9749 H2 Physics
2018 GCE A-Level Suggested Solutions

Paper 1

1 **A**

$$T^2 = 4\pi^2 \frac{L}{g}$$

$$g = \frac{4\pi^2 L}{T^2}$$

$$\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T}$$

$$\frac{\Delta T}{T} \times 100\% = \frac{\left(\frac{\Delta g}{g} - \frac{\Delta L}{L}\right) \times 100\%}{2} = \frac{\left(\frac{2}{100} - \frac{0.05}{6.25}\right) \times 100\%}{2} = 0.6\%$$

2 **A** Let s be displacement and x be distance:

For object P:

$s_p = \frac{1}{2} t_2 v$ and $x_p = \frac{1}{2} t_2 v$

For object Q:

By symmetry, $s_Q = 0$ and

$$x_Q = \text{area under graph} = 2(\frac{1}{2})(\frac{t_1}{2} \times \frac{v}{2}) + 2(\frac{1}{2})(\frac{t_2 - t_1}{2} \times \frac{v}{2}) = \frac{t_2 v}{4}$$

3 **B**

$$\begin{aligned} \text{Impulse} = \text{change in momentum} &= \Delta p \\ &= m\ (v_f - v_i) \\ &= 0.080(18 - (-23)) \\ &= 3.3\ \text{Ns} \end{aligned}$$

4 **C** Since trolleys stick together after collision, collision is completely inelastic. Momentum is conserved and velocities of both trolleys are the same after collision. Taking right as positive

$$\begin{aligned} \text{Initial momentum} &= \text{Final momentum} \\ m_1 u_1 + m_2 u &= (m_1 + m_2) v \\ 5.0(4.0) + (2.0)(-3.0) &= (5.0 + 2.0) v \\ 14 &= 7.0 v \\ v &= 2.0\ \text{ms}^{-1} \end{aligned}$$

$\Rightarrow p_i = 14$ Ns and $v = 2.0\ \text{ms}^{-1}$

5 **A** Since the broom is balanced at O, the CG of the broom is 1.05 m from end of X.

Let m be the mass of the broom,

Since the broom is in balance again,

$$\sum \tau = 0$$
$$0.200(1.05 - 0.10 - 0.27) = m(0.27)$$
$$\Rightarrow m = 0.504 \text{ g}$$

6 **A** Without the barge:
Weight supported by bridge $= W_{water}$

With the barge:
Weight supported by bridge
$= W_{water} + W_{barge} - W_{waterdisplaced}$

Since the barge is floating: $W_{barge} = W_{waterdisplaced}$
$\Rightarrow$ Weight supported by bridge $= W_{water}$

$\therefore$ There is no extra weight supported by the bridge

7 **C**

$$P \propto Fv \propto kv^3$$
$$\frac{P_2}{P_1} = \left(\frac{v_2}{v_1}\right)^3$$
$$P_2 = \left(\frac{40}{20}\right)^3 = 184 \text{ kW}$$

8 **B** Conventional current flows from a higher electric potential to lower electric potential. S is at a lower electric potential than R. An electron has a negative charge and has a higher electric potential energy at S (less negative).

Point S is lower than point R. Sine GPE = mgh, GPE at S is lower than at R (independent of charge).

9 **D** Both P and Q are on the same rotating disc => angular velocity is the same for P and Q.

Angular displacement θ is the same for both.

10 **A** When the stone is vertically above the centre of the circle:
Taking downwards as positive:

$$T + W = Mr\omega^2$$
$$T = Mr\omega^2 - W$$

11 **C** A: Free falling of object. No need rockets
B: Gravitational force provides for centripetal force (object moves in circular path)
D: initial momentum can provide it with enough energy to travel directly outwards from surface of the earth.

C: The rockets need to keep firing for spacecraft to follow a straight line, if not gravitational force will cause it change direction and take on a circular/spiraling path towards earth.

12 **D**

$$PV = nRT$$

$$\frac{1}{P} = \frac{1}{nRT}V$$

Since gradient, $g \propto \frac{1}{nT}$

$$g_{new} = \frac{1}{4}g_{old}$$

13 **D** X: $Q_{net} < 0$ i.e. $T_{x,initial} < 30°C$
Y: $Q_{net} = 0$ i.e. Y is at thermal equilibrium with its surrounding $T_{y,initial} = 30°C$
Z: $Q_{net} > 0$ i.e. $T_{z,initial} > 30°C$

14 **C**

$$\sum U = 0$$

$$U_{12} + U_{21} = 0$$

$$Q_{12} - W_{bysystem12} + Q_{21} - W_{bysystem21} = 0$$

$$W_{bysystem21} = 2800 - 600 + 1000 = 3200 \text{ kJ}$$

15 **D** A: Peak-peak value is 70 cm
B: KE_{max} occurs when velocity is max. i.e. $t = T/4$
C: Restoring force is proportional to acceleration. i.e. a is maximum at the amplitudes.
D: The gradient of the x-t graph gives the instantaneous velocity and is a maximum at $t = T/4$

16 **C**

$$I \propto A^2, \ \lambda \propto \frac{1}{f}$$

Let wave Y have amplitude A and frequencey f

$$I_X = \left(\frac{2A}{A}\right)^2 I_Y = 4I_Y$$

$$\lambda_X = \left(\frac{\frac{1}{2f}}{\frac{1}{f}}\right)\lambda_Y = \frac{1}{2}\lambda_Y$$

17 **D**

Fringe separation, $\Delta x = \dfrac{\lambda D}{d} \;\Rightarrow\; \Delta x \propto \lambda$

$\dfrac{\Delta x_2}{\Delta x_1} = \dfrac{\lambda_2}{\lambda_1}$

$\Delta x_2 = \dfrac{600}{450}(2.4) = 3.2$ mm

Note: $\Delta x_1 = 2(1.2) = 2.4$ mm

18 **C**

Distance from end of tube to the first node = 0.17 m.
L = λ_1 = 0.68 m

The next time a node is detected at the same position, (by sketching waveform)
0.17 m = $3\lambda_2/4$. Hence L = 0.68 = $3\lambda_2$
v = $f\lambda_2$
340 = f (0.68/3)
f = 1500 Hz

19 **C**

Definition: The **electric field strength** at a point is defined as the electric force exerted per unit positive charge placed at that point

20 **A**

$E = -\dfrac{dV}{dx}$. When the distance between two equipotential lines are larger, the electric field strength is smaller and vice versa. As the objects are of opposite charges, the electric field strength is always towards the right.

