2025 Preliminary Examination H2 Physics Paper 2 Solutions

1 **(a)**

$$\rho = \frac{m}{abc}$$
$$= \frac{0.234}{(5.13\times10^{-2})(11.38\times10^{-2})(1.72\times10^{-2})}$$
$$= 2330 \text{ kg m}^{-3}$$

(b)

$$\rho = \frac{m}{abc}$$
$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$$
$$\Delta\rho = \left(\frac{0.002}{0.234} + \frac{0.01}{5.13} + \frac{0.01}{11.38} + \frac{0.01}{1.72}\right)(2330)$$
$$= 40 \text{ kg m}^{-3}$$
$$\rho = (2330 \pm 40) \text{ kg m}^{-3}$$

(c) zero error / incorrect calibration
of calipers / balance

2 **(a)** Let *n* be number of 5.0 g masses.

By principle of moments, take moments about the edge of the table,
Total anti-clockwise moments = total clockwise moments

$$(1.5)(9.81)\left(\frac{0.10}{2}\right) = (0.11)(9.81)(0.50-0.10) + n(5.0\times10^{-3})(9.81)(0.80)$$
$$n = 7.75$$

Therefore, the maximum number of masses is <u>**7**</u>.

(b) Let tension in string be *T*.

Consider forces acting on the metre rule and taking moments about the edge of the table,
string holding the 1.5 kg mass will cause a reduction of anti-clockwise moments

$$= T\left(\frac{0.10}{2}\right) = 0.050T$$

string attached to ruler at midpoint will cause a reduction of clockwise moments

$$= (T\sin 60^\circ)(0.40) = 0.346T$$

Since the reduction of clockwise moments is greater, there will be a <u>net anticlockwise moment</u> acting on the metre rule.

Hence <u>**more**</u> 5.0 g masses can be placed (compared to **(a)**) before the cantilever topples.

3 **(a)** The <u>vertical displacement of the yoke</u> is <u>$r\sin(\omega t)$</u>.
Hence, the acceleration is $-\omega^2 r\sin(\omega t) = -\omega^2 x$, which is the defining equation of <u>simple harmonic motion</u>.

