= 5.85 \times 10^{-3}\ m^3$ — 1

(ii) $p = \dfrac{nRT}{V - nb}$
$= \dfrac{2 \times 8.31 \times 300}{5.85 \times 10^{-3} - 2 \times 3.0 \times 10^{-5}}$ — 1
$= 8.6 \times 10^5$ Pa — 1

(d) (i) T_1, T_2 = initial temp. in compartments A, B respectively
T = final temp.
$K.E._{final} = K.E._A + K.E._B$
$3 \times CT = 1 \times CT_1 + 2 \times CT_2$ (C = constant) — 1
$T = \dfrac{T_1 + 2T_2}{3}$
$= \dfrac{350 + 2 \times 300}{3}$ — 1
$= 317$ K — 1

(ii) $p = \dfrac{nRT}{V - nb}$
$= \dfrac{3 \times 8.31 \times 317}{2 \times 5.85 \times 10^{-3} - 3 \times 3.0 \times 10^{-5}}$ — 1
$= 6.8 \times 10^5$ Pa — 1

				Marks
10.	(a)	(i)	flux change (in one turn), $\Delta\bar{\phi} = (0.20 \times 0.01) \times 2$	1
			$= 0.004$ Wb	
			average emf, $\varepsilon = N\dfrac{\Delta\bar{\phi}}{\Delta t}$	
			$= 100 \times \dfrac{0.004}{0.1}$	1
			$= 4$ V	1
		(ii)	average current, $I = \dfrac{\varepsilon}{R}$	
			$= \dfrac{4}{50}$	
			$= 0.08$A ($= 80$ mA)	1
		(iii)	quantity of charge, $Q = It$	
			$= 0.08 \times 0.1$	1
			$= 0.008$ C	1
	(b)	(i)	angular frequency, $\omega = 2\pi f = 10\pi$	
			flux, $\bar{\phi} = 0.20 \times 0.01 \cos(10\pi t)$	1
			emf, $\varepsilon = N\dfrac{d\bar{\phi}}{dt}$	
			$= -100 \times 0.20 \times 0.01 \times 10\pi \sin(10\pi t)$	
			$= -6.28 \sin(10\pi t)$	1
			$\therefore$ current, $I = \dfrac{\varepsilon}{R} = -\dfrac{6.28}{50}\sin(10\pi t)$	
			$= -0.126 \sin(10\pi t)$	1
		(ii)	$I_{r.m.s.} = \dfrac{I_0}{\sqrt{2}}$	
			$= \dfrac{0.126}{\sqrt{2}}$	1
			$= 0.089$ A	1
		(iii)	average power $= I^2_{r.m.s.} R$	
			$= 0.089^2 \times 50$	1
			$= 0.40$ W	1

73-AL-PHY-2B
Marking Scheme

Marks

11 (i) $V_{out} = V_{in}$ 1

(ii) (I) Use in high resistance voltmeters such as digital voltmeters or electrometers. 1

(II) To match a high impedence source to a low impedence load such as in current amplifier. 1

(i) initial charge $Q_0 = 10 \times 10^{-6} \times 5.0$
$= 5.0 \times 10^{-5}$ C $(= 50\ \mu C)$ 1

(ii) discharging current $i = -\dfrac{dQ}{dt}$ 1

$V_{in} = \dfrac{Q}{C}$ 1

$V_{out} = A_0(iR)$ 1

$= -A_0 R\dfrac{dQ}{dt}$

And $V_{in} = iR + V_{out}$ 1

$\dfrac{Q}{C} = -R\dfrac{dQ}{dt} - A_0 R\dfrac{dQ}{dt}$

$\dfrac{dQ}{dt} = -\dfrac{Q}{(1 + A_0)RC}$

(iii) $\displaystyle\int_{Q_0}^{Q} \frac{dQ}{Q} = \frac{-1}{(1 + A_0)RC}\int_0^t dt$ 1

$\ln\dfrac{Q}{Q_0} = \dfrac{-t}{(1 + A_0)RC}$ 1

$Q = Q_0\, e^{\frac{-t}{(1 + A_0)RC}}$

$= 5.0 \times 10^{-5}\, e^{\frac{-10 \times 3600}{1.0 \times 10^{5} \times 2 \times 10^{6} \times 10 \times 10^{-6}}}$ 1

$= 4.91 \times 10^{-5}$ C $(= 49.1\mu C)$

				Marks
12.	(a)	(i)	U → Th : α-particle Th → Pa : β-particle	1
		(ii)	$N = N_0 e^{-kt}$ half-life $T_{1/2} = \dfrac{\ln 2}{k}$	1
			$7.1 \times 10^8 = \dfrac{\ln 2}{k}$ $\therefore \dfrac{N}{N_0} = e^{-kt}$ $= e^{-\frac{\ln 2}{7.1 \times 10^8} \times 10^8}$	
			$= e^{-9.763 \times 10^{-10} \times 10^8}$	1
			$= 0.91$ (or 91%)	1
	(b)	(i)	mass defect $= (235.0439\text{ u} + 1.0087\text{ u}) - (90.9234\text{ u} + 141.9164\text{ u} + 3 \times 1.00087\text{ u})$	1
			$= 236.0526\text{ u} - 125.3659\text{ u}$ $= 0.1867\text{ u}$ ($= 0.3099 \times 10^{-27}$ kg)	1
		(ii)	no. of U-235 nuclides split per second $a = \dfrac{4.00 \times 10^{-5}}{235.0439 \times 1.66 \times 10^{-27}}$ $= 1.025 \times 10^{20}$	1
			∴ rate of energy production $= a\,[0.1867 \times 1.66 \times 10^{-27} \times (3 \times 10^8)^2]$	1
			$= 1.025 \times 10^{20} \times 2.789 \times 10^{-11}$ $= 2.86 \times 10^9$ W	1
	(c)		Liquid/gas coolant absorbs heat as it flows around the reactor core, and	1
			the thermal energy is transferred to water which is then converted to steam.	1
			The turbine of a generator is driven by the steam to produce electricity.	1

Marks

1. (a) (i) At the zero mark. 1 1

(ii) Net force $F = 2(kx)$

$= 2(24 \times 0.06)$

$= 2.88$ N 1

Acceleration $a = \frac{F}{m}$

$= \frac{2.88 \text{ N}}{2 \text{ kg}}$

$= 1.44 \text{ m s}^{-2}$ 1

Direction : to the right 1 3

(iii) Attach a light cardboard to the trolley in a transverse direction to the motion by using air damping. 1 1

or Attach a light metal plate to the trolley along the direction of motion and normal to a transverse magnetic field by using electromagnetic damping. 1 1 2

(b) (i) In place free from gravity 1

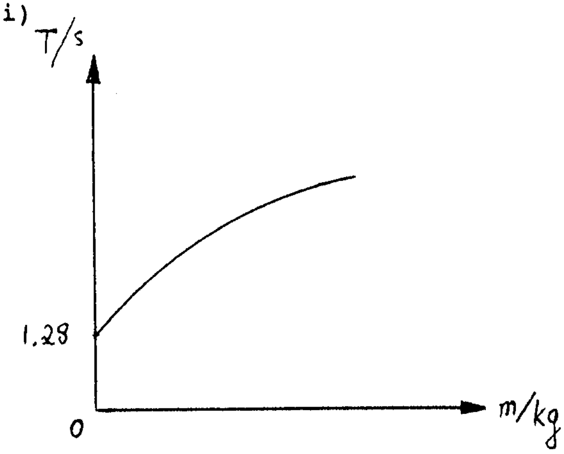
or Inside a spacecraft orbiting the earth 1 1

(ii) Period $T = 2\pi\sqrt{\frac{m}{k}}$ 1

$= 2\pi\sqrt{\frac{2}{2(24)}}$

$= 1.28$ s 1 2

(iii)

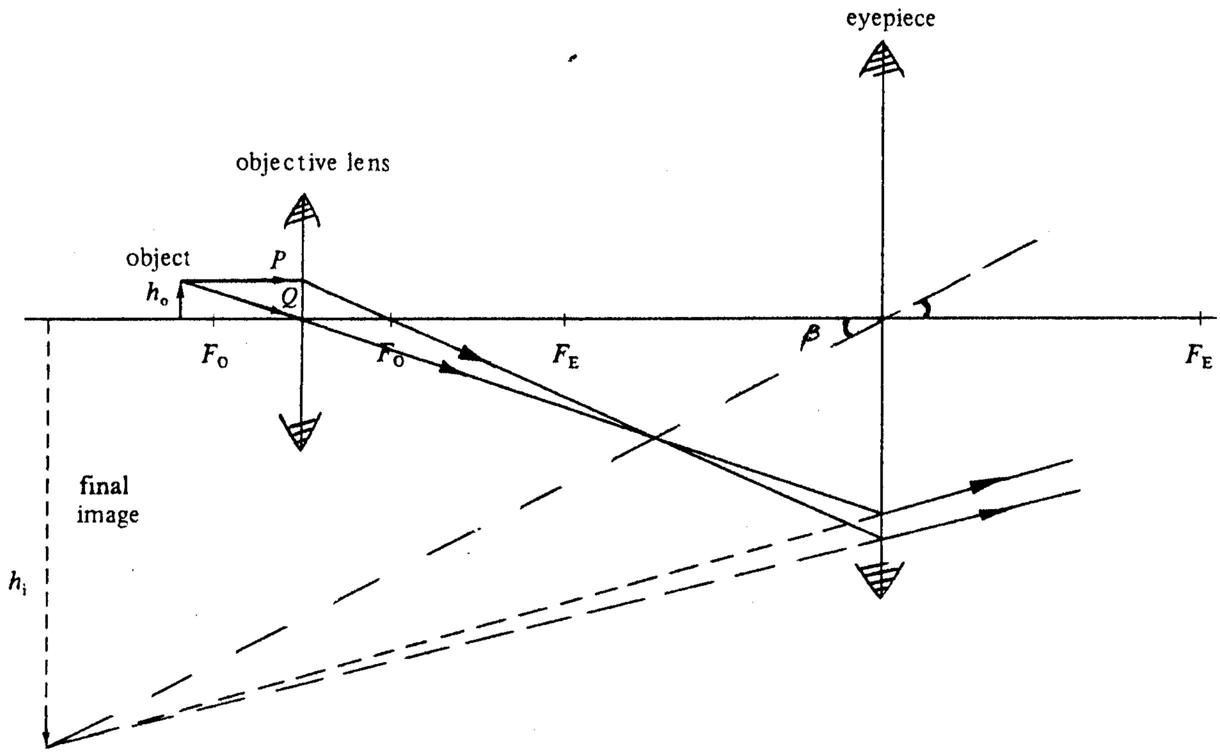


"+" y-intercept 1

shape of curve correct 1 2

Marks

2. (a) (i) (ii)



2+1
3

(iii) Linear magnification = $\dfrac{\text{height of image}}{\text{height of object}}$ 1

Angular magnification = $\dfrac{\text{visual angle of the image}}{\text{visual angle of the object}}$ 1 2

(iv) Without microscope, visual angle of the object $\alpha = \dfrac{h_0}{D}$

With microscope, visual angle of the image $\beta = \dfrac{h_i}{D}$ 1

$\therefore$ angular magnification = $\dfrac{\beta}{\alpha} = \dfrac{h_i}{h_o}$ 1 2

(b) (i) All the light from the objective lens (or the object) would pass through *X*. 1
The image is then brightest 1
and the field of view is greatest. 1 3

(ii) Matching the beam to the diameter of the pupil. 1 1

3. (a) Gravitational force is always attractive. (Work has to be done to bring an object from any point outside the planet to infinity) 1 1

(b) (i) ΔP.E. = $2000 \times (62.53 - 55.58) \times 10^6$ J 1
$= 1.39 \times 10^{10}$ J 1 2

(ii) $\because \dfrac{mv^2}{r} = \dfrac{GmM}{r^2}$

k.e. = $\dfrac{1}{2}mv^2 = \dfrac{GmM}{2r}$ 1

$= \dfrac{2000}{2} \times (55.58 \times 10^6)$ J 1

$= 5.558 \times 10^{10}$ J 1 3

(c) k.e. at surface = p.e. gained 1

$\dfrac{1}{2}mv^2 = m\ (62.53 \times 10^6)$

$v = 11.2\ \text{km s}^{-1}$ 1 2

Marks

3. (d) (i) Gravitational field = - potential gradient 1

$$= \frac{(55.66 - 55.50) \times 10^6}{810000 - 790000}$$

$$= 8\ \text{N kg}^{-1} \text{ or } 8\ \text{m s}^{-2}\ (\pm\ 0.5\ \text{N kg}^{-1})$$ 1 2

(ii) Gravitational potential $\propto \frac{1}{r}$, Gravitational field $\propto \frac{1}{r^2}$

$\therefore$ gravitational field at surface $= 8 \times \left(\frac{62.53}{55.58}\right)^2$ 1

$= 10\ \text{N kg}^{-1}\ (\pm\ 0.5\ \text{N kg}^{-1})$ 1

or $-\frac{GM_p}{(R_p + 8 \times 10^5)} = -55.58 \times 10^6$

$-\frac{GM_p}{R_p} = -62.53 \times 10^6$ 1

On solving, $R_p = 6.40 \times 10^6$ m

Gravitational field strength at the surface

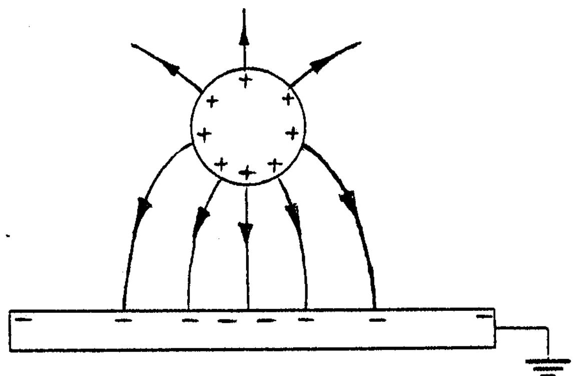
$$\frac{GM_p}{R_p^2} = \left(\frac{GM_p}{R_p}\right)\left(\frac{1}{R_p}\right)$$

$$= 62.53 \times 10^6 \times \frac{1}{6.40 \times 10^6}$$

$$= 9.8\ \text{N kg}^{-1}$$ 1 2

4. (a) (i) The potential of the sphere is raised (or lowered) by 1 V when a charge of 5×10^{-11} C is added to it. 1 1

(ii) (I)



2 2

(II) Due to the negatively induced charges on the plate nearby, the potential of the sphere is lowered. 1

As $C = \frac{Q}{V}$, $\therefore$ capacitance is increased. 1

or Separation between sphere and plate is closer than before, $\therefore$ capacitance is increased. 1 1 2

(b) (i) To ensure the capacitor is uncharged initially. 1

or To discharge the capacitor completely. 1 1

(ii) *R* is first set to its maximum value with a suitable reading on the microammeter and then decrease its resistance gradually. 1 1 2

(iii) CRO/high resistance voltmeter/ electrometer/digital voltmeter 1 1

(iv) (I) $R = \frac{6\ \text{V}}{60\ \mu\text{A}}$ 1

$= 100\ \text{k}\Omega$ 1 2

(II) $Q = It$

$= (60\ \mu\text{A})(80\ \text{s})$ 1

$= 4800\ \mu\text{C}$

& $C = \frac{Q}{V} = \frac{4800}{4}$

$= 1200\ \mu\text{F}$ 1 2

Marks

5. (a) (i) min. wavelength $\lambda_{min} = 1.2 \times 10^{-11}$ m 1

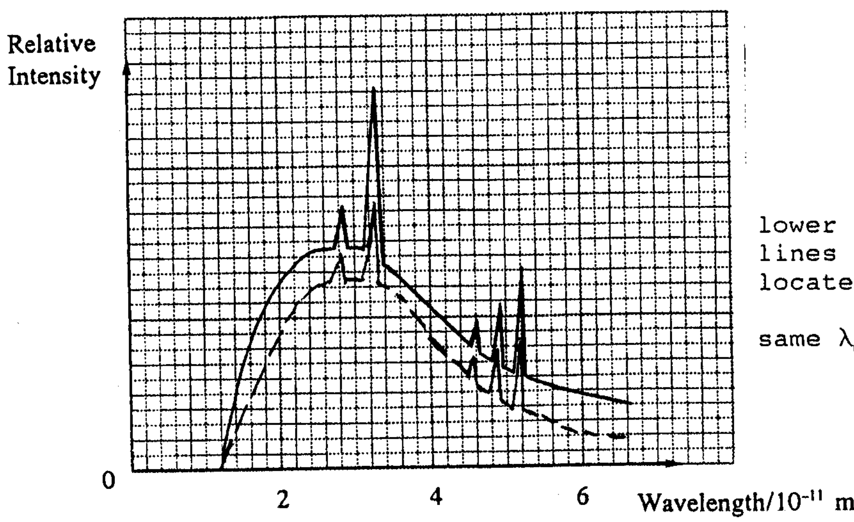
max. energy of X-ray photons $= \frac{hc}{\lambda} = \frac{(6.6 \times 10^{-34})\ (3 \times 10^{8})}{1.2 \times 10^{-11}}$

$= 1.65 \times 10^{-14}$ J 1 2

(ii) $V = \frac{1.65 \times 10^{-14}\ J}{1.6 \times 10^{-19}\ C}$

$= 103$ kV 1 1

(iii)



lower intensity/ lines correctly located 1

same λ_{min} 1 2

(b) n = no. of e⁻ striking the target per second
$n\ (1.65 \times 10^{-14}) \times 0.995 = 600$ 1
$n = 3.65 \times 10^{16}$ 1 2

(c) Continuous spectrum - some electrons are stopped by the target and their k.e. is converted directly to X-rays (Bremsstrahlung/ braking radiation). 1
The bombarding electron may be brought to rest in one or more collisions in which they give up energy gradually, thus emitted photons are of different wavelengths. 1

Line spectrum - some bombarding electrons have sufficient energy to dislodge the inner electrons of a target atom, leaving a vacant 1 space in the shell, as electrons of upper shells fill the vacancy, photons of definite frequencies are emitted. 1 4

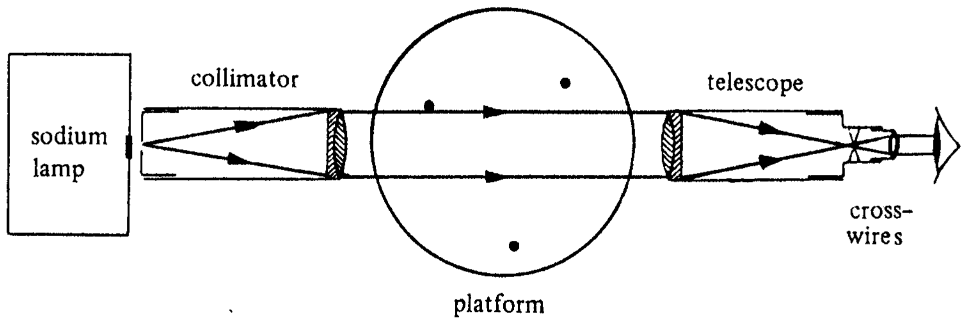
(d) X-rays are emitted when the high energy electrons from the cathode of the TV are stopped. 1
Method : reduce the accelerating potential 1
<u>or</u> use lead-glass for screen to absorb the X-rays 1 2

Marks

6. (a) (i) The fringe separation (or fringe width) increases. 1 1

(ii) This grating has more slits but 1
the slit separation is the same as the first one. 1 2

(b) (i)



2 2

(ii) Apply $d \sin \theta = n\lambda$

1st line : $1684 \sin \left[\frac{134°22' - 45°40'}{2}\right] = 2\lambda_1$ 1

$\lambda_1 = 588.6$ nm 1

2nd line : $1684 \sin \left[\frac{134°26' - 45°36'}{2}\right] = 2\lambda_2$ 1

$\lambda_2 = 589.3$ nm 1 4

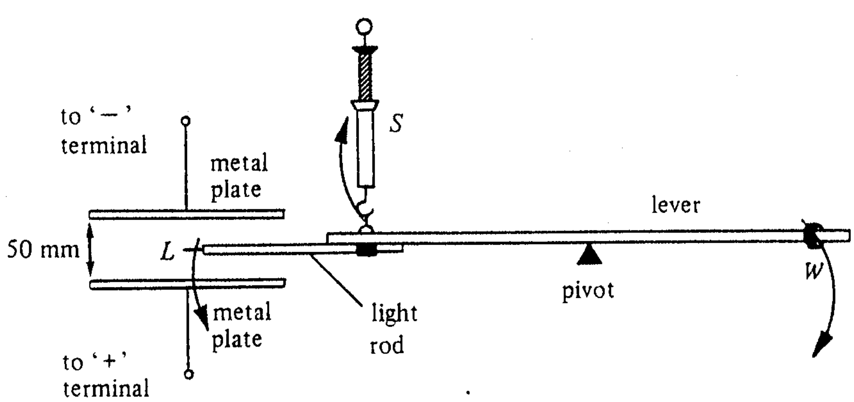
(iii) The two yellow lines may not be distinguished if their angular separation is small. 1
or Larger diffraction angle corresponds to smaller measurement error. 1 1

7. (a) (i) The charges on L will be lost if the laboratory is humid. 1 1

(ii) Wood/plastic - any good insulators. 1 1

(b) (i) downwards 1 1

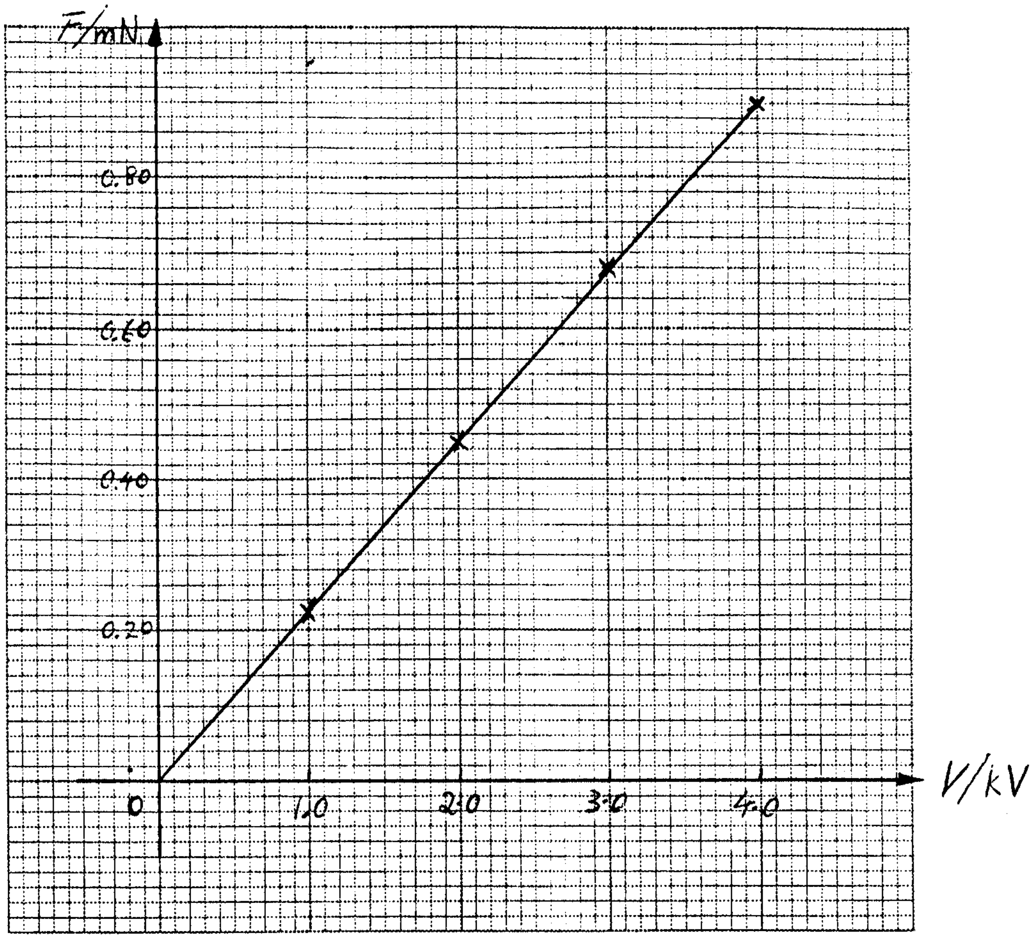
(ii)



2 2

Marks

7. (c) (i)



axes labelled with appropriate scales 1
points correctly plotted 1
correct graph : straight line through origin 1 3

(ii) Slope $m = \dfrac{0.72 \times 10^{-3} - 0}{3.2 \times 10^{3} - 0}$ 1

$= 2.25 \times 10^{-7}\ N\ V^{-1}$

As the metal plate *L* lies at the central position between the parallel plates, electric field E is assumed uniform. 1

$\because E = \dfrac{V}{d}$ and $F = QE$ (Accept any other reasonable assumptions)

$\therefore F = Q\dfrac{V}{d}$ 1

So slope $= \dfrac{Q}{d} = 2.25 \times 10^{-7}$

$\dfrac{Q}{50 \times 10^{-3}} = 2.25 \times 10^{-7}$

$Q = 1.13 \times 10^{-8}\ C$ 1 4

(d) Attach a mirror at the mid-point of the lever to reflect a fine light beam onto a screen, so the horizontal position of the lever is adjusted with increased accuracy. 1

or Place a spirit-level on the lever to adjust its horizontal position with increased accuracy. 1 1

Marks

8. (a) (i) It is the (back) e.m.f. induced in the coil per unit rate of change of current in the coil (i.e. $L = \frac{-E}{\frac{dI}{dt}}$) 1

or The flux linkage through the coil per unit current passing the coil (i.e. $L = \frac{\phi}{I}$) 1 1