21 **A**

$P = I^2 R = I^2 \dfrac{\rho L}{A}$

$\rho = \dfrac{PA}{I^2 L} = \dfrac{(400\times10^{-3})(1.2\times10^{-3})(1.5\times10^{-2})}{(40\times10^{-3})^2(1.8\times10^{-2})} = 0.25\ \Omega$ m

22 **A**

Since cells are in parallel,
$V = 3\times1.5 = 4.5$ V

$r_{eq} = \left(\dfrac{1}{3r} + \dfrac{1}{3r}\right)^{-1} = 0.3\ \Omega$

23 **D**

$R_{Total} = \dfrac{V}{I} = \dfrac{6.0}{0.5} = 12\ \Omega$

$\mathrm{R_{eq}} = 12 - (1.0 + 9.0) = 2.0\ \Omega$

$\dfrac{1}{\mathrm{R_{eq}}} = \dfrac{1}{6} + \dfrac{1}{R}$

$R = 3.0\ \Omega$

$V_{6.0\Omega} = \dfrac{2}{12}(6.0) = 1.0\ \Omega$

$I = \dfrac{1.0}{3.0} = 0.33$ A

24 A Since the square coil is in equilibrium, $\sum \tau = 0$

$$W \times \frac{L}{2} \sin 30° = F_B L \cos 30°$$
$$F_B = \frac{W \tan 30°}{2}$$
$$NBIL = \frac{W \tan 30°}{2}$$
$$B = \frac{W \tan 30°}{2NIL}$$
$$= \frac{0.12 \tan 30°}{2(50)(0.40)(60 \times 10^{-3})}$$
$$= 0.029 \text{ T}$$

25 A When the bar magnet approaches the coil, magnetic flux linkage increases. Since there is a rate of change of magnetic flux linkage, there is induced emf. By Lenz's law, the induced current flows in the direction to set up a magnetic field to oppose the increase in flux linkage. When the bar magnet is within the long coil of wire, there is no rate of change of magnetic flux linkage hence there is no induced emf and the object continues to accelerate. When the bar magnet leaves the coil (now at a higher speed), magnetic flux linkage decreases. By Lenz's law, the induced current will now flow in the opposite direction to set up a magnetic field to oppose the decrease in flux linkage.

26 A The magnetic flux density of a solenoid = $\mu_0 n I$

$$B_P = B_Q \Rightarrow \mu_0 n_P I = \mu_0 n_Q I$$

27 C

$$\langle P \rangle_{rectified} = \frac{\langle P \rangle}{2} = \frac{P_0}{4}$$
$$\langle P \rangle_{rectified}$$
$$= \frac{I_0^2 R}{4}$$
$$= \frac{(7.6)^2 (9.4)}{4}$$
$$= 140 \text{ W}$$

28 A

$$\Delta E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} (3 \times 10^{8})}{(633 \times 10^{-9})} = 1.96 \text{ eV}$$
$$\Delta E_{W \to X} = 20.66 - 18.70 = 1.96 \text{ eV}$$

29 C Standard Nuclear Notation: ${}^{\text{Mass No}}_{\text{Atomic No}}X$

30 **B**

$A = \lambda N$ and $t_{1/2} = \dfrac{\ln 2}{\lambda}$ i.e. $t_{1/2} \propto \dfrac{1}{\lambda}$

$$\frac{t_{1/2,\,X}}{t_{1/2,\,Y}} = \frac{\lambda_Y}{\lambda_X} = \frac{\dfrac{A_Y}{N_Y}}{\dfrac{A_X}{N_X}} = \frac{A_Y}{N_Y}\left(\frac{N_X}{A_X}\right) = \frac{(4.60\times10^{7})(4.00\times10^{19})}{(2.00\times10^{19})(3.68\times10^{8})} = 0.250$$

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Paper 2

1 **(a)** The principle of moments states that, for a body to be in rotational equilibrium, the sum of the clockwise moments about any point must equal the sum of the anticlockwise moments about that same point. [1]

(b) **(i)** Since C.G. is nearer support A, the tension at support A is greater than that in support B, i.e., $T_A = \frac{7}{3}T_B$.

Since $T_A + T_B = mg$, we have

$$\tfrac{7}{3}T_B + T_B = \tfrac{10}{3}T_B = mg$$

So $T_B = \frac{3}{10}mg = \frac{3}{10} \times 4.5 \times 9.81 = 13\text{ N}$ (2 s.f.) [1]

and $T_A = \frac{7}{3}T_B = 31\text{ N}$ (2 s.f.) [1]

(ii) Taking moments about support A,

$$mg \times (d - 0.20) = T_B \times 0.60$$ [1]

$$d = \frac{T_B \times 0.60}{mg} + 0.20 = \tfrac{3}{10} \times 0.60 + 0.20 = 0.38\text{ m (2 s.f.)}$$ [1]

(c) The horizontal component of the force exerted by each support is to balance the horizontal force exerted by the wind on the sign so as to maintain equilibrium. [1]

2 **(a)** Hooke's Law states that the extension of a body is proportional to the applied load, provided the proportionality limit is not exceeded. [1]

(b) For a compression of 85 mm,

Elastic potential energy stored in spring $=$ Area under graph

$$= \frac{1}{2}(0.085)(6.8)$$ [1]

$$= 0.289\text{ J}$$ [1]

(c) By the principle of conservation of energy,

Loss in EPE of spring $=$ Gain in GPE of ball $+$ Gain in KE of ball [1]

$$0.289 = (0.042)(9.81)(0.40) + \frac{1}{2}(0.042)v^2$$ [1]

$$v = 2.43\text{ m s}^{-1}$$ [1]

(d) **(i)** For the ball to move in the circular track, at P, <u>the weight of the ball and normal contact force on the ball provides for the centripetal force</u>. [1]

$$N + mg = F_C \quad \Rightarrow \quad F_C - mg = N$$

In order for the ball not to fall off the track, <u>N must be greater than zero</u>. Therefore, [1]

$$F_C - mg > 0$$
$$F_C > mg$$
$$\frac{mv^2}{r} > mg$$
$$v > \sqrt{rg} \quad [1]$$

