SOLUTIONS

Q1

(a)(i) Potential at P = $2\left(\frac{20}{30}\right)$ volts 1 potential divider 1
Potential at Q = $2\left(\frac{200}{300}\right)$ volts 1 " " 1
PD. across PQ = 0 1 (1 mark for quoting result only) 1

(ii) Replace 100Ω by variable resistance R. 1
Put a galvo. across PQ
Vary R until zero current tho' galvo then 1
$\frac{X}{R} = \frac{20}{200}$
$X = \frac{R}{10}$ 1

Alternative methods acceptable

TOTAL 6

(b)(i) no. of photons/sec $n = \frac{\text{power } (P)}{\text{Energy of one photon } (hf)} = \frac{P}{hf}$ 1
'Incident' Force = rate of change of momentum
$= n\left(\frac{hf}{c}\right)$ 1
$= \left(\frac{P}{hf}\right)\left(\frac{hf}{c}\right) = \frac{P}{c}$ 1
$= \frac{100 \times 10^{-3}}{3 \times 10^{8}}$
$= 3{\cdot}33 \times 10^{-10}$ N 1

4

(ii) As only 95% reflected
'Reflected' Force = $\left(\frac{95}{100}\right)$ $3{\cdot}33 \times 10^{-10}$ 1
Total force = total rate of change of momentum
$= (3{\cdot}33 + 3{\cdot}16)\, 10^{-10}$ N
$= 6{\cdot}49 \times 10^{-10}$ N 1

2

(iii) Good vacuum
Black surface increases in temperature creates increase in velocity of molecules 'reflected' from it, thus greater force than on shiny metal. Hence anti-clockwise rotation 2

Ultra high vacuum, no molecular forces, reflecting surface has greater force so small clockwise rotation 2

TOTAL 10

(i) g increased to $g_1 = \left(g + \frac{EQ}{m}\right)$ 1

$$T_1 = 2\pi\sqrt{\frac{\ell}{g_1}}$$ 1

(ii) New effective g, g_2, produced by resultant of mg and EQ i.e. $g_2 = \sqrt{g^2 + (EQ/m)^2}$. (The equilibrium position is at an angle of $\tan^{-1}(EQ/mg)$). The period

$$T_2 = 2\pi\sqrt{\frac{\ell}{g_2}}. \quad \text{where } g_2^2 = g^2 + (EQ/m)^2$$ 2

(iii) New effective g, g_3, given by $g_3 = \sqrt{g^2 + (EQ/m)^2}$.
However if bob oscillating along x-axis, with no component velocity perpendicular to x-axis, the force for oscillations along x-axis will be ~~the~~ same as for $E = 0$

$$T_3 = 2\pi\sqrt{\frac{\ell}{g}}.$$ 2

TOTAL 6

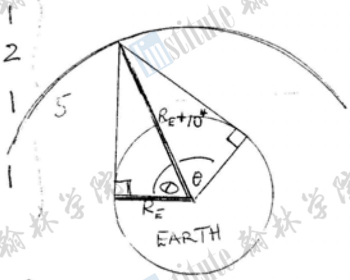
(d) Max. separation $= 2\theta$ 1

$= 2\cos^{-1}\left(\frac{R_E}{R_E + 10^4}\right)$ 2

$= 2\cos^{-1}\left(\frac{6\cdot38\times10^6}{6\cdot38\times10^6 + 10^4}\right)$ 1

$= 2\cos^{-1}\left(\frac{638}{639}\right)$

$= 6\cdot4^\circ$ 1



Reflections from the surface of the Earth
or Variations in direction of reflecting layer

TOTAL

3

(e) (i) $[a] = [pV^2] = [\text{Pa m}^{-6}]$ or $[MLT^{-2}L^{-2}L^6] = [ML^5T^{-2}]$
$= \text{kg m}^5\text{s}^{-2}$
accept any of these results with or without mol^{-1} — 1

$[b] = [V] = [L^3]$ or m^{+3}
accept any result of these two with or without mol^{-1} — 1

(iii) $n = 2.00$, $T = 200\text{K}$, $V = 6.00 \times 10^{-3}\ m^3$

$$p = \frac{nRT}{V-nb} - \frac{n^2a}{V^2} = \frac{(2.00)(8.31)(200)}{6.00\times10^{-3} - 2.00\,(3.9\times10^{-5})} - \frac{(2.00)^2(0.14)}{(6.00)^2(10^{-6})} \quad 2$$

$$= \frac{33.26\times10^2}{(6.00 - 7.8)10^{-5}} - \frac{0.56}{36\times10^{-6}}$$

$$= (0.5616 - 0.0155)\,10^6$$

$$= \underline{0.546 \times 10^6\ \text{Pa}} \quad 1$$

2 marks for generalization with either "n^2" or 'n' missing. One mark for both absent.