(ii) Resistance is frequency independent but inductive reactance depends on frequency. 1

or Resistance dissipates power but inductive reactance does not. 1 1

(b) (i) The inductor has zero resistance. 1 1

(ii) Phase difference $= \frac{2}{12} \times 2\pi$

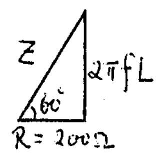
$\phi = \frac{\pi}{3}$ (or 60°) 1

y_1 (for applied voltage) leads y_2 (for current) by ϕ. 1 2

(iii) $2\pi fL = R \tan 60°$ 1

$L = \frac{200 \tan 60°}{2\pi(50)}$

$= 1.1$ H



phasor diagram 1

1 3

(iv) Voltage of the supply,

$V_{r.m.s.} = I_{r.m.s.} Z$ 1

$= (50 \times 10^{-3})(400)$

$= 20$ V 1 2

(or $V_{r.m.s.} \cos 60° = I_{r.m.s.} R$)

9. (a) *H* would be smaller. 1

As the number of 'particles' decreases, the volume occupied would decrease. 1 2

(b) Increasing the rotating speed of the motor makes the pellets move faster, so increases the rate of momentum change and the frequency of collision, resulting in a bigger force/pressure. 1 1 1 3

(c)

ANY THREE
- pellets occupy finite volume while ideal gas molecules do not occupy volume 1
- intermolecular forces exist between pellets but not for ideal gas molecules 1
- pellets collide inelastically but ideal gas molecules collide elastically 1
- energy has to be supplied to pellets but not for ideal gas molecules 1 3

(d) (i) As $P = NKT\left(\frac{1}{V}\right)$ 1

$\therefore$ slope of the graph $= NKT = \frac{2.2\times10^2 - 1.1\times10^2}{5\times10^3 - 2.5\times10^3}$ 1

$= 0.044$ N m

$\sqrt{\overline{c^2}} = \sqrt{\frac{3KT}{m}}$

$= \sqrt{\frac{3NKT}{Nm}}$

$= \sqrt{\frac{3 \times 0.044}{0.01}}$ 1

$= 3.6$ m s^{-1} 1 4

(ii) No, since there is also air of 1 atm inside the cylinder which balances the air pressure on the other side of the piston. 1 1 2

Marks

10. (a)

ANY TWO
- Infinite input impedance (draws no current from the input supply 1
- Zero output impedance (transfers full voltage to a load) 1
- Infinite open-loop gain 1
- Infinite band width of frequency response 1 2

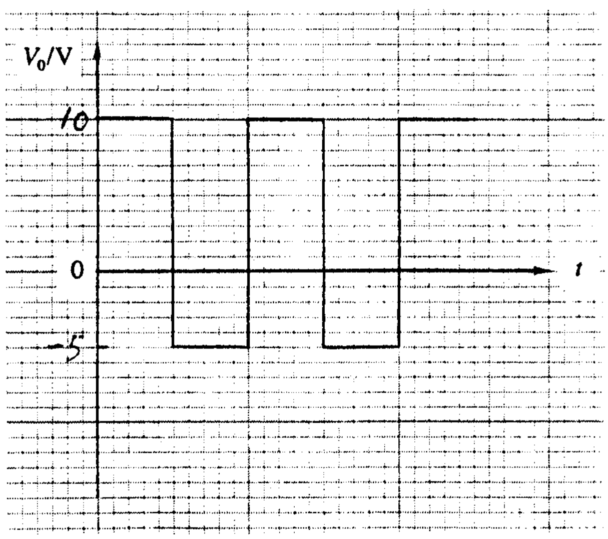
(b) Since current between V_+ and V_- is negligible, V_- and V_+ are at nearly the same potential, 1
so $V_x = V_- \approx V_+ = 0$ V 1 2

(c) (i) $I_A = \frac{3}{10}$ mA $= 0.3$ mA 1 1

(ii) $\because I_B = \frac{4}{20}$ mA $= 0.2$ mA
$I = (0.3 - 0.2)$ mA $= 0.1$ mA 1
Current flows from X to Z 1 2

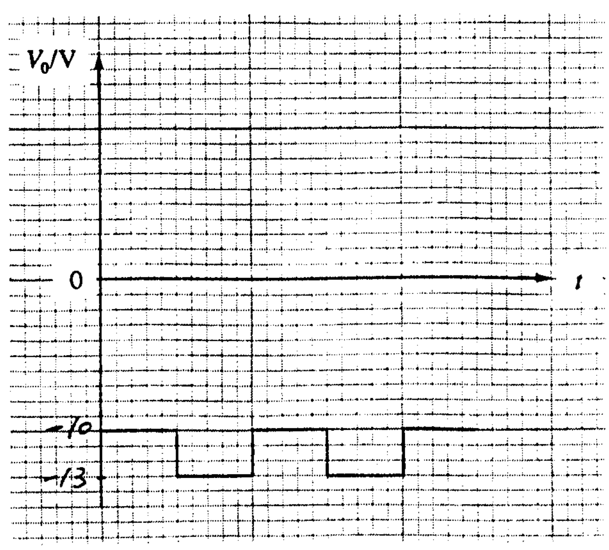
(d) $V_0 = -(0.1 \text{ mA})(50 \text{ k}\Omega)$ 1
$= -5$ V 1 2

(e) (i)



correct shape 1
correct scale 1 2

(ii)



correct shape 1
correct scale 1 2

Marks

1. (a) $0.1 \times 10 = k \times 0.05$
$k = 20 \text{ N m}^{-1}$ 1 <u>1</u>

(b) (i) $T = 2\pi\sqrt{\frac{m}{k}}$ 1

$= 2\pi\sqrt{\frac{0.1}{20}}$
$= 0.44$ s 1 <u>2</u>

(ii) Apply $\ddot{x} = -\omega^2 x$
Since downward acceleration of the pan should not exceed g,
$\therefore \ddot{x}_{max} = -\omega^2 A$ 1
$-10 = -\frac{20}{0.1}A \quad (\omega^2 = \frac{k}{m})$ 1
$A = 0.05$ m (or 5 cm) 1 <u>3</u>

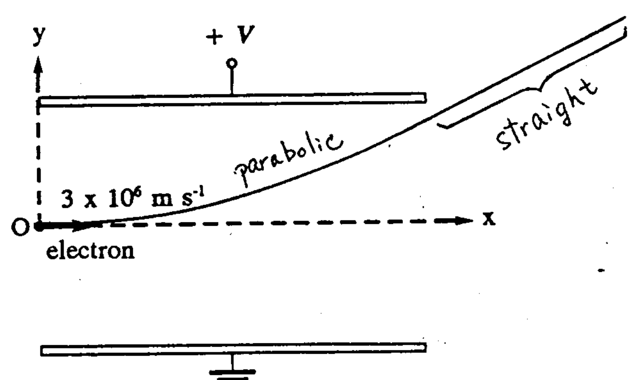
(iii) (I) Amplitude, $A = \frac{0.10 - 0.06}{2}$ m
$= 0.02$ m (or 2 cm) 1 <u>1</u>

(II) $P.E._e + P.E._g + K.E. = 0.109$ J 1
$P.E._e + 0.1 \times 10 \times 0.06 + 0 = 0.109$ J
$P.E._e(\max) = 0.049$ J 1 <u>2</u>

(c) The period remains at 0.44 s as T depends on m and k but not g. 1
The maximum amplitude becomes smaller as g is smaller. 1 <u>2</u>

2. (a) upwards/positive y-direction 1 <u>1</u>

(b)



2

<u>2</u>

(c) Change in electric potential energy = change in k.e. 1
$= [\frac{1}{2}(9 \times 10^{-31})(5 \times 10^6)^2 - \frac{1}{2}(9 \times 10^{-31})(3 \times 10^6)^2]$ J
$= 7.2 \times 10^{-18}$ J 1 <u>2</u>

(d) $v^2 = v_x^2 + v_y^2$
$(5 \times 10^6)^2 = (3 \times 10^6)^2 + v_y^2$
$v_y = 4 \times 10^6 \text{ m s}^{-1}$ 1
$\because a_x = 0 \therefore$ acceleration $= a_y = \frac{v_y - u_y}{t}$ 1
$= \frac{4 \times 10^6 - 0}{5 \times 10^{-8}} \text{ m s}^{-2}$
$= 8 \times 10^{13} \text{ m s}^{-2}$ 1 <u>3</u>

Marks

2. (e) $x = v_x t$
$= (3 \times 10^6)(5 \times 10^{-8})$ m
$= 0.15$ m — 1

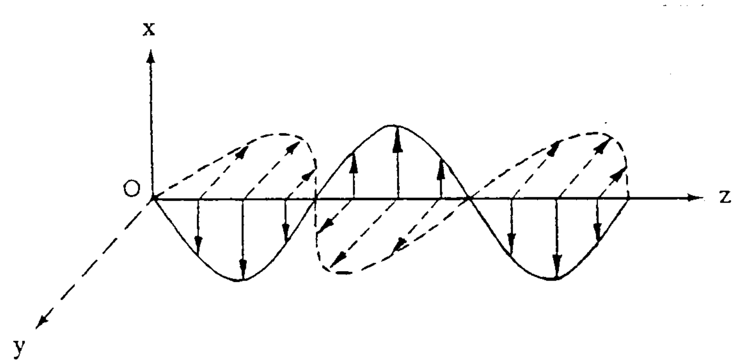
$y = \left(\frac{v_y + u_y}{2}\right) t$
$= \left(\frac{4 \times 10^6 + 0}{2}\right)(5 \times 10^{-8})$ m
$= 0.1$ m — 1

or $y = \frac{1}{2} a_y t^2$
$= \frac{1}{2}(8 \times 10^{13})(5 \times 10^{-8})^2$ m
$= 0.1$ m — 1 2

(f) F_x and a_x remain zero, — 1
so $t = 5\times10^{-8}$ s unchanged. — 1
$E = \frac{V}{d}$ doubled, F_y and a_y doubled, — 1
so $y = \frac{1}{2} a_y t^2$ doubled and equals 0.2 m — 1 4

3. (a) magnetic field — 1 1

(b)



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2

(c) The rod should be parallel to the x-axis (vertical), — 1
so that the electric field of the e.m. wave sets the
electrons into oscillations along the rod. — 1 2

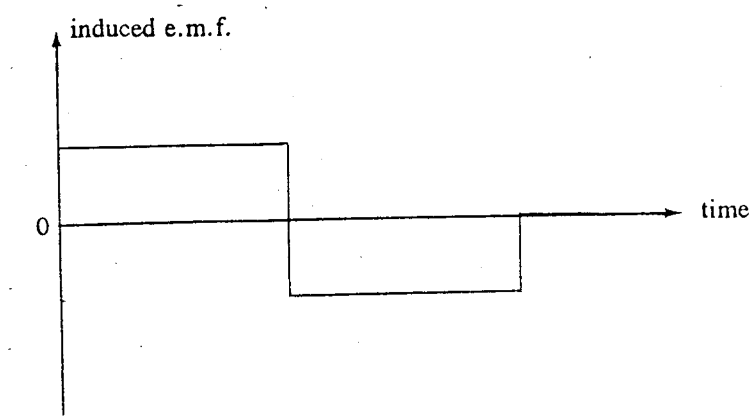
(d) (i) The signal received by the antenna decreases much
(or no signal), — 1
as the grid absorbs most of the incident e.m. waves. — 1 2

(ii) The signal received by the antenna remains unchanged. — 1
Practically no induced emf/current occurs in the
conducting wires, as the grid does not absorb the e.m.
waves. — 1 2

(e) The plane circular loop should be placed on an x-z plane, — 1
so that maximum rate of change of flux occurs through the
loop. — 1 2

Marks

4. (a)



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2

(b) $E_{induced} = B.b.v$ 1

$I = \dfrac{E_{induced}}{R}$

$= \dfrac{Bbv}{R}$ 1 2

(c) Total thermal energy $= I^2 R \Delta t$ 1

$= \left(\dfrac{Bbv}{R}\right)^2 R \left(\dfrac{2a}{v}\right)$ 1

$= \dfrac{2B^2b^2\ v\ a}{R}$ 1 3

(d) gravitational potential energy 1 1

(e) (i) weight = magnetic force 1

$mg = IbB$ 1

(ii) Total thermal energy $= \dfrac{2B^2b^2\ v\ a}{R}$

$= 2\ BbI\ a$ 1

$= 2\ mg\ a$ 1

or

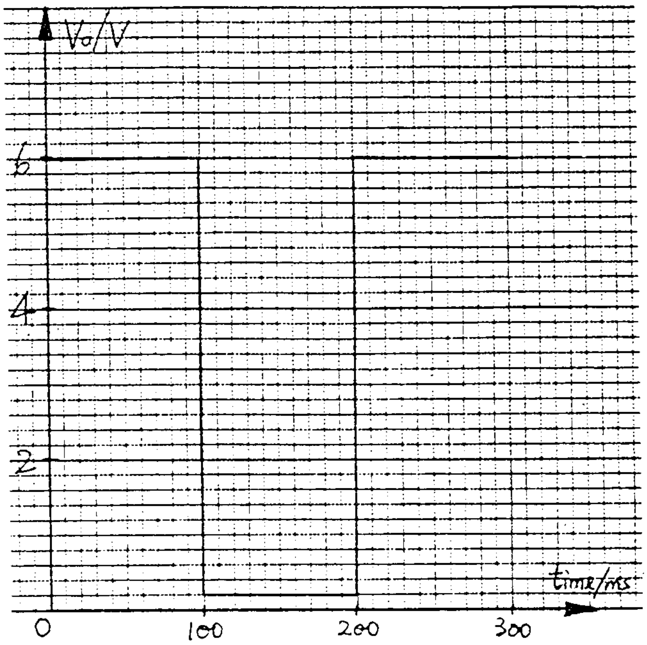
Total thermal energy = lost in gravitational p.e.

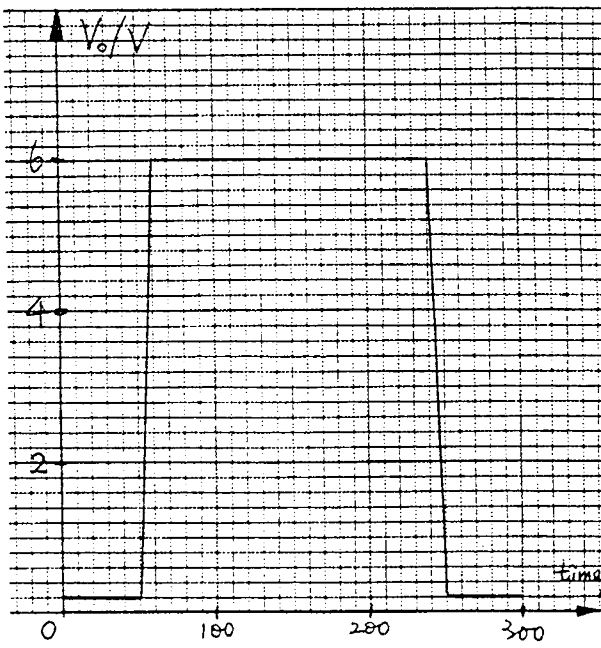
= mg (2a) 1

= 2 mg a 1 2

Marks

5. (a) (i) (ii)





@2 4

(b) (i) voltage across R_c, V_c = (6 − 0.2) V
= 5.8 V (or 6 V) 1

$I_c = \dfrac{V_c}{R_c} = \dfrac{5.8}{1.5 \times 10^3}$ A
= 3.87×10^{-3} A (or 4×10^{-3} A) 1

$I_B = \dfrac{I_c}{\beta} = \dfrac{3.87 \times 10^{-3}}{80}$ A
= 4.83×10^{-5} A (or 5×10^{-5} A) 1 3

(ii) $R_B = \dfrac{V_i - V_{BE}}{I_B} = \dfrac{1 - 0.5}{4.83 \times 10^{-5}}\ \Omega$ 1
= $10.4 \times 10^3\ \Omega$ (or $10 \times 10^3\ \Omega$) 1 2

(c) (i) Optimal bias voltage should be 0.75 V
$\dfrac{R_1}{R_2} = \dfrac{6 - 0.75}{0.75}$ 1
= 7 1 2

(ii) Voltage gain $\left|\dfrac{\Delta V_o}{\Delta V_i}\right| = \beta \dfrac{R_c}{R_B}$

$\Delta V_o = 80 \times \dfrac{1.5 \times 10^3}{10.4 \times 10^3} \times 0.24$ 1
= 2.77 V (or 2.88 V) 1 2

Marks

6. (a) (i) $E = \frac{V_o}{d}$ and $C_1 = \frac{\varepsilon_o A}{d}$

$\therefore E = \frac{C_1}{\varepsilon_o A} V_o$ 1

$= \frac{3.70 \times 10^{-10}}{8.85 \times 10^{-12} (0.25)^2} V_o$

$= 669\ V_o$ 1 2

(ii) By (a)(i) $3 \times 10^6 = 669\ V_o$ 1

$V_o = 4485$ V 1 2

(b) (i) $C_1 = \frac{Q_1}{V}$ and $C_2 = \frac{Q_2}{V}$

$\therefore \frac{C_2}{C_1} = \frac{Q_2}{Q_1} = \frac{0.60}{0.12}$ (as charge is proportional to output current) 1

$\frac{C_2}{C_1} = 5$ 1 2

(ii) $Q_1 = C_1 \times 500$, $Q_2 = C_2 \times 500$

After removing mica,

(*) $Q' = C_1 V'$ $(Q_1' = Q_2' = Q',\ V_1' = V_2' = V')$ 1

Total charges conserved,

$Q_1 + Q_2 = Q' + Q'$ 1

$500\ C_1 + 500\ C_2 = 2Q'$

$500\ C_1 + 500(5C_1) = 2Q'$

$Q' = 1500\ C_1$

$= 1500\ (3.70 \times 10^{-10})$ C

$= 5.55 \times 10^{-7}$ C 1

$C_1 V' = 1500\ C_1$ (by (*))

$V' = 1500$ V 1 4

(c) ANY TWO
- to keep the plates apart 1
- to raise the capacitance 1
- to reduce the chance of electric breakdown (so that a large potential difference can be used) 1 2

7. (a) hard/flat 1 1

(b) Adjust the position of the reflecting plate *R* such that the microphone *M* detects alternating maximum and minimum signals when moving between the loudspeaker and the plate. 1
Finely adjust *the position of R* until the microphone *M* detects little or no signal at the minimum positions. 1 2

Note : If little or no multiple reflection occurs, stationary waves always exist without any shifting of the position of R.

(c)

Wavelength λ/cm	Period T/ms
13.9	0.40
11.8	0.34
9.8	0.28
7.9	0.22
6.1	0.16

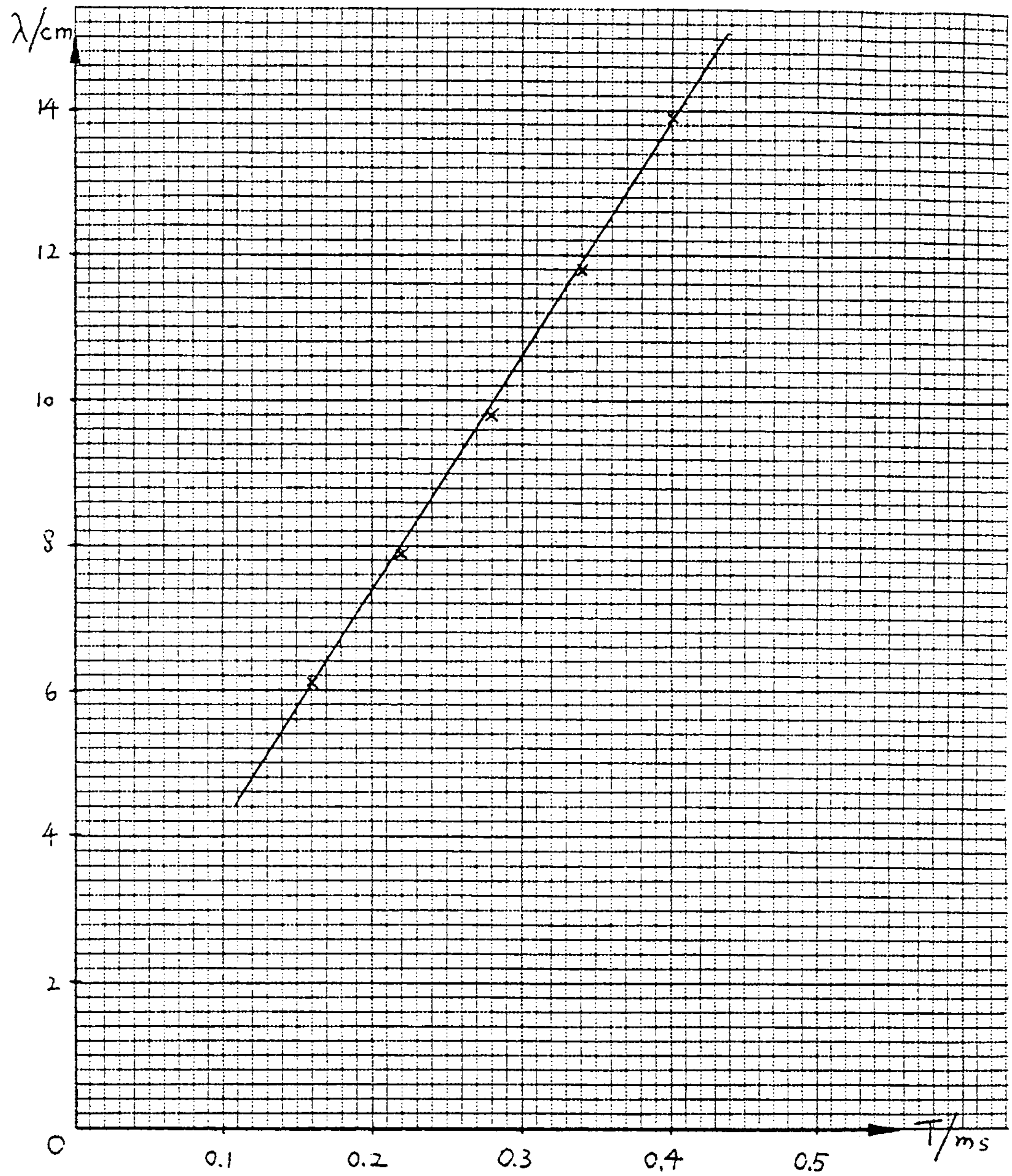
2 2

(i) $\lambda = \frac{68.7 - 27.0}{6} \times 2$ cm 1 1

$= 13.9$ cm

Marks

7. (c) (ii)



axes labelled with appropriate scales 1
points correctly plotted 1
correct graph : straight line (not passing through the origin when extrapolated) 1 3

(iii) As $v = f\lambda \Rightarrow \lambda = vT$

$$\therefore \text{ slope } = v = \frac{0.122 - 0.054}{(0.35 - 0.14) \times 10^{-3}} \text{ m s}^{-1}$$ 1

$$= 324 \text{ m s}^{-1}$$ 1 2

(iv) Points plotted would be very crowded if frequencies of uniform intervals were used (as $T = \frac{1}{f}$). 1 1

(v) There exists systematic error in the measurement of wavelength (positions of M) by the metre rule or/and in the readings of the frequencies of the signal generator. 1 1

(d) Less reflections from walls or nearby objects. 1
Surround the apparatus with soft/sound-absorbing materials. 1 2
(or far away from walls)

Note : Multiple reflections from the bench and the CRO cannot be avoided even if the experiment is performed outdoors.

