## 2013 A-Level H2 Physics Suggested Solutions

### Paper 1

**1** **A** The scattering of data points around the best fit line suggests that the results are imprecise. Using $s = ut + \frac{1}{2}at^2 \Rightarrow t^2 = \frac{2}{g}s$ and value of gradient, $g$ = 9.804 m s$^{-2}$ (close to 9.81 m s$^{-2}$) and is accurate.

**2** **C** Normal A4 paper is 80 grams per square meter (gsm). Area of A4 paper is 21.0 cm by 29.7 cm. (Use ruler to measure exam question paper). Mass of a single sheet = 80 × 0.210 × 0.297 = 5 g

**3** **A**

$$s = ut + \frac{1}{2}at^2 \quad \Rightarrow \quad s = \frac{1}{2}at^2$$

$$12 = \frac{1}{2}a(2)^2 - \frac{1}{2}a(1)^2$$

$$a = 8.00 \text{ m s}^{-2}$$

$$s_{3\text{ to }4} = \frac{1}{2}a(4)^2 - \frac{1}{2}a(3)^2 = 28 \text{ m}$$

**4** **D** Velocity of stone passing edge of cliff on its way down is 10 m s$^{-1}$ downwards

$$s = ut + \frac{1}{2}at^2 = (10)(1.2) + \frac{1}{2}(9.81)(1.2)^2 = 19.1 \text{ m}$$

**5** **C** For elastic collision, relative speed of approach = relative speed of separation, $u_1 - u_2 = v_2 - v_1$. Only option C is correct.

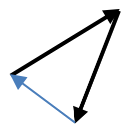
**6** **B**

$$\frac{\Delta m}{\Delta t} = \frac{\rho A \Delta x}{\Delta t} = Av\rho$$

$$F = \frac{\Delta p}{\Delta t} = \frac{\Delta mv}{\Delta t} = Av^2\rho$$

**7** **A** pressure due to fluid $= \rho gh = (600)(9.81)(0.200) = 1177$ Pa

**8** **D** For equilibrium, the third force must form a closed vector triangle with the other two forces. Hence, it must act in the Z direction.



**9** **C**

$$P = \frac{Fv}{0.20} = 1400 \times 9.81 \times 1.6 \times \frac{100}{20} = 109872 \text{ W}$$

**10** **A** The sum of the three types of energies must be 120 J.
Option B is wrong because kinetic energy at bottom must be 0.
Option C is wrong because the total energy in middle is not conserved.
Option D is wrong because kinetic energy throughout the motion cannot be constantly at 0.

**11** **B** There are only two forces acting on the ball, the weight of the ball and the tension in the thread. The resultant of these two forces provides the required centripetal force for the ball to move in a circle.

**12 D**

$$\frac{1}{2}mv^2 = 5.0\times10^{-13}$$

$$v = 2.447\times10^{7}$$

$$a_c = \frac{v^2}{r} = \frac{(2.447\times10^7)^2}{0.6} = 9.98\times10^{14}\ \text{m s}^{-2}$$

**13 A**

$$g = \frac{GM}{r^2}$$

when $r = 2$ , $g = \frac{64}{2^2} = 16$

when $r = 4$ , $g = \frac{64}{4^2} = 4$

**14 A** Centripetal force is provided by gravitational force

At P, $a = \frac{GM}{r^2}$

At Q, $a_Q = \frac{GM}{(3r)^2} = \frac{1}{9}\frac{GM}{r^2} = \frac{1}{9}a$

**15 D** GPE is linear as it is proportional to height.
KE is an inverted parabola with a value of zero at the equilibrium position.
EPE is a curve with increasing values as extension increases (displacement downwards).

**16 C** $v_{\max} = \omega x_0 = 2\pi(75)(0.01) = 4.71\ \text{m s}^{-1}$

**17 C**

$$n = \frac{PV}{RT}$$

$T' \to 5T$ and $P' \to 2P$

$$n_{final} = \frac{V}{R}\left(\frac{2P}{5T}\right) = 0.4n$$

$$n_{escape} = n - 0.4n = 0.6n$$

**18 C**

$$P_1 = m_1 l + h$$

$$P_2 = m_2 l + h$$

$$P_1 - P_2 = m_1 l - m_2 l$$

$$l = \frac{P_1 - P_2}{m_1 - m_2}$$

**19 B**

$$I = k{x_0}^2$$

$$v_{\max} = \omega x_0$$

Thus maximum speed of air molecules increases.
Speed of wave is independent of intensity and is dependent on temperature and mass of a molecule in the medium.

**20** **A** The crests are locations of nodes of the stationary wave, which have no amplitude and has no effect on the powder.

$2\lambda = 0.2$ m

$v = f\lambda$

$f = \dfrac{330}{0.1} = 3300$ Hz

**21** **B** For the first order maxima to be symmetrical about the zeroth order, the incident beam must be normal to the grating.
Option A will result in two sets of diffraction patterns.
Option B will result in greater separation between the first bright fringe and central fringe on the screen.
Option D will result in fringes that are not sharp.

**22** **B** With no change in frequency and wavelength of the wave, the two waves undergo destructive interference at P and constructive interference at Q. The destructive interference at P is less complete and results in an increase in loudness. The constructive interference at Q will result in a lower resultant amplitude and decrease in loudness.

**23** **C** By conservation of energy, initial KE + initial EPE = final KE + final EPE

$$\frac{1}{2}m\left(v_1\right)^2 + 0 = \frac{1}{2}m\left(v_3\right)^2 + (-e)V$$

$$\frac{1}{2}m\left(v_3 - v_1\right)^2 = eV$$

**24** **B** Direction of gravitational field always point towards the mass, while the direction of the electric field lines can be towards or away from the charge, depending on whether it is a negative or positive charge.

**25** **A** LDR, metal wire and thermistors have $I$-V graphs that pass through origin and only a diode has nearly linear portion that is far from the origin.