(iv) $pV = nRT$

$$p = \frac{nRT}{V} = \frac{(2.00)(8.31)(200)}{600\times10^{-5}} = \underline{0.554\times10^6\ \text{Pa}} \quad 1$$

(v) b is the volume occupied by the molecules — 1
a/V^2 is reduction in pressure due to molecular attractions — 1

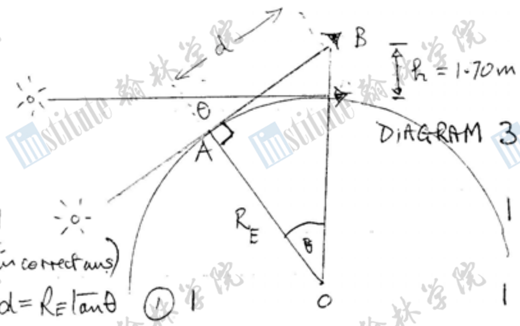
TOTAL 8

f) (i) $X = aY^b$
$\ln X = \ln a + b\ln Y$ — 1
Plot $\ln(X)$ against $\ln(Y)$ — 1
gradient b — 1
intercept $\ln(a)$, hence a obtained — 1

(ii) $X^3 = (cY+d)^2$
$X^{3/2} = cY + d$ — 1
Plot $X^{3/2}$ against Y — 1
Gradient c — 1
intercept d. — 1

TOTAL 8

4



i) In right angle triangle OAB
let $AB = d$

$$d^2 + R_E^2 = (R_E + h)^2$$

$$d^2 = 2R_E h + h^2 \qquad 1$$

As $R_E \gg h$, (student can retain h^2 and obtain correct ans)

$$d^2 = 2R_E h \quad \text{AND} \quad d = R_E \tan\theta \quad (1) \qquad 1$$

As Earth rotates through $360°$ in 24 hour

$$\frac{\theta}{360} = \frac{11{\cdot}1}{24 \times 60 \times 60} \qquad 2$$

$$\theta = \frac{360\,(11{\cdot}1)}{24 \times 60 \times 60} = 0{\cdot}04625° \quad (2) \qquad 1$$

3

From (1) $\qquad R_E = \dfrac{2h}{\tan^2\theta} \qquad 1$

As $h = 1{\cdot}70$ m and $\theta = 0{\cdot}04625°$

$$R_E = \frac{2(1{\cdot}70)}{\tan^2(0{\cdot}04625)} = \underline{5{\cdot}22 \times 10^6 \text{ m}} \qquad 1$$

2

2
1
1
1
1
2
1
1

TOTAL 10

ii) The strength of the tides depend on the gradient of the gravitational force field. This is strongest at the ports along the line joining the centres of the Earth and Moon. Consequently there are two high tides each day at every port.

This gradient is smallest at ports that subtend an angle of 90° at the centre of the Earth with the line joining the centres of the Earth and Moon; low tides

Consequently in the diagram, Q and R have high tides and P has a neap/or low tide.

Any reasonable explanation plus correct conclusions acceptable.

4

2

TOTAL 6

(i) Energy lost = 200 MeV

$$\text{Lost mass } \Delta m = \frac{(200)\,10^6\,(1.60\times10^{-19})}{(3.00\times10^8)^2}\ \text{kg} \quad (E=mc^2)$$

$$\text{Lost mass } \Delta m = 3.56\times10^{-28}\ \text{kg}.$$

Decrease in mass, $\Delta m = 3.56\times10^{-28}$ kg — 2

The speed v of the two masses is given by

$$m = m_0\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

$$m^2\left(1-\frac{v^2}{c^2}\right) = m_0^2 \quad 1$$

$$m^2 - m_0^2 = m^2\left(\frac{v^2}{c^2}\right) \quad 1$$

$$(m-m_0)(m+m_0) = m^2\left(\frac{v^2}{c^2}\right) \quad 1$$

As $m \simeq m_0$ and $\Delta m = m - m_0$ we can write, approximately,

$$\Delta m\,(2m_0) = m_0^2\left(\frac{v^2}{c^2}\right)$$

$$2\,\Delta m = m_0\left(\frac{v^2}{c^2}\right) \quad 1$$

$$v = c\sqrt{\frac{2\Delta m}{m_0}} \quad 1$$

$$= (3.00\times10^8)\sqrt{\frac{2(200\times10^6)}{2.21\times10^5\times10^6}}$$ Using MeV masses

$$= 1.41\times10^5\ \text{ms}^{-1} \quad 1$$

TOTAL 8

(j) (i) $v^2 = 2as$

$$a = v^2/2s = \frac{(12)^2}{2(40)} = 1.80\ \text{ms}^{-1}$$ 2

(ii) Coff. $\mu = \dfrac{\text{Force}}{\text{Normal Reaction}} = \dfrac{ma}{mg} = \dfrac{1.80}{9.81}$