Hence, $v_{min} = \sqrt{(0.20)(9.81)} = 1.4 \text{ m s}^{-1}$

(ii) v_{min} depends only on the radius of the circular arc and magnitude of g. Hence, it remains unchanged when a ball of larger mass is used [1]

3 (a) Diffraction is the spreading of waves after passing through an aperture or round an obstacle. [1]

(b) Slit width = 12×10^{-6} m

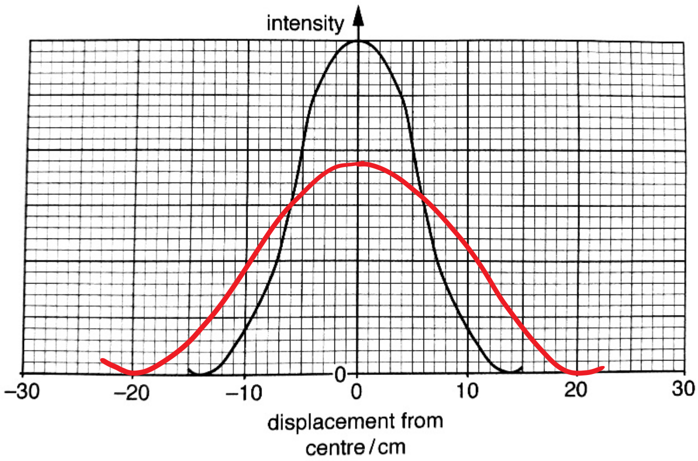
$$\sin\theta = \frac{\lambda}{(12 \times 10^{-6})} \quad [1]$$

For small angles, $\sin\theta \approx \tan\theta$.

From the graph, distance of first minima to central axis = 14 cm. Hence,

$$\tan\theta = \frac{\lambda}{(12 \times 10^{-6})}$$
$$\frac{14 \times 10^{-2}}{2.7} = \frac{\lambda}{(12 \times 10^{-6})} \quad [1]$$
$$\lambda = 6.22 \times 10^{-7} \text{ m} \quad [1]$$

(c)



[1]
[1]

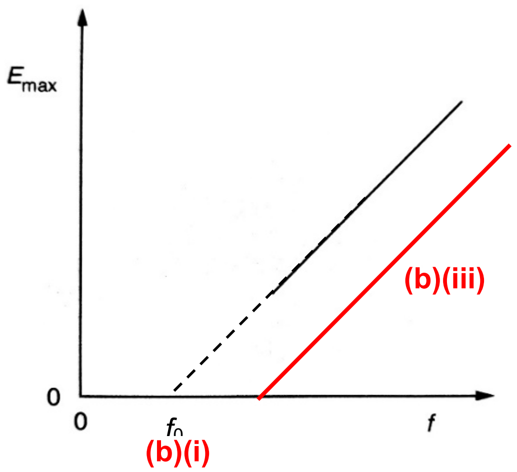
Lower intensity
Larger central width

(d) **(i)** The central bright fringe (or central maximum) becomes wider. [1]
The position of the first minimum on either side of a single-slit diffraction pattern is determined by the equation $\sin\theta = \dfrac{\lambda}{\text{slit width}}$.
A longer wavelength would mean that the first minimum occurs at a larger angle of deviation θ away from the central axis (or center of the diffraction pattern). [1]

(ii) White light is made up of a range of wavelengths and the human eye perceives seven colors in this range of wavelengths. The single-slit diffraction pattern depends on wavelength λ and slit width d by the equation $\sin\theta = \dfrac{\lambda}{d}$. This shows that the spreading increases with wavelength. Violet/blue light spreads the least and red light spreads the most. Since each wavelength forms a pattern centered at the same point on the screen, the different colors will overlap at the center of the screen and this is seen as white light. As one moves away from the center, violet/blue light will be seen first, followed by the other colors and lastly red. This explains why the edges of the central maximum are colored. [1] [1]

4 **(a)** In the photoelectric effect, electrons from the surface of a metal will be released only when electromagnetic radiation of a frequency above a certain minimum value, known as the threshold frequency, is incident on its surface. [1]

(b) **(i)**



[1]

[1]

(ii) The gradient is the Planck constant h. [1]

(c) **(i)** $\frac{hc}{\lambda} = \phi + \frac{1}{2}mv_{max}{}^2$ [1]

$$v_{max} = \sqrt{2\left[\frac{(hc/\lambda)-\phi}{m}\right]}$$ [1]

$$= \sqrt{2\left[\frac{\left((6.63\times10^{-34})(3.0\times10^{8})/(490\times10^{-9})\right)-(2.5)(1.6\times10^{-19})}{(9.11\times10^{-31})}\right]}$$ [1]

$= 1.14\times10^{5}\ \text{m s}^{-1}$ [1]

(ii) **1.** The frequency of blue light is above the threshold frequency of europium while that of red light is below. Hence, photoemission occurs from the surface of europium and the negative charge on the gold leaf decreases. [1]

2. When light of frequency below threshold frequency (or wavelength above threshold wavelength) is incident on the europium, no photoemission occurs. Hence the position of the gold leaf remains the unchanged. [1]
When light of frequency above threshold frequency (or wavelength below threshold wavelength) is incident on the europium, photoemission occurs, leaving behind more positive charge. Hence the gold leaf will rise even more. [1]

5 **(a)** Mass of 1 copper atom $= \frac{0.0635}{6.02\times10^{23}} = 1.055\times10^{-25}$ kg [1]

Number density of copper atoms $= \frac{8960}{1.055\times10^{-25}} = 8.49\times10^{28}\ \text{m}^{-3}$ [1]

Since copper has 1 charge carrier (conduction electron) per atom, the number density of charge carriers in copper is $8.49\times10^{28}\ \text{m}^{-3}$ [1]

(b) $P = I^2R \quad \Rightarrow I = \sqrt{\frac{P}{R}} = \sqrt{\frac{5.0}{30}} = 0.4082$ A [1]