**26** **A** terminal pd $= \varepsilon - Ir$

thus, since $r_Q$ is larger, terminal pd of P is larger

$P_{output} = I(\text{terminal pd})$

thus power output of P is also larger

**27** **D** $R = \dfrac{\rho l}{A}$

let $t$ be the thickness of the metal sheets, $4.0 = \dfrac{\rho x}{xt}$

total resistance $= 4.0 + \dfrac{\rho(2x)}{\left(\frac{x}{2}\right)t} = 4.0 + 4\left(\dfrac{\rho x}{xt}\right) = 20$

**28** **A** when rheostat is set to 0 $\Omega$,

$V = \frac{10}{20} \times 40 = 20$ V

when rheostat is set to 20 $\Omega$,

$V = \frac{10}{40} \times 40 = 10$ V

**29** **A** for charges passing through undeflected,

$F_B = F_E$

$Bqv = qE$

$v = \frac{E}{B} = \frac{3.0 \times 10^5}{1.5 \times 10^{-2}} = 2.0 \times 10^7 \text{ m s}^{-1}$

**30** **B** maximum magnetic flux linkage, $\Phi = NBA\cos\theta$

$= (35)(2.1 \times 10^{-4})(7.0 \times 10^{-5})$

$= 5.145 \times 10^{-7}$

maximum magnetic flux, $\phi = BA\cos\theta$

$= (2.1 \times 10^{-4})(7.0 \times 10^{-5})$

$= 1.47 \times 10^{-8}$

**31** **A** Magnetic flux density due to wire XY is into the page on the right side of XY. Magnetic flux density is higher near the wire.
Induced e.m.f. in option C and D is zero.

**32** **A** $Q = It$. Area under $I$ – t graph is the amount of charge

**33** **B** amplitude, $A = 0.5$ V

period, $T = 0.2$ s

equation is $V = A\sin\left(\frac{2\pi}{T}\right) = 0.5\sin(10\pi t)$

**34** **B**

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

turns ratio for 1st transformer $= \dfrac{10}{N_s}$

$$V_{s1} = \frac{V_p N_s}{10}$$

$$I_{s1} = \frac{10 I_p}{N_s}$$

turns ratio for 2nd transformer $= \dfrac{30}{N_s}$

$$V_{s2} = \frac{V_p N_s}{30}$$

$$I_{s2} = \frac{30 I_p}{N_s}$$

**35** **B**

$$\frac{hc}{\lambda} = \phi + \text{KE}_{\text{max}}$$

$$\begin{aligned}\text{KE}_{\text{max}} &= \frac{hc}{\lambda} - \phi \\ &= \frac{6.63\times10^{-34}\times3.0\times10^{8}}{80\times10^{-9}} - 1.6\times10^{-19}\times4.3 \\ &= 1.798\times10^{-18}\ \text{J} \\ &= 11.23\ \text{eV}\end{aligned}$$

**36** **C** Not in 9749 syllabus

**37** **B** Not in 9749 syllabus

**38** **B** Not in 9749 syllabus

**39** **C** let $N_0$ be the initial number of Antimony-124 nuclei,

$N_{An}$ be the number of Antimony-124 after time $t$,

$N_{Te}$ be the number of Tellurium-124 after time $t$

$$N_{An} = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

$$N_{Te} = N_0 - N_{An}$$

$$\frac{N_{Te}}{N_{An}} = \frac{N_0 - N_{An}}{N_{An}} = \frac{N_0 - N_0 e^{-\lambda t}}{N_0 e^{-\lambda t}} = \frac{1 - e^{-\frac{\ln 2}{t_{1/2}}(t)}}{e^{-\frac{\ln 2}{t_{1/2}}(t)}} = 6$$

$$6e^{-\frac{\ln 2}{t_{1/2}}(t)} = 1 - e^{-\frac{\ln 2}{t_{1/2}}(t)}$$

$$7e^{-\frac{\ln 2}{t_{1/2}}(t)} = 1$$

$$-\frac{\ln 2}{60}(t) = \ln\left(\frac{1}{7}\right)$$

$t = 168.4$ days

**40** **D** In beta decays, the nucleon number is unchanged and the proton number increases by 1.

In alpha decay, the nucleon number decreases by 4 and the proton number decrease by 2.

## Paper 2 Structured Questions

**1** **(a)** Distance moved along cable, $s = \frac{1}{2}at^2 = \frac{1}{2}(1.5)(2.0)^2$ M1

$= 3.0 \text{ m}$

Vertical height $= 3.0\sin 40^\circ$ M1

$= 1.93 \text{ m}$ A1

**(b)** **(i)** At constant speed, N = W = (95)(9.81) = 932 N A1

**(ii)** Since the cable car is at constant speed, there is <u>no resultant force acting on it</u>. Hence, the vector sum of forces in all directions must be zero. Since <u>N and W are the only forces in the vertical direction</u>, their magnitudes must be equal. B1

**(c)** **(i)** <u>Weight</u> of the man, <u>normal contact force</u> from the floor of the cable car and <u>friction between the man and the floor</u> of the cable car. B1

**(ii)** Normal reaction is larger than weight, giving rise to acceleration in the upward direction. B1
Friction causes a horizontal acceleration. B1

The resultant acceleration is in the direction of the rope.

**(d)** Distance moved along cable for 120 s at constant speed $= (3.0)(120) = 360 \text{ m}$ M1

Distance moved along cable for last 3.0 s $= \frac{1}{2}(3.0 + 0)(3.0) = 4.5 \text{ m}$

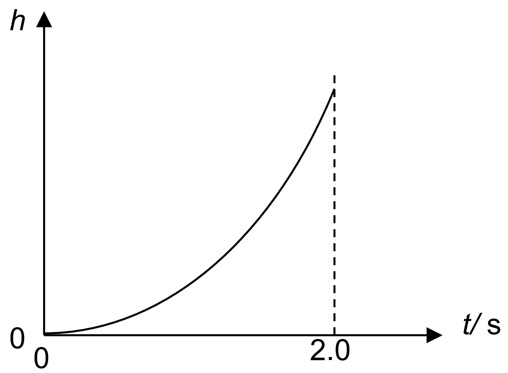
Total vertical height $= 1.93 + 360\sin 40^\circ + 4.5\sin 40^\circ$ M1