$= 0.183$ — 2

(iii) Loss in KE $= \frac{1}{2}(60)(12)^2 = 4.32\times10^3$ J — 2

(iv) Mass of ice melted $= \dfrac{4.32\times10^3}{330\times10^3}$ kg

$= 1.31\times10^{-2}$ kg — 2

TOTAL 8

Q1 c

(k) (i) This is the region illuminated by the Sun. The dark region faces away from the Sun 1

(ii) The dark region of the Moon is illuminated by light reflected by the Earth. So it is not completely black.

(iii) Assume the Earth and Moon are perfect reflectors of light and an equal distance from the Sun.
Intensity of light hitting the Earth and Moon

$$I \propto \frac{1}{R_{ES}^2}$$

where K is a constant NOT REQUIRED)

Of the light hitting the Earth only a fraction

$$f = \left(\frac{R_E^2}{R_{EM}^2}\right)$$

Any derivation that depends on $(R_E/R_{EM})^2$ acceptable

will reach the moon. This assumes energy radiated and received isotropically in all directions, an order of magnitude calculation. Some students might include a factor of K of order 1 to account for the non-ideal conditions; $f = K\left(\frac{R_E}{R_{EM}}\right)^2$

Now $$f = \left(\frac{6038 \times 10^6}{3{\cdot}83 \times 10^8}\right)^2$$

$$= 2{\cdot}8 \times 10^{-4}$$

Any correct order of mag. calculation acceptable

The crescent is $\frac{1}{f}$ brighter, a factor of $3{\cdot}6 \times 10^4$, than the surrounding area of the Moon.

TOTAL

Q1 7

(l) (i) Mass of air hitting sail per sec $= \alpha A v$ where α is a const

Rate of change of momentum of air hitting sail assuming velocity of air reduced by impact with air

$= (\alpha A v)(\beta v)$ where β a const

$= k v^2$ where $k = \alpha A \beta$ 2

(ii) Force $= k v^2$

$[MLT^{-2}] = [k]\,[L^2T^{-2}]$

$[k] = [MLT^{-2}L^{-2}T^{+2}]$

$[k] = [ML^{-1}]$ 2

(iii) Dimensional analysis

ALTERNATIVELY: a direct analysis acceptable 3

Assume

$k = c\rho^p A^q$.

where c, p and q constants

$[k] = [ML^{-1}] = [(ML^{-3})^p]\,[L^{2q}]$

Equating power of M

$1 = p$

Thus k proportional to ρ. 3

(iv) The resistive dissipative forces of the water increase more rapidly with speed than the wind force. 1

8

(m) The region of the wheel at the ground is instantaneously at rest and consequently clearly photographed. 1

The top of the wheel, travelling along the road at speed v, is moving at $2v$. Intermediate regions of the wheel have intermediate speeds between 0 and $2v$ — the higher the speed the more blurred the photographic image 1

2

TOTAL 4

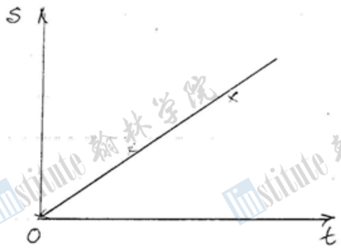
8

iii) (i) The lightening travels at speed $c = 3\times10^8\ ms^{-1}$
Thunder travels at speed of sound $334\ ms^{-1}$
So lightening arrives almost instantaneously 1

(ii)

t/s	Δt/s	Distance ($\Delta t \times V_{sound}$)/m	Dist. Storm travelled s
0	32.5	10,855	0
49.1	18.0	6,012	(10855 − 6012) = 4843.
82.7	8.0	2,672	(10855 − 2672) = 8183.

2



2

Gradient of s − t graph gives $u = (98\cdot8 \pm \cdot8)\ ms^{-1}$ 1

6

Calculation producing two estimates of u, and average taken, equally acceptable — 6 marks.
(One correct estimate of u — only 4 marks)

SOLUTION | Mark 9

Q2 (a) (i) $h = \frac{1}{2}gt^2 = \frac{1}{2}(9.81)(10.2)^2 = 510$ m 2

(ii) $t_2 = \frac{510}{334} = 1.53$ s 2

(iii) $\Delta h = t_2 *$ final velocity of stone $= 1.53\,(10.2g) = 153$m

Accuracy: (510 ± 153)m ~ 30% accuracy 2

Any other reasonable estimate from $(15 \to 40)\%$ acceptable

TOTAL 6

(b)