(b) (i) 1. $v_0 = \omega y_0$

$= \omega r$

$= \left(\dfrac{2\pi}{0.40}\right)(0.080)$

$= 1.3 \text{ m s}^{-1}$

2. $a_0 = \omega^2 y_0$

$= \left(\dfrac{2\pi}{0.40}\right)^2 (0.080)$

$= 20 \text{ m s}^{-2}$

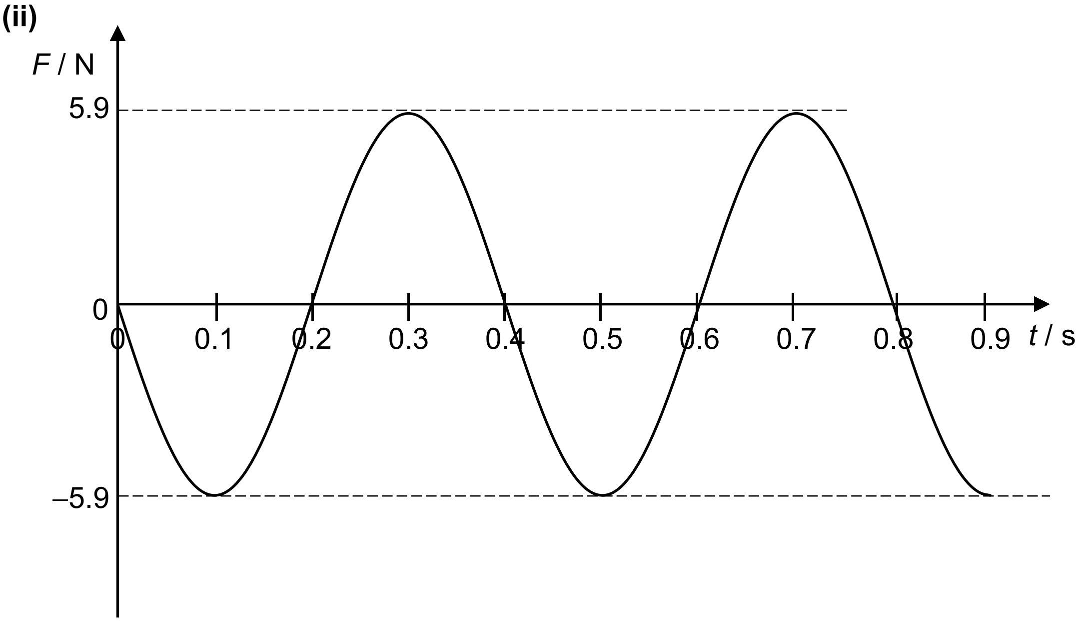
or

$a_0 = \omega v_0$

$= \left(\dfrac{2\pi}{0.40}\right)(1.3)$

$= 20 \text{ m s}^{-2}$

(ii)



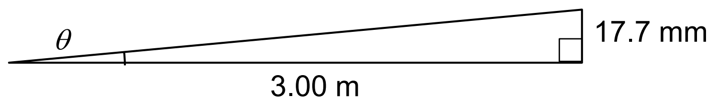
4 (a) (i) When the path difference between the waves that meet at the screen is integer multiple of wavelength of the light, they meet in phase and there is constructive interference, forming bright fringe.

When the path difference between the waves that meet at the screen is odd integer multiple of half wavelength of the light, they meet in antiphase and there is destructive interference, forming dark fringe.

correct path difference
meeting in phase / antiphase
constructive / destructive interference

(ii) The single slit diffraction pattern from each slit forms the envelope of the double slit interference pattern. Where the minima of the single slit diffraction pattern coincide with the bright fringes of the double slit interference pattern, these bright fringes cannot be observed and will be seen missing from the interference pattern.

(b) (i)



$$b\sin\theta = \lambda$$

$$\begin{aligned} b &= \frac{\lambda}{\sin\theta} \\ &= \frac{\lambda}{\tan\theta} \quad (\because \sin\theta \approx \theta \approx \tan\theta \text{ as } \theta \text{ is small}) \\ &= \frac{590\times10^{-9}}{\left(\frac{35.4\times10^{-3}}{2}\right)\left(\frac{1}{3.00}\right)} \\ &= 1.00\times10^{-4}\text{ m} \\ &= 0.100\text{ mm} \end{aligned}$$

(ii) According to the Rayleigh criterion, the two diffraction patterns are just distinguishable if the central maximum of one diffraction pattern coincides with the first minimum of the other (diffraction pattern).

This means the minimum angular separation θ_{min} of the two central maxima for the patterns to be resolved is $\theta_{min} \approx \frac{\lambda}{b} = \frac{590\times10^{-9}}{0.100\times10^{-3}} = 0.0059\text{ rad}$.

Since the angle between the two beams of light is smaller than 0.0059 rad, the two diffraction patterns are unresolved.

5 **(a)** gas that obeys $pV \propto T$ for all values of p, V and T
where p is pressure, V is volume and T is thermodynamic temperature

(b)

$$\begin{aligned} n &= \frac{pV}{RT} \\ &= \frac{(1.6\times10^{6})(0.20)}{8.31(22+273.15)} \\ &= 130\text{ mol} \end{aligned}$$

(c)

$$\frac{1}{2}Mc_{\text{r.m.s.}}{}^{2} = \frac{3}{2}RT \quad (\text{where } M \text{ is the molar mass})$$

$$\begin{aligned} c_{\text{r.m.s.}} &= \sqrt{\frac{3RT}{M}} \\ &= \sqrt{\frac{3(8.31)(22+273.15)}{4.2\times10^{-2}}} \\ &= 420\text{ m s}^{-1} \end{aligned}$$

(d) When gas reaches equilibrium with surroundings, its pressure is 3.6×10^{4} Pa.

$$n' = \frac{p'V}{RT'} = \frac{(3.6\times10^{4})(0.20)}{8.31(-50+273.15)} = 3.8827\text{ mol}$$

$$m = 3.8827(4.2\times10^{-2}) = 0.16\text{ kg}$$

6 **(a)** The amount of energy transformed from **chemical** to electrical per unit charge (driven around a complete circuit).