$= 236 \text{ m}$

Gain in GPE $= mgh = (95)(9.81)(236)$ A1

$= 220000 \text{ J}$

**(e)** **(i)**

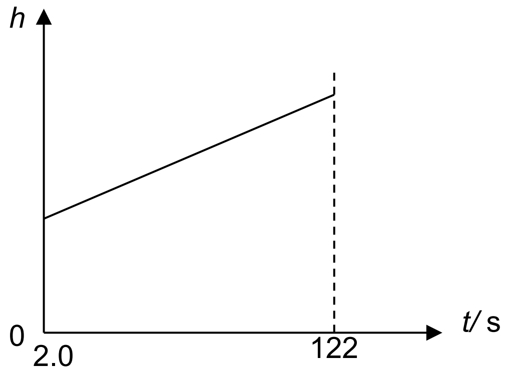



A1

<u>Note:</u>

- At t = 0 gradient is 0
- Positive increasing gradient
- Curve must reach t = 2.0 s

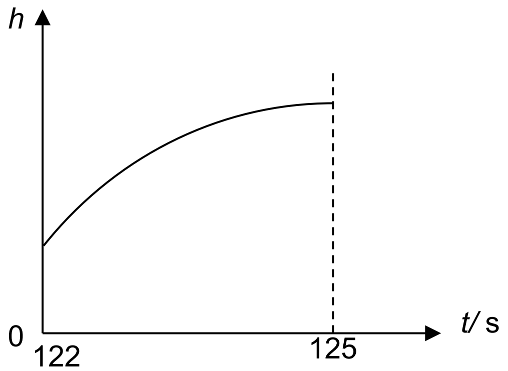
**(ii)**




A1

Note:
- Positive constant gradient
- Graphs should not start at $h$ = 0 m
- Graph must reach $t$ = 122 s

**(iii)**




A1

Note:
- Positive decreasing gradient
- Curve should not start at $h$ = 0 m
- Final gradient must show that final speed is zero.
- Curve must reach $t$ = 125 s

**2** **(a)** Impulse of a force is defined as the <u>product of the force and the time for which it acts</u>. B1

**(b)** **(i)** Area under graph = impulse = $m\Delta v$ C1

$$\left|\frac{1}{2}(0.75-0.25)(-0.32)\right| = (0.150)\,\Delta v$$ M1

$$\Delta v = 0.53 \text{ m s}^{-1}$$ A1

**(ii)** **1.** The velocity decreases at an increasing rate (i.e., larger and larger deceleration) from $t$ = 0.25 s to $t$ = 0.50 s. B1

B1

The velocity reaches zero at $t$ = 0.50 s.

**2.** The velocity increases from zero in opposite direction to its initial direction with decreasing rate until it becomes 0.265 m s $^{-1}$ at $t$ = 0.75 s. B1

**3 (a) (i)** The resultant of all the forces acting on the object must always be constant in magnitude and perpendicular to the direction of motion. B1

**(ii)** The direction of the velocity is changing constantly with time. Hence, the velocity is changing and there is an acceleration. B1

**(b) (i)** Since gravitational force gives rise to the centripetal acceleration of the satellite, B1

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$r = \frac{GM}{v^2}$$

$$= \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{(2500)^2}$$ M1

$$= 6.4 \times 10^7 \text{ m}$$

$$= 6.4 \times 10^4 \text{ km}$$ A1

**(ii) 1.** Since the potential energy of the satellite is given by $E_p = -\frac{GMm}{r}$, the potential energy of the satellite would decrease as it becomes more negative. B1

**2.** Since the kinetic energy of the satellite is given by the $E_k = \frac{GMm}{2r}$, the kinetic energy of the satellite would increase as its magnitude gets larger. B1

**4 (a)** The internal energy of an ideal gas is the sum of the kinetic energies of the molecules in the gas due to their random motion. B1

**(b) (i)** Mass of air in oven = number of mol × mass of 1 mol

$$= \left(\frac{PV}{RT}\right)(0.030)$$

$$= \left[\frac{(1.0 \times 10^5)(0.075)}{(8.31)(25 + 273.15)}\right](0.030)$$ M2

$$= 0.091 \text{ kg}$$ A1

**(ii)** From the Ideal Gas Equation,

$$V = \frac{nRT}{P}$$

$$\frac{M}{\rho} = \frac{nRT}{P}$$

$$\rho = \left(\frac{M}{n}\frac{P}{R}\right)\frac{1}{T}$$

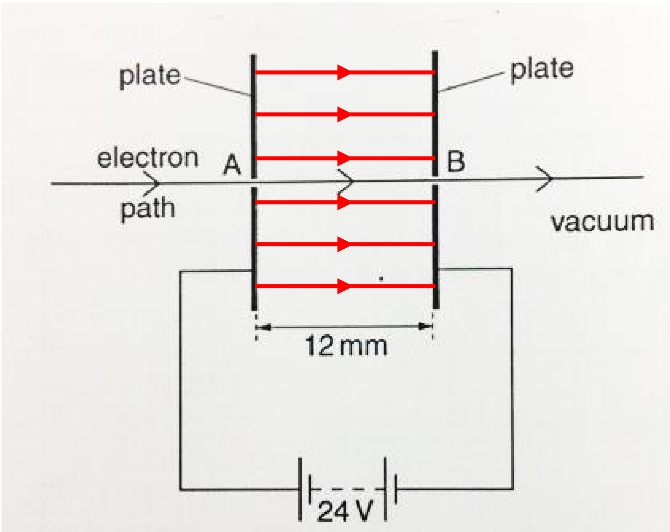
M1

Since $\frac{M}{n}$ = mass of one mol, $\rho \propto \frac{1}{T}$

$$\frac{\rho_{25^\circ}}{\rho_{200^\circ}} = \frac{200+273.15}{25+273.15}$$

$$= 1.6$$ A1

**5** **(a)**




Points to note:

- Field lines point from left to right
- Ruler must be used
- Field lines must touch the plates
- Even spacing between field lines

B1

**(b)** **(i)** $F = q\frac{V}{d}$

$$= \left(1.6\times10^{-19}\right)\left(\frac{24}{12\times10^{-3}}\right)$$ M1

$$= 3.2\times10^{-16}\ \text{N}$$ A1

**(ii)** $W = Fd$

$$= \left(3.2\times10^{-16}\right)\left(-12\times10^{-3}\right)$$ M1

$$= -3.8\times10^{-18}\ \text{J}$$

Force and displacement of electron are opposite in direction, thus work done should be negative.