$t_1 + t_2 = 10.2$ (1) (total time) 1

$h = \frac{1}{2}gt_1^2$ (2) (stone) 1

$h = 334\,t_2$ (3) (sound wave) 1

From (2) & (3)

$334\,t_2 = \frac{1}{2}gt_1^2$ (4)

$t_2 = \frac{9.81}{668}t_1^2$ (5) 1

Substituting (5) into (1)

$t_1 + \frac{9.81}{668}t_1^2 = 10.2$

$t_1^2 + \frac{668}{9.81}t_1 - \frac{10.2(668)}{9.81} = 0$

$t_1 = \frac{1}{2}\left[-\frac{668}{9.81} \pm \sqrt{\left(\frac{668}{9.81}\right)^2 + 4\left(\frac{10.2(668)}{9.81}\right)}\right]$ 2

Only +ve times acceptable,

$t_1 = 34.046\left[-1 + \sqrt{1.59917}\right]$

$t_1 = 9.01 \pm 0.01$ s 1

$t_2 = 1.19 \pm 0.01$ s 1

Sub^n into (3)

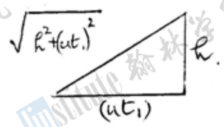
$h = 334\,t_2 = 334\,(1.19) = 397 \pm 3$ m 1

TOTAL 10

c) $t_1 + t_2 = 10.2$ $\frac{1}{2}$

$h = \frac{1}{2}gt_1^2$ $\frac{1}{2}$

$h^2 + (ut_1)^2 = (334\,t_2)^2$ 1 2



d) $t_1 + t_2 = 10.2$ $\frac{1}{2}$

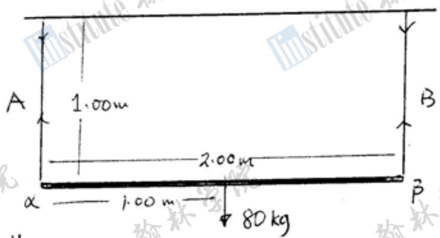
$h = -ut_1 + \frac{1}{2}gt_1^2$ 1 2

$h = 334\,t_2$ $\frac{1}{2}$

SOLUTION

10/
3

a)



i) Resolving vertically

$$T_A + T_B = 80g = 784.8\ N$$

By symmetry $\quad T_A = T_B = 392\ N$

[Alternatively by moments about β. $\quad 2.00\,T_A = 1.00\,(80g)$

$$T_A = 40g = 392N$$

Similarly $\quad T_B = 392N$] $\quad$ 2

(ii) For A, extension x_A given by

$$Y_A = \frac{\text{stress}}{\text{strain}} = \frac{\dfrac{392}{\pi(0.80)^2 10^{-6}}}{\left(\dfrac{x_A}{1.00}\right)} = 12.4\times10^{10}$$

$$\underline{x_A = 1.57\ \text{mm}}$$

(iii) For B, extension x_B given by

$$Y_B = \frac{\dfrac{392}{\pi(0.50)^2 10^{-6}}}{\left(\dfrac{x_B}{1.00}\right)} = 9.00\times10^{10}$$

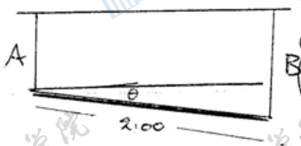
$$\underline{x_B = 5.55\ \text{mm}}$$ $\quad$ 3

iv) $\quad \theta \simeq \sin\theta = \dfrac{x_B - x_A}{2.00}$

$$= \frac{3.98\times10^{-3}}{2.00} \text{ radians}$$

$$= 1.99\times10^{-3} \text{ radians}$$

or $\quad = 0.114^{\circ}$



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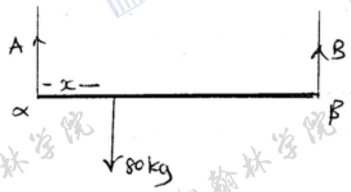
b) (i) Assuming rod horizontal

$$T_A + T_B = 180 \qquad 1$$

Moments about β

$$(2.00 - x)\,80g = 2.00\,T_A$$

$$T_A = \frac{(2.00 - x)\,80g}{2.00} \qquad 1$$



$$Y_A = \frac{\text{stress}}{\text{strain}} = \frac{\dfrac{T_A}{\pi(0.50)^2 10^{-6}}}{x_A} = 12.4\times10^{10} \qquad 1$$

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$$x_A = \frac{T_A}{12.4 \times 10^{10} \pi (0.80)^2 10^{-6}}$$

Substituting for T_A

$$x_A = \frac{(2.00 - x)\,40g}{12.4 \times 10^{10} \pi (0.80)^2 10^{-6}} \qquad 1 \qquad 4$$