Cross sectional area, $A = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{0.36\times10^{-3}}{2}\right)^2 = 1.018\times10^{-7}\ \text{m}^2$ [1]

$I = nevA \Rightarrow v = \frac{I}{neA}$ [1]

$$= \frac{0.4082}{(3.4\times10^{28})(1.6\times10^{-19})(1.018\times10^{-7})}$$

$= 7.37\times10^{-4}\ \text{m s}^{-1}$ [1]

(c) The resistance of the wire will be doubled since resistance is proportional to length of wire (for a constant cross sectional area) $R = \rho\frac{L}{A}$. [1]

With the same p.d. applied, the current flowing through the wire would be halved since $I = \dfrac{V}{R}$. [1]

Hence, drift velocity of the electrons will be halved since $v \propto I$ as number density, electron charge, cross sectional area and temperature remain unchanged. [1]

6 (a) (i) Current in Q is the same as current in P. So

$$V_{\text{out}} = IR_{\text{Q}} = 27 \times 10^{-3} \times 90 = 2.4 \text{ V (2 s.f.)}$$ [1]

(ii) From Fig. 6.1,

$$0.027 \times (R_P + 90) = 9.0$$
$$R_P = 243\ \Omega$$ [1]

Equivalent resistance of thermistor in parallel with Q is

$$R_{eq} = \left(\frac{1}{120} + \frac{1}{90}\right)^{-1} = 51.4\ \Omega$$ [1]

Using potential divider rule,

$$V_{\text{out}} = \frac{R_{eq}}{R_{eq} + R_P} \times 9.0 = 1.6 \text{ V}$$ [1]

(iii) Resistance of thermistor decreased with increased temperature.
This results in a lower R_{eq} and total resistance of the circuit. [1]
So current in P increases and p.d. across P is higher. [1]
Therefore, V_{out} decreased. [1]

(b) Angle subtended by resistance wire

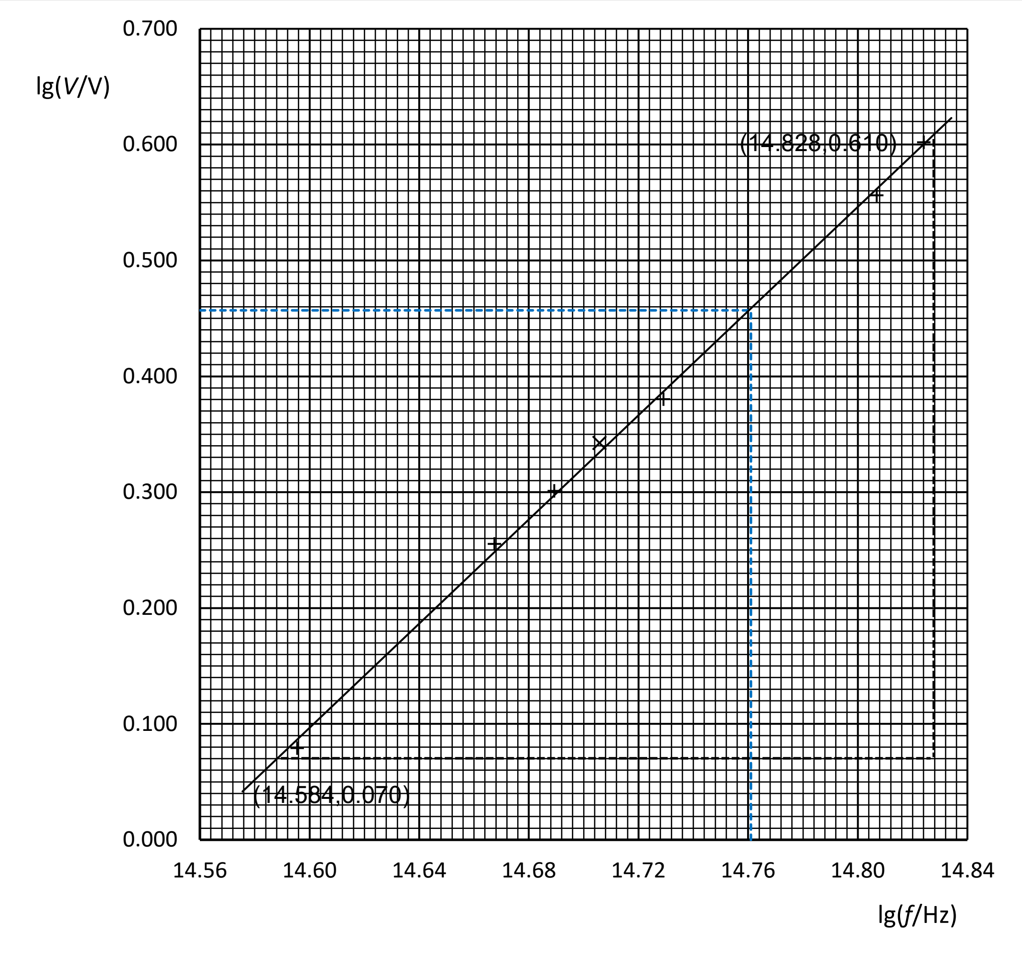
$$\theta_T = \frac{L}{r} = \frac{6.5}{1.2} = 5.42 \text{ rad} = 310^\circ$$ [1]

Since the wire is uniform, the resistance of any segment of the wire is proportional to the angle subtended by that segment. [1]
Using potential divider rule,

$$V_{\text{out}} = \frac{\theta_{\text{AB}}}{\theta_T} \times 9.0 = \frac{92}{310} \times 9.0 = 2.7 \text{ V (2 s.f.)}$$ [1]

7 **(a)** The frequency *f* of the emitted light increases with increasing p.d. *V*. [1]

(b)



(i) Correct plot [1]

(ii) Appropriate line of best fit [1]

(iii) n = gradient $= \dfrac{0.610 - 0.070}{14.828 - 14.584} = \dfrac{0.540}{0.244} = 2.21$ [2]

(c) **(i)** Frequency of light

$$f = \frac{c}{\lambda} = \frac{3.0 \times 10^{8}}{520 \times 10^{-9}} = 5.77 \times 10^{14} \text{ Hz}$$ [1] [1]