**(iii)** Loss in KE = Gain in EPE or Work done by electric force on electron

$$\frac{1}{2}m\left(u^2 - v^2\right) = qV = W$$ C1

$$\frac{1}{2}\left(9.11\times10^{-31}\right)\left(\left(4.5\times10^{6}\right)^2 - v^2\right) = 3.84\times10^{-18}$$ M1

$$v = 3.4\times10^{6}\ \text{m s}^{-1}$$ A1

**6 (a)** The photoelectric effect is a phenomenon in which electrons are emitted from a metal surface when electromagnetic radiation of sufficiently high frequency is incident on the surface. B1

**(b)** According to the particulate theory of light, electromagnetic radiation is made up of discrete quanta of energy known as photons.
The energy of each photon is *hf*, where *h* is the Planck constant and *f* is the frequency of the radiation. B1
To have photoemission, each electron must gain an amount of energy more than the work function $\Phi$ of the metal. B1
Since an electron can only absorb one photon, each photon must have a minimum frequency of $\frac{\Phi}{h}$, which is the threshold frequency. B1

**7 (a)** From -190 °C to 10 °C, resistance increases at a steady rate. B1
From 10 °C to 40 °C, resistance decreases at an increasing rate.
From 40 °C to 100 °C, resistance decreases at a steady rate.
From 100 °C to 200 °C, resistance decreases at a decreasing rate. B1

**(b)** If *R* and $\theta$ are inversely proportional, their product $R\theta$ at any point on the graph would be a constant. B1

When $\theta$ = 70 °C, $R\theta$ = (1400)(70) = 98000 Ω °C
When $\theta$ = 125 °C, $R\theta$ = (440)(125) = 55000 Ω °C B1

Since the $R\theta$ values are not constant, the proposal is not correct.

**(c) (i)** R/ Ω = 200 Ω A1
$T^{-1}$/ $10^{-3}$ $K^{-1}$ = 1000 × 1/(160 + 273.15) = 2.31
ln(R/ Ω) = 5.30

**(ii)** Point plotted correctly on grid (best fit line is not credited here) A1
[Refer to graph below]

**(d) (i)**

$$R = Ae^{E_g/2kT}$$

$$\ln R = \ln A + \left(\frac{E_g}{2k}\right)T^{-1}$$ M1

The equation shows that a graph of ln R against $T^{-1}$ would yield a straight line with positive gradient. This corresponds to the graph in Fig. 7.3. M1

**(ii) 1.** [Refer to graph below]
Best fit line credited here. B1

Gradient = $\dfrac{(5.82-4.96)}{(2.440-2.240)\times10^{-3}}=\dfrac{E_g}{2k}$ M1

$$E_g=2\left(1.38\times10^{-23}\right)\left[\frac{(5.82-4.96)}{(2.440-2.240)\times10^{-3}}\right]$$

$=1.2\times10^{-19}$ J

$=0.75$ eV A1

**2.** Using (2.440 × $10^{-3}$, 5.82),

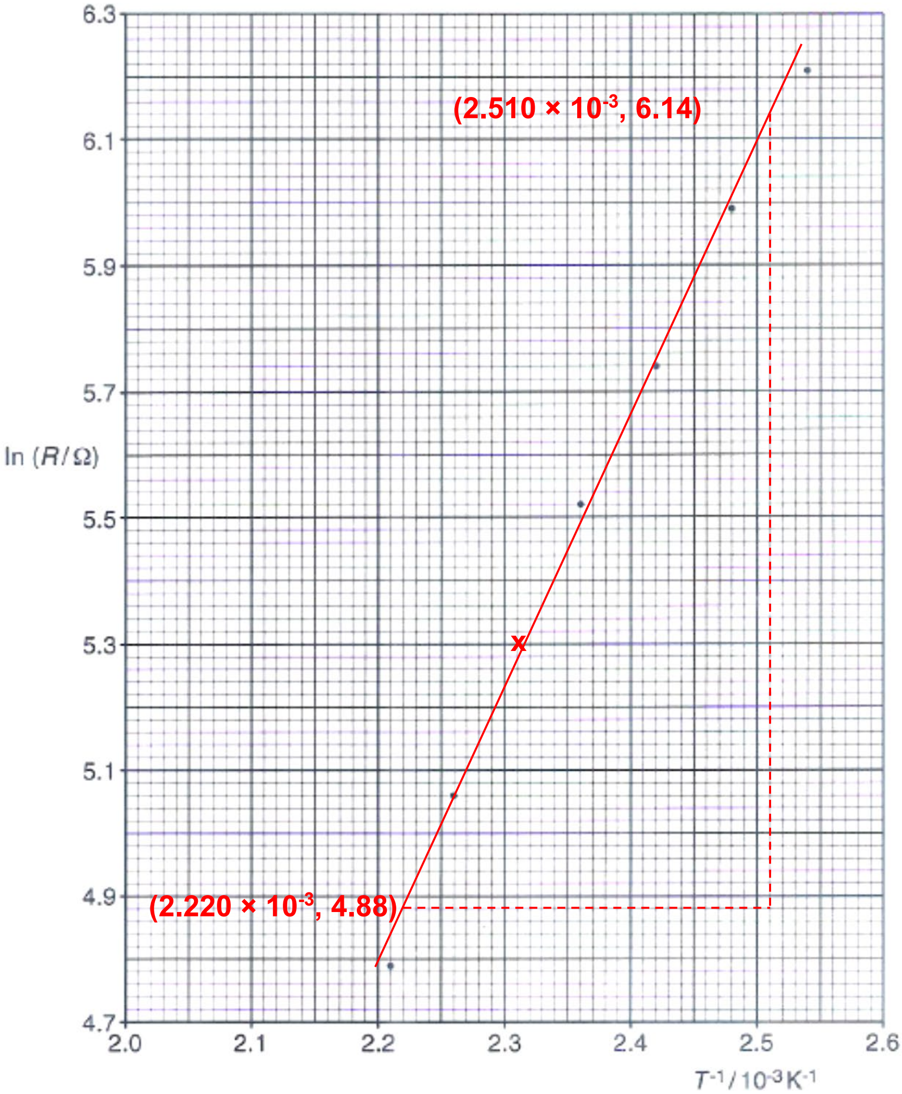
$$5.82=\ln A+\left[\frac{(5.82-4.96)}{(2.440-2.240)\times10^{-3}}\right]\left(2.440\times10^{-3}\right)$$ M1