(ii) Similarly for B $\quad x_B = \dfrac{T_B}{9.00 \times 10^{10} \pi (0.5)^2 10^{-6}} \qquad 2$

Moments about α

$$80gx = T_B (2.00)$$
$$T_B = 40gx \qquad 1$$

Thus

$$x_B = \frac{40gx}{9.00 \times 10^{10} \pi (0.5)^2 10^{-6}} \qquad 1 \qquad 4$$

(iii) If $x_A = x_B$

$$\frac{(2-x)\,40g}{12.4\ (0.80)^2} = \frac{40gx}{9.00\ (0.50)^2} \qquad 2$$

$$(2-x)\,40g = 3.527\,(40gx)$$
$$80g = 40gx\,(4.527)$$
$$x = \frac{2}{4.527} \qquad 1$$

$$\underline{x = 0.441\ \text{m}} \qquad 1 \qquad 4$$

12

12/

SOLUTION

Q4 (a)

(i) Power = Resistive Force × Speed when travelling at $30\,ms^{-1}$

Resistive force $R = \frac{1350}{30} = 45N$ 2

(ii) Flexing of tyre at low pressure causes loss of energy by heating etc (compare motion with a flat tyre with inflated type.) 1

(iii) $I = 1350\left(\frac{1}{0.97}\right)\frac{100}{25} = 5.56\ kW$ 2

(iv) Less weight
Better aerodynamics
etc } any suitable reason 1

(v) Straight track, flat track
sufficient friction for rolling wheels without slipping etc.
Race when Sun overhead } any two suitable reasons 2

TOTAL 8

(b) (i) $a = \frac{1}{m}\left(F_1 - kv_1^2\right)$ 2

(ii) At $30\,ms^{-1}$, $R = kv^2$

$45 = k(30)^2$

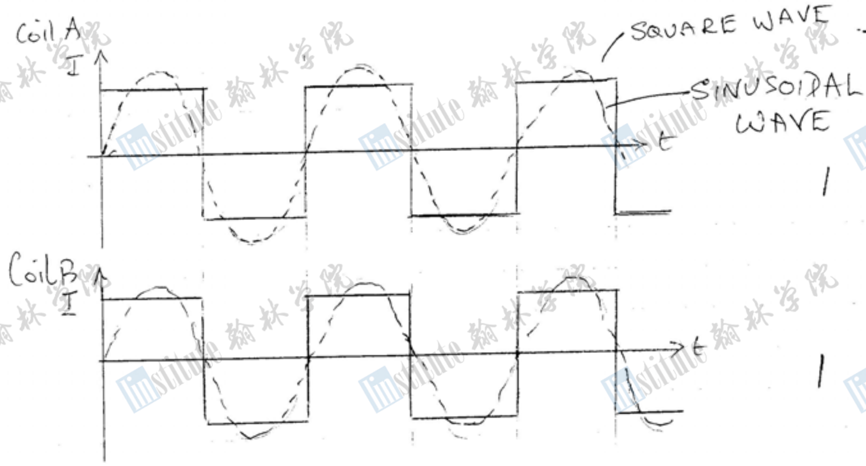
$k = 0.0500\ kg\,m^{-1}$ } 2

$F = 45\ N$ 1

TOTAL 5

(c) (i) A ensures that magnetic polarity of coils is synchronised so that there is always a force on the magnet forcing the rotation; half cycle attracting, half cycle repelling 2

(ii) Both coils have same periodic current. Ideally a 'square' variation but sinusoidal [illegible]



13

1

1

$I = I_0 \sin \omega t$

OR

$I = I_0 \quad 0 < t < \frac{T}{2}$

$= -I_0 \quad \frac{T}{2} < t < T$

etc.

ALTERNATIVELY

$I = I_0 \quad nT < t < (n + \frac{1}{2})T$

$= -I_0 \quad (n - \frac{1}{2})T < t < nT$

n integer 0, 1, 2, . . .

1

(iii) Currents decrease as motor speeds up due to back emf, Lenz's Law.

2

7

14

SOLUTION

Q5 (a) Time taken to travel 3 km $= \frac{3\times10^3}{3\times10^8}$ s $\quad (c = 3\times10^8\ \mathrm{ms^{-1}})$

$= 10^{-5}$ s

As he was only able to measure times in excess of 10^{-1}s, he could not measure 10^{-5}s. Consequently a null result. 1

Thus he could only conclude that light travelled at a speed that was greater than $\frac{3\times10^3}{10^{-1}} = 3\times10^4\ \mathrm{ms^{-1}}$. 1

Minimum accuracy of time measurement ~ 10^{-5}s 2

TOTAL 4

b) (i) When Earth moving towards Jupiter, P_1 to P_2, light from Io "eclipse" takes a shorter and shorter time to travel from Jupiter to Earth