(b) $R_{PR} = \dfrac{\rho\ell}{A} + \dfrac{\rho\ell'}{A'}$

$= \left(5.0\times10^{-7}\right)\left[\dfrac{90\times10^{-2}}{5.7\times10^{-8}} + \dfrac{10\times10^{-2}}{\left(\dfrac{80}{100}\right)\left(5.7\times10^{-8}\right)}\right]$

$= 8.9912$

$= 9.0\ \Omega$

(c) **(i)** $I = \dfrac{V}{R}$

$= \dfrac{9.0}{8.9912+25}$

$= 0.26\ \text{A}$

(ii) When galvanometer shows a null reading, $V_{PQ} = E$.
$E = IR_{PQ}$

$= 0.26477\left(5.0\times10^{-7}\right)\left[\dfrac{65\times10^{-2}}{5.7\times10^{-8}} + \dfrac{10\times10^{-2}}{\left(\dfrac{80}{100}\right)\left(5.7\times10^{-8}\right)}\right]$

$= 1.8\ \text{V}$

Alternatively,

$R_{PQ} = \left(5.0\times10^{-7}\right)\left[\dfrac{65\times10^{-2}}{5.7\times10^{-8}} + \dfrac{10\times10^{-2}}{\left(\dfrac{80}{100}\right)\left(5.7\times10^{-8}\right)}\right] = 6.7982\ \Omega$

$E = \left(\dfrac{R_{PQ}}{R_{PR} + R_{\text{variable resistor}}}\right)\times 9.0$

$= \left(\dfrac{6.7982}{8.9912+25}\right)\times 9.0$

$= 1.8\ \text{V}$

(d) **(i)** As there is <u>no current in the solar cell</u>, <u>potential difference (p.d.) across its internal resistance is zero</u>. Hence, the terminal p.d. of the solar cell is equal to E and $V_{PQ} = E$.

(ii) The <u>resistance</u> of a potentiometer of uniform cross-sectional area is <u>smaller</u> and therefore the <u>potential difference</u> across the potentiometer is now <u>smaller</u>. Hence, the balance length would be <u>longer</u> $V_{PQ} = \left(\dfrac{L_{PQ}}{L_{PR}}\right)V_{PR}$.

or
The <u>potential drop</u> across the first 75 cm of the potentiometer wire is now <u>lower</u> as the <u>resistance</u> across it is <u>lower</u>. Hence, <u>balance length</u> would be <u>longer</u>.

7 **(a)** **(i)** Nuclei that have the same number of protons but different number of neutrons.

(ii) Time taken for the number of undecayed nuclei to be reduced to half its original number.
or
Time for activity to halve.

(b) **(i)** ${}^{40}_{19}K \rightarrow {}^{40}_{20}Ca + {}^{0}_{-1}\beta^{-}$ + antineutrino (or neutrino)
one mark each for each correct decay product including mass and atomic numbers

(ii)
$$E = (\Delta m)c^2$$
$$= (39.963998 - 39.962591)(1.66 \times 10^{-27})(3.00 \times 10^{8})^2$$
$$= 2.102058 \times 10^{-13} \text{ J}$$
$$= 1.31 \text{ MeV}$$

(c) The ratio of potassium to argon to calcium is 2:1:9.
$$N = N_0 e^{-\lambda t}$$
$$\ln\left(\frac{N}{N_0}\right) = -\lambda t$$
$$t = \frac{1}{\lambda}\ln\left(\frac{N_0}{N}\right)$$
$$= \frac{t_{1/2}}{\ln 2}\ln\left(\frac{N_0}{N}\right)$$
$$= \frac{1.25 \times 10^9}{\ln 2}\ln\left(\frac{2+1+9}{2}\right)$$
$$= 3.23 \times 10^9 \text{ years}$$

8 **(a)** **(i)** Time taken to reach the top $t = \left(\frac{900}{2.5}\right)$
Let n be the number of passengers.
P = rate of gain of gravitational potential energy of passengers
$$= \frac{nmgh}{t}$$
$$= \frac{2(24)(75)(9.81)(300)}{\left(\frac{900}{2.5}\right)}$$
$$= 29430 = 29000 \text{ W}$$

Alternatively, the vertical speed of the $(v \sin\theta)$, can be used instead
$$P = Fv$$
$$= (nmg\sin\theta)v = nmgv\sin\theta$$
$$= [2(24)](75)(9.81)(2.5)\left(\frac{300}{900}\right)$$
$$= 29430 = 29000 \text{ W}$$