$A=9.35\times10^{-3}\ \Omega$ A1

**(e)** A n-type semiconducting material has lower resistance than an intrinsic semiconducting material. B1

This is because in the n-type semiconducting material, the electrons from the donor atom reside in the donor level which is just below the conduction band. With a small amount of energy, these electrons readily move into the conduction band, increasing the number of negative charge carriers. B1

**(f)** A semiconducting material's resistance decreases as temperature increases. This is because the number density of charge carriers increase when temperature increases.
In metals, the number density of charge carriers does not increase with temperature. Instead the frequency of the electron-lattice collisions increase and this leads to an increase in resistance of the metal with increase temperature. B1


6.3
6.1
5.9
5.7
5.5
5.3
5.1
4.9
4.7
ln (R / Ω)
2.0
2.1
2.2
2.3
2.4
2.5
2.6
T⁻¹ / 10⁻³ K⁻¹
(2.510 × 10⁻³, 6.14)
(2.220 × 10⁻³, 4.88)

**Paper 3 Structured Questions**

**1** **(a)** Work done per unit mass (by an external force) in bringing a small test mass from infinity to that point. [1]

**(b)** Conservation of mechanical energy:

$$KE_i + GPE_i = KE_f + GPE_f$$

$$\frac{1}{2}m(0)^2 + \left(-\frac{GMm}{\infty}\right) = \frac{1}{2}mv^2 + \left(-\frac{GMm}{R}\right)$$ [1]

$$0 + 0 = \frac{1}{2}v^2 + \left(-\frac{GM}{R}\right)$$

$$\Rightarrow v = \sqrt{\frac{2GM}{R}}$$ [1]

$$= \sqrt{\frac{2\left(6.67\times10^{-11}\right)\left(6.4\times10^{23}\right)}{3.4\times10^{6}}} = 5011 \approx 5.0\times10^{3}\ \text{m s}^{-1}$$

**(c)** **(i)** mean kinetic energy of a molecule of an ideal gas is proportional to the thermodynamic temperature:

$$\langle KE\rangle = \frac{3}{2}kT \Rightarrow \frac{1}{2}mv_{\text{r.m.s.}}^2 = \frac{3}{2}kT$$ [1]

$$\Rightarrow T = \frac{mv_{\text{r.m.s.}}^2}{3k} = \frac{\left(4\times1.66\times10^{-27}\right)\left(5.0\times10^{3}\right)^2}{3\left(1.38\times10^{-23}\right)} = 4.0\times10^{3}\ \text{K}$$ [1]

**(ii)** Mars is further away from the Sun; the temperature on Mars is much smaller than 4000 K. [1]

The r.m.s. speeds of He-4 gas atoms at the temperatures on Mars is therefore much smaller than the escape speed, so He-4 gas is found on the surface of Mars. [1]

**2** **(a)** **(i)** $P_R = I^2R$ [1]

$$9.0 = I^2(4.0)$$

$$I = \sqrt{\frac{9.0}{4.0}} = 1.5\ \text{A}$$ [1]

**(ii)** $P_T = IE$ [1]

$$13.5 = (1.5)E$$

$$E = \frac{13.5}{1.5} = 9.0\ \text{V}$$ [1]

**(b)** **(i)** Rate at which electrical energy is dissipated in the internal resistance of the battery. [1]

**(ii)** $(P_T - P_R) = I^2 r$

at $R = 4.0\ \Omega$, we have

$13.5 - 9.0 = 1.5^2 r$ [1]

$\Rightarrow r = \dfrac{4.5}{1.5^2} = 2.0\ \Omega$ [1]

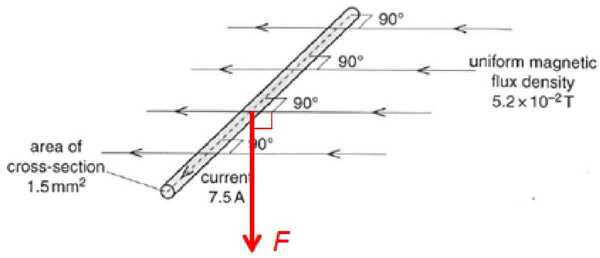
**(c) (i)** $2.0\ \Omega$ [1]

**(ii)** $\eta = \dfrac{P_R}{P_T} = \dfrac{10.0}{20.0} = 0.5 = 50\%$ [1]

**(iii)** The efficiency $\eta$ of power transfer would increase when R increases from $4\ \Omega$ to $10\ \Omega$ [1]

Note: $\eta = \dfrac{P_R}{P_T} = \dfrac{IR}{I(R+r)} = \dfrac{R}{R+r}$, so $\eta$ tends to 1 as $R$ becomes larger.

**3 (a) (i)**




[1]

A ruler should be used to draw straight lines, to improve accuracy.