Marks

8. (a) (i) (I) Voltmeter reading increases and ammeter reading remains constant (or decreases slightly). 1

(II) Voltmeter reading remains constant (or increases slightly) and ammeter reading decreases. 1 2

(ii) (I) His choice is right as the order of magnitude of the resistance is about $10^3 \sim 10^4$ which is much 1
greater than that of the ammeter. 1

(II) Calculated value of $R = \dfrac{6}{0.8 \times 10^{-3}}$
$= 7\,500\ \Omega$
True value of $R = 7\,500\ \Omega - 20\ \Omega = 7480\ \Omega$ 1 3

(b) (i) 0 - 2 V to 0 - 5 V
0 - 10 Ω to 0 - 100 Ω 1 1

(ii) $E = V + Ir \Rightarrow V = -Ir + E$ 1
$\therefore$ emf E = y-intercept = 1.6 V 1
internal resistance r = − slope = 4 Ω 1 3

(iii) Maximum power $= \left(\dfrac{E}{r + r}\right)^2 r$
$= \dfrac{E^2}{4r}$ 1

Efficiency $= \dfrac{\dfrac{E^2}{4r}}{\left(\dfrac{E}{r + r}\right) E} \times 100\%$ 1
$= 50\%$ 1 3

9. (a) (i) energy required = area under the graph from 3×10^{-10} m to 9×10^{-10} m
$= \frac{1}{2}(9.6 \times 10^{-10})[(9 - 3) \times 10^{-10}]$ J 1
$= 2.88 \times 10^{-19}$ J 1 2

(ii) Work done by external agent to reduce the separation from 3×10^{-10} m to 2.88×10^{-10} m
$= \frac{1}{2}(14.4 \times 10^{-10})[(3 - 2.88) \times 10^{-10}]$ J
$= 8.64 \times 10^{-21}$ J 1
$\therefore$ potential energy $= -2.88 \times 10^{-19} + 8.64 \times 10^{-21}$ J
$= -2.80 \times 10^{-19}$ J 1 2

(b) (i) Interatomic 'spring' constant,
$k = \dfrac{[9.6 - (-14.4)] \times 10^{-10}}{[3.08 - 2.88] \times 10^{-10}}$ N m^{-1} 1
$= 120$ N m^{-1}

Young modulus, $E = \dfrac{k}{r}$
$= \dfrac{120}{3 \times 10^{-10}}$ Pa
$= 4 \times 10^{11}$ Pa 1 2

(ii) Breaking stress $= \dfrac{9.6 \times 10^{-10}}{(3 \times 10^{-10})^2}$ Pa 1
$= 1.07 \times 10^{10}$ Pa 1 2

(c) Copper is more stiff (larger Young modulus). 1
Copper is less strong (smaller breaking stress). 1 2

Marks

10. (a) (i) $\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

$= \dfrac{\ln 2}{1.3 \times 10^{9}}$ year^{-1} 1

$= 5.33 \times 10^{-10}$ year^{-1} (or 1.69×10^{-17} s^{-1}) 1 2

(ii) The decay constant of a radioactive isotope is the fraction of the total number of active nuclei present which decays in unit time. 2 2

(b) $A = A_o e^{-\lambda t}$

$1.6 = 4.8\ e^{-5.33 \times 10^{-10} t}$ 1

$t = 2.06 \times 10^{9}$ years (or 6.50×10^{16} s) 1 2

(c) - The number of undecayed/active nuclei present. 1

- The decay constant (or half-life) of the radioactive isotope (i.e. the stability of the radioactive isotope) 1 2

(d) The magnitude of the binding energy of ^{40}K is smaller than that of ^{40}Ar and 1

energy is released when ^{40}K decays to ^{40}Ar. 1 2

(e) As the decay rate is small, the contribution from the background radiation is significant. 1

(or the fluctuation due to random variation is large.) 1

1. (a) (i) Horizontal : $vt = 1.35$ —— ①

Vertical : $0.40 - 0.15 = \frac{1}{2}(10)t^2$ —— ② 1

② → ① : $v = 6.0 \text{ m s}^{-1}$ 1 2

(ii) Loss in p.e. = gain in k.e.

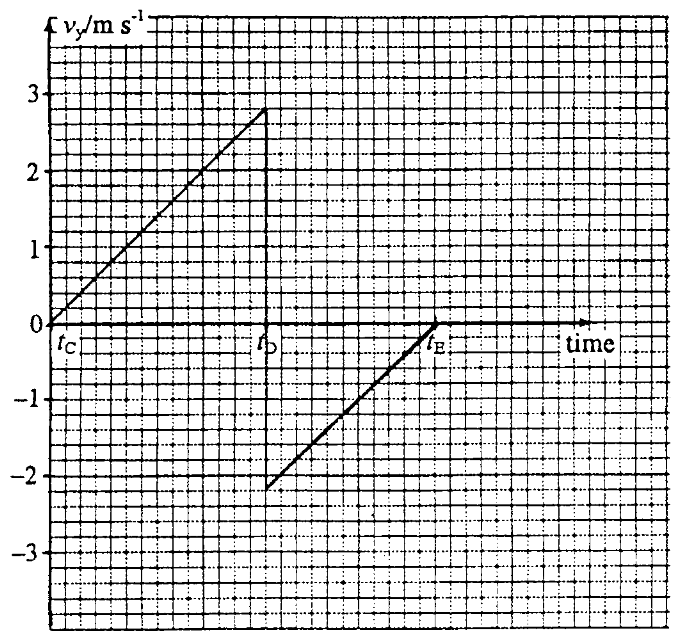
$m(10)(0.4) = \frac{1}{2}m\left(v_f^2 - v^2\right)$ 1

$v_f = 6.7 \text{ m s}^{-1}$ 1 2

(iii) uniform acceleration/deceleration shown 1

correct slope (from C to D and from D to E) 1

correct shape 1



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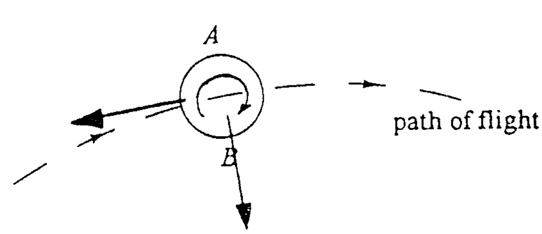
(b) (i)



2

(ii) The spinning ball drags the surrounding air during its flight, the air flow at side A is slower than that at side B. 1

According to Bernoulli's principle, the pressure at A is greater than that at B and a sideways force acting towards side B results. 1 2

Marks

2. (a) (i) $T_1 = T_2 = 50$ N — 1

$$E_1 = \frac{T_1 / A_1}{e_1 / l} \Rightarrow 6.9 \times 10^{10} = \frac{50/\pi\left(0.6 \times 10^{-3}\right)^2}{e_1 / 0.8}$$ 1

$\Rightarrow e_1 = 5.1 \times 10^{-4}$ m (extension of the aluminium wire) — 1

Similarly, $e_2 = 8.7 \times 10^{-4}$ m (extension of the brass wire) — 1 — 4

(ii) $$\theta \simeq \sin^{-1} \frac{(8.7 - 5.1) \times 10^{-4}}{1.4}$$ 1

$= 2.6 \times 10^{-4}$ rad (or 0.015°) — 1 — 2

(iii) Toward A, with the aluminium wire in a greater tension. — 1 — 1

(b) (i) $T_1 / A_1 = 2.2 \times 10^8$ and $T_2 / A_2 = 4.7 \times 10^8$ — 1

$T_1 = 2.2 \times 10^8 \times \pi (0.6 \times 10^{-3})^2$ and $T_2 = 4.7 \times 10^8 \times \pi (0.4 \times 10^{-3})^2$

$= 249$ N $\qquad = 236$ N

$$\therefore \text{max. mass} = \frac{249 + 236}{10}$$ 1

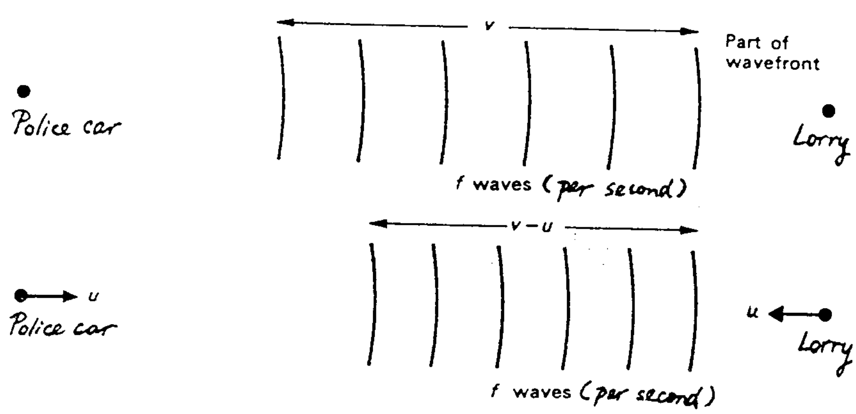
$= 48.5$ kg — 1 — 3

(ii) Taking moment about A,

$485 \times d = 236 \times 1.4$ — 1

$d = 0.68$ m — 1 — 2

3. (a) (i)



1

$$\lambda' = \frac{330 - u}{f} = \frac{330 - u}{1000}$$ 1

$$\therefore f' = \frac{330 + u}{\lambda'}$$ 1

$$f' = \frac{330 + u}{330 - u} f = \frac{330 + u}{330 - u} \times 1000$$ 1 — 4

(ii) $$f'' = \frac{330 - u}{330 + u} f$$ 1

$$\Delta f = f' - f'' = \left[\frac{330 + u}{330 - u} - \frac{330 - u}{330 + u}\right] f$$ 1

$$200 = \frac{1320u}{330^2 - u^2} \times 1000$$

$u = 16.6$ m s^{-1} — 1 — 3

(b) 'Red shift' of the light emitted from distant stars/galaxies. — 1
Stars/galaries emit light which is similar to that from the stars/sun in our galaxy but
with wavelengths in the observed spectrum shifted towards the red end (longer wavelengths). — 1
This suggests distant stars/galaxies are moving away from us according to Doppler effect. — 1 — 3

4. (a) (i) $pV = nRT$

$(0.2 \times 10^5)(0.4) = 1 \times 8.31 \times T$ 1

$T = 960$ K 1 2

(ii) $\sqrt[3]{\dfrac{0.4}{6.02 \times 10^{23}}}$ 1

$= 8.7 \times 10^{-9}$ m 1 2

(b) As the separation between the helium atoms ($\sim 10^{-8}$ m in (a)(ii)) is almost hundred times the atomic diameter ($\sim 10^{-10}$m), the short range intermolecular forces are negligible. 1 1 2

(c) (i) A to $B = 0$ J 1

B to $C = \dfrac{(0.4 + 0.2) \times 10^5}{2} \times (0.6 - 0.4)$

$= 6000$ J 1

C to $A = (0.2 \times 10^5)(0.4 - 0.6)$

$= -4000$ J 1 3

(ii)

$pV = \dfrac{1}{3} Nm\overline{c^2}$

$N(\dfrac{1}{2} m\overline{c^2}) = \dfrac{3}{2} pV$ 1

$= \dfrac{3}{2}(0.2 \times 10^5)(0.4)$

$= 12\,000$ J 1 2

(iii) $Q = \Delta U + W$

$= 0 + 2000$ J 1

$= 2000$ J 1 2

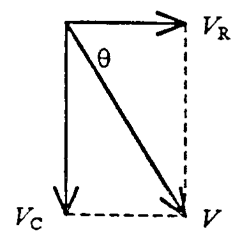
Marks

5. (a) (i) Peak voltage $V = 6.5$ V 1

Frequency $f = \dfrac{1}{4 \times 2.5 \times 10^{-3}}$

$= 100$ Hz 1 2

(ii)



2 2

(iii) $\tan\theta = \dfrac{\frac{1}{\omega C}}{R}$ 1

$= \dfrac{1}{2\pi(100)4.7 \times 10^{-6}(110)}$

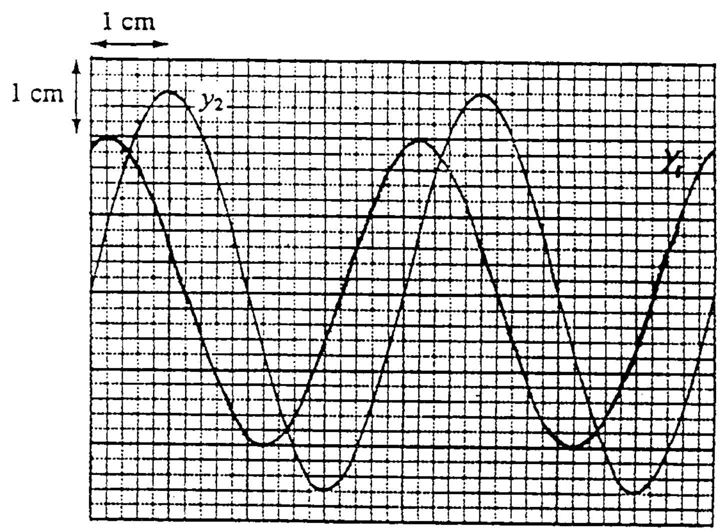
$\theta = 72°$ 1 2

(iv) $V_R = V\cos\theta$ 1

$= 6.5\cos 72°$

$= 2.0$ V 1 2

(v)



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2

(b) (i) Peak current $I = \dfrac{V}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}$ 1

When $V_L = V_C$ or $\omega L = \dfrac{1}{\omega C}$, current is maxmum ($I_{max} = \dfrac{V}{R}$). 1

For other values of L, the current is smaller than the maximum one. 2

(ii) $\omega L = \dfrac{1}{\omega C}$

$L = \dfrac{1}{[2\pi(100)]^2 4.7 \times 10^{-6}}$ 1

$= 0.54$ H 1 2

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Marks

6. (a) (i) Decrease. 1
Since the weight is greater than the tension so as to provide an unbalanced force for the acceleration. 1 2

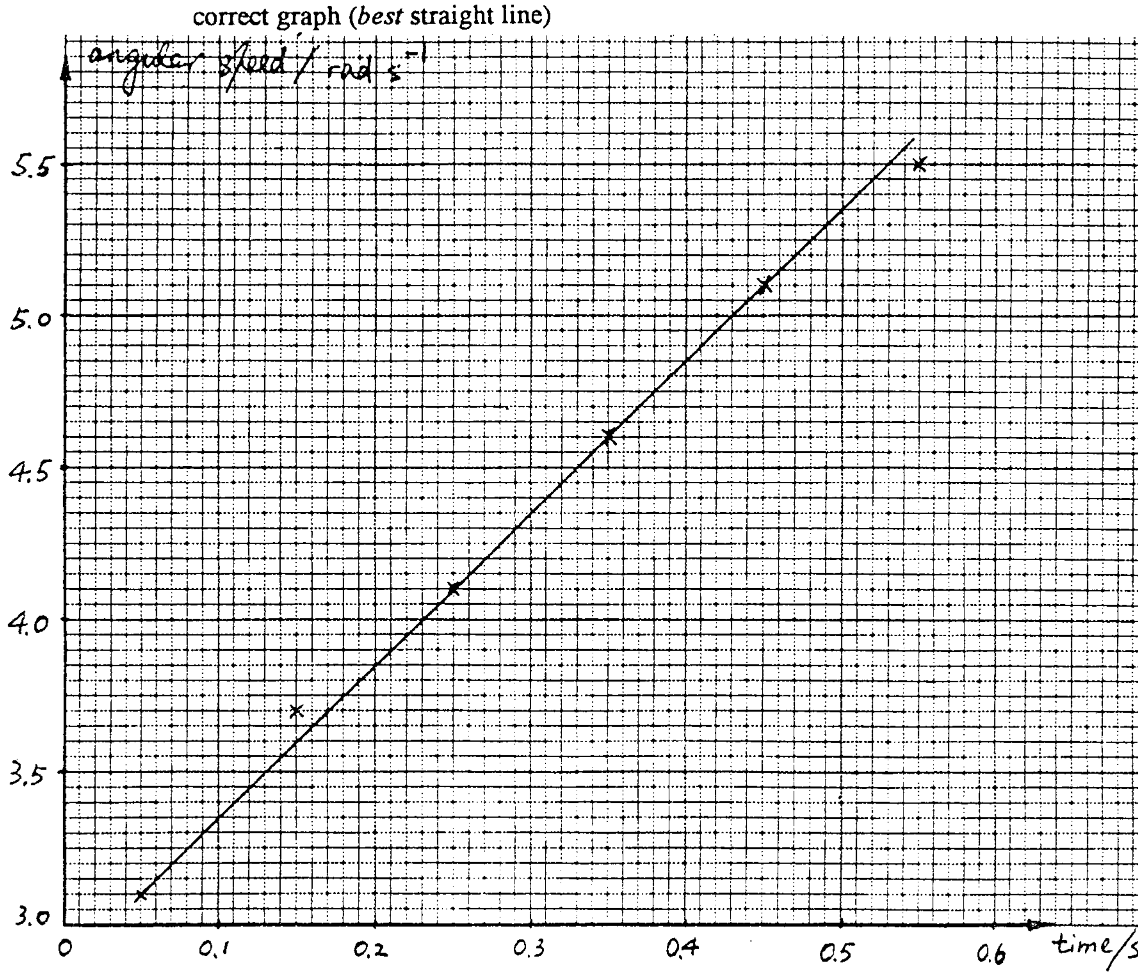
(ii) $a = r\alpha$ $(a = 0.02\ \alpha)$ ----- ① 1
$mg - T = ma$ $(30 - T = 3a)$ ----- ② 1
$Tr = I\alpha$ $(0.02\ T = I\alpha)$ ----- ③ 1 3

(b) (i)

	1st 10 periods	2nd 10 periods	3rd 10 periods	4th 10 periods	5th 10 periods	6th 10 periods
$\Delta\theta$/rad	0.31	0.37	0.41	0.46	0.51	0.55
ω/rad s^{-1}	3.1	3.7	4.1	4.6	5.1	5.5

1 1

(ii) axis labelled with appropriate scales 1
points correctly plotted 1
correct graph (*best* straight line) 1



3

(iii) Slope = α $= \dfrac{5.1 - 3.1}{0.4}$ 1
$= 5.0$ rad s^{-2} 1
As $a = 0.02\ \alpha = 0.10$ m s^{-2} (by ①)
& $30 - T = 3 \times 0.10$ (by ②)
$T = 29.7$ N 1
& $0.02 \times 29.7 = I \times 5.0$ (by ③)
$I = 0.119$ kg m^2 1

(c) The flywheel ensures the smooth/steady running of the car as 1
it stores kinetic energy when explosion takes place inside a cylinder and releases kinetic energy in between those explosions. 1 2

7. (a) (i) When S is closed, current starts to flow in the coil and produces magnetic flux. Thus a change/increase of flux linkage occurs through the ring. 1
By Lenz Law, an induced e.m.f./current is created in the ring so as to oppose the change and therefore it jumps up momentarily. 1
However, when the current reaches its steady value, no change of flux results and the ring falls back. 1 3

(ii) The ring will float in air. 1
Magnetic levitation of, say, a train. 1 2

(Note : The underlying principles for the experiment is very complicated, therefore the explanation in (i) should not be used directly in (ii).)

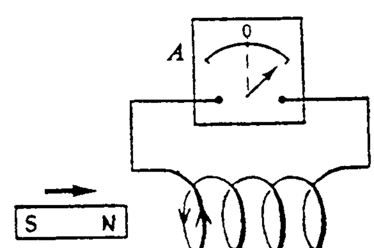
(iii) Rate of increase in internal energy

$$= \frac{7.8 \times (40-25)}{50}$$ 1

$= 2.3\ \mathrm{J\ s^{-1}}$ 1 2

(b) (i) $10^4\ (\Omega)$ 1 1

(ii) (I)



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2

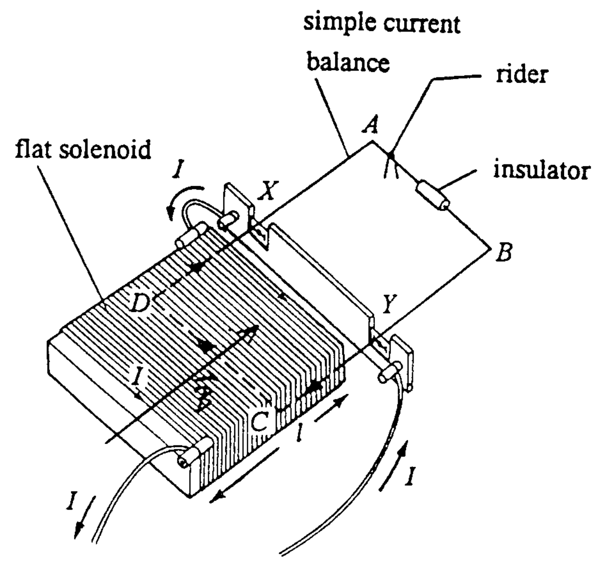
(II) Work done by the student in pushing the magnet. 1 1

(III) ANY THREE
- Move the magnet more quickly.
- Use more than one magnet (with the same pole facing the coil or a stronger magnet
- Use a coil with more turns
- Insert a soft iron in the coil

(give 1 mark for one or two correct answers) 2 2

 Marks

8. (a)



1

1

(b) (i) $F = I\ell B$

$= I\,(0.2)\dfrac{4\pi \times 10^{-7} \times 600 \times I}{0.5}$ 1

$= 3.0 \times 10^{-4}\, I^2$ 1 2

(ii) $10^{-4} \times 10 = 3.0 \times 10^{-4}\, I^2$ 1

$I = 1.8$ A 1 2

(c) ANY ONE

- Avoid overheating of the wires and keep the current constant, therefore the current should be switched off after a reading is taken 2
- Arm CD should be perpendicular to the magnetic field in the solenoid, otherwise the force acting on CD becomes $IlB\sin\theta$. 2
- Arm CD should be along N-S direction so as to minimize the effects of the earth's magnetic field 2 2

(Accept any other reasonable answers)

(d) Yes. When the direction of the a.c. changes, the magnetic field in the solenoid changes accordingly, 1 making the direction of the magnetic force on arm CD remains downward. 1 2

(e) The calculated value of I is smaller than the actual value because the magnetic field 1 strength at arm CD is less than that suggested by the formula $\dfrac{\mu_0 NI}{l}$. 1 2

Marks

9. (a) The minimum energy/work done for liberating an electron from the surface of a metal. 1 1

(b) Part of the energy gained by an electron from a photon is lost through a number of collisions with the surrounding electrons/ions. 1 1

(c) (i)

$$h\frac{c}{\lambda} = \text{k.e.}_{\max} + \Phi$$

$$6.63\times10^{-34}\,\frac{3\times10^{8}}{230\times10^{-9}} = \text{k.e.}_{\max} + 2.21\times1.60\times10^{-19}$$ 1

$$\text{k.e.}_{\max} = 5.11\times10^{-19}\text{ J (or 3.19 eV)}$$ 1 2

(ii) $eV_s = \text{k.e.}_{\max}$

$$V_s = \frac{5.11\times10^{-19}}{1.60\times10^{-19}}$$ 1

$$= 3.19\text{ V}$$

1

(d) Energy supplied per second $= 3 \times (8.0 \times 10^{-3})^2$ 1

$= 1.92 \times 10^{-4}$ J

Energy of each photon $= 6.63 \times 10^{-34} \times \dfrac{3\times10^{8}}{230\times10^{-9}}$ 1

$= 8.65 \times 10^{-19}$ J

$\therefore$ No. of photoelectrons emitted per second $= \dfrac{1.92\times10^{-4}}{8.65\times10^{-19}}$

$= 2.22 \times 10^{14}$ 1 3

(e) Stopping potential would increase as the energy of each photon increases, 1
the maximum k.e. of the photoelectrons emitted increases. 1
The number of photoelectrons emitted per second would decrease since intensity is constant 1
and each photon has more energy, the number of photons arrive per second decreases. 1 4

10. (a) The heater supplies energy to the cathode so that the free electrons in the cathode have 1
enough energy to escape from the cathode by thermionic emission. 1 2

(b) (i) The kinetic energy of the electron is greater than or equal to the first excitation energy of xenon. 1 1

(ii) 7.0 V 1 1

(c) To ensure that the electron, having lost kinetic energy in an inelastic collision, is carried 1
back to *G*; and this is indicated by a drop in the current. 1 2

(d) The electron gains kinetic energy from its electric potential energy during its acceleration; 1
part of which is then lost in an inelastic collision with a xenon atom and 1
the remaining energy is for overcoming the negative p.d. between *G* and *A*. 1 3

Marks

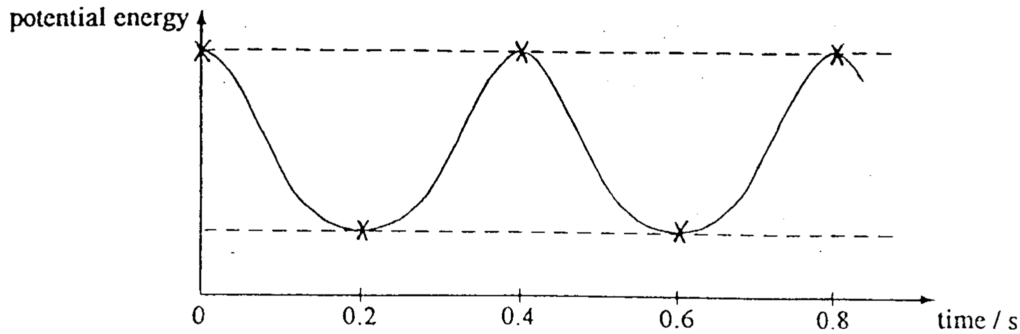
1. (a) $T_1 = k(e + x)$ and $T_2 = k(e - x)$ 1

Equation of motion : $-(T_1 - T_2) = m\ddot{x}$ 1

$m\ddot{x} + 2kx = 0$ or $m\ddot{x} + 20x = 0$ 1

as $\ddot{x} \propto -x$, $\therefore$ s.h.m. 1 4

(b) (i)



1

1

(ii) $T = 0.4$ s 1

As $\omega^2 = \dfrac{2k}{m}$

$(\dfrac{2\pi}{T})^2 = \dfrac{2k}{m}$ 1

$(\dfrac{2\pi}{0.4})^2 = \dfrac{20}{m}$ 1

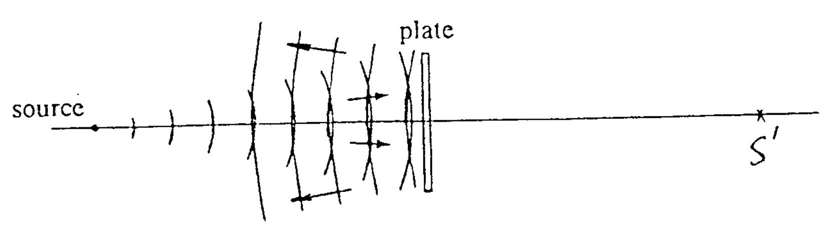
$m = 0.08$ kg 1 4

(c) (i) unchanged 1

(ii) unchanged 1 2

2. (a) Microwaves/radiowaves 1 1

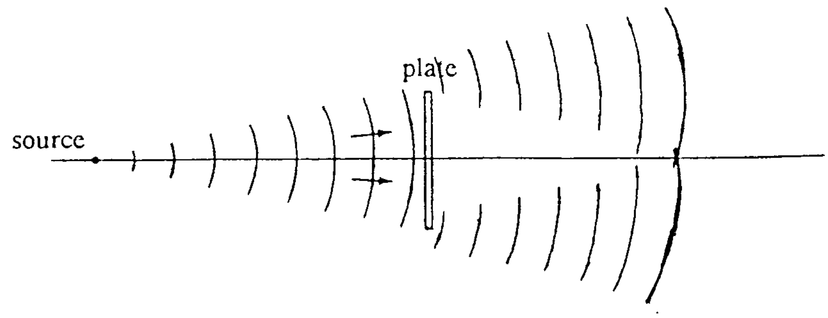
(b) (i)