(ii) Any one point from:
It does not account for:
1. energy losses due to friction in the moving parts of the chair lift
2. drag forces acting on the moving chairs, which vary with wind conditions.
3. additional ski equipment which would result in the average mass being more than 75 kg

(b) (i) $N = mg\cos\theta = (75)(9.81)\cos 9.0° = 726.69 \text{ N} = 730 \text{ N}$

Alternatively,
from the graph $a_g = 1.540$ (acceptable range $a_g = 1.525$ to 1.550),

$$N = \frac{ma_g}{\tan 9°} = \frac{(75)(1.540)}{\tan 9°} = 729.24 = 730 \text{ N}$$

or

$$N = \sqrt{(mg)^2 - (ma_g)^2} = \sqrt{[(75)(9.81)]^2 - [(75)(1.540)]^2} = 726.63 = 730 \text{ N}$$

(ii) $f = \mu N = 0.080(726.69)$
$= 58.135 = 58 \text{ N}$

(iii)
$$mg\sin\theta - f = ma$$
$$75(9.81)\sin 9.0° - 58.135 = 75a$$
$$a = 0.76 \text{ m s}^{-2}$$

Alternatively,
From Fig. 8.4, when $\theta = 9.0°$ and $\alpha = 0°$, $a_g = 1.54 \text{ m s}^{-2}$.
$$ma_g - f = ma$$
$$75(1.54) - 58.135 = 75a$$
$$a = 0.76 \text{ m s}^{-2}$$

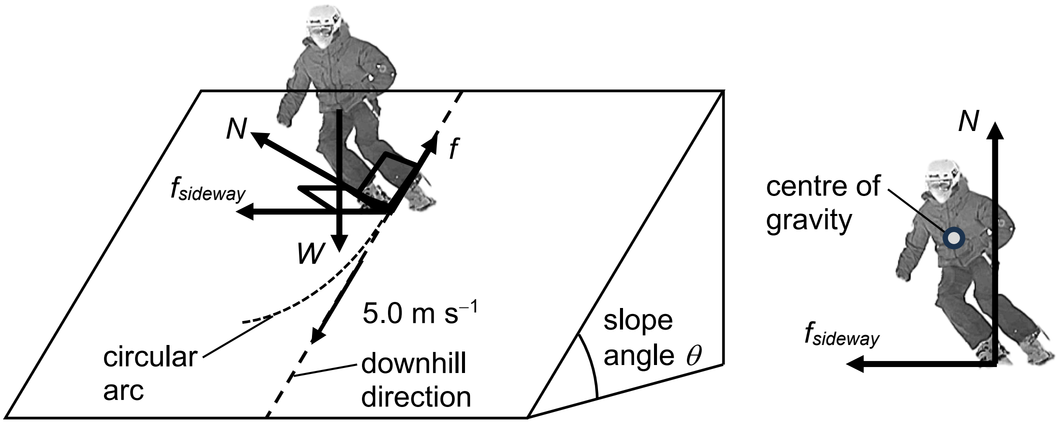
(c) (i) $f = \mu N = \mu mg\cos\theta = (0.12)(75)(9.81)\cos 22.0° = 81.861 = 82 \text{ N}$

(ii) In order to maintain constant speed, the acceleration of the skier is zero.
$$f = ma_g$$
$$a_g = \frac{f}{m} = \frac{81.861}{75}$$
$$= 1.0915 = 1.1 \text{ m s}^{-2}$$
From Fig. 8.4, the corresponding ski angle is 72.5°.

(iii) The skier can decrease the ski angle.

(d) (i) From Fig. 8.7, for hard snow, when $\beta = 61°$, $r = 9.2$ m.
$$F_C = \frac{mv^2}{r} = \frac{(75)(5.0)^2}{9.2}$$
$$= 200 \text{ N}$$

(ii) The centripetal force is provided by the sideway friction.
Taking moments about the centre of gravity of the skier, the moment due to the normal contact force must be equal to the moment due to the sideway friction.
As edge angle increases, the perpendicular distance of the line of action of normal contact force from the centre of mass of skier increases while the perpendicular distance of the line of action of sideway friction decreases. Hence, sideway friction increases.



Note:
Weight (*W*) and normal contact force (*N*) act in the vertical plane and do not provide the centripetal force.
As seen in Fig. 8.6, the skis do not sink into the snow and create a sloped surface that is parallel to the bottom of the skis.