**(ii)** $\dfrac{F}{L} = BI$ [1]

$= (5.2\times10^{-2})(7.5)$

$= 0.39\ \text{N m}^{-1}$ [1]

**(b) (i)** Force per unit length on the wire:

$\dfrac{F}{L} = 0.39\ \text{N m}^{-1}$ (1)

Number of free electrons per unit length of the wire is

$\dfrac{N}{L} = \dfrac{N}{V}A = (7.8\times10^{28}\ \text{m}^{-3})(1.5\times10^{-6}\ \text{m}^2) = 1.17\times10^{23}\ \text{m}^{-1}$ (2) [1]

The magnitude of the force on each free electron is $\dfrac{F}{N}$, obtainable by the ratio of equations (1) and (2): [1]

$\dfrac{(1)}{(2)} \Rightarrow \dfrac{F}{N} = \dfrac{0.39}{1.17\times10^{23}} = 3.3\times10^{-24}\ \text{N}$

**(ii)** $F_1 = Bev$ [1]

$\Rightarrow v = \dfrac{F_1}{eB} = \dfrac{3.3\times10^{-24}\ \text{N}}{(1.60\times10^{-19}\ \text{C})(5.2\times10^{-2}\ \text{T})} = 4.0\times10^{-4}\ \text{m s}^{-1}$ [1]

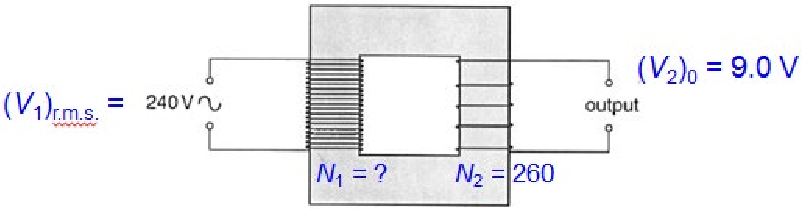
$\{\text{speed} = 4.0\times10^{-4}\ \text{m s}^{-1} = 0.40\ \text{mm s}^{-1} < 1\ \text{mm s}^{-1}\}$

**(c)** The electric field is set up in the wire with a speed approaching the speed of light, and electrons along the whole circuit start to move at nearly the same time. [1]
The time that it takes any individual electron to get from the switch to the lamp isn't really relevant. [1]

{A good analogy is a group of soldiers standing at attention when the sergeant orders them to start marching; the order reaches the soldiers' ears at the speed of sound, which much faster than their marching speed, so all the soldiers start to march essentially in unison.}

**4** **(a)** The e.m.f. induced in a circuit is directly proportional to the rate of change of the magnetic flux linkage of the circuit. [2]

**(b)** **(i)**




$$\frac{(V_2)_0}{(V_1)_0} = \frac{N_2}{N_1}$$

$$\Rightarrow \frac{(V_2)_0}{\sqrt{2}\,(V_1)_{\text{r.m.s.}}} = \frac{N_2}{N_1} \Rightarrow \frac{9.0}{\sqrt{2}\,(240)} = \frac{260}{N_1}$$ [1]

$$\therefore N_1 = 260\left(\frac{\sqrt{2}\,(240)}{9.0}\right) = 9805$$ [1]

So $N_1$ = 9800 (to 2 s.f.) or 9810 (to 3 s.f.) [1]

**(ii)** The induced emf across the primary coil, $V_p$, is in phase with the input p.d. $V_{in}$ if the transformer is ideal. The current flowing in the primary coil varies sinusoidally producing a magnetic field that varies sinusoidally and in phase. This changing magnetic field causes a changing magnetic flux linkage in both the primary and the secondary coils and hence inducing emf's in both. [1]
If $B = B_o \sin\omega t$, [1]

$$V_p \propto \frac{dB}{dt} \propto \cos\omega t, \qquad V_s \propto \frac{dB}{dt} \propto \cos\omega t$$ [1]

Hence $V_p$ and $V_s$ are in phase, which means that $V_s$ and $V_{in}$ are in phase.

**5** **(a)** **(i)**

$$E = hf = h\frac{c}{\lambda}$$ [1]

$$\lambda = \frac{hc}{E} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{4.53\times10^{-14}} = 4.39\times10^{-12}\ \text{m}$$ [1]

**(ii)**

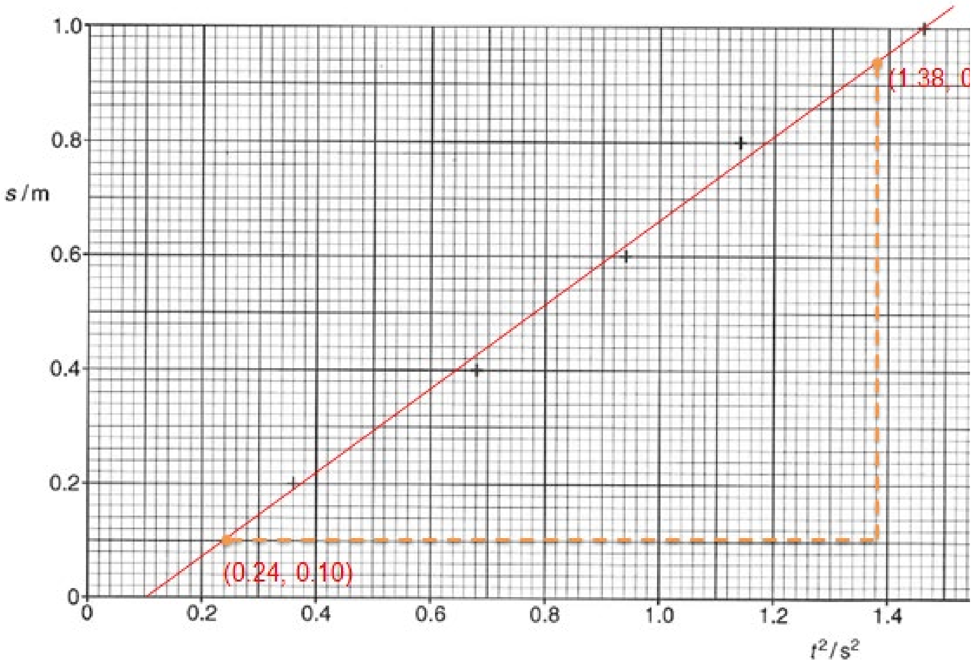
$$p_\gamma = \frac{h}{\lambda}$$ [1]

$$= \frac{6.63\times10^{-34}}{4.39\times10^{-12}} = 1.51\times10^{-22}\ \text{kg m s}^{-1}$$ [1]

**(b)** Since the arsenic-74 nucleus is at rest before the decay, total initial momentum is zero. [1]

By conservation of momentum, the nucleus must carry a momentum equal and opposite to that of the gamma ray photon so that the total momentum is still zero after the decay. [1]