2

2

(ii)



1

Waves are diffracted at the edge of the plate and therefore reach the shadow behind the plate. 1 2

Marks

(c) (i) Speed of $S' = 40 \text{ m s}^{-1}$ 1

$\Delta f = f' - f = \frac{u}{c} f$ 1

$= \frac{40}{3 \times 10^8} \times 10^{10}$

$= 1300 \text{ Hz}$ 1 3

(ii) The change in frequency (i.e. the beat frequency) is very small ($\sim 10^3$) compared with the frequency of the waves ($\sim 10^{10}$), therefore if the frequency of the reflected waves is to be measured, the instrument should be accurate at least up to the 7th digit. 1 1 2

3. (a) (i) $T = ke$

$= 9.6 \times 10^2 (2\pi \times 0.01)$ 1

$= 60.3 \text{ N}$ 1 2

(ii) Work done $=$ energy stored 1

$= \frac{1}{2} (9.6 \times 10^2)(2\pi \times 0.01)^2$

$= 1.89 \text{ J}$ 1 2

(b) (i) Consider the wave along AB, $v = \sqrt{\frac{T}{m}}$

$= \sqrt{\frac{60.3}{6.4 \times 10^{-4} / 0.36}}$ 1

$= 184 \text{ m s}^{-1}$

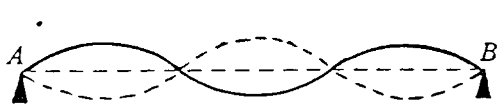
So $v = f\lambda$

$184 = f(0.36 \times 2)$ 1

$f = 256 \text{ Hz}$ 1 3

(ii)
- transverse Vs longitudinal 1
- stationary Vs travelling 1
- different speeds/wavelengths 1 3

(iii)



1

1

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4. (a) (i) The CRO of practically infinite resistance reads the e.m.f. of the cells (4.5 V). 1
However, the voltmeter only reads the p.d. across PQ as there is current flowing in 1
the circuit, some of the p.d. drops across the 10-kΩ resistor. 1 3

(ii) $4.5 \times \dfrac{R_v}{R_v + 10} = 4.1$ 1

$R_v = 102.5\ \text{k}\Omega$ 1

Reading : 4.5 V 1 3

(b) (i) Let r be the resistance of the coil and I_C its current

Consider the shunt, $0.1 = (50 \times 10^{-6} - I_C)(9.8 \times 10^3 + 200)$ 1

$I_C = 40\ \mu\text{A}$ 1

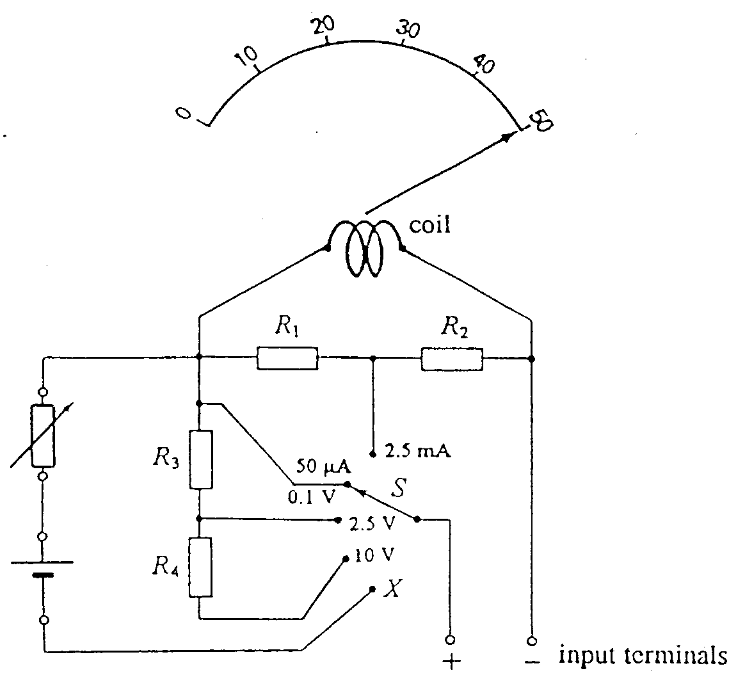
For the coil, $0.1 = 40 \times 10^{-6}\, r$ 1

$r = 2.5\ \text{k}\Omega$ 1 4

(ii) $(10 - 2.5) = 50 \times 10^6 \times R_4$ 1

$R_4 = 150\ \text{k}\Omega$ 1 2

(iii)



2

Short circuit the input terminals and adjust the rheostat until the pointer indicates
full-scale deflection to the right. 1 3

Marks

5. (a) The back e.m.f induced in the inductor per unit rate of change of current. 1 1

(b) (i) When there is a change of current, back e.m.f. $\varepsilon_b = -L\frac{dI}{dt}$ is produced by the inductor, , therefore only part of the applied p.d. is used for driving the current. 1 1 2

$(V = IR + L\frac{dI}{dt})$

(ii) At $t = 0$ s, $V = L\frac{dI}{dt}$

$9 = L\ \frac{10\times10^{-3}}{2\times10^{-3}}$ 1

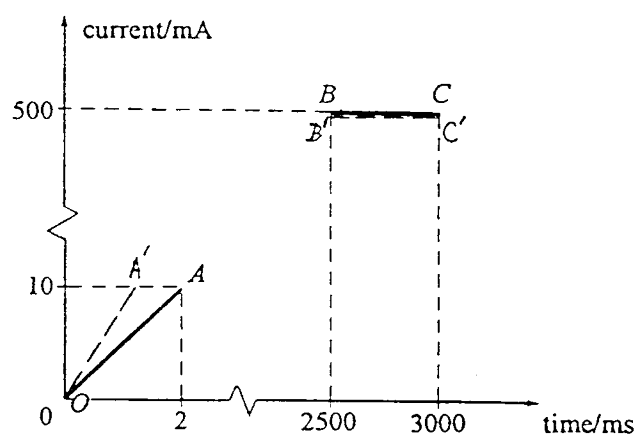
$L = 1.8$ H 1 2

(iii) At steady state, $V = IR$

$9 = 500 \times 10^{-3} R$ 1

$R = 18\Omega$ 1 2

(iv)



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2

(c) (i) The energy stored in the magnetic field of the inductor. 1 1

(ii) $\frac{1}{2} L I^2 = \frac{1}{2} CV^2$ 1

$1.8\ (500 \times 10^{-3})^2 = C\ (350)^2$ 1

$C = 3.6\ \mu F$ 1 3

Marks

6. (a) (i) The electric field of the waves vibrates on certain planes; vertical planes containing the aerial in this case. 1 1

(ii) When the antenna is vertical i.e. parallel to, the aerial, the signal received is maximum; however it decreases to a minimum when the antenna is rotated till it is horizontal. The plane-polarized nature of the waves is demonstrated, implying that the waves must be transverse. 1 1 1 3

(iii) The waves reflected from the plate to the antenna suffers a phase change of π, destructive interference occurs between the direct and reflected waves reaching the antenna. Therefore the microammeter reading decreases. 1 1 1 3

(b) (i) When alternating currents (of various frequencies) flow in coil L', e.m.f.'s of the same frequencies can be induced in L by mutual induction. 1 1 2

(ii) Although the currents in the aerial coil induce currents of various frequencies in coil L, only the current with frequency equals the resonant frequency of the LC circuit can develop a large p.d. (at that frequency) across C. 1 1 2

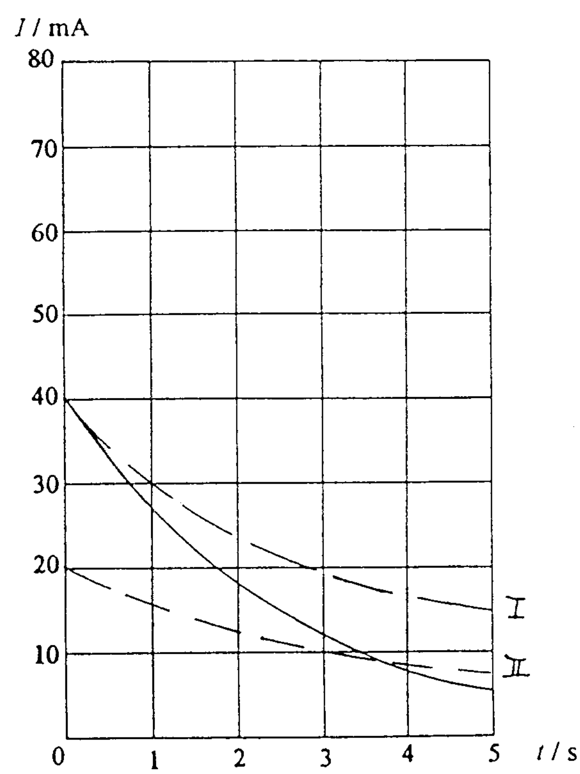
(iii) Resistance of coil L can be minimized so that the reception is better as the resonant current at the wanted frequency increases. 1 1 2

7. (a) (i) As the capacitor charges up ($Q\uparrow$), voltage across it increases ($V_C = \frac{Q}{C}\uparrow$) therefore 1

the e.m.f. for driving the current decreases, so $\frac{V - V_c}{R} = I\downarrow$ 1 2

(ii) The charges stored in the capacitor. 1 1

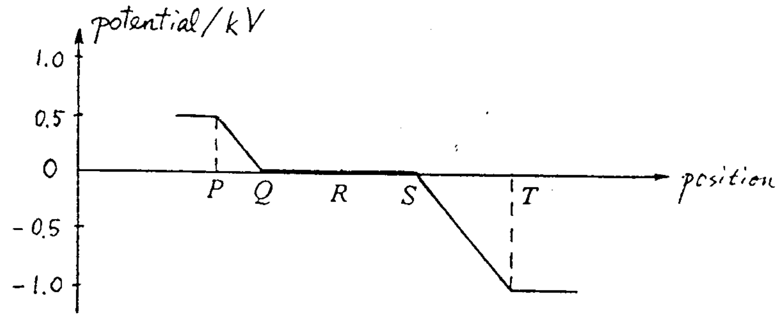
(iii)



4

Marks

(b) (i)

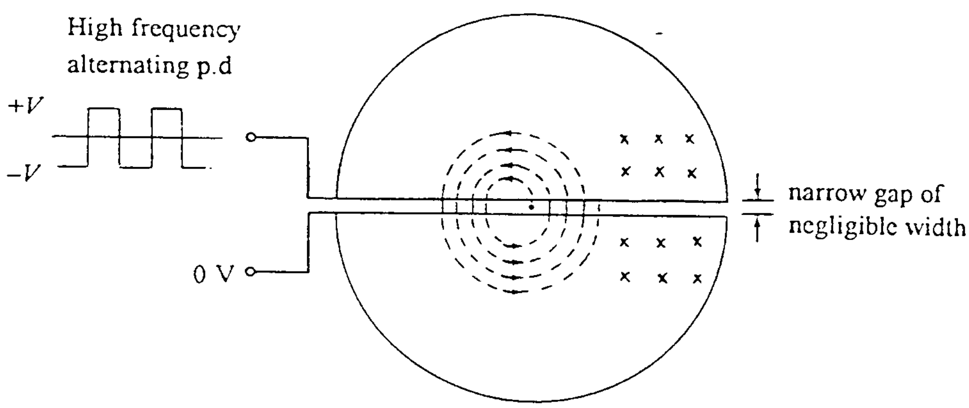


3

(ii) The strip deflects to the right and the extent of deflection remains unchanged when moving the strip between the plates. 1 1
This is because the electric field is constant between the plates. 1

(iii) unchanged. 1

8. (a) (i)



1

(ii) $qvB = \frac{mv^2}{r}$ 1

$v = \frac{qBr}{m}$ 1

As the force on the proton is perpendicular to its motion, no work is done on the proton. 1

(iii) Time $= \frac{\pi r}{v}$ 1

$= \pi \left(\frac{m}{qB}\right)$ which is constant 1

(b) (i) 2 (e x 10 kV) = 20 keV 1

(ii) No. of revolutions required $= \frac{1\text{MeV}}{20\text{keV}} = 50$ rev 1

Time required $= 50\ (2 \times \frac{\pi m}{qB})$ (by (a) (iii)) 1

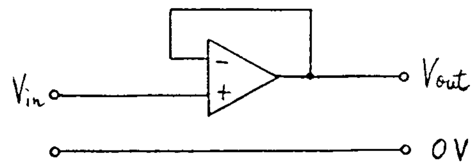
$= 100\ \frac{\pi \times 1.66 \times 10^{-27}}{1.60 \times 10^{-19} \times 1.5}$

$= 2.17 \times 10^{-6}$ s 1

Marks

9. (a) $V_{out} = A_0 (V_+ - V_-)$
$V_+ - V_- = \frac{15}{10^5} = 1.5 \times 10^{-4}$ V or 150 μV — 1 — 1

(b) (i)



2 — 2

(ii) As the open-loop gain is very large (infinite for an ideal op amp), the two input terminals are nearly at the same potential — 1
i.e. $V_{in} = V_+ \approx V_- = V_{out}$ — 1
- used as a buffer between a high impedance (low current) circuit and a low impedance (high current) circuit (e.g. electrometer) — 1 — 3

(c) (i) When it is dark, most of the p.d. drops across the LDR as its resistance is higher than that of the 50-kΩ rheostat, so $V_Y < V_X$ and LED is off as V_{out} is negative. — 1, 1
When it is bright, resistance of LDR decreases, p.d. across the 50-kΩ rheostat increases until $V_Y > V_X$, LED is on as V_{out} becomes positive. — 1 — 3

(ii) 5 V — 1
resistance of LDR is 10 kΩ
$R_{rheostat}$ / 10 kΩ = 30 kΩ/15 kΩ — 1
$R_{rheostat}$ = 20 kΩ — 1 — 3

10. (a) (i) When $d \leq 7$ mm, absorption of β rays increases with d. — 1
For $d > 7$ mm, nearly all β rays are absorbed but the aluminum plates have little or no effect on γ rays. — 1 — 2

(ii) 1.5 ± 0.1 mm — 1 — 1

(iii) The penetrating power of α-particles is very weak, most are stopped by the absorber plates. — 1 — 1

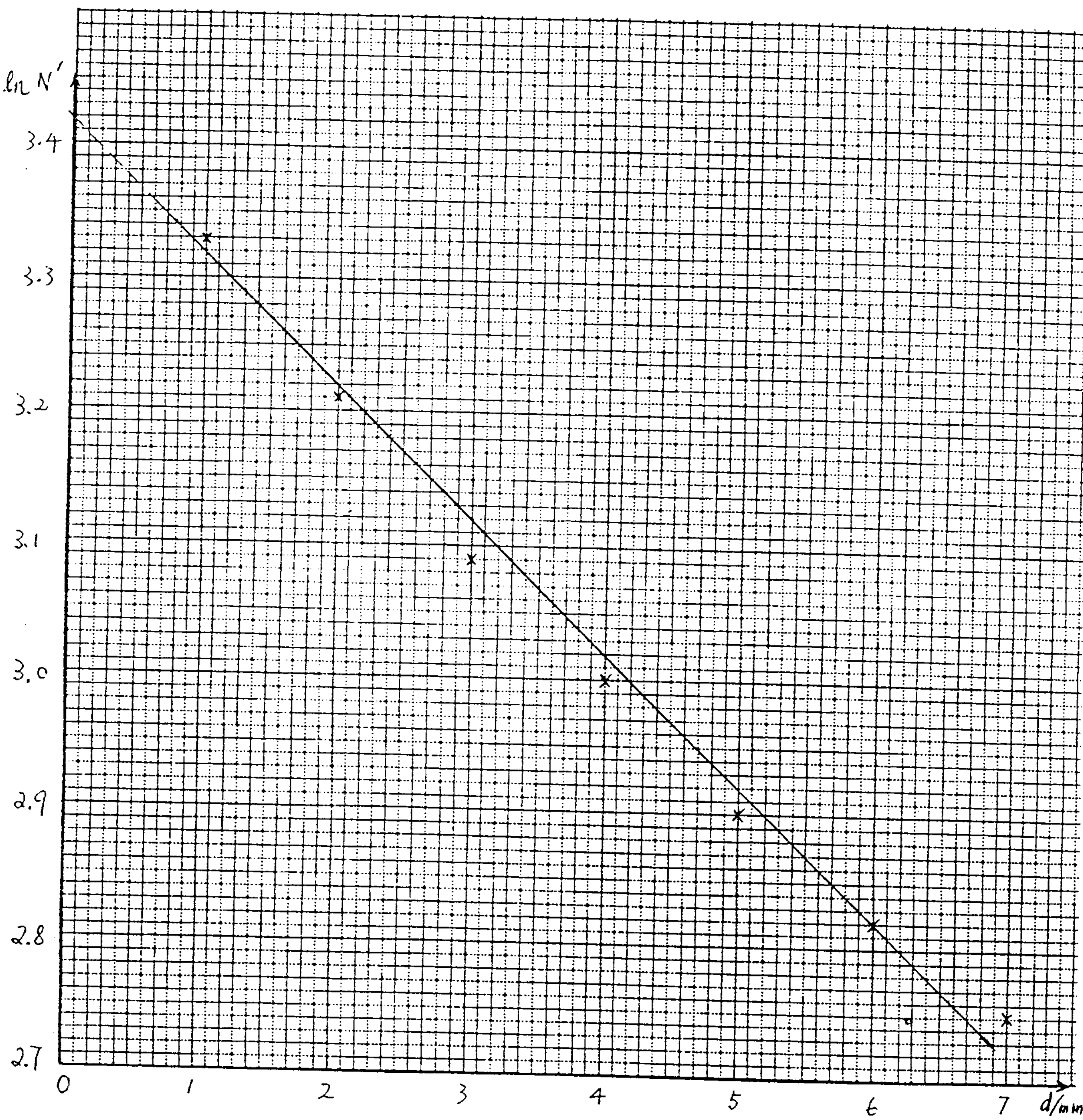
(b) (i) The 'corrected' count rates (N') are obtained by deducting the background count rate from the count rates (N) taken. — 1 — 1

Mark

(ii)

d / mm	1	2	3	4	5	6	7
N' / s^{-1}	28.0	24.8	22.0	20.0	18.2	16.8	15.7
ln N'	3.33	3.21	3.09	3:00	2.90	2.82	2.75

1



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4

(iii) Slope $= \dfrac{2.86 - 3.14}{5.6 - 2.8}$ 1

$= -0.1 \text{ mm}^{-1}$

ln $N' = -0.1\,d + 3.42$ 1

or $N' = 31\,e^{-0.1d}$

2

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				Marks	
1.	(a)		0 N	1	1
	(b)	(i)	$g' = \dfrac{GM_E}{r^2}$	1	
			$= \dfrac{GM_E}{R_E^2} \dfrac{R_E^2}{r^2}$		
			$= 10 \dfrac{(6.4\text{x}10^6)^2}{(6.4\text{x}10^6 + 6\text{x}10^5)^2}$	1	
			$= 8.4 \text{ N kg}^{-1}$	1	3
		(ii)	$mg' = \dfrac{mv^2}{r}$	1	
			$8.4 = \dfrac{v^2}{7\times10^6}$		
			$v = 7.6 \text{ x } 10^3 \text{ m s}^{-1}$	1	
			And $T = \dfrac{2\pi r}{v}$	1	
			$= \dfrac{2\pi(7\text{x}10^6)}{7.6\text{x}10^3}$		
			$= 5.7 \text{ x } 10^3 \text{ s}$	1	4
	(c)	(i)	$E = \dfrac{-GM_E m}{r} + \dfrac{1}{2}mv^2$	1	
			$E = \dfrac{-GM_E m}{r} + \dfrac{1}{2} \dfrac{GM_E m}{r} \quad (\because \dfrac{GM_E m}{r^2} = \dfrac{mv^2}{r})$	1	
			$E = \dfrac{-GM_E m}{2r}$		2
		(ii)	By (c) (i), the shuttle should decrease its speed so that E becomes	1	
			more negative, that is r decreases accordingly and the shuttle spirals	1	
			into an orbit of smaller radius.		2
2.	(a)	(i)	Gravitational p.e. becomes elastic p.e. at D	1	
			$mgh = 50 \text{ x } 10 \text{ x } 40$		
			$= 2 \text{ x } 10^4 \text{ J}$	1	2
		(ii)	Elastic p.e. $= \dfrac{1}{2}kx^2$	1	
			$2 \text{ x } 10^4 = \dfrac{1}{2}k(25)^2$		
			$k = 64 \text{ N m}^{-1}$	1	2
	(b)	(i)	AB : free falling, only gravitational force acting.	1	
			BC : both mg (downwards) & T (upwards) acting, $mg > T$.		
			CD : both mg & T acting, $mg < T$.	1+1	3
		(ii)	equilibrium position : 22 ~ 23 m from the bridge	1	
			amplitude : 17 ~ 18 m	1	2

Marks

(iii) $\omega^2 = \dfrac{k}{m}$ — 1

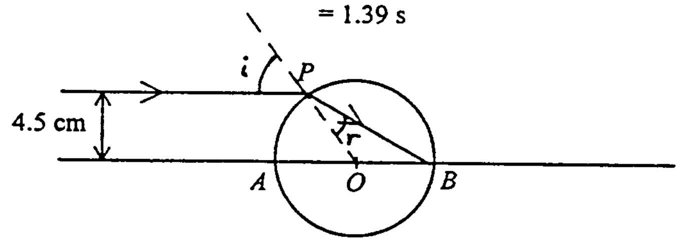
$\omega = \sqrt{\dfrac{64}{50}} = 1.13 \text{ rad s}^{-1}$

Time taken from C to D is $\dfrac{1}{4}T = \dfrac{1}{4}(\dfrac{2\pi}{\omega})$ — 1

$= \dfrac{1}{4}(\dfrac{2\pi}{1.13})$

$= 1.39$ s — 1 — 3

3. (a)



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2

(b) $i = \sin^{-1}(\dfrac{4.5}{5.0})$

$= 64.2°$ — 1 — 1

(c) $n = \dfrac{\sin 64.2°}{\sin 28.6°}$ — 1

$= 1.88$ — 1 — 2

(d) $\lambda_{air} = \dfrac{c}{f}$ — 1

$= \dfrac{3\text{x}10^8}{5.4\text{x}10^{14}}$

$= 5.55 \times 10^{-7}$ m

$n = \dfrac{\lambda_{air}}{\lambda_{glass}}$ — 1

$1.88 = \dfrac{5.55\text{x}10^{-7}}{\lambda_{glass}}$

$\lambda_{glass} = 2.95 \times 10^{-7}$ m — 1 — 3

(e) By $n_w \sin i = n_g \sin r$ — 1

$1.33 \sin 64.2° = 1.88 \sin r$

$r = 39.6°$ — 1

The light ray would not intersect the diameter AOB before it leaves the glass sphere as the angle of refraction r is greater than $\angle PBA = 32.1°$. — 1 — 3

Marks

4. (a) 6 V. 1
It remains unchanged at 6 V. 1 2

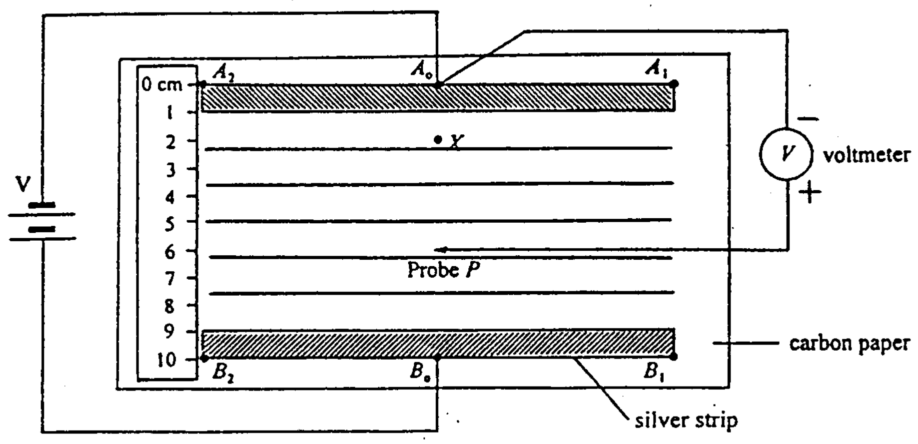
(b) (i) Constant potential on the two strips due to zero resistance. 1
Resistance increases uniformly in the region between the strips, therefore potential rises uniformly. 1 2

(ii) $E = \frac{V}{d}$

$= \frac{6}{0.08}$ 1

$= 75\ \text{V m}^{-1}$ or $0.75\ \text{V cm}^{-1}$ (upwards, from B_o to A_o) 1+1 3

(iii)



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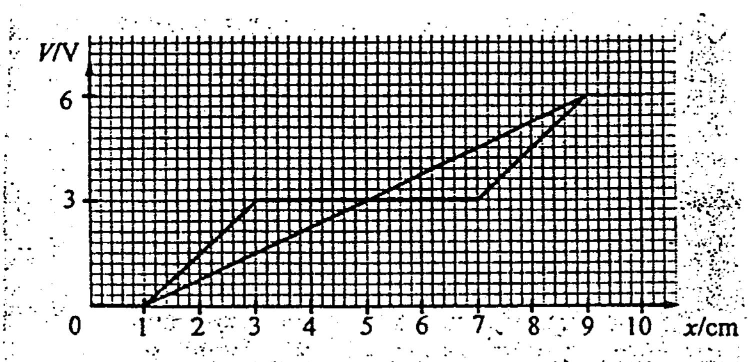
2