Thus period of rotation of Io appears to be reducing 2

(ii) Similarly period extended when moving away from Jupiter, Q_1 to Q_2 2

Light travels additional distance across diameter of Earth's orbit around the Sun. This takes 22 minutes, so 2

$$c = \frac{3\times10^{11}}{22\times60} = 2.3\times10^8\ \mathrm{ms^{-1}}$$ 2

TOTAL 8

c) Wheel moves through $\frac{1}{2\times720}$ of a revolution between transmission and reception of light. For wheel rotating at 12.6 revs s^{-1}

Time taken $= \frac{1}{2(720)(12.6)}$ s 2

Distance travelled $= 2\times8633$ m

Thus $c = (2\times8633)/(2\times720\times12.6)$ 1

$= 3.13\times10^8\ \mathrm{ms^{-1}}$ 1

If path length $2L$ and rate of rotation n, then

$c = (2L)(2\times720)n$ 1

$\frac{\Delta c}{c} = \frac{\Delta n}{n}$ 2

Substituting, $\Delta c = (0.04)c$ as $\frac{\Delta n}{n} = 4\% = \frac{4}{100}$

$= 0.12\times10^8\ \mathrm{ms^{-1}}$

$c = (3.13 \pm 0.12)\,10^8\ \mathrm{ms^{-1}}$ 1

TOTAL 8

SOLUTION 15

Q6 (a) (i) $F_c = \frac{2Q}{4\pi\varepsilon_0 d^2}\hat{AC} + \frac{2Q}{4\pi\varepsilon_0 d^2}\hat{CB}$ 1

$= \frac{2Q}{4\pi\varepsilon_0 d^2}\hat{AB}$

ie force magnitude $\frac{2Q}{4\pi\varepsilon_0 d^2}$ along $\vec{AB}$ 2

$F_0 = \frac{2Q}{4\pi\varepsilon_0 d^2}\hat{AO} + \frac{2Q}{4\pi\varepsilon_0 (2d)^2}\hat{OB} = \frac{6Q}{4(4\pi\varepsilon_0)d^2}\hat{AO} = \frac{3Q}{2(4\pi\varepsilon_0)d^2}\hat{AO}$ 1

ie force of magnitude $\frac{3Q}{2(4\pi\varepsilon_0)d^2}$ along $\vec{AO}$ 2

(ii) $V_c = \frac{2Q}{(4\pi\varepsilon_0)d} - \frac{2Q}{(4\pi\varepsilon_0)d} = 0$ 1

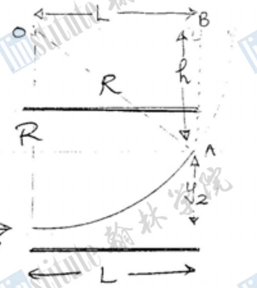
$V_0 = \frac{2Q}{(4\pi\varepsilon_0)d} - \frac{2Q}{(4\pi\varepsilon_0)(2d)} = \frac{Q}{(4\pi\varepsilon_0)d}$ 1

(iii) Potentials at A and D, due to $(-2Q)$, are equal.
Work done in taking $+2Q$ along ACGEED to D is zero. 2

10

(b) (i) Force on charge q $= Eq$.
Acceleration of q $= Eq/m$ 1
Time taken to transverse plates $= \left(\frac{L}{v}\right)$ 1
Using "$y = \frac{1}{2}at^2$", 1

$y_1 = \frac{1}{2}\frac{Eq}{m}\left(\frac{L}{v}\right)^2$



(ii) Circular motion of q with constant v

$Bqv = \frac{mv^2}{R}$
$\therefore R = \frac{mv}{Bq}$ } 2 R radius of path 2

From diagram

$y_2 = R - h$

But $h = \sqrt{R^2 - L^2}$ using Pythagoras's Th. in AOB.

$\therefore y_2 = R - \sqrt{R^2 - L^2}$ where $R = \frac{mv}{Bq}$ } 2 2

(iii)
If E and B forces balance, $Eq = Bqv$ or $E = Bv$ or $v = \frac{E}{B}$ 1
Substituting for v in the result obtained in b(i)