**6 (a) (i)**




Line of best-fit

Since $s = \left(\frac{1}{2}a\right)t^2$, gradient of the graph = $\frac{1}{2}a$ [1] [1]

$$\text{gradient} = \frac{(0.94)-(0.10)}{(1.38)-(0.24)} = \frac{0.84}{1.14} = 0.74$$ [1] [1]

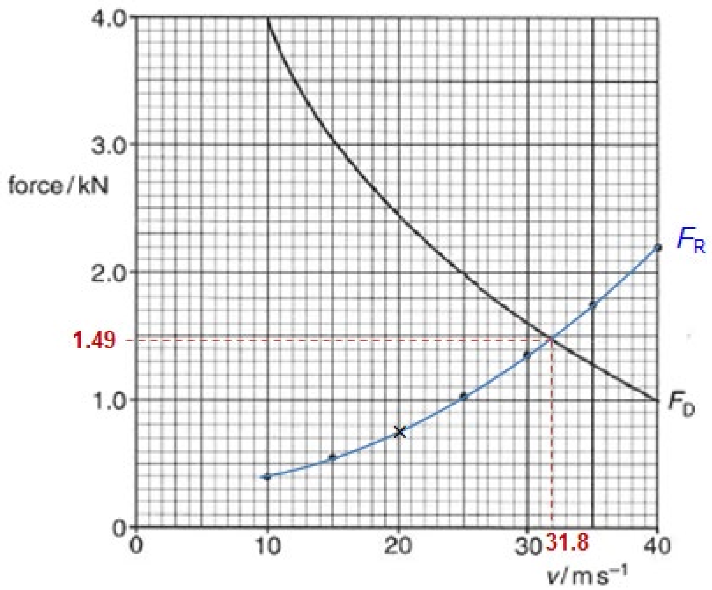
$$\frac{1}{2}a = 0.74 \Rightarrow a = 1.5 \text{ m s}^{-2}$$ [1]

**(ii)**
1. The data points scatter about the line of best-fit. [1]
2. The line of best fit does not pass through the origin. [1]

**(iii)** By drawing the line of best fit, we are akin to taking average, allowing the random errors of the data to offset each other. [1]

**(b) (i)** $F_R = 280 + 1.2(20)^2 = 760 \text{ N}$ [1]

**(ii)**




**(iii)** **1.** If $F_D > F_R$, the car will speed up; if $F_D < F_R$, the car will slow down. [1]

So the car travels with a maximum speed when $F_D = F_R$. [1]

Its maximum speed = 31.8 m s$^{-1}$ [1]

**2.** at $v = 31.8$ m s$^{-1}$, $F_D = F_R = 1500$ N, so

$$P = F_D v$$
$$= (1500)(31.8)$$ [1]
$$= 47700 \text{ W}$$ [1]

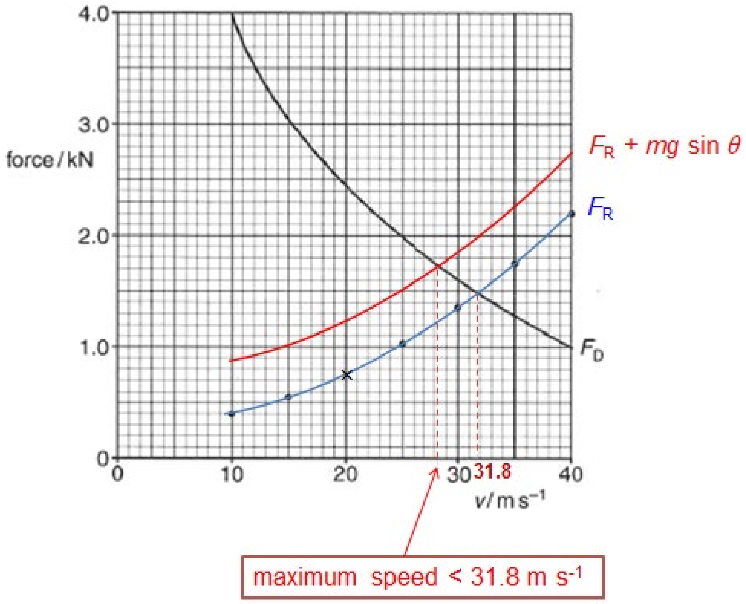
**3.**

$$F_{net} = F_D - F_R$$ [1]
$$F_D - F_R = ma$$
$$(2.45 - 0.76) \times 10^3 = 950a$$ [1]
$$a = 1.78 \text{ m s}^{-2}$$ [1]

**(c)** When the car is travelling up a slope, the component of its weight along the slope <u>($mg \sin \theta$) opposes its motion</u>, in addition to $F_R$. [1]

For constant speed, $F_D$ must be larger than $F_R$, with the difference $F_D - F_R$ equal to $mg\sin\theta$. [1]

From Fig. 6.3, the maximum speed will be lower. [1]




**7** **(a)** The pressure in the fluid increases with depth. The pressure at the bottom of the body is larger than the pressure at the top of the body. [1]
The upward force at the bottom of the body is larger than the downward force at the top of the body. The resultant of these two forces gives rise to the upthrust. [1]

**(b)** The tube with its content floats upright, i.e. the upthrust is balanced by the weight [1]

$\rho g V_{liquid} = mg$ [1]

$V_{liquid}$ is the volume of the liquid displaced by the tube: $V_{liquid} = Ah$

$\therefore \rho g(Ah) = mg \Rightarrow m = \rho Ah$ [1]

**(c)** **(i)** The expression can be written as $a = -(k)x$,
where $k = (\rho Ag/m)$, is a <u>positive</u> constant. [1]
It shows that

- the acceleration $a$ of the tube is <u>directly proportional to the displacement</u> $x$ ($k$ is the proportionality constant), and [1]
- the <u>acceleration is in opposite direction to the displacement</u> (due to the negative sign) [1]