(c) (i)



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2

(ii) As $E = \frac{V}{d}$, $E\uparrow$ as $d\downarrow$ (i.e. potential gradient increases) 2 2

Marks

5. (a) (i) mass defect, $\Delta m = \dfrac{174.4}{934}$ — 1

$= 0.1867$ u

$0.1867 = 235.0439 - (141.9164 + 90.9234 + 2m_n)$ — 1

$m_n = 1.0087$ u — 1 — 3

(ii) No. of U-235 nuclei $= \dfrac{1.0\text{x}10^{4}}{235.0439\text{x}1.66\text{x}10^{-27}}$

$= 2.563 \times 10^{28}$ — 1

Energy released $= 2.563 \times 10^{28} \times 174.4$ MeV — 1

$= 4.47 \times 10^{30}$ MeV (or 7.15×10^{11} MJ) — 1 — 3

(iii) $\dfrac{4.47\text{x}10^{30}\text{x}1.6\text{x}10^{-19}\text{x}0.4}{500}$ — 1

$= 5.72 \times 10^{8}$ s (or 1.59×10^{5} hr or 6620 days or 18.1 yr) — 1 — 2

(iv) The percentage of U-235 in the fuel rods will decrease with time. — 1
Chain reaction cannot be maintained when the concentration of U-235 in the fuel rods falls below a certain value. — 1 — 2

(b) Insert all the boron-steel/control rods into the reactor core — 1
so as to absorb the neutrons. — 1 — 2

Marks

6. (a) mass of liquid column = $\rho (Ah)$ 1

$\therefore$ pressure $= \dfrac{\rho A h g}{A}$ 1 2

$= \rho g h$

(b) (i) $p_X - p_Y = \rho g h$ 1

$= 1200 \times 10 \times 0.03$

$= 360 \text{ N m}^{-2}$ 1 2

(ii) $p_X + \dfrac{1}{2}\rho v_X^2 = p_Y + \dfrac{1}{2}\rho v_Y^2$

$p_X - p_Y = \dfrac{1}{2}\rho (v_Y^2 - v_X^2)$ 1

$360 = \dfrac{1}{2} \times 1200 \times (0.8^2 - v_X^2)$

$v_X = 0.2 \text{ m s}^{-1}$ 1

And $A_X = \dfrac{0.8}{0.2} \times 4 \times 10^{-5}$ 1

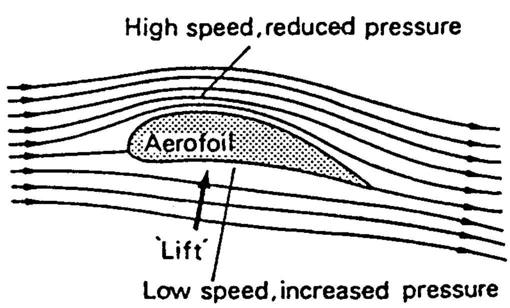
$= 1.6 \times 10^{-4} \text{ m}^2$ 1 4

(iii) Rate of work done $= (p_X - p_Y) A_X v_X$ 1

$= 360 \times 1.6 \times 10^{-4} \times 0.2$

$= 0.012 \text{ W}$ 1 2

(c)



2

The velocity of air flow is faster at the upper side than at the lower side of the aircraft wing. According to Bernoulli's principle, the pressure and hence the force is greater at the lower side of the aircraft wing. 1 1 4

7. (a) (i) $B = \mu_0 n I_S$ $\quad \varepsilon = I_C R$ 1

$\dfrac{d(BA)}{dt} = I_C R$ 1

$\mu_0 n A \dfrac{dI_S}{dt} = I_C R$

$4\pi \times 10^{-7} \dfrac{100}{0.45} (0.01)^2 \dfrac{I_{max}}{0.04} = 0.01 \times 10^{-6} \times 100$ 1

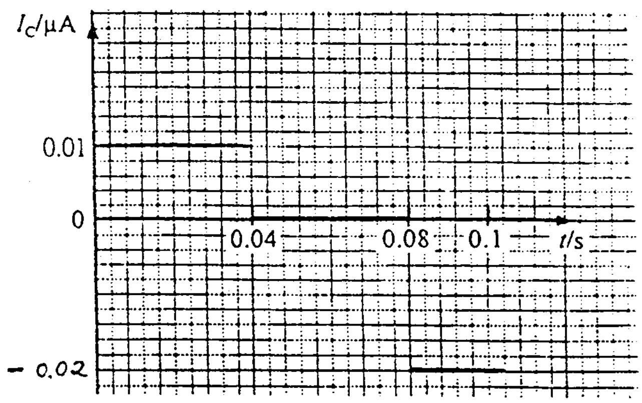
$I_{max} = 1.43 \text{ A}$ 1 4

(ii)
- neglect the inductance of the coil
- coil is placed at the centre of the solenoid
- coils of the solenoid are closely packed
- magnetic field strength is uniform over the area of the coil
- coil is not placed near the two ends of the solenoid

ANY TWO @1 2 2

Marks

(iii)



2

2

(b) To minimize the inductance of the connecting wires. 1 1

(c) (i) 0.01 μA 1

(ii) 2 μV 1 2

8. (a) $nb = 2.7 \times 10^{-5}$ 1

$0.5\, b = 2.7 \times 10^{-5}$

$b = 5.4 \times 10^{-5}\ (\text{m}^3\ \text{mol}^{-1})$ 1 2

(b) $\Delta U = U_A - U_C$

$= \frac{3}{2} n R (T_A - T_C)$ 1

$= \frac{3}{2}\ (0.5)\ (8.31)\ (310 - 80)$

$= 1430$ J 1 2

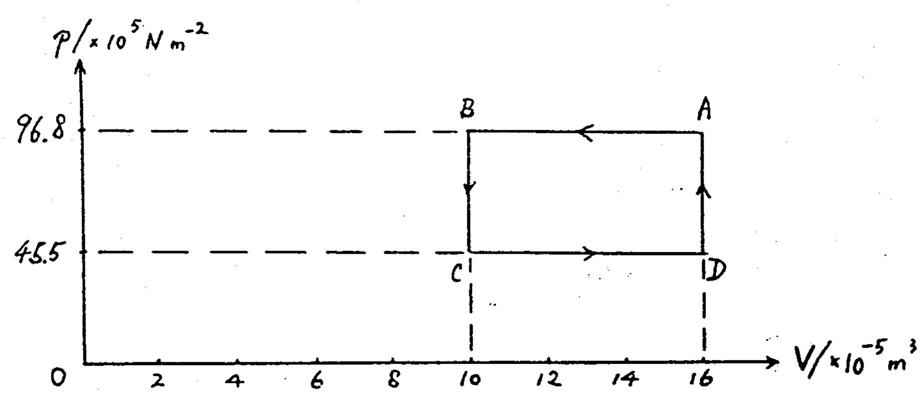
(c) (i) $p_A = \frac{nRT}{V - nb}$

$= \frac{(0.5)(8.31)(310)}{(16 - 2.7) \times 10^{-5}}$ 1

$= 96.8 \times 10^5$ N m^{-2} 1

& $p_C = 45.5 \times 10^5$ N m^{-2} 1 3

(ii)



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2

(iii) Work done by the gas $= 45.5 \times 10^5 \times (16 - 10) \times 10^{-5}$ 1

$= 273$ J 1 2

(d) $\Delta U = W + Q$

$1430 = -273 + Q$ 1

$Q = 1703$ J 1 2

Marks

9. (a) (i) 8.0 V 1 1

(ii) 0.8 V 1 1

(iii) $G = \dfrac{8-0.3}{1.5-0.8}$ 1

$= 11$ 1

$G = \beta \dfrac{R_L}{R_B}$

$11 = \beta \dfrac{2.5}{12}$ 1

$\beta = 52.8$ 1 4

(b) (i) To filter away the steady/constant/d.c. component of the signal. 1 1

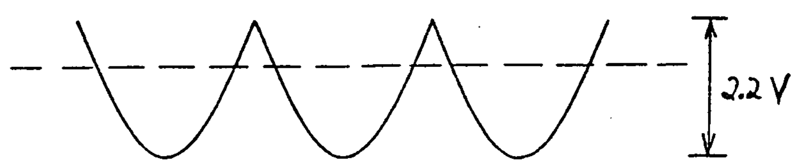
(ii) biasing input voltage $= 8 \times \dfrac{16}{16+125}$ 1

$= 0.91$ V

$\therefore V_p \leq 1.5 - 0.91 = 0.59$ V 1 2

(Accept other answers for considering the coupling effect.)

(iii)



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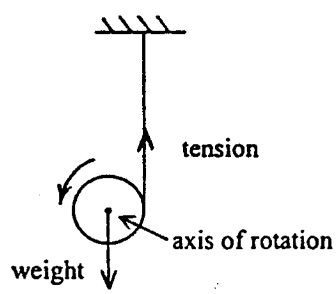
2

10. (a) (i)



1

1

(ii) By $v^2 = u^2 + 2as$

$v^2 = 2(\frac{2}{3}g)s$ 1

$\frac{1}{2}m v^2 = \frac{2}{3}mgs$ ---- ❶

So, loss in p.e. = gain in linear k.e + gain in rotational k.e. 1

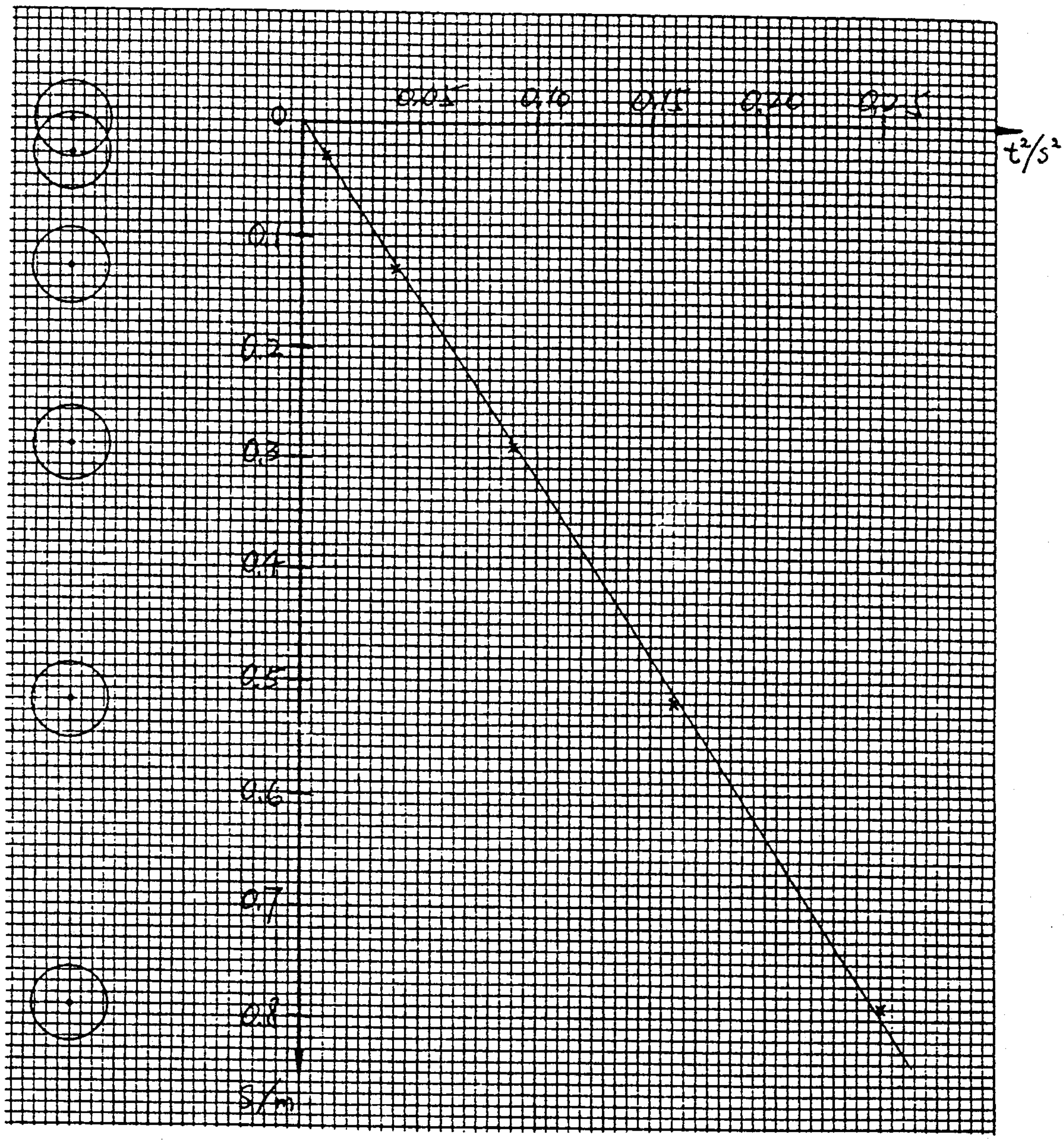
$mgs = \frac{2}{3}mgs$ + gain in rotational k.e. (by ❶) 1

Thus gain in rotational k.e. $= \frac{1}{3}mgs$ 3

(iii) All forces acting on the disc are vertical (i.e. no horizontal forces). 1 1

Marks

(b) (i)



Axes labelled with appropriate scales	1	
Points correctly plotted	1	
Correct graph (*best* straight line)	1	3
(ii) $s = \frac{1}{2}at^2$ slope $= \frac{1}{2}a$	1	
$\therefore 3.2 = \frac{0.8-0}{0.25-0} = \frac{1}{2}a$ $a = 6.4 \text{ m s}^{-2}$	1	
By (a) (ii), $a = \frac{2}{3}g \Rightarrow g = 9.6 \text{ N kg}^{-1}$	1	3

Marks

1. (a) 4.6 ± 0.1 cm — 1 — 1

(b) Avoid the formation of bubbles adhering the ball bearings, — 1
which will affect the volume measured. — 1
Or Tilting the measuring cylinder and let the bearings run along the wall of the cylinder.
Or Avoid the splashing of water when putting the bearings into the cylinder. — 2

(c) (i) vernier calipers — 1 — 1

(ii) density $= \dfrac{\text{mass}}{\text{volume}}$ — 1

$$= \frac{25.00\times10^{-3}}{\pi(\frac{9.40\times10^{-3}}{2})^2 4.6\times10^{-2}}$$ — 1

$= 7830$ kg m^{-3} — 1 — 3

(iii) % uncertainty in ρ = % uncertainty in mass + % uncertainty in volume — 1

$$= \frac{0.01}{25.00}\times100\% + 2\times\frac{0.05}{9.40}\times100\% + \frac{0.1}{4.6}\times100\%$$ — 1

$= 0.04\% + 1\% + 2\%$

$= 3\%$ — 1 — 3

(d) Use micrometer screw gauge to measure the diameter of the ball bearings. — 1

Average diameter of ball bearings $= 2(\pi(\frac{9.40\times10^{-3}}{2})^2 4.6\times10^{-2} \div 20 \div \frac{4}{3}\pi)^{\frac{1}{3}}$ — 1

$= 6.73 \times 10^{-3}$ m or 6.73 mm

% uncertainty in volume $= 3\text{x}\dfrac{0.01}{6.73}\text{x}100\% = 0.4\%$ — 1 — 3

Marks

2. (a) (i) 3, 11, 19 — 1 — 1

(ii) $\lambda = 5$ cm — 1

$$f = \frac{1}{2 \times 10 \times 10^{-6}}$$

$= 50$ kHz — 1

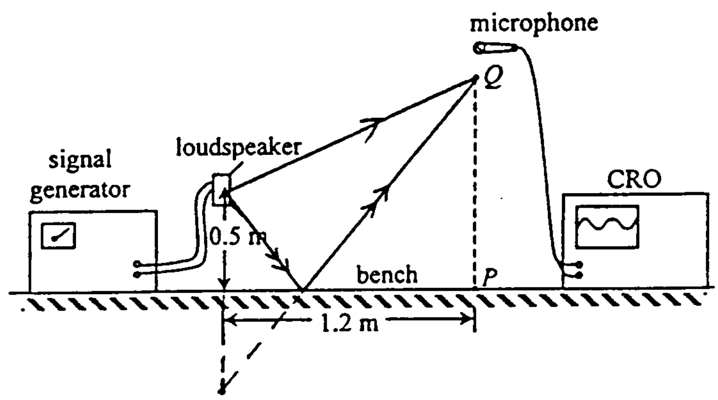
$v = f\lambda$

$= 50\text{x}10^{3} \text{ x } 5\text{x}10^{-2}$ — 1

$= 2500 \text{ m s}^{-1}$ — 1 — 4

(b) (i) A compression is reflected as a compression at the bench surface. — 1 — 1

(ii)



1

For a certain point along PQ, the sound waves coming directly from the loudspeaker interfere with those reflected from the bench. Due to the path difference between the waves, constructive interference and destructive interference occur alternately as the path difference changes. — 1, 1 — 3

(iii) path difference $\Delta = \sqrt{1.2^2 + (1.1 + 0.5)^2} - \sqrt{1.2^2 + (1.1 - 0.5)^2}$ — 1+1

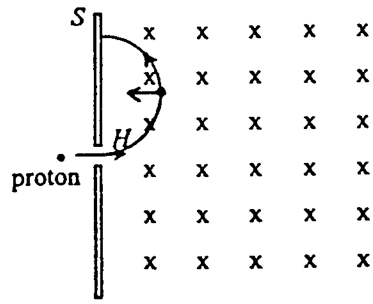
$= 0.658$ m

$\Delta = 4\lambda = 0.658$ — 1
$\lambda = 0.165$ m

$v = f\lambda$
$= 2\text{x}10^{3} \text{ x } 0.165$
$= 330 \text{ m s}^{-1}$ — 1 — 4

Marks

3. (a)



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2

(b) (i) $qV_0 = \frac{1}{2}mv^2$ 1

As $qvB = \frac{mv^2}{r}$ 1

$r = \frac{mv}{qB}$

$r = \frac{m}{qB}\sqrt{\frac{2qV_0}{m}}$

$d = 2r = \frac{2}{B}\sqrt{\frac{2mV_0}{q}}$ 1

For a proton, $d = 0.18$ m 1 4

(ii) Time taken $T = \frac{\pi r}{v}$ 1

$= \frac{\pi m}{qB}$ (by $r = \frac{mv}{qB}$ in (i)) 1

$= \frac{\pi \times 1.67\times10^{-27}}{1.6\times10^{-19}\times0.05}$

$= 0.66$ μs (or 6.6×10^{-7} s) 1 3

(c) As $d \propto \sqrt{\frac{m}{q}}$, 1

$\frac{d_x}{d_p} = \sqrt{\frac{m_x}{m_p}\bullet\frac{q_p}{q_x}}$

$\frac{0.26}{0.18} = \sqrt{\frac{m_x}{m_p}\bullet\frac{1}{2}}$

$m_x = 4\ m_p$ 1

Nucleus X is a helium nucleus ($^4_2$He) or an α-particle. (Deduction should be consistent with the result calculated.) 1 3

				Marks	
4.	(a)	(i)	Gain $= \dfrac{-R_f}{R_i}$		
			$\dfrac{15}{5} = \dfrac{R_f}{10\text{k}\Omega}$	1	
			$R_f = 30\text{ k}\Omega$	1	2
		(ii)	The circuit amplifies the input signal linearly by 3 times and	1+1	
			with a change of sign, i.e. a negative feedback inverting amplifier.	1	3
	(b)		$\dfrac{R}{15k\Omega} = \dfrac{12-4.5}{4.5}$	1	
			$R = 25\text{ k}\Omega$	1	2
	(c)	(i)	$V_P = 5.5$ V and $V_Q = 4.5$ V	1	
			For $V_{in} < V_Q = 4.5$ V, Op amp 2 gives a high output that makes LED Y light up	1	
			For $V_{in} > V_P = 5.5$ V, Op amp 1 gives a high output that makes LED X light up.	1	3
		(ii)	$15\text{ k}\Omega : R_1 : R_2 = 4.5 : 1 : 6.5$	1	
			$R_1 = 3.3\text{ k}\Omega$	1	
			$R_2 = 21.7\text{ k}\Omega$	1	3
5.	(a)		α-source	1	
			- normally the source can hardly enter the body and it is harmful only when it has entered the body	1	
			- short range with low activity and the source is sealed, therefore it is safe in normal use	1	3
	(b)	(i)	$I_0 = 2000 \times 5 \times 10^4 \times 1.6 \times 10^{-19}$	1	
			$= 1.6 \times 10^{-11}$ A	1	
			Dust or air particles may carry away some of the ions.	1	3
		(ii)	$I = I_0 e^{-kt}$	1	
			$5\times10^{-12} = 1.6\times10^{-11} e^{-k(10yr)}$	1	
			$k = 0.116\text{ yr}^{-1}$		
			$t_{1/2} = \dfrac{\ln 2}{k} = \dfrac{\ln 2}{0.116}$		
			$= 5.96$ yr (or 1.88×10^8 s)	1	3

Marks

6. (a) $f' = f\dfrac{(1+\frac{v}{c})^{\frac{1}{2}}}{(1-\frac{v}{c})^{\frac{1}{2}}}\bullet\dfrac{(1+\frac{v}{c})^{\frac{1}{2}}}{(1+\frac{v}{c})^{\frac{1}{2}}}$ 1

$= f\dfrac{(1+\frac{v}{c})}{(1-(\frac{v}{c})^2)^{\frac{1}{2}}}$

$= f(1+\frac{v}{c})$ (as $(\frac{v}{c})^2 \to 0$) 1 2

(b) (i) When the satellite is close to the tracking station, its direction of motion (or velocity) makes an angle with the line joining the satellite and the station. The Doppler effect is thus due to the component of its velocity, which varies. 2 2

(ii) $\Delta f_1 = f' - f_o = f(1+\frac{v}{c}) - f_o$ ——— ①

$\Delta f_2 = f'' - f_o = f(1-\frac{v}{c}) - f_o$ ——— ② 1

$\Delta f_1 - \Delta f_2 = 2f\frac{v}{c}$ 1

$7000 - 2000 = 2\,(100 \times 10^6)\,\dfrac{v}{3\times10^8}$

$v = 7500 \text{ m s}^{-1}$ 1 3

(iii) By ①, $7000 = 100 \times 10^6\,(1 + \dfrac{7500}{3\times10^8}) - f_o$ 1

$f_o = 99.9955$ MHz 1 2

(iv) No, it is only the velocity 'observed' from the tracking station, the rotation of the earth together with the tracking station is not taken into account. 2 2

Marks

7. (a) (i) A : frictional force, B : normal reaction, C : weight 1
Force C (weight) 1 2

(ii) The ball bearing is initially at rest and all the forces acting on it are on a vertical plane. 2 2

(iii) $\omega^2 = \frac{5g}{7R} = \frac{5\times 10}{7\times 0.15}$ 1

$\omega = 6.9 \text{ rad s}^{-1}$

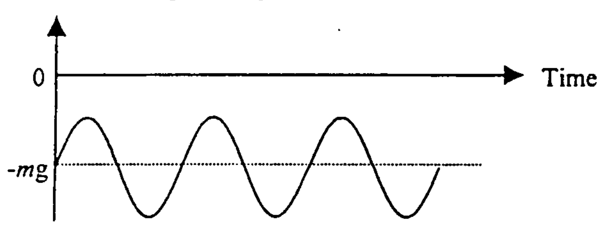
$T = \frac{2\pi}{\omega}$ 1

$= \frac{2\pi}{6.9}$

$= 0.91 \text{ s}$ 1 3

(iv) The hollow sphere has a greater moment of inertia, so for the same loss in potential energy, its speed of rotation and thus the linear speed when passing the centre of the lens are smaller than those of the bearing. 1 1 1 3

(b) (i) Force acting on the platform



2

2

(ii) When the downward acceleration of the platform is equal to (or greater than) the gravitational acceleration, the slotted weight will lose contact with the platform (normal reaction = zero) 1

Maximum acceleration = $\omega^2 A = g$ 1

$(2\pi f_0)^2 A = g$

$f_0 = \frac{1}{2\pi}\sqrt{\frac{10}{1.5\times 10^{-2}}}$ 1

$= 4.1 \text{ Hz}$ 1 4

(iii) f_0 remains unchanged as the acceleration is independent of mass. 1+1 2

Marks

8. (a) (i) At low frequency, the reactance of C and hence the impedance of the circuit is high so the ammeter reading is small. 1
As frequency increases, both the reactance of C and the impedance of the circuit decrease so the ammeter reading increases. 1 1 3

(ii) (I) $T = \frac{1}{f} = \frac{1}{2\times10^3} = 0.5$ ms 1

time base = 0.125 ms per cm 1

V_R leads V_O by $180° \times \frac{4}{10} = 72°$ (or $\frac{2\pi}{5}$ or $\frac{T}{5}$) 1+1

(or using $\cos\theta = \frac{4}{13}$) 4

(II) r.m.s. of $V_R = \frac{4}{\sqrt{2}}$

$= 2.8$ V

r.m.s. of $V_O = \frac{13}{\sqrt{2}}$

$= 9.2$ V

Either peak value correct 1
Able to find r.m.s. values 1
Correct r.m.s. values 1 3

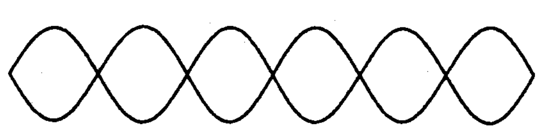
(III) $\tan 72° = \frac{\frac{1}{\omega C}}{R}$ 1

$C = \frac{1}{2\pi(2000)(5.5)\tan 72°}$ 1

$= 4.7\ \mu$F 1 3

(b) (i) At low frequency, bulb Y lights up while bulb X is dim as the reactance of L is low but that of C is high. 1 1
As frequency increases, bulb X glows gradually and bulb Y decreases in brightness. 1 3

(ii)



2

At resonance (1 kHz), large and nearly equal currents flow through C and L approximately at antiphase, therefore the total current through bulb Z is very small. 1 3

Marks

9. (a) (i) $V_0 = \frac{-GM_E}{R_E}$

$= \frac{-GM_E}{R_E^2} \bullet R_E$ 1

$= -10 \times 6400 \times 10^3$

$= -6.4 \times 10^7$ J kg^{-1} 1 2

(ii) $V_\infty = 0$ J kg^{-1} 1

Minimum energy per kg $= 0 - (-6.4 \times 10^7)$

$= 6.4 \times 10^7$ J 1 2

(b) 1989 N1 is too close to Neptune that it is lost in the glare of the reflected sunlight from Neptune. 1 1
or 1989 N1 and Neptune cannot be resolved when observed from earth.