$\lg f = 14.761$

From Fig. 7.1, lg $V = 0.455$ [1]
$V = 2.85$ V

(ii)

$$\text{number} = \frac{Pt}{E_{\text{photon}}} = \frac{10 \times 60}{3.8 \times 10^{-19}} = 1.6 \times 10^{21}$$ [2]

(iii) p.d. across series resistor

$V_R = 4.5 - 2.85 = 1.65$ V [1]

$R = \dfrac{V_R}{I} = \dfrac{1.65}{0.020} = 82.5\ \Omega$ (2 s.f.) [1]

(d) The quantity of 730 mAh is the *total charge* available from the power source. [1]
The time and current can vary provided when the product of current and time was calculated, gave 730 mAh = $730 \times 10^{-3} \times 3600 = 2628$ C. [1]

(e) $$\frac{\text{efficiency of LED}}{\text{efficiency of incandescent lamp}} = \frac{800/10}{840/60} = 5.7$$ [2]

(f) **(i)** Cost of operating the bulbs of equivalent brightness for 50k hours is as follow:

LED: $\text{cost} = 0.010 \times 50000 \times 0.22 + 35.95 = \$145.95$

CFL: $\text{cost} = 0.014 \times 50000 \times 0.22 + 5 \times 3.95 = \$173.75$

Incandescent: $\text{cost} = 0.060 \times 50000 \times 0.22 + 42 \times 1.25 = \$712.50$

The total cost of operating LED and CFL are comparable and *much lower* than for incandescent bulb. This is mainly due to the much *higher efficiency of LED and CFL* compared to the incandescent bulb. [1] [1]

(ii) Cost of operating the bulbs of equivalent brightness for 50k hours is as follow:

LED: $\text{cost} = 0.010 \times 50000 \times 0.22 + 35.95 = \$145.95$

CFL: $\text{cost} = 0.014 \times 50000 \times 0.22 + 5 \times 3.95 = \$173.75$

The total cost of operating one traffic light is *slightly lower* using LED. However, since the lifespan of CFL (416 days) is 1/5 that of LED (2083 days or 5.7 years), CFL needs to be *replaced more frequently*. So there is a *higher cost* associated with changing CFL (not reflected in table) compared to LED. [1] [1]
Therefore, it is *recommended* that LTA progressively replaced CFL with LED when the bulbs are due for replacement. [1]

(iii) Incandescent bulbs are inefficient and generates large quantities of heat that could melt the snow on the traffic lights. [1]

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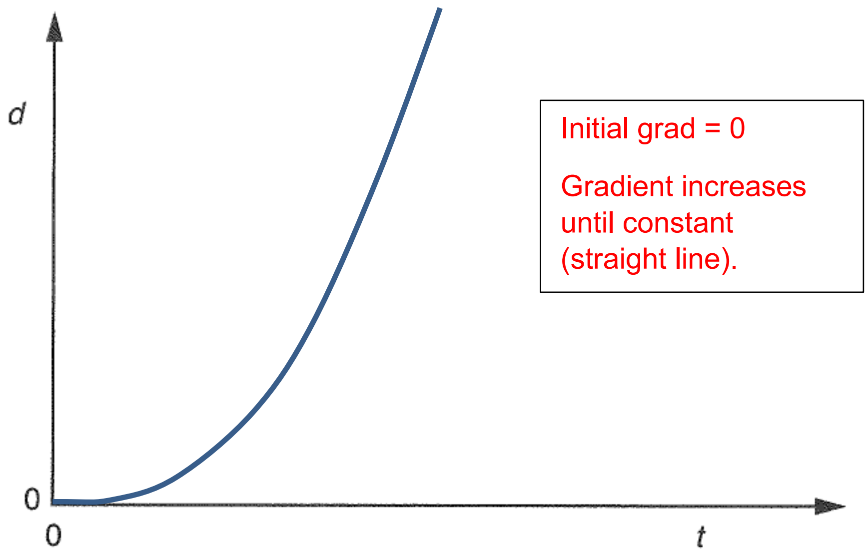
Paper 3 Section A

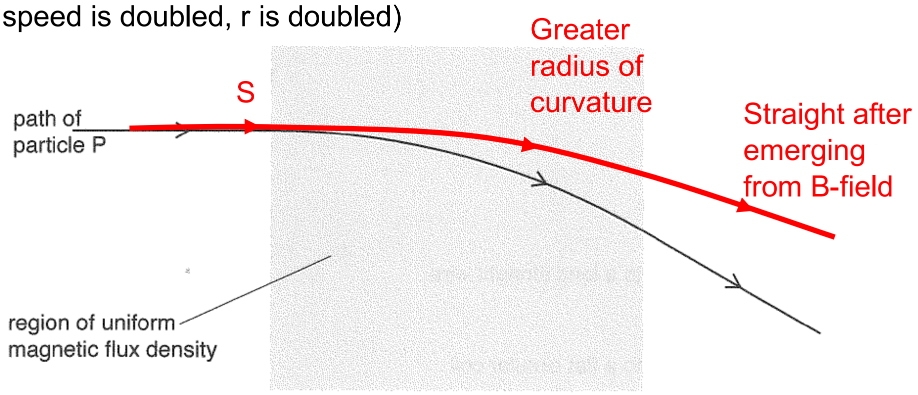
1 **(a)** (Since question mentions “fall through air”, air-resistance should therefore be considered. Question also mentions fall from “tall building”, hence most likely ball will reach terminal velocity.
Gradient of *d*-*t* graph gives speed, hence initial gradient = 0 and increases till constant.)