$y_1 = \frac{1}{2}\frac{Eq}{m}L^2\left(\frac{B}{E}\right)^2$ 1

$\frac{q}{m} = \frac{2y_1 E}{B^2 L^2}$ 1

TOTAL 10

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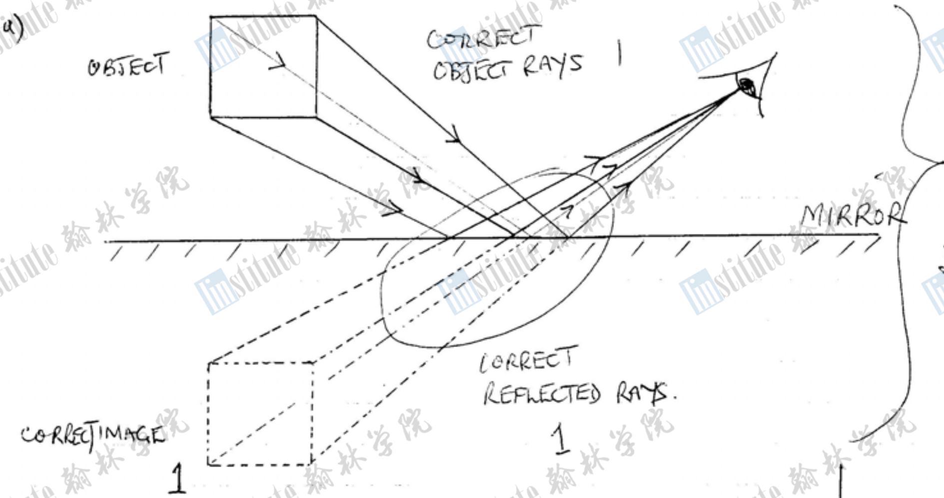
SOLUTION

27 a)



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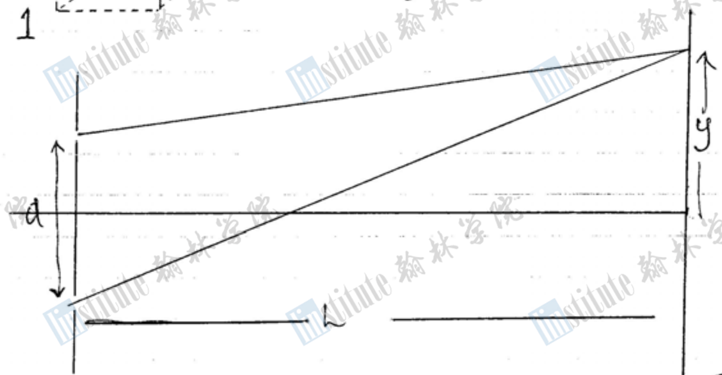
b)



Path Difference $p_D = \sqrt{L^2+\left(y+\frac{d}{2}\right)^2} - \sqrt{L^2+\left(y-\frac{d}{2}\right)^2}$ | CORRECT PATH DIFF

$= L\left(1+\frac{1}{L^2}\left(y+\frac{d}{2}\right)^2\right)^{\frac{1}{2}} - L\left(1+\frac{1}{L^2}\left(y-\frac{d}{2}\right)^2\right)^{\frac{1}{2}}$ (1)

Expanding by Binomial Th.

$= \frac{1}{2L}\left(y+\frac{d}{2}\right)^2+\dots - \frac{1}{2L}\left(y-\frac{d}{2}\right)^2+\dots$

$= \frac{1}{2L}\,2dy+\dots$ $\left(\frac{1}{2}\right)$

$p_D = \frac{dy}{L}+\dots$ $\quad = n\lambda$

For constructive interference

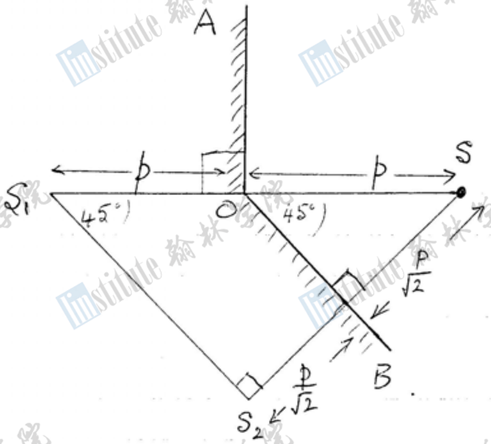
$\frac{dy}{L} = n\lambda$ | CORRECT CONDITION where n is an integer (1)

$y = \frac{n\lambda L}{d}$ | $\left(\frac{1}{2}\right)$ CORRECT RESULT Alternative proofs acceptable

3

7

c)



(i) At the positions S_1 and S_2 indicated in the diagram. Reflection in vertical mirror, AO, imaged at S_1 a distance p behind AO. Reflection in inclined mirror, OB, at distance $(p/\sqrt{2})$ behind mirror at S_2, SS_2 $\perp^r$ to mirror 2

(ii) S_1 and S_2 act as virtual sources of coherent light producing an interference pattern on a screen placed parallel to S_1S_2 in front of mirrors: S_1 and S_2 behave as slits in a Young's slit arrangement 3