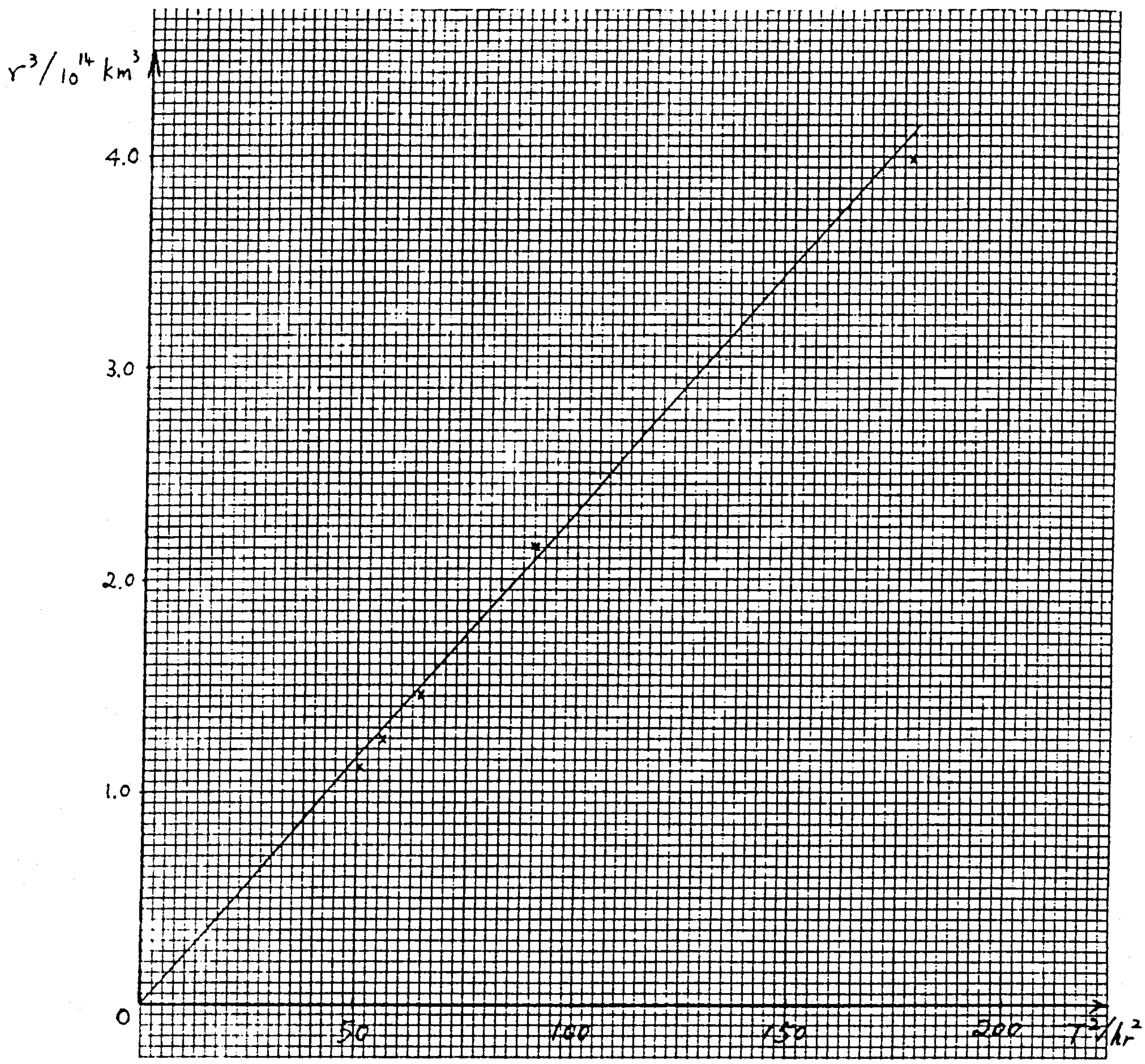
(c) (i) Orbits of the satellites are circular. 1
Or Assume Neptune is stationary.
Or Neglect the gravitational pull of nearby planets/satellites. 1

(ii)

T^2/hr^2	177	64	90	56	50
$r^3/10^9$ km^3	3.99×10^5	1.45×10^5	2.16×10^5	1.25×10^5	1.12×10^5

Marks

(c) (ii)



Appropriate quantities are chosen for plotting the graph 1
Points correctly plotted 1
Correct graph (*best* straight line) 1

$$\text{slope} = \frac{2.90\times10^{23}-0}{125\times(3600)^2-0}$$ 1

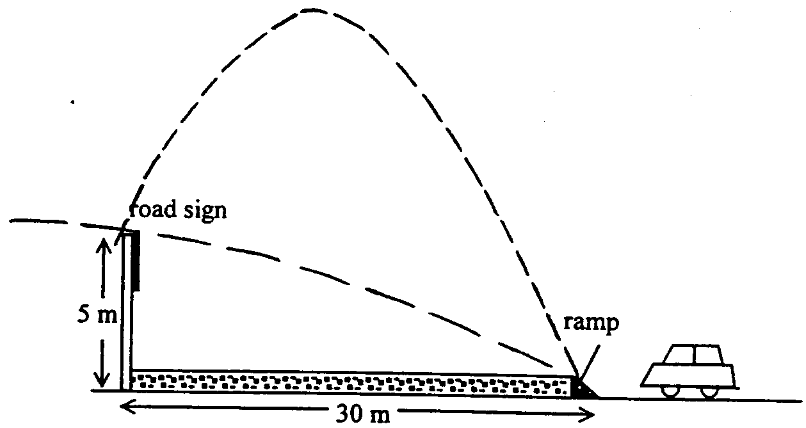
$= 1.79\text{x}10^{14}$ (m^3 s^{-2}) (or $2.32\text{x}10^{12}$ km^3 hr^{-2})

$$\therefore \text{slope} = \frac{GM}{4\pi^2} = 1.79\text{x}10^{14}$$ 1

$$M = \frac{1.79\times10^{14}\times4\pi^2}{6.7\times10^{-11}}$$

$= 1.05\text{x}10^{26}$ kg 1 6

1. (a) Marks



2

2

(b) $u\cos\theta\ t = 30$
$0 = u\sin\theta - gt$
$(u\sin\theta)^2 - 2g(5) = 0$

1 mark for **at least one** equation correct
2 marks if **all** equations correct 2

On solving, (i) $u = 31.6\ \text{m s}^{-1}$ 1
(ii) $\theta = 18.4°$ 1
(iii) $t = 1$ s 1 5

(c)

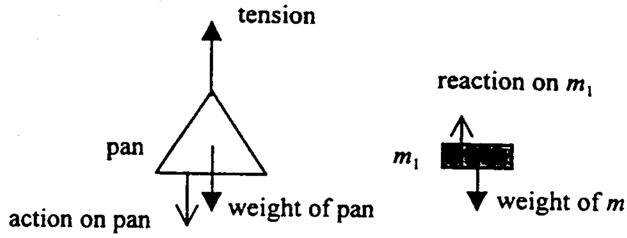
$F = ma$ (or $Fs = \frac{1}{2}mu^2 - \frac{1}{2}mu_1^2$) 1

$-8000 = 1000\ a$
$a = -8\ \text{m s}^{-2}$

And $v^2 = u^2 + 2\,a\,s$
$31.6^2 = u_1^2 + 2\,(-8)(39)$
$u_1 = 40.3\ \text{m s}^{-1}$ 1 2

(d) The car in fact took a parabolic path due to gravity. 1
The actual angle of projection should be greater than 9.5°, consequently the above relation would give an over-estimated value of u. 1 2

2. (a) Marks



3

<u>3</u>

(b) (Rest or) uniform motion 1 <u>1</u>

(c) $(m + M)g - T = (m + M)a$ & $T - Mg = Ma$ } (or $mg = (m + 2M)a$) 1

On solving, $a = \dfrac{mg}{m+2M}$

$= 0.32 \text{ m s}^{-2}$

& $T = Mg + Ma$ 1

$= 1.55 \text{ N}$ 1 <u>3</u>

(d) By $v^2 = u^2 + 2as$

$v^2 = 2(0.32)(0.36)$ 1

$v = 0.48 \text{ m s}^{-1}$ 1 <u>2</u>

(e) At equilibrium, $mg = kx_0$ 1

$0.01 \times 10 = 4x_0$

$x_0 = 0.025$ m below O 1

For s.h.m., $\omega = \sqrt{\dfrac{k}{m+2M}}$

$= \sqrt{\dfrac{4}{0.01 + 2 \times 0.15}}$ 1

$= 3.6 \text{ rad s}^{-1}$ 1 <u>4</u>

			Marks	
3.	(a)	Ensure that the full range of discharging current and therefore discharging time is obtained.	1	1
	(b)	- uncertainty in starting the stop watch - uncertainty in the readings of current - uncertainty in the readings of time - uncertainty due to the tolerance of the resistor - uncertainty due to the resistance of the microammeter } ANY TWO @1	2	2
	(c)	Reduce the random error in the readings taken.	1	1
	(d)	$V = IR$ $= 50 \times 10^{-6} \times 100 \times 10^{3}$ $= 5$ V (minimum value)	1	
		Therefore the e.m.f. of battery is 6 V.	1	2
	(e) (i)	$\ln I = -9.4 \times 10^{-2} t - 9.9$ (compared with $I = I_0 e^{\frac{-t}{RC}}$)	1	
		slope $= \dfrac{-1}{RC} = -9.4 \times 10^{-2}$	1	
		$C = 106 \times 10^{-6}$ F	1	3
	(ii)	Time constant $RC = 100 \times 10^{3} \times 106 \times 10^{-6}$ $= 10.6$ s << 60 s	1	
		The charging time is much greater than the time constant so the capacitor can be considered as fully charged.	1	2
	(iii)	y-intercept less negative (larger initial current) or steeper slope (more negative)	1	1

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Marks

4. (a) $PV = \frac{1}{3} Nm\overline{c^2}$

$P = \frac{1}{3} \rho \overline{c^2}$ — 1

$\sqrt{\overline{c^2}} = \sqrt{\frac{3 \times 16 \times 10^5}{1.57}}$

$= 1750 \text{ m s}^{-1}$ — 1 — 2

(b) $W = P\,\Delta V$ — 1

$= 10^5 \times 1.2$

$= 1.2 \times 10^5$ J (or 120 kJ) — 1 — 2

(c) (i) Initially, $P_0 V_0 = n_0 RT$ for the gas inside the cylinder. — 1

After inflating one balloon, $P_1 V_0 = n_1 RT$ in the cylinder

$P_b V_b = n_b RT$ in the balloon

Since $n_0 = n_1 + n_b$ — 1

$P_0 V_0 = P_1 V_0 + P_b V_b$

$|\Delta P| = P_0 - P_1 = \frac{P_b V_b}{V_0} = \frac{10^5 \times 1.2}{0.5}$

$= 2.4 \times 10^5$ Pa — 1 — 3

(ii) After inflating k balloons, $P_k V_0 = P_0 V_0 - k(P_b V_b)$ — 1

$P_k = P_0 - k(\frac{P_b V_b}{V_0}) > 10 \times 10^5$

$16 \times 10^5 - k(2.4 \times 10^5) > 10 \times 10^5$

$k < 2.5$

Therefore at most 2 balloons should be inflated. — 1 — 2

(d) Work has to be done against the atmospheric pressure as well as the intermolecular forces between the gas molecules, therefore by the conservation of energy heat is transferred from the surroundings into the cylinder. — 2 — 2

Ma

5. (a) voltage follower

(b) At the beginning when the p.d. between the metal can and the sample increases, more ions migrate to the opposite electrodes per unit time, ionization current increases, p.d. across the resistor also increases.

When the p.d. is greater than ~20 V, all the ions produced in unit time would be collected by the can or sample. 1

The p.d. across the resistor is saturated as further increase in applied p.d. would not increase the ionization current. 1

(c) (i) mass defect = 238.0508 – (234.0436 + 4.0026) = 0.0046 u 1

energy released = 0.0046 × 934

= 4.30 (MeV) 1

(ii) Saturated ionization current = $\dfrac{70\times10^{-3}}{10^{9}}$ 1

$= 70 \times 10^{-12}$ A

number of positive ions produced = $\dfrac{70\times10^{-12}}{1.6\times10^{-19}}$

$= 4.38 \times 10^{8}$ (ionizations per second) 1

(iii) energy needed to produce 4.38×10^{8} ionizations

$= 4.38 \times 10^{8} \times 30$ 1

$= 1.31 \times 10^{4}$ MeV

activity = $\dfrac{1.31\times10^{4}}{4.30}$ = 3050 (disintegrations per second) 1

Assumption : - all α particles emitted have undergone ionization. 1

or - nearly all the energy released in the decay goes to the α particle

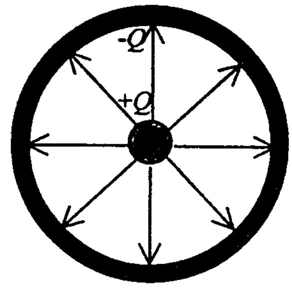
(iv) No.

- The ionization power of β particles is very weak. 1
- The β particles emitted do not possess the same amount of energy. 1
- The penetrating power of β particles is high/ range of β particles is long. 1

} ANY TWO

Marks

6. (a)



1

(b) (i) (I) $V_{AA'} = \sqrt{{V_S}^2 - {V_R}^2}$ 1

$= \sqrt{2.00^2 - 1.80^2}$

$= 0.87$ V (r.m.s.) 1

(II) $V_{AA'} = I\left(\frac{1}{\omega C}\right)$ & $V_R = IR$ 1

So $\frac{V_{AA'}}{V_R} = \frac{1}{\omega CR}$

$C = \frac{1.80}{0.87 \times 2\pi \times 100 \times 10^3 \times 10 \times 10^3}$ 1

$= 3.3 \times 10^{-10}$ F

$C_0 = \frac{C}{3.0} = 1.1 \times 10^{-10}$ F m^{-1} 1

(ii) (I) Zero 1

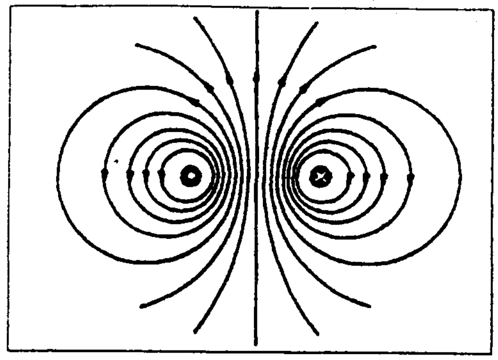
(II) $X_L = \omega L$

At 100 kHz, $X_L = 2\pi \times 100 \times 10^3 \times 10^{-7} = 0.06\ \Omega$ m^{-1} 1

At 1 MHz, $X_L = 2\pi \times 1 \times 10^6 \times 10^{-7} = 0.6\ \Omega$ m^{-1}

1 MHz is better since the order of magnitude of X_L is comparable to that of the resistor. 1

7. (a) (i) Marks



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2

(ii) $B = \dfrac{4\pi\times10^{-7}\times5}{2\pi}\left(\dfrac{1}{0.02}-\dfrac{1}{0.07}\right)$ 1

$= 3.6 \times 10^{-5}$ T 1 2

(iii) Hall probe. 1 1

(b) (i) Steady d.c. would produce a static magnetic field which would easily mix up with the earth's magnetic field. 1

Even with large d.c. current the B-field produced is weak and is therefore difficult to detect. 1 2

(ii) (I) The CRO trace represents the induced e.m.f. in the search coil and it is proportional to the peak value of the sinusoidal B-field produced by the wires. 1

- The search coil detects alternating B-field. Therefore the earth's field is not detected. 1
- Measureable induced e.m.f. can be produced by increasing the frequency even with relatively small current. 1 3

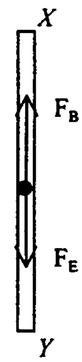
(II)
- the length of the wire should be as long as possible ~ 2 m
- the two wires should be well away from any magnetic materials
- set-up should be well away from any stray fields, such as those from mains socket
- twist the two connecting wires
- adjust the orientation of the coil so that the peak-to-peak value of the trace on the CRO is maximum
- avoid placing the coil near the ends of the wires

ANY TWO @1

(Accept any other reasonable answers) 2 2

Marks

8. (a) (i)



1

1

(ii) Magnetic force acting on a moving electron, $F_B = Bev$
Electrons migrate to Y, making there more negative, an E-field is set up across XY 1
Electrons also experience the electric force, $F_E = eE = e\varepsilon/l$ 1
If the two forces are equal, migration stops and the p.d. across the two ends becomes steady. 1

$$Bev = \frac{e\varepsilon}{l}$$

$$\Rightarrow \quad \varepsilon = Blv$$ 3

(b) (i) $$\frac{GMm}{R^2} = \frac{mv^2}{R}$$ 1

$$\Rightarrow \quad \frac{gR_E^2}{R} = v^2 \qquad \text{(or } g' = 8.86 \text{ m s}^{-2}\text{)}$$ 1

$$\Rightarrow \quad v = \sqrt{\frac{10\times(6.4\times10^6)^2}{6.8\times10^6}}$$
$$= 7800 \text{ m s}^{-1}$$ 1 3

(ii) $\varepsilon = Blv = 30 \times 10^{-6} \times 20 \times 10^3 \times 7800$
$= 4700$ V 1

- the cable is always perpendicular to the B-field
- the magnetic field is uniform over this 20-km cable
- the satellite and the shuttle move with the same speed

} ANY TWO @1 2

(i.e. ensure that v, l and B are mutually perpendicular) 3

(iii) Current direction: upward. 1
The ions and free electrons in the ionosphere would complete the circuit for electric power generation. 2 3

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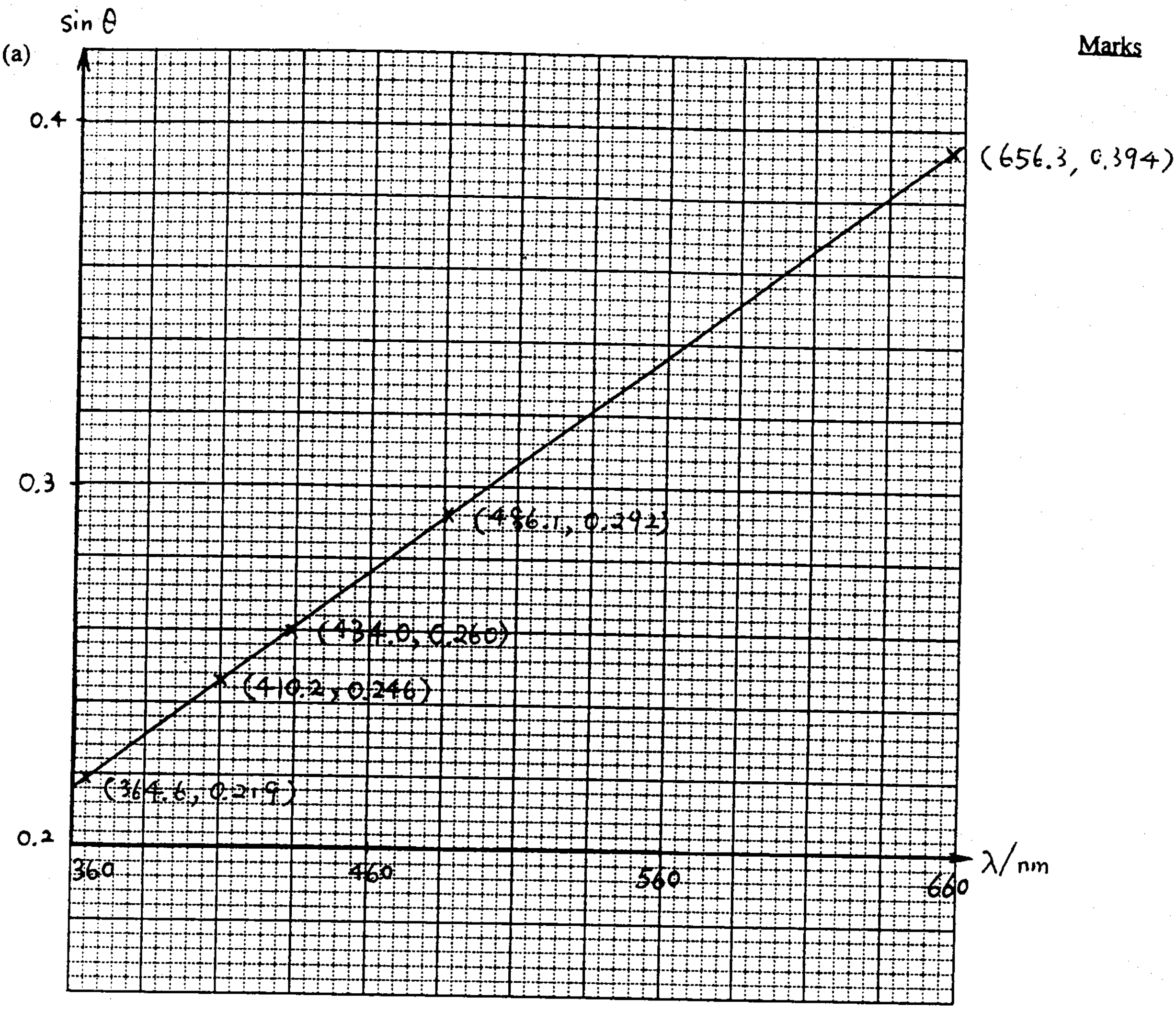
Marks

9. (a)



Appropriate quantities are chosen for plotting the graph 1
Points correctly plotted 1
Correct graph 1

$$\frac{1}{d} = \text{slope} = \frac{0.375 - 0.225}{625 - 375}\ \text{nm}^{-1}$$ 1

$= 600$ (lines per mm) 1 5

(b) (i) $\lambda = 434.0$ nm 1 1

(ii) ultra-violet 1 1

(c) Electrons transitions from a high energy level to a lower one within an excited atom. 1
Energy levels are discrete/quantized. 1 2

(d) (i) $\lambda = (364.6\text{ nm})\ \dfrac{n^2}{n^2 - 4}$

$$h\frac{c}{\lambda} = \frac{-hc}{364.6\text{nm}} \times 4\left(\frac{1}{n^2} - \frac{1}{4}\right) \qquad \left(\text{i.e. } h\nu = K\left(\frac{1}{n^2} - \frac{1}{4}\right)\right)$$ 1 1

(ii) $K = \dfrac{-6.626\times10^{-34} \times 3\times10^{8}}{364.6\times10^{-9}} \times 4 \times \dfrac{1}{1.6\times10^{-19}}$ 1

$= -13.6$ (eV) 1

Negative value means the electron is bounded and the magnitude is the energy of that 1
level with respect to $E\infty$. 1 4

Marks

10. (a) (i) Feeding back a certain portion of the output to the inverting input — 1

(or feeding back part of the output to the input, and they are in antiphase.)