[1]

[1]

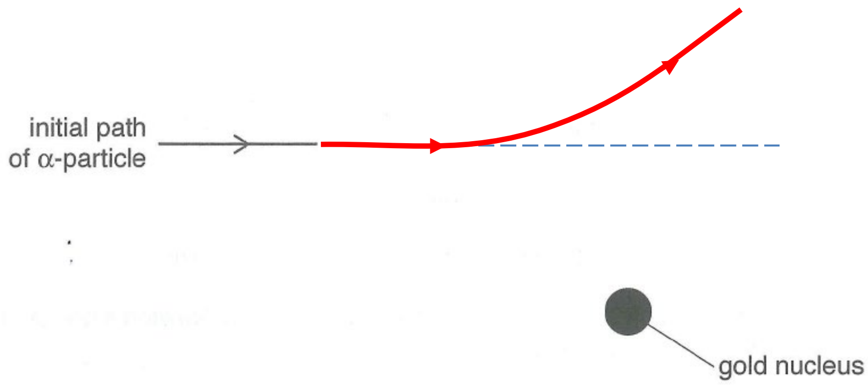
(b) (magnetic force provides for centripetal force
Bqv = m v^2 / r
r = mv / Bq
If speed is doubled, r is doubled)



[1]

[1]

(c)



[1]
[1]

[curved path deviates away from gold nucleus, about 45°)

2 **(a)** A **gravitational field** is a region of space in which a mass placed in that region experiences a gravitational force. [2]

(b) **(i)** The diameters (10^6 and 10^5 km) are very much smaller than the separation of the two stars (10^{13} km), hence they can be considered as point masses. [1]

(ii)
$$F = \frac{GMm}{r^2}$$
$$= \frac{(6.67\times10^{-11})(2.0\times10^{30})(2.4\times10^{29})}{(4.0\times10^{16})^2}$$ [1]
$=2.00 \times 10^{16}$ N [1]
(remember to change km to m)

(c) Since the mass of the Sun is very large, the value of acceleration is small (although the force acting on it is large). In fact, $a = \frac{F}{m} = \frac{2.00\times10^{16}}{2.0\times10^{30}} = 1.0\times10^{-14}$ m s^{-2} which is extremely small. [2]
Hence the force has little effect on its motion.

(Examiners' report seems to indicate the examiners expect numerical value of acceleration to be calculated)

3 **(a)** **(i)**
$$F = q\frac{\Delta V}{d}$$
$$= (3.2\times10^{-19})\frac{900}{3.6\times10^{-2}}$$ [2]
$$= 8.0\times10^{-15}$$
(shown)

(ii) $F = ma$

$$a = \frac{8.0 \times 10^{-15}}{6.6 \times 10^{-27}}$$

$$= 1.21 \times 10^{12} \text{ m s}^{-2}$$ [2]

(b) Consider horizontal motion :

$$0.075 = ut$$
$$= 4.1 \times 10^{5} \times t$$
$$t = 1.83 \times 10^{-7} \text{ s}$$ [1]

Within this time, vertical distance moved is:

$$y = \frac{1}{2}at^2$$
$$= \frac{1}{2} \times 1.2 \times 10^{12} \times \left(1.83 \times 10^{-7}\right)^2$$ [1]
$$= 0.020 \text{ m}$$

This is more than the 1.8 cm between its original path and the lower plate. Hence, the particle will collide with the lower plate. [1]

4 **(a)** **(i)** The **magnetic flux density** of a magnetic field is numerically equal to the force per unit length, [1]
acting on a long straight conductor carrying a unit current [1]
at right angles to a uniform magnetic field. [1]

(ii) The magnetic flux linkage of a coil is the product of the number of turns of the coil, its area, and the magnetic flux density that passes through its area perpendicularly. [2]

(Note: Examiners expect candidates to define magnetic flux rather than just saying flux linkage is the product of magnetic flux and the number of turns)

(b) When the switch is closed, the current in the coil increases from zero to maximum in a very short duration of time.

Hence the magnetic flux density in the coil (due to the flow of current) changes from zero to maximum.

By Faraday's Law, the change of magnetic flux linkage through the aluminum ring in that short duration of time induces an induced e.m.f. and hence an induced current flows in the ring.

The direction of the induced current will be such as to oppose the sudden increase in flux linkage, causing the ring to move away from the coil. [4]

(c) No, the insulator will not move up vertically.
Since the ring is not conducting, there is no induced current in the ring. Hence there will be no opposing magnetic field produced by the ring to repel the ring upwards. [2]

5 **(a)** r.m.s. value of an alternating current has the same value of a steady current that can produce the same average <u>rate</u> of heat dissipation in the same resistive load. [2]
(Note : question requires reference to "heating effect", hence need to modify the definition given in lecture notes in this context.)

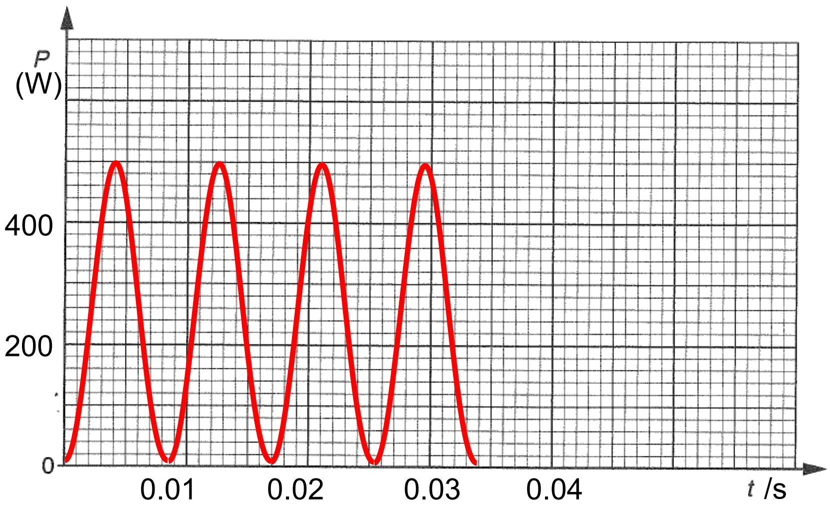
(b) **(i)** Since it is a sinusoidal function,

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120 \text{ V}$$ [1]

(ii) $\omega = 377$
$2\pi f = 377$
$f = 60$ Hz [2]

(iii) $\langle P \rangle = V_{rms}^2 / R$
$= 120^2 / 58$
$= 250$ W [2]

(c) Peak power = 2 $\langle P \rangle$ = 497 W
$T = 1/f = 0.017$ s



[3]

6 **(a)** A photon is a quantum of electromagnetic radiation or energy. [2]
Its energy E is given by $E = h f$
where h : Planck constant and f : frequency of the photon.