(iii) Parallel to S_1S_2 which is parallel to OB 2

(iv) d is the distance between S_1 and S_2 $= 2p\cos 45^0 = \sqrt{2}p$. 2

(v) $L = D + \frac{p}{\sqrt{2}} = D + \frac{\sqrt{2}}{2}p$ · where D is distance of screen from O. 2

(vi) d becomes smaller and consequently y becomes larger for given n. When S_1 and S_2 coincide, at 180° between mirrors, there is no interference. 3

SOLUTIONS

28 Conservation of momentum: $m_1 v_1 = m_1 v + m_2 v_2$ (1) 2

m_1 = mass of neutron
v_1 = initial speed of neutron

m_2 mass of second particle
v_2 speed of second particle

Conservation of energy $\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_1 v^2 + \frac{1}{2} m_2 v_2^2$ (2) 2

From (1) $m_1 (v_1 - v) = m_2 v_2$ (3)

From (2) $m_1 (v_1^2 - v^2) = m_2 v_2^2$

or $m_1 (v_1 - v)(v_1 + v) = m_2 v_2^2$ (4)

Dividing (3) into (4)

$v_1 + v = v_2$ (5)

Thus sub^g. (5) into (1)

$$\underline{v = \left(\frac{m_1 - m_2}{m_1 + m_2} \right) v_1}$$

→ 4

(i)

$$v = \frac{1.0087 - 1.0073}{1.0087 + 1.0073} \, 2.0 \times 10^7 \text{ ms}^{-1}$$

$$\underline{= + 1.4 \times 10^4 \text{ ms}^{-1}}$$

1

(ii)

$$v = \frac{1.0087 - 11.9934}{1.0087 + 11.9934} \, 2 \times 10^7 \text{ ms}^{-1}$$

$$\underline{= - 1.68 \times 10^7 \text{ ms}^{-1}}$$

1

After many collisions ~~the~~ speeds of the neutrons will be such that the distribution of speeds is the room temperature distribution 2

TOTAL 12

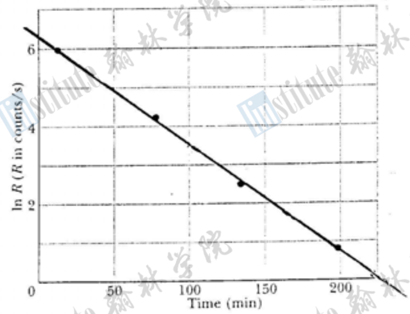
SOLUTION

19 (a) $R = R_0 e^{-\lambda t}$ 1

$\ln(R) = \ln(R_0) - \lambda t$ 2

Plot $\ln(R)$ against t for straight line graph 1

gradient $(-\lambda)$ intercept $\ln(R_0)$ at $t=0$. 1



3

From the graph, $-\lambda = \dfrac{0 - 6\cdot20}{225 - 0} = -0\cdot0275 \text{ min}^{-1}$ 2

$\lambda = 0\cdot0275 \text{ min}^{-1} = 0\cdot000458 \text{ s}^{-1}$ 1

or $= 1\cdot65 \text{ hours}^{-1}$

$T_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda}$ (1) $\simeq 25\cdot2 \text{ mins}$ (1) $= 1512 \text{ s}$ 2

TOTAL 13

b) (i) The proportions remain virtually constant. A must have a long half life for it to exist 1

(ii) $N(t) = N_0 e^{-\lambda t} = N_0 e^{-n \ln 2}$ where $n = \dfrac{t}{T_{\frac{1}{2}}}$, half life $T_{\frac{1}{2}}$. 2

$\dfrac{N(t)}{N_0} = \dfrac{1}{10^{11}} = \left(e^{-\ln 2}\right)^n = \left(\tfrac{1}{2}\right)^n$.

Taking $\log_{10}$ $11 = n \log_{10} 2 = n(0\cdot3010)$ 1

$n = 37$

Thus $t = 37 \times 10^8 = 3\cdot7 \times 10^9$ years 1

(iii) 10^{11} atoms decay to one atom of C, neglect intermediate decay with lifetime of 60 s as it is much less than 10^8 years. 2

TOTAL 7

SOLUTIONS

19

b) Conservation of momentum: $mv = (m+M)V$ (1) 2

V is speed after bullet lodged in block

Conservation of energy $\frac{1}{2}(m+M)V^2 = (m+M)gh$ (2) 2

Eliminating V from (1) & (2)

$$\left.\begin{aligned}\frac{1}{2}(m+M)\left(\frac{mv}{m+M}\right)^2 &= (m+M)gh \\ \frac{1}{2}\left(\frac{mv}{m+M}\right)^2 &= gh\end{aligned}\right\} \quad 1$$

$$v = \left(\frac{m+M}{m}\right)\sqrt{2gh} \quad 1$$

The block plus bullet swings up with simple harmonic motion – comment on amplitude and/or period. 2

8