- gain is predictable (more or less independent of the characteristics of the op-amp)
- stability is higher
- distortion of the output is less, i.e. amplification is more linear
- gain is constant over a wider range/band of frequencies

ANY TWO @1 — 2 — 3

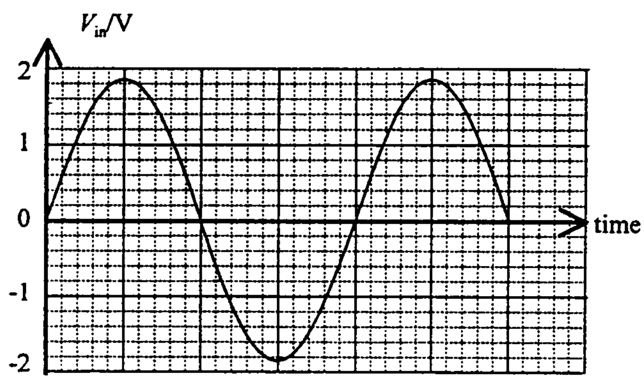
(ii) Gain will increase. — 1 — 1

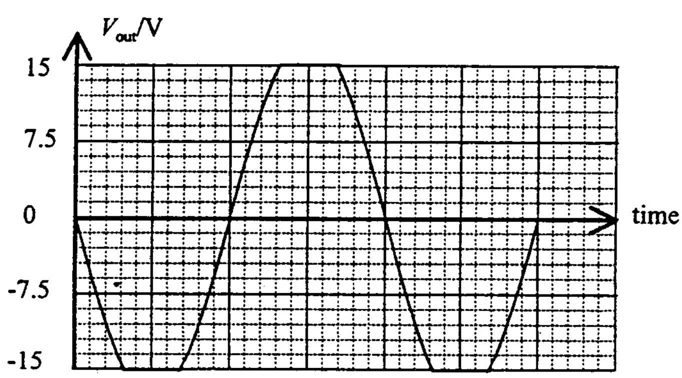
(iii) $V_{out} = -V_{in}\dfrac{R_f}{R_i}$ — 1

Ans. (I) -100 mV — 1 — 2

(II) -15 V (saturation)

(iv)





2 — 2

(b) (i) Gain = $\dfrac{R_f}{R_i} = \dfrac{0.5}{10\times10^{-3}}$ — 1

$R_f = \dfrac{0.5}{10\times10^{-3}}\times 10\ \text{k}\Omega$

$= 500\ \text{k}\Omega$ — 1 — 2

(ii) A step-up transformer differs from an amplifier in a way that it does not have a high impedance input and the op amp draws its power from a separate source. — 1, 1 — 2

				Marks	
1.	(a)	(i)	F_A : friction	1	
			F_B : (normal) reaction	1	2
		(ii)	$F_A = mg$	1	
			max $F_A = 0.4\ F_B$		
			$mg \le 0.4\ m\omega^2 r$	1	
			$\omega^2 \ge \dfrac{g}{0.4r}$ — (*)		
			$\omega^2 \ge \dfrac{10}{(0.4)(2.5)}$		
			$\omega \ge 3.2\ (s^{-1})$	1	3
		(iii)	Unchanged. As the centripetal force is proportional to max F_A as well as the weight,	1	
			the minimum spinning speed (eqn. (*)) does not depend on the mass.	1	2
	(b)		The space station should rotate about an axis through its centre and normal to the plane containing the station with a constant angular speed such that the centripetal acceleration at the	1	
			periphery equals 10 m s^{-2}.	1	
			$a = \omega^2 r$		
			$10 = \omega^2(1.0 \times 10^3)$		
			$\omega = 0.1\ s^{-1}$ (or 0.016 rev s^{-1} or 0.95 rev min^{-1})	1	3
2.	(a)	(i)	T_1, T_2 are tensions in the upper and lower strings respectively.		
			$T_1 = T_2 + mg$	1	1
		(ii)	$(0.6)(0.15) = (0.6)(0.05) + m(10)$	1	
			$m = 0.006$ kg	1	2
	(b)	(i)	0.05 m	1	1
		(ii)	Suppose the bead is displaced downwards by a small distance y, the tension in the upper string would increase by $0.6\,y$ and the tension in the lower string would decrease by $0.6\,y$, resulting in a restoring force of $-1.2\,y$ (upwards)	1	
			$-1.2\,y = m\ddot{y}$		
			$\therefore\ T = 2\pi\sqrt{\dfrac{m}{1.2}}$	1	
			$= 2\pi\sqrt{\dfrac{0.006}{1.2}}$		
			$= 0.44$ s	1	3
	(c)	(i)	$F = ma$		
			$(0.6)(0.05) = 0.006\,a$	1	
			$a = 5$ m s^{-2}	1	2
		(ii)	$mg = ky_0$	1	
			$(0.006)(10) = 0.6\,y_0$		
			$y_0 = 0.1$ m (i.e. the new equilibrium position is at 0.5 m below A)	1	
			The s.h.m. towards the new equilibrium position therefore has an amplitude of 0.05 m		
			$v_{max} = \omega' A'$	1	
			$= \sqrt{\dfrac{k}{m}}\,A'$		
			$= \sqrt{\dfrac{0.6}{0.006}}\,(0.05)$	1	
			$= 0.5$ m s^{-1}	1	5

Marks

3. (a) The current-carrying wire is subjected to alternating vertical forces due to the magnetic field, 1
forced vibration results. 1 2

(b) (i) $f_0 = 25$ Hz 1

$v = f_0\lambda$ (or $v = 75 \times 0.8$)
$= 25\ (2 \times 1.2)$ 1
$= 60\ \text{m s}^{-1}$ 1 3

(ii) As λ unchanged and f increased, $v = f\lambda$ has to be increased in order to restore the pattern. So either increase T by using a heavier mass M or replace the wire by another 1
one of smaller mass per unit length m ($v = \sqrt{\dfrac{T}{m}}$). 1 2

(c) Unchanged. 1
The velocity depends on T and m only. 1 2

4. (a) (i) $B = \dfrac{\mu_0 NI}{\ell}$

$= \dfrac{(4\pi \times 10^{-7})\,(1 \times 10^{3})\,(60 \times 10^{-3})}{0.5}$ 1

$= 1.5 \times 10^{-4}$ T 1

Assumption : solenoid is long since 5.0 cm diameter << 50 cm length 1 3

(ii) $\Phi = NBA$ 1

$= (1 \times 10^{3})\,(1.5 \times 10^{-4})\left(\pi\left(\dfrac{5.0 \times 10^{-2}}{2}\right)^{2}\right)$

$= 2.96 \times 10^{-4}$ Wb 1

Total flux linkage $\Phi = N\phi = LI$ 1
$(1 \times 10^{3})\,(2.96 \times 10^{-7}) = L\,(60 \times 10^{-3})$
$L = 4.9 \times 10^{-3}$ H 1 4

(b) (i) $I = I_0 e^{-\frac{Rt}{L}}$

As $\dfrac{R}{L}$ is constant, for small t, $I \approx I_0\left(1 - \dfrac{Rt}{L}\right)$ is approximately linear 2 2

(ii) $R = \dfrac{V}{I_0}$

$= \dfrac{3\ \text{V}}{60\ \text{mA}}$ 1

$= 50\ \Omega$ 1

slope of the graph $= \dfrac{-R}{L} I_0$ 1

$\dfrac{19 \times 10^{-3}}{30 \times 10^{-6}} = -\dfrac{50}{L}(60 \times 10^{-3})$ (i.e. $\dfrac{R}{L} = 1.06 \times 10^{4}\ \Omega\ \text{H}^{-1}$)

$L = 4.7 \times 10^{-3}$ H 1 4

(iii) Stray inductance / flux leakage / there exists inductance, say, in the connecting wires. 1 1

Marks

5. (a) (i) $I_{max} = \left(\frac{12}{0.8}\right)$ 1

$= 15\text{ A}$ 1 2

(ii) Connect a 'starting' resistance in series with the motor and gradually reducing it as the motor speeds up. 1 1 2

(b) (i) The coil of the motor has inductance, therefore the rise in current will generate an e.m.f. $(-L\frac{dI}{dt})$ which opposes its rise at the initial stage. 1 1

(ii) The back e.m.f. ε_b is proportional to the speed of rotation of the armature. When the motor is first switched on, the back e.m.f. is zero; it increases as the motor speeds up and at the same time the current decreases accordingly. 1

Eventually the rotating speed and thus the back e.m.f. become steady, the current reaches the working value. 1 2

(c) (i) $T = NBAI$

$= (120)(0.5)(0.002)(2)$ 1

$= 0.24\text{ N m}$ 1 2

(ii) (I) $\varepsilon - \varepsilon_b = IR$ 1

$12 - \varepsilon_b = (2)(0.8)$

$\varepsilon_b = 10.4\text{ V}$ 1

(II) Efficiency $= \frac{I\varepsilon - I^2R}{I\varepsilon} \times 100\%$ (or $\frac{\varepsilon_b}{\varepsilon} \times 100\%$) 1

$= \frac{(2)(12) - (2)^2(0.8)}{(2)(12)} \times 100\%$

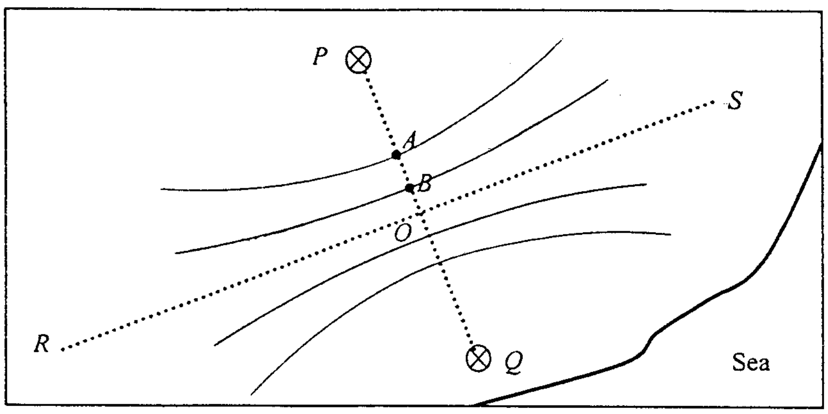
$= 87\%$ 1 4

Marks

6. (a) The signal is maximum/strong along line *ROS* and it decreases gradually with distance from *P* and *Q*. 1
The interference is constructive along line *ROS* whereas alternate constructive and destructive interference occurs along line *POQ*. 1 2

(b)
$$v = f\lambda$$
$$3 \times 10^8 = 60 \times 10^6 \lambda$$
$$\lambda = 5 \text{ m}$$ 1
$$\therefore AB = \frac{\lambda}{2}$$ 1
$$= 2.5 \text{ m}$$ 1 3

(c)



2

2

(d) The superposition of waves at *A* is destructive originally. If the transmission station at *Q* is suspended, the detector only receives the radio signal from *P*, which is larger than the original signal (destructive). 1

The energy distribution of the interference pattern is not uniform, being concentrated in areas with constructive interference. 1 Without station *Q*, the total energy decreases but it distributes more uniformly over the area. 1 3

Marks

7. (a) Longitudinal waves : the vibrations are parallel to the direction of wave propagation. 1
Transverse waves : the vibrations are perpendicular to the direction of wave propagation. 1

(b) (i) $v_P = \dfrac{700\times10^3}{75}$

$= 9.33 \times 10^3$ m s^{-1} 1

$v_S = 5.83 \times 10^3$ m s^{-1} 1 2

(ii) $v_P = \sqrt{\dfrac{E}{\rho}}$

$9.33 \times 10^3 = \sqrt{\dfrac{E}{2.5\times10^3}}$ 1

$E = 2.18\times 10^{11}$ N m^{-2} 1 2

(c) (i) Smallest *S-P* interval, amplitude largest, earliest registered signal 1 1

(ii) *A* : 700 km 1
B : 420 km 1

Position Z 1 3

(d) The natural frequency of bridge *F* is close to the (driving) frequency of the quake waves. 1
Therefore bridge *F* absorbs energy more efficiently and therefore develops a larger amplitude of vibration (resonance). 1 2

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Marks

8. (a) $V = \varepsilon - Ir$ 1

The potential drop across the internal resistance of the battery increases. 1 2

(b)

V/I (Ω)	4.40	8.92	11.9	15.7	20.9
$1/I$ (A^{-1})	1.25	2.00	2.50	3.13	4.00

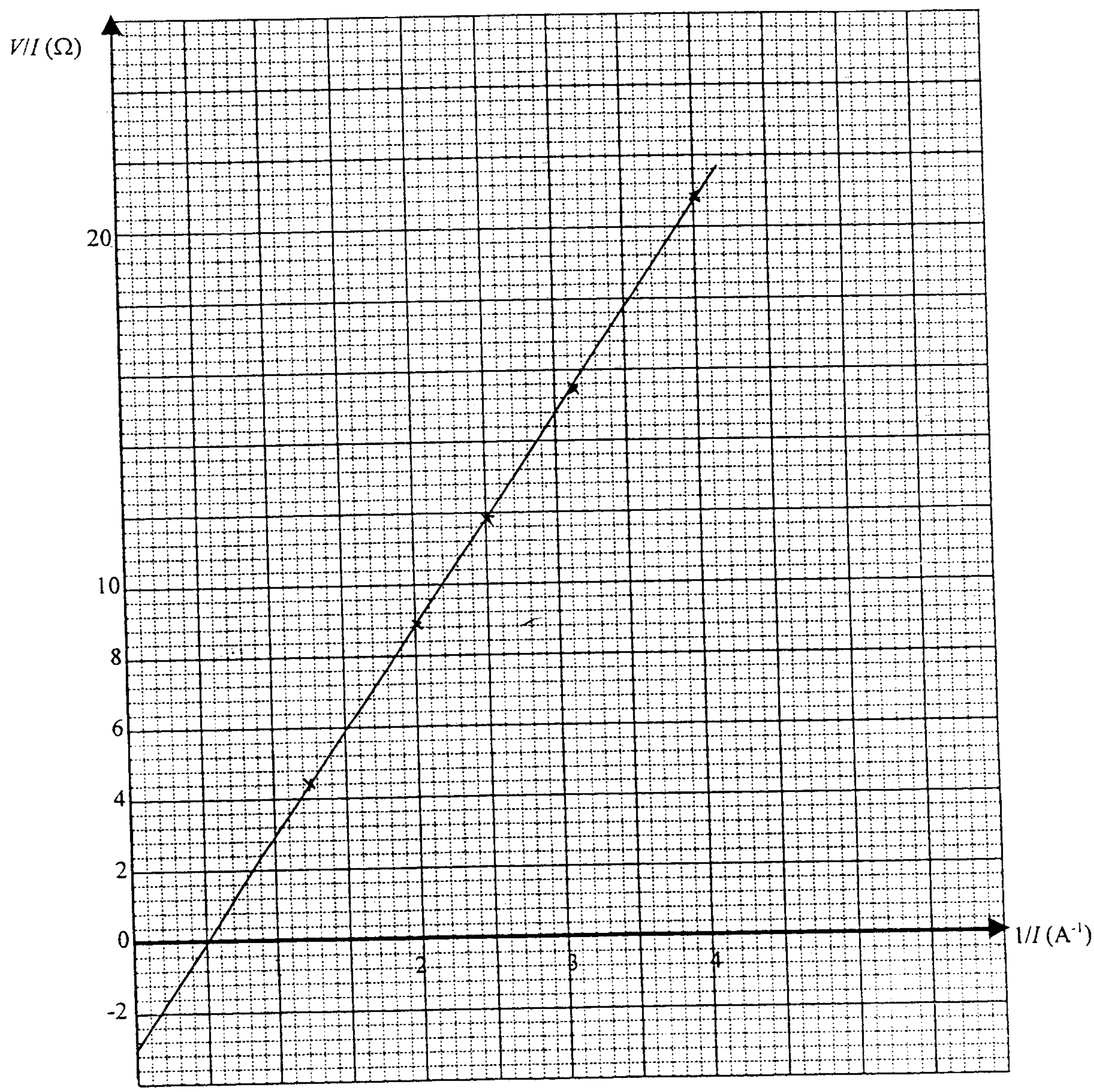
1

According to the graph $\left(\frac{V}{I} \text{ against } \frac{1}{I}\right)$

ε = slope of the graph = $\frac{16.0 - 4.0}{3.2 - 1.2}$ 1

$\varepsilon = 6.0$ V 1

$r = 3.0\ \Omega$ (the magnitude of the y-intercept) 1



Axes labelled with appropriate scales, points correctly plotted 1

Correct graph 1 6

(c) Plot a graph of $P = IV$ against $R = \frac{V}{I}$, which should be a curve whose peak value corresponds 1

to the value of R necessary for the battery to deliver maximum output power. 1 2

Marks

8. (d) resistance of the basic meter $r_0 = \dfrac{1\text{ mV}}{0.01\text{ mA}}$

$= 100\ \Omega$ 1

Conversion to an ammeter : Add a shunt of resistance r_s in parallel with the coil 1

$(0.01\text{ mA} \times 100)(100\ \Omega) = (1\text{A} - 0.01\text{ mA} \times 100)\, r_s$

$r_s = 0.1\ \Omega$ 1

Conversion to a voltmeter : Add a multiplier of resistance r_m in series with the coil 1

$(0.01\text{ mA} \times 100)(100\ \Omega + r_m) = 6$

$r_m = 5.9\text{ k}\Omega$ 1 5

(e) The measured value R_1' is smaller than the actual value. 1

$$R_1' = \left(\frac{1}{R_1} + \frac{1}{R_v}\right)^{-1} \quad (R_v = 6\text{ k}\Omega \text{ from (d)})$$

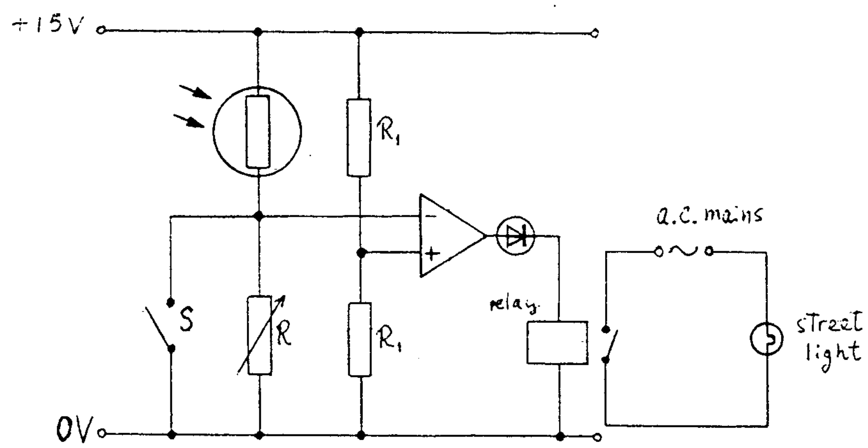
$$= \left(\frac{1}{1000} + \frac{1}{6000}\right)^{-1}$$

$= 860\ \Omega$ 1

Percentage error : $\dfrac{R_1 - R_1'}{R_1} \times 100\% = \dfrac{1000-860}{1000} \times 100\%$

$= 14\%$ 1 3

				Marks	
9.	(a)	(i)	resistance of LDR >> 8 kΩ, almost all the supply voltage is dropped across the LDR.	1	
			A CRO can be used.	1	2
		(ii)	4 kΩ	1	1
	(b)	(i)	As an amplifier, the operational amplifier responds uniformly within its linear region; whereas a comparator behaves as a digital (non-linear) device which compares the potentials at the two inputs. The comparator therefore serves as a switching device.	2	2
		(ii)	In daylight, the resistance of the LDR is small compared to R, $V_- > V_+$, V_o is LOW and the street light is OFF.	1	
		or	In the dark, the resistance of the LDR is large compared to R, $V_- < V_+$, V_o is HIGH and the street light is ON.		
			When switch S is closed, $V_- = 0$ V $< V_+$, the street light is ON	1	



4

6

10. (a)

$$pV = nRT$$
$$(12 \times 10^5)(100 \times 10^{-6}) = n(8.31)(273) \qquad 1$$
$$n = 0.0529 \qquad 1 \qquad 2$$

(b) (i) $W = 0$ J — 1

(ii) $pV = \frac{1}{3}Nm\overline{c^2}$

$$(12 \times 10^5)(100 \times 10^{-6}) = \frac{1}{3}(0.0529)(6.02 \times 10^{23})(4.52 \times 10^{-26})\overline{c^2} \qquad 1$$
$$\sqrt{\overline{c^2}} = 500 \text{ m s}^{-1} \qquad 1 \qquad 3$$

(c) (i)

$$n_1 + n_2 = n_0 \qquad 1$$
$$\frac{pV_1}{RT_1} + \frac{pV_2}{RT_2} = n_0$$
$$\frac{p}{8.31}\left(\frac{100 \times 10^{-6}}{373} + \frac{500 \times 10^{-6}}{273}\right) = 0.0529 \qquad 1$$
$$p = 2.09 \times 10^5 \text{ Pa} \qquad 1$$

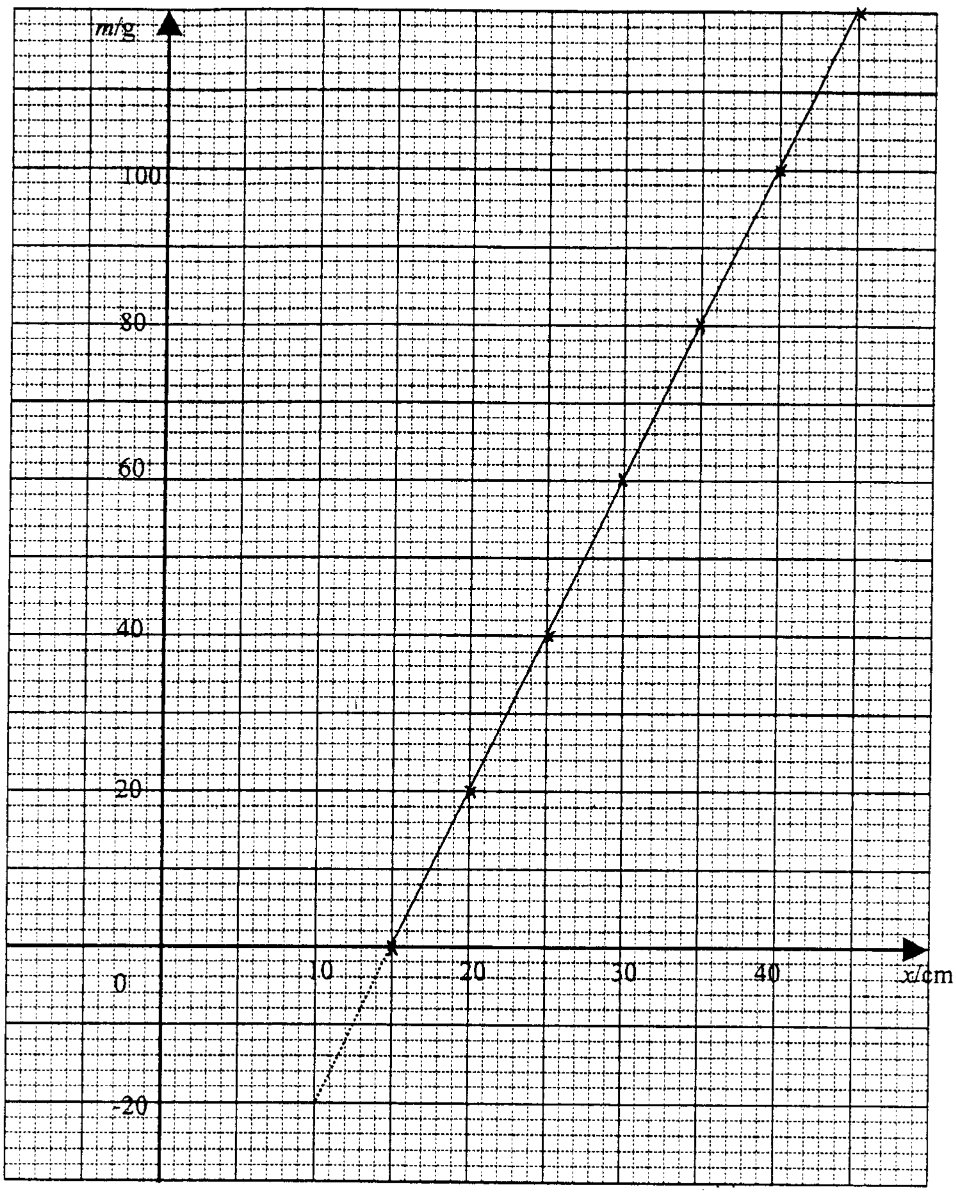
(ii)

$$n_1 = \frac{pV_1}{RT_1} = \frac{(2.09 \times 10^5)(100 \times 10^{-6})}{(8.31)(373)}$$
$$= 0.0068 \text{ mole} \qquad 1$$

Net amount of gas flow from A to B: $\frac{0.0529}{6} - 0.0068 = 0.002$ (mole) — 1 5

Marks

1. (a) (i)



Axes labeled with appropriate scales 1

Points correctly plotted 1

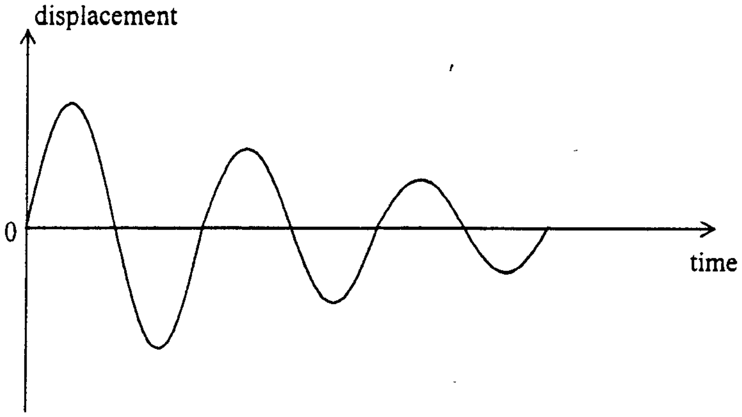
Correct graph 1 3

(ii) Slope × g gives the force constant k 1

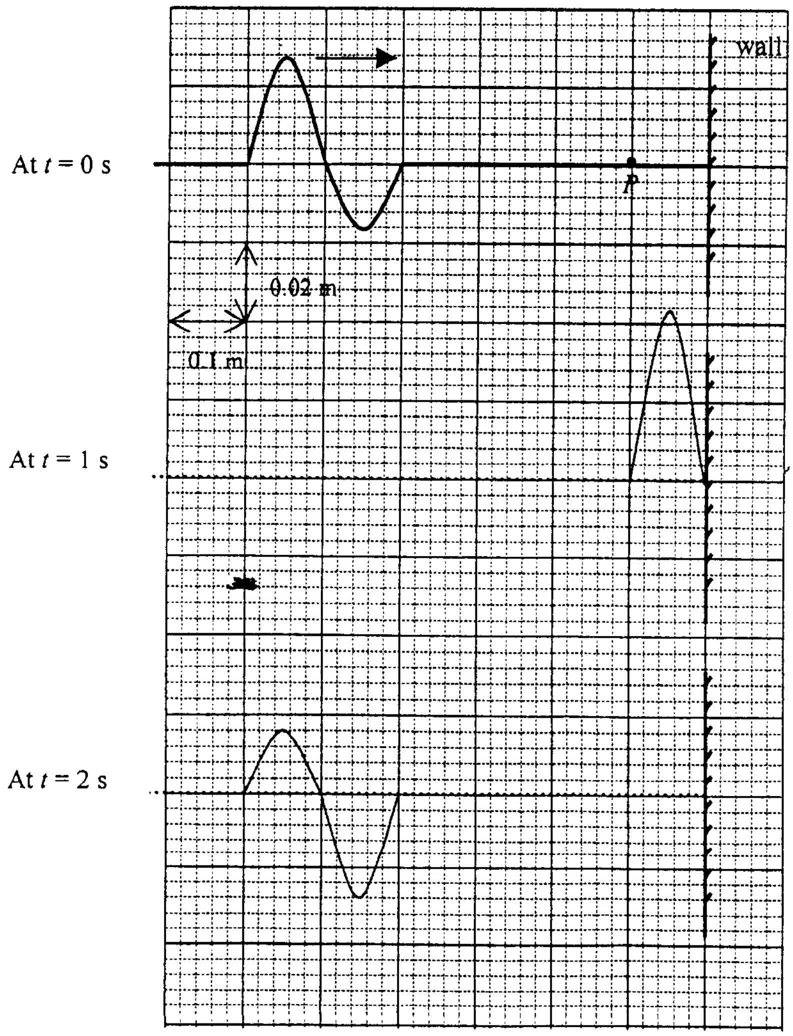
$$\text{Slope} = \frac{(96-16)\times 10^{-3}}{(39-19)\times 10^{-2}}$$ 1