(b) **(i)** $E = h f = h c / \lambda$
$= (6.63\times10^{-34})(3.00\times10^{8}) / 680\times10^{-9}$
$= 2.9\times10^{-19}$ J [2]

(ii) $P = IA$

$$P = \frac{NE}{t}$$

Hence $\dfrac{N}{t} = \dfrac{IA}{E}$

$= \dfrac{(3.1\times10^{3})\,\pi(0.6\times10^{-3})^2}{2.9\times10^{-19}}$ [2]

$=1.2\times10^{16}$ s^{-1} (shown)

(c) No. of photons reflected per second $= 0.55\times1.2\times10^{16} = 6.6\times10^{15}$ s^{-1}

No. of photons absorbed per second $= 0.45\times1.2\times10^{16} = 5.4\times10^{15}$ s^{-1}

Momentum of each photon $= \dfrac{h}{\lambda} = \dfrac{6.63\times10^{-34}}{6.8\times10^{-7}} = 9.75\times10^{-28}$ kg m s^{-1}

For the reflected photons, change in momentum per photon $= 2p\cos52^o$

$= 2\times9.75\times10^{-28}\times\cos52^o$

$= 1.2\times10^{-27}$ kg m s^{-1}

Hence, force due to the reflected photons

$= 1.2\times10^{-27}\times6.6\times10^{15}$ [6]

$= 7.92\times10^{-12}$ N

For the absorbed photons, change in momentum per photon $= 9.75\times10^{-28}$ kg m s^{-1}

Hence, normal force due to the absorbed photons

$= 6.00\ \times10^{-28}$kg m s$^{-1}\times5.4\times10^{15}$

$= 3.24\times10^{-12}$ N

Hence total normal force due to the laser

$= 7.92\times10^{-12} + 3.24\times10^{-12}$

$= 1.12\times10^{-11}$ N

7 **(a)** **(i)** The count rate detected from a radioactive decay fluctuates with time. [1]

(ii) The amount of radioactive decay of a radioactive sample is not affected by physical factors such as temperature and pressure. [1]

(b) **(i)** At t = 0, activity = 5.80 × 10^5 s^{-1} [3]

Activity of 2.90 × 10^{-5} s^{-1} occurs at t = 15 days. Hence, half-life is about 15 days.

At t = 5 days, activity = 4.60 × 10^5 s^{-1}

Activity of 2.30 × 10^{-5} s^{-1} occurs at t = 20 days. Hence, half-life is about 15 days.

Hence, the half-life $\frac{15+15}{2} = 15$ days

λ= ln 2 / $T_{1/2}$ = ln 2 / (15×24×60×60) = 5.3×10^{-7} s^{-1}. (shown)

(Note, the examiners say full credit is given only if candidates take more than one measurement of the half-life.

(ii) $A_0 = \lambda N_0$

From graph, $A_0 = 5.8 \times 10^5$

Hence $N_0 = \frac{5.8\times10^5}{5.3\times10^{-7}}$

1 mole has a mass of 32 g

6.02×10^{23} nuclei has a mass of 32 g

Hence N_0 nuclei has a mass of $= \frac{5.8\times10^5}{5.3\times10^{-7}} \times \frac{32}{6.02\times10^{23}}$

$= 5.8 \times 10^{-11}$ g [2]

Section B

8 **(a)** **(i)** The internal energy of a system is the sum of the kinetic energy, due to the random motion of the molecules, and the potential energy, associated with the intermolecular forces of the system. [1]

The internal energy of the system is dependent only on the state of the system. [1]

(ii) $+q$: heat supplied to the system [1]
$+w$: work done on the system [1]

(b) **(i)** An ideal gas is a gas which obeys the equation of state $pV = nRT$ [1] where p is the pressure of the gas, V is the volume of the gas, n is the amount of gas in moles, R is the molar gas constant and T is the thermodynamic temperature of the gas. [1]

(ii) **1.**
$$V = 1.2 \times 10^4 \text{ cm}^3 = 1.2 \times 10^4 \times 10^{-6} = 1.2 \times 10^{-2} \text{ m}^3$$
$$T = 57 \ {}^\circ\text{C} = 57 + 273.15 = 330.15 \text{ K}$$
[1]

$$pV = NkT$$
$$N = \frac{pV}{kT}$$
$$= \frac{(5.4 \times 10^5)(1.2 \times 10^{-2})}{(1.38 \times 10^{-23})(330.15)}$$
[1]
$$= 1.42 \times 10^{24} \text{ molecules}$$
[1]

2.
$$\text{mean K.E., } E_K = \frac{3}{2}kT$$
$$= \frac{3}{2}(1.38 \times 10^{-23})(330.15)$$
[1]
$$= 6.83 \times 10^{-21} \text{ J}$$
[1]

3. Since the potential energy of an ideal gas is zero, the internal energy of the ideal gas is the total kinetic energy of the gas molecules. [1]

$$\text{total internal energy} = \text{mean K.E.} \times \text{no. of molecules}$$
$$= E_K \times N$$
$$= (6.834 \times 10^{-21})(1.422 \times 10^{24})$$
$$= 9717.9$$
$$= 9720 \text{ J}$$
[1]

(c) **(i)** increase in internal energy $= U_{155°C} - U_{57°C}$

$$= \frac{3}{2}NkT_{155°C} - \frac{3}{2}NkT_{57°C}$$

$$= \frac{3}{2}Nk\left(T_{155°C} - T_{57°C}\right) \quad [1]$$

$$= \frac{3}{2}\left(1.422\times10^{24}\right)\left(1.38\times10^{-23}\right)\left(155-57\right) \quad [1]$$

$$= 2884.6692$$

$$= 2880 \text{ J} \quad [1]$$

(ii) **1.** The first law of thermodynamics states that the increase in internal energy of the gas is equal to the sum of the thermal energy supplied to the gas and the work done on the gas. i.e. $\triangle U = Q + W$. [1]

Since $\triangle U = Q$, $\Rightarrow W = 0$

Since there is no work done on the gas, this implies that the volume of the gas is remains constant during the heating process. [1]

2. no. of moles of gas, $n = \dfrac{N}{N_A} = \dfrac{1.422\times10^{24}}{6.02\times10^{23}}$

$$C = \frac{\text{thermal energy supplied}}{n\times\text{increase in temperature}} = \frac{\text{increase in internal energy}}{n\times\text{increase in temperature}} \quad [1]$$

$$C = \frac{2884.6692}{\left(\dfrac{1.422\times10^{24}}{6.02\times10^{23}}\right)\left(155-57\right)}$$

$$= 12.4614$$

$$= 12.5 \text{ J mol}^{-1}\text{ K}^{-1} \quad [1]$$

9 **(a)** **(i)** Simple harmonic motion is the periodic motion of a particle about a fixed point such that its acceleration is proportional to its displacement from the fixed point and is always directed towards the point. [1] [1]

(ii) **1.** The graph shows that the acceleration of the ball is always opposite in sign to its displacement.