**(ii)** The defining equation of simple harmonic motion is $a = -\omega^2 x$, where $\omega$ is the angular frequency.

Comparing the given expression $a = -\left(\dfrac{\rho Ag}{m}\right)x$ with $a = -\omega^2 x$, we have [1]

$$\omega^2 = \frac{\rho Ag}{m} \Rightarrow \omega = \sqrt{\frac{\rho Ag}{m}}$$ [1]

$$f = \frac{1}{2\pi}\sqrt{\frac{\rho Ag}{m}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{(1.0\times10^{3}\ \text{kg m}^{-3})(4.2\times10^{-4}\ \text{m}^{2})(9.81\ \text{m s}^{-2})}{(32\times10^{-3}\ \text{kg})}}$$ [1]

$$= 1.8\ \text{Hz}$$

**(d) (i) 1.**

$$T = \frac{1.50}{3} = 0.500\ \text{s}$$ [1]

$$f = \frac{1}{T}$$ [1]

$$= \frac{1}{0.500\ \text{s}} = 2.00\ \text{Hz}$$

**2.**

$$f = \frac{1}{2\pi}\sqrt{\frac{\rho A g}{m}}$$

$$\Rightarrow f \propto \sqrt{\rho}$$ [1]

$$\Rightarrow \frac{f_{liquid}}{f_{water}} = \sqrt{\frac{\rho_{liquid}}{\rho_{water}}} \Rightarrow \frac{2.00}{1.8} = \sqrt{\frac{\rho_{liquid}}{1.0\times10^3}} \Rightarrow \rho_{liquid} = 1.2\times10^3\ \text{kg m}^{-3}$$ [1]

**(ii) 1.** 1. Viscous forces due to the liquid act on the tube causes the tube to lose energy gradually. [1]

2. The tube is constantly displacing fluid along the path of its oscillation, hence losing energy in the form of kinetic energy of the fluid displaced. [1]

**2.** The amplitude decreases from 1.50 cm to 0.85 cm from 0 s to 1.0(

The speed (and kinetic energy) is zero at both 0 s and 1.00 s.

Decrease in total energy during the first 1.00 s

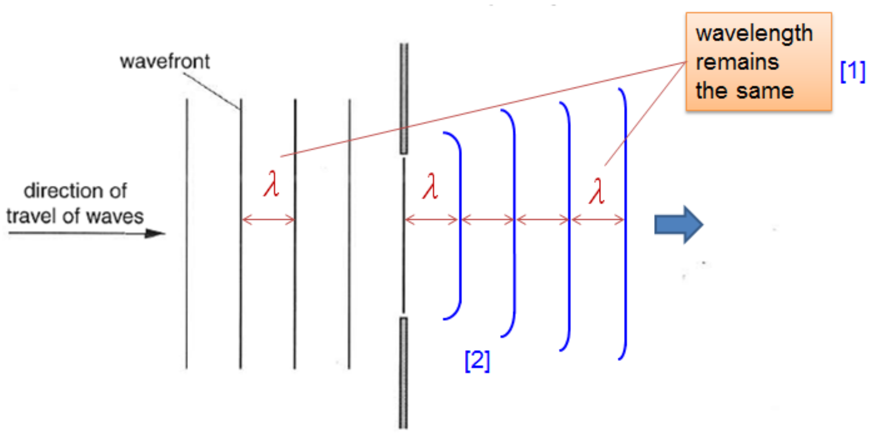
$$= \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$$ [1]

$$= \frac{1}{2}m\omega^2\left(x_i^2 - x_f^2\right)$$ [1]

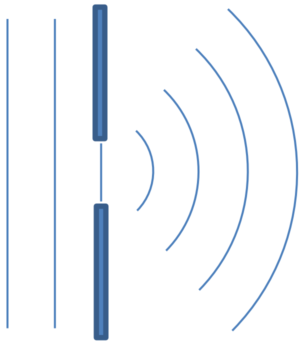
$$= \frac{1}{2}(0.032)(2\pi(2.00))^2\left(0.0150^2 - 0.0085^2\right)$$

$$= 3.86\times10^{-4}\ \text{J}$$ [1]

**8 (a) (i)**



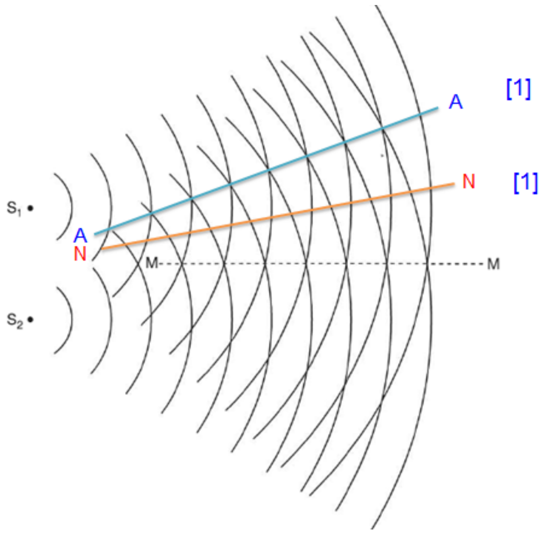
**(ii)** The spreading becomes more pronounced, ie larger angle of diffraction. The wavefront becomes more circular.



**(b)** **(i)** Coherent sources emit waves that have a constant phase difference. [1]

[1]

**(ii)**




**(c)** **(i)** [1]

$$\lambda = \frac{ax}{D}$$

$$= \frac{(0.00120 \text{ m})(0.0013 \text{ m})}{2.47 \text{ m}}$$ [1]

$$= 6.31579 \times 10^{-7} \text{ m}$$

$$= 6.3 \times 10^{-7} \text{ m}$$ [1]

Answer to 2 sf

[1]

**(ii)** $\lambda = \frac{ax}{D}$ is valid only if $D$ is much greater than $a$. [1]

**(iii)** **1.** Since the amplitude of two arriving waves are now different: [1]

- bright fringes are less bright (resultant amplitude there is lower)
- dark fringes are not completely dark (resultant amplitude there is not zero)

[1]

Contrast of the fringe pattern is reduced.

**2.** Bright fringes are less bright due to less light passing through each slit. [1]

More fringes are seen as the light from both slits are diffracted more, producing larger degree of overlapping of light on the screen. [1]

**3.** For the part of the screen nearer to the slits, the fringe separation is smaller. [1]
For the part of the screen further from the slits, the fringe separation is larger. [1]