$\therefore k = 4\ \text{N m}^{-1}$ 1

Draw the line x = 10.0 cm, the magnitude of the intercept gives the mass of the pan, m_o = 20 g (or by calculation) 1 4

				Marks	
1.	(b)	(i)	$(m + m_o)\,g = ke$	1	
			$(0.080 + 0.020)\,(10) = 4e$		
			0.0196 $\quad e = 0.25$ m		
			i.e. $x = 0.35$ m or 35 cm (or read from the graph)	1	
			$T = 2\pi\sqrt{\dfrac{m + m_o}{k}}$	1	
			$= 2\pi\sqrt{\dfrac{0.1}{4}} = 0.99$ s	1	4
		(ii)		2	
					2

2. (a) (i)



Marks: 1 (at $t = 1$ s), 2 (at $t = 2$ s); total 3

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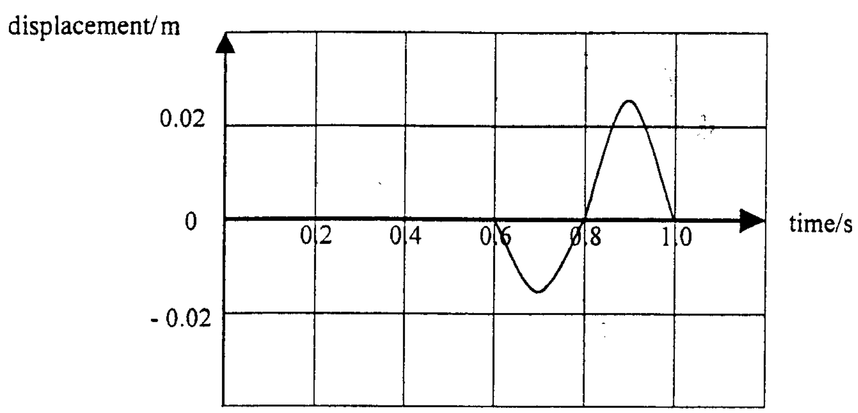
Marks

2. (a) (ii)

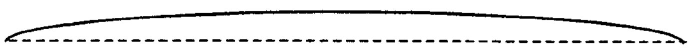


2

2

(b) (i) The mechanical energy (or kinetic energy) of the wire is transferred to the wave energy (or kinetic energy) of the sound in air. 1

Wave on the wire is transverse while the sound heard is longitudinal.
Wave on the wire is stationary while the sound heard is progressive. 1
Wave on the wire has a different speed from that of the sound heard. 1
(accept any other reasonable answers) 1 4

(ii)  1

Lowest possible frequency is 25 Hz. 1 2

(iii) Doubling the weight will double the tension (T), and with the wavelength unchanged

$f \propto v \propto \sqrt{T}$ 1

$f = 100\sqrt{2} = 141$ Hz 1 2

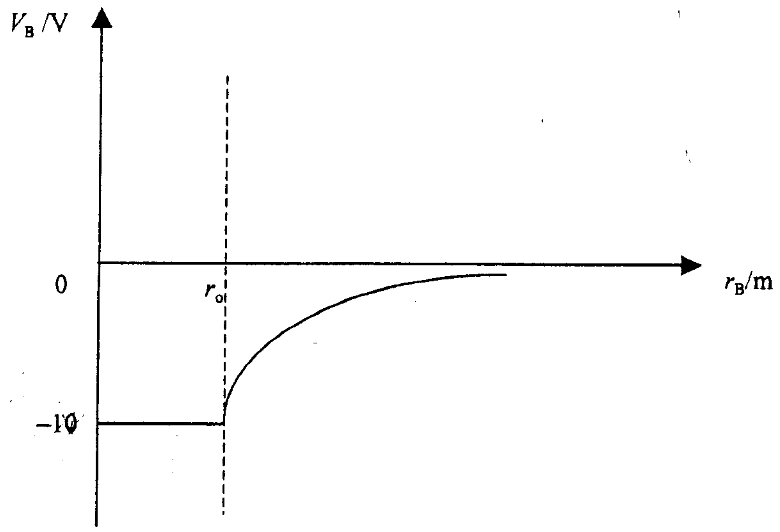
Marks

3. (a) (i) $V_o = \dfrac{-Q}{4\pi\,\varepsilon_o\,r_o}$ 1 1

(ii) $-10 = \dfrac{-2.2\times10^{-11}}{4\pi\,(8.85\times10^{-12})\,r_o}$ 1

$r_o = 2.0\times10^{-2}$ m or 2.0 cm 1 2

(iii)



2

2

(b) (i) $F = \dfrac{Q\,q}{4\pi\,\varepsilon_o\,r^2}$

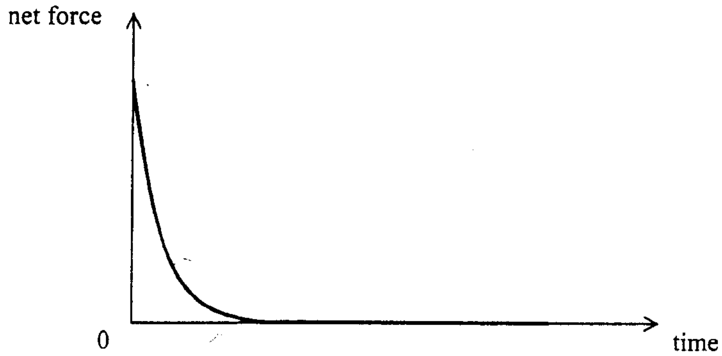
$= \dfrac{2.2\times10^{-11}}{4\pi\,(8.85\times10^{-12})\,(0.05)^2}\,q$ 1

$= 79\,q$ (away from O or to the right) 1 + 1 3

(ii) $\dfrac{1}{2}m\,v^2 \geq \dfrac{Q\,q}{4\pi\,\varepsilon_o\,r_B}$ 1

$v^2 \geq \dfrac{(2.2\times10^{-11})\,(1.76\times10^{11})}{2\,\pi\,(8.85\times10^{-12})\,(0.05)}$

$v \geq 1.2\times10^6$ m s^{-1} 1 2

				Marks	
4.	(a)	3 (atm) (1 mark if only the pressure due to sea water is given)		2	2
	(b)	(i) $\frac{P_1}{T_1} = \frac{P_2}{T_2}$			
		$\frac{18.0}{273+27} = \frac{P_2}{273+21}$		1	
		$P_2 = 17.6$ (atm)		1	2
		(ii) $n_o = n_1 + n_2$		1	
		$P_o V_o = P_1 V_o + P_b V_b$			
		$(17.6)(0.02) = P_1 (0.02) + (3)$		1	
		$P_1 = 16.1$ (atm)		1	3
		(iii) $\frac{17.6 - 16.1}{17.6}$		1	
		$= 0.085$		1	2
	(c)			1	
		At the beginning, the upthrust is greater than the sum of the weight and water resistance (which increases with the speed), the balloon accelerates; however it soon reaches the terminal speed when the upthrust is balanced by the sum of the weight and water resistance.		1 1	3

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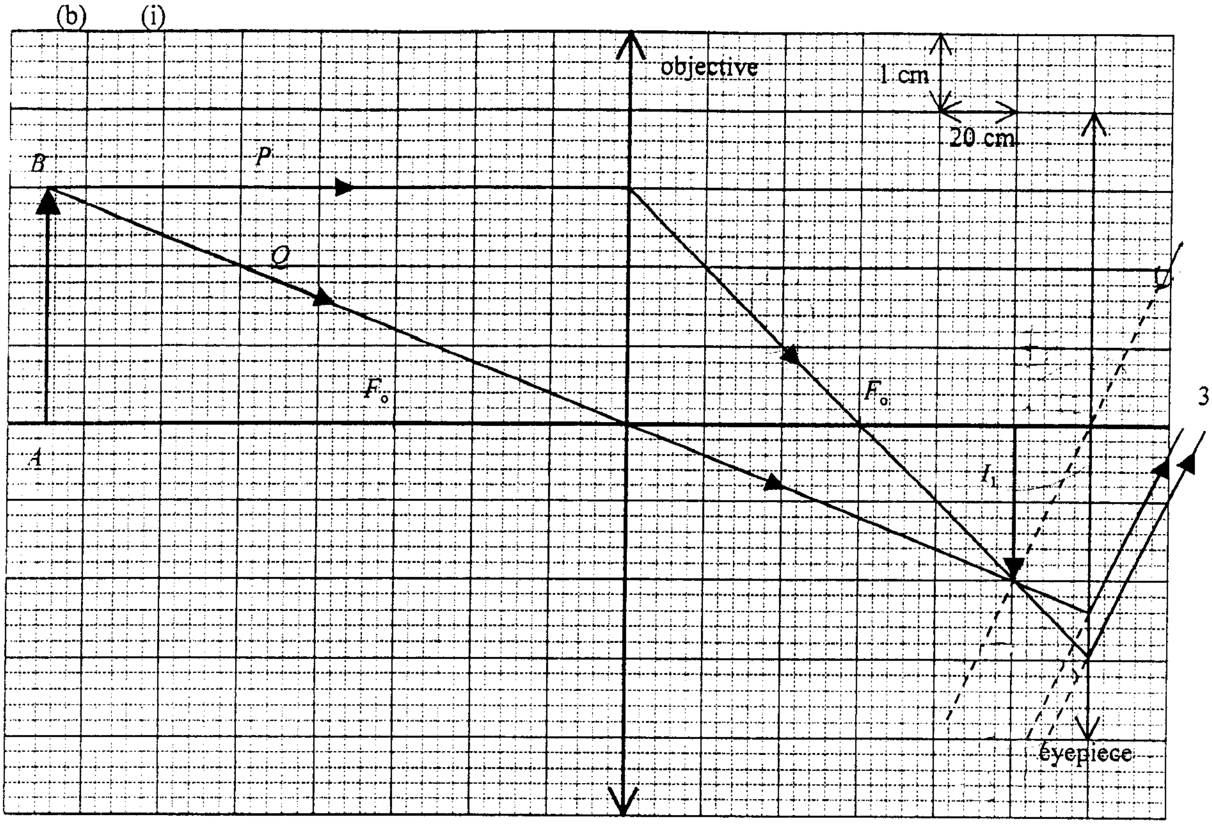
Marks

5. (a) (i) 80 cm — 1 — 1

(ii) 3 — 1 — 1

(b) (i)



3

3

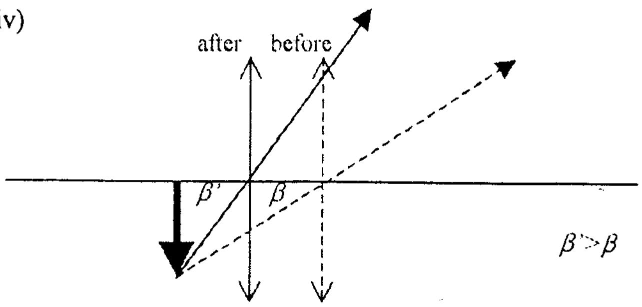
(ii) Height of the first image (I_1) = 2.0 cm — 1

Separation of the objective and the eyepiece = 1.2 m — 1 — 2

(iii) $$\frac{\frac{2\text{cm}}{20\text{cm}}}{\frac{3\text{cm}}{(1.5+1.2)\text{m}}}$$ — 1

$= 9$ — 1 — 2

(iv)



The eyepiece has to be moved towards the first image to produce a final image at *D*. — 1
A larger visual angle results in a larger angular magnification. — 1
The eye will easily get tired as the ciliary muscle contracts to make the eye lens bulged. — 1

3

			Marks	
6. (a) (i)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$		1	
	$g_o \frac{R_E^2}{r^2} = \frac{v^2}{r}$	(i.e. use $g_o = \frac{GM}{R_E^2}$ or $g_1 = g_o \frac{R_E^2}{r^2} = 9.3\ \text{m s}^{-2}$)	1	
	$v^2 = 10 \frac{(6.4\times10^6)^2}{(6.4\times10^6 + 2.4\times10^5)}$			
	$v = 7.9 \times 10^3\ \text{m s}^{-1}$	(range: $7.8 \times 10^3\ \text{m s}^{-1} \sim 7.9 \times 10^3\ \text{m s}^{-1}$)	1A	3
(ii)	$m g_1 = m g_o (\frac{R_E}{r})^2$	(or $\frac{mv^2}{r} = \frac{(60)(7.9\times10^3)^2}{(6.4\times10^6 + 2.4\times10^5)}$)	1	
	$= (60)(10)(\frac{6.4\times10^6}{6.64\times10^6})^2$			
	$= 5.6 \times 10^2\ \text{N}$	(range: $5.5 \times 10^2\ \text{N} \sim 5.7 \times 10^2\ \text{N}$)	1A	2

(b) (i) The weight of the astronaut is all used for centripetal acceleration, therefore the astronaut is no longer being pulled to the floor. (no reaction or 'free falling' not accepted.) — 1 — 1

(ii) Since some momentum of A is transferred to B by so doing, the velocity of B can be reversed such that $V_B \geq V_A$. (Accept any other reasonable answers like the direction of A is reversed) — 1, 1 — 2

(iii) $u_A = 1\ \text{m s}^{-1}$, $u_B = -1\ \text{m s}^{-1}$

$v_A = v_B = v$, v_1 = velocity of toolbox flying towards B

By the conservation of linear momentum,

$(60 + 30)(1) + (60)(-1) = (60 + 60 + 30)v$ ---------- (*) (A, box and B) — 1

$v = 0.2\ \text{m s}^{-1}$ — 1

Consider the toolbox and astronaut B, and by the conservation of linear momentum,

$30 v_1 + (60)(-1) = (30 + 60)(0.2)$ — 1 — 4

$v_1 = 2.6\ \text{m s}^{-1}$ — 1A

<u>or</u> using $(60 + 30)(1) = 60v + 30v_1$ ---------- (1) (A and box)

$30v_1 + (60)(-1) = (30 + 60)v$ ---------- (2) (box and B)

with A, B and box move with common velocity v

(There are altogether 3 momentum conservation equations, for any TWO correct equations award 1 mark for each equation **with correct numerical substitution**. 1 mark for considering the common velocity v. 1 mark for the correct answer of v_1)

(iv) $W = \frac{1}{2}(30)(2.6^2 - 1^2)$ (Accept word equations such as $W = KE_f - KE_i$) — 1 — 2

$= 86\ \text{J}$ — 1A

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Marks

7. (a) (i) $(3 \times 10^8)(500) = 1.5 \times 10^{11}$ m — 1A — 1

(ii) $\dfrac{G M_s m}{r^2} = m\left(\dfrac{2\pi}{T}\right)^2 r$ (1 mark for employing $\omega = \dfrac{2\pi}{T}$ in a correct equation) — 1

$$M_s = \left(\frac{2\pi}{T}\right)^2 \frac{r^3}{G}$$

$$= \left(\frac{2\pi}{3.2\times10^7}\right)^2 \frac{(1.5\times10^{11})^3}{6.7\times10^{-11}}$$ — 1

$$= 2 \times 10^{30}\text{ kg}$$ — 1A — 3

(iii) $(1.35 \times 10^3)(4\pi \times (1.5 \times 10^{11})^2)$

$= 3.8 \times 10^{26}$ W — 1

1A — 2

(b) (i) The temperature in the sun's core is so high that the protons have sufficient kinetic energy to overcome the strong coulomb/electrostatic repulsion between them. — 1, 1 — 2

(ii) $\Delta m = (4)(1.00728) - 4.00150$ — 1

$= 0.02762$ u

$\Delta E = (\Delta m) c^2 = (0.02762)(1.66 \times 10^{-27})(3 \times 10^8)^2$ — 1

$= 4.15 \times 10^{-12}$ J

accept $\Delta E = \Delta m \times 931$ MeV $= 0.02762 \times 931$ MeV $= 25.7$ MeV Energy released per kg of protons $= \dfrac{25.7}{(4)(1.00728)(1.66\times10^{-27})}$ $= 3.84 \times 10^{27}$ MeV $= 6.2 \times 10^{14}$ J

Energy released per kg of protons $= \dfrac{4.15\times10^{-12}}{(4)(1.00728)(1.66\times10^{-27})}$

$= 6.2 \times 10^{14}$ J (or 3.8×10^{27} MeV)

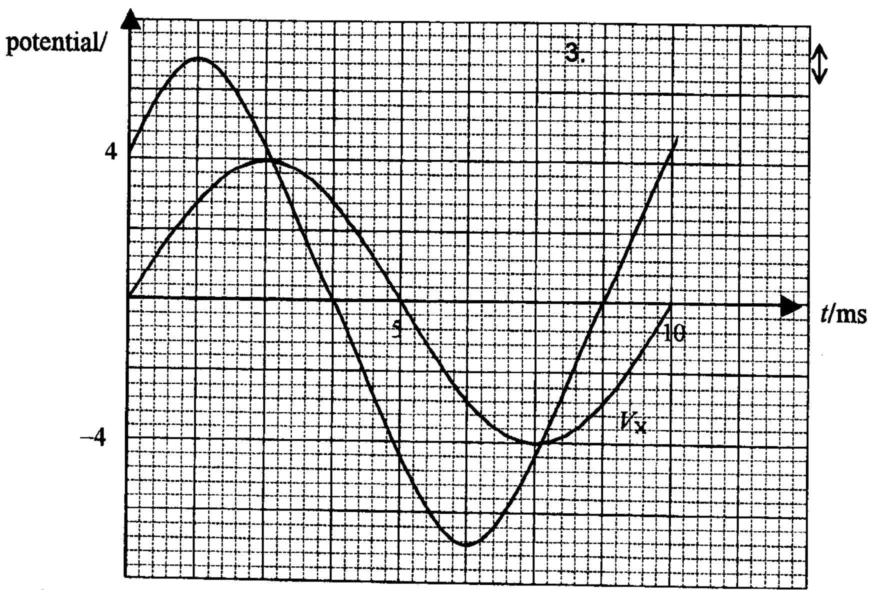
1A — 3

(iii) $\dfrac{(2\times10^{30})(6.2\times10^{14})}{3.8\times10^{26}} \cdot \dfrac{1}{3.2\times10^7}$ — 1

$= 1 \times 10^{11}$ (years) — 1A — 2

				Marks	
8.	(a)	(i)	*AB* is not perpendicular to *AD*	1	
			i.e. the phase angle between the inductor and the resistor is less than 90°		1
		(ii)	7.1 V (accept $5\sqrt{2}$ V)	1A	1
		(iii)	$\dfrac{4}{50\times10^{-3}}$	1	
			$= 80\ \Omega$	1A	2
		(iv)	$\dfrac{1}{4}\times 80$ (or $\dfrac{1}{5\times10^{-3}}$)	1	
			$= 20\,\Omega$	1A	
			$5 = (50\times10^{-3})(2\pi\times100)L$	1	
			$L = 160$ mH	1A	4
		(v)	Phase angle between *AC* and *AD*, $\theta = 45°$		
			Power factor $= \cos\theta = 0.7$	1A	
			Power factor $= \dfrac{\text{actual power dissipated}}{\text{apparent power delivered}}$	1	
			When frequency increases, power factor decreases.	1	3

(b)

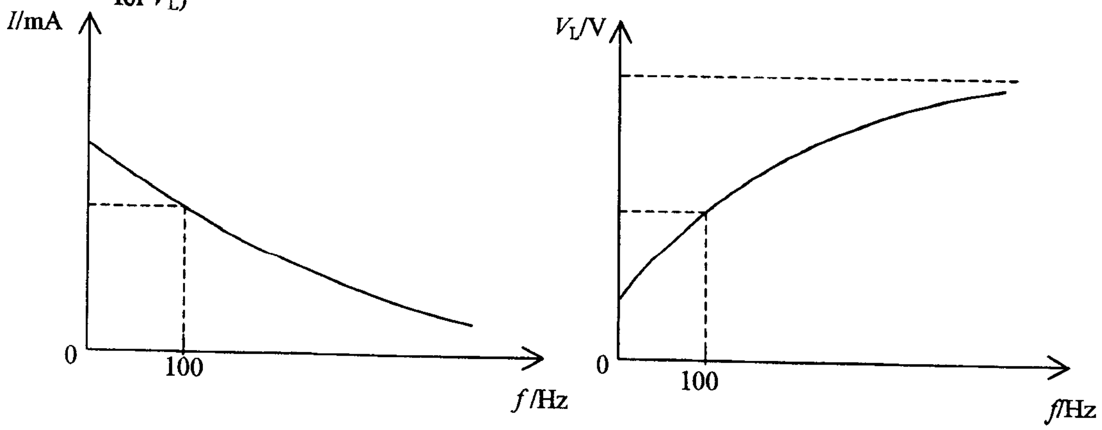


Within 3 div

2

2

(c) (In each figure, 1 mark is given for labelling a correct value: 50 or 71 for *I*, 1.4, 5.1 or 7.1 for V_L)



2+2

4

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Marks

9. (a) (i) At $r = r_o$, $F = 0 \Rightarrow r_o = \dfrac{b}{a}$ (i.e. $F = \dfrac{-a}{r_o^2} + \dfrac{b}{r_o^3} = 0$) 1

$$= \frac{2\times10^{-40}}{2\times10^{-30}}$$

$$= 10^{-10}\text{ m}$$ 1A 2

(ii) The term $-\dfrac{a}{r^2}$ represents the attractive force and it dominates when $r > r_o$. 1

The term $\dfrac{b}{r^3}$ represents the repulsive force and it dominates when $r < r_o$. 1

The magnitudes of both terms decrease with r, but with the repulsive force term decreases much faster. 2

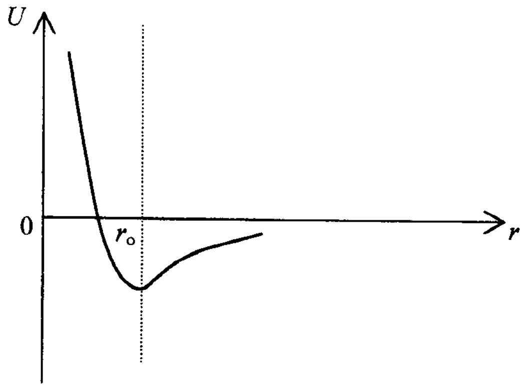
(b) (i) $U = -\int F \cdot dr$ 1

$= -\int_\infty^r \left(-\dfrac{a}{r^2} + \dfrac{b}{r^3}\right) dr$ 1

$= -\dfrac{a}{r} + \dfrac{b}{2r^2}$

or $F = -\dfrac{dU}{dr} = -\dfrac{d}{dr}\left(-\dfrac{a}{r} + \dfrac{b}{2r^2}\right) = -\dfrac{a}{r^2} + \dfrac{b}{r^3}$ (1 mark only unless the constant for U is shown to be zero) 2

(ii)



2

2

(iii) $U_o = \dfrac{a}{r_o} - \dfrac{b}{2r_o^2}$ (substitute $r = r_o$ into U)

$= 2 \times 10^{-20} - 10^{-20}$ 1

$= 10^{-20}$ J 1A 2

(c) (i) The graph of F against r near r_o is approximately linear with negative slope, indicating the force is restoring and is proportional to the displacement of Q from $r = r_o$. 1 1 2

(ii) 'spring constant' $k = -\dfrac{dF}{dr}$ (at $r = r_o$) (or $k = |$ slope of F - r graph at $r = r_o|$) 1

$= \dfrac{a^4}{b^3}$ 1

$= 2\text{ N m}^{-1}$

(Note: $U = \dfrac{1}{2}kr^2$ is not correct although the value for k is the same)

$f = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$ 1

$= \dfrac{1}{2\pi}\sqrt{\dfrac{2}{3.2\times10^{-27}}}$

$= 4 \times 10^{12}$ Hz (range: 3.9×10^{12} Hz ~ 4.1×10^{12} Hz) 1A 4

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