This means that when the ball is displaced to the right, it will accelerate to the left; and when it is displaced to the left, it will accelerate to the right. Hence, it will be an oscillatory motion. [1]

2. There is a curvature to the line at larger positive values of x. [1]

(b) **(i)** **1.** The plate is at the highest point of its oscillation, and about to move downwards. [1]

2. $a = -\omega^2 x$

Maximum acceleration occurs at the amplitudes of the oscillation. Sand first loses contact when acceleration of the plate first reaches g = 9.81 m s^{-2} at the amplitude at the top of its oscillation. [1]

$$a_{max} = \omega^2 x_0$$

$$g = (2\pi f)^2 x_0$$

$$x_0 = \frac{g}{(2\pi f)^2}$$

$$= \frac{9.81}{4\pi(13)^2} \quad [1]$$

$$= 1.47 \text{ mm} \quad [1]$$

(ii) From equation in **(i) 2.**, the amplitude is only dependent on the frequency and is independent of the mass of the object. [1]
The minimum amplitude will be unchanged. [1]

(c) (i) 1.

$$E_T = E_{K,max} = \frac{1}{2} m v_{max}{}^2$$

$$= \frac{1}{2} m(\omega x_0)^2$$

$$= \frac{1}{2} m(2\pi f x_0)^2$$

$$= \frac{1}{2}(1.2)(4\pi^2)(2.5)^2(3.4\times10^{-2})^2 \quad [1]$$

$$= 0.1711$$

$$= 0.171 \text{ J} \quad [1]$$

2.

$$E_T = E_K + E_P = 2E_K \quad \text{for } (E_K = E_P)$$

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

$$= 2\left(\frac{1}{2} m(\omega x)^2\right)$$

$$= 2\left(\frac{1}{2} m(2\pi f x)^2\right) \quad , \quad x = d$$

$$= 4m\pi^2 f^2 d^2 \quad [1]$$

$$d = \pm\left(\frac{E_T}{4m\pi^2 f^2}\right)^{1/2}$$

$$= \pm\left(\frac{0.1711}{4(1.2)\pi^2(2.5)^2}\right)^{1/2}$$

$$= \pm 0.02404 \text{ m}$$

$$= \pm 2.40 \text{ cm} \quad [1]$$

(ii) The total energy

$E_T = \frac{1}{2} m v_{max}{}^2 = \frac{1}{2} m\omega^2 x_0{}^2 = 0.1711\ \text{J}$

is constant independent of displacement.

E_K at displacement $x = \frac{1}{2} m v^2 = \frac{1}{2} m\omega^2 (x_0{}^2 - x^2)$

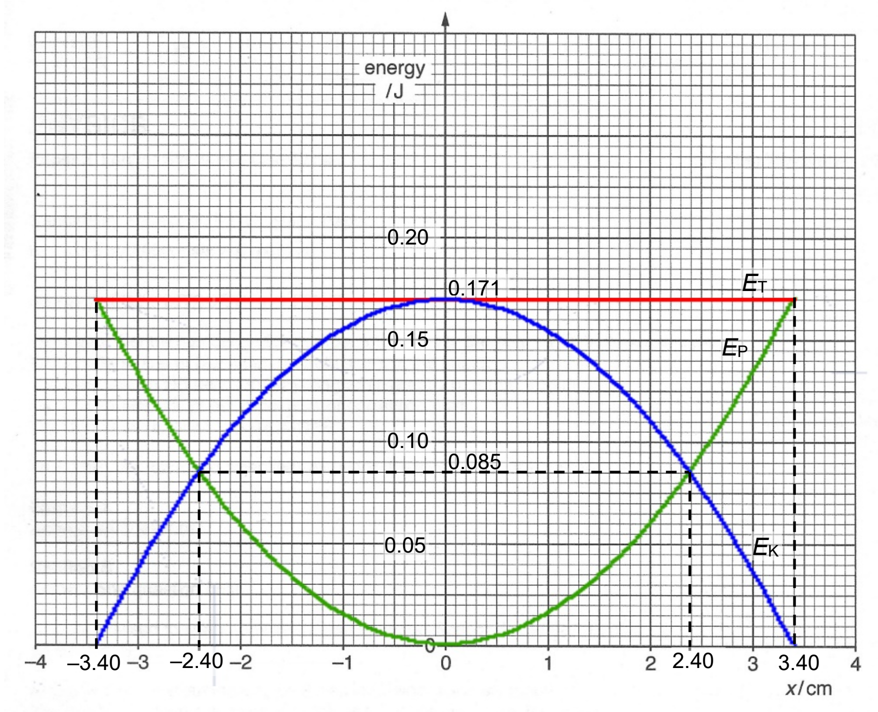
Hence, the kinetic energy is an inverted parabola, with value $E_K = E_T = 0.1711\ \text{J}$ at x = 0 cm (equilibrium position, maximum speed),

$E_K = \frac{1}{2} E_T = \frac{1}{2} \times 0.1711 = 0.0855\ \text{J}$ at $x = \pm 2.40$ cm (from **(c)(i)**),

and E_K = 0 J at x = x_0 = ±3.4 cm (at maximum displacement, speed = 0).

E_P at displacement $x = \frac{1}{2} k x^2 = \frac{1}{2} m\omega^2 x^2$, which is a parabola.

Notice that $E_P = E_T - E_K$.



Correct shape of total energy graph – [1]
Correct shape of kinetic energy graph – [1]
Correct shape of potential energy graph – [1]
Graphs end at the correct amplitude (3.40 cm) – [1]
Correct maximum energy value of each graph – [1]
Kinetic and potential energy graphs intersect at the correct displacement and energy values – [1]