2014 GCE A-Level 9646 H2 Physics Suggested Solutions

Paper 1 Solutions

1 **C** Absolute error presented to 1 sf = 3 m s^{-1}
Quantity presented to same precision as absolute error = 348 m s^{-1}
Speed = (348 ± 3) m s^{-1}

2 **A** 5 μm = 5000 nm (not visible $\Rightarrow$ not B, C)
0.5 μm = 500 nm (visible $\Rightarrow$ A or D)
Radio waves are in the range of cm to m (not D)

3 **A** Gravitational field strength
= initial acceleration
= gradient of graph when object is just released from rest
= 6 m s^{-2}

4 **D** Let total distance travelled be x. Use s = ut + ½ at^2.

For initial 0.25 x:
0.25 x = 0 + ½ (9.81) t^2

For final 0.75 x:
x = 0 + ½ (9.81) $(t + 1)^2$
$\Rightarrow$ 2 (9.81) t^2 = ½ (9.81)$(t^2 + 2t + 1)^2$
$\Rightarrow$ $3t^2 - 2t - 1 = 0$
$\Rightarrow$ t = 1 s

Total = 1 + 1 = 2 s

5 **D** Since system total momentum is non-zero, both spheres cannot be at rest simultaneously in order to conserve momentum.

6 **C** Let the required tension be T. Isolate the wagons 3, 4, 5 and 6 and apply N2L.

$$T - 4f = ma$$

$$T - (4 \times 4000\text{ N}) = 4 \times \left(6.0 \times 10^4\text{ kg}\right) \times \left(0.15\text{ m s}^{-2}\right)$$

$$T = 52\text{ kN}$$

7 **C** Work done in stretching the fibre is given by the area under the force-extension graph. When force is increased from 0 to F, the extension increases, work is done <u>on</u> the fibre, and this work is the area P. When the force is reduced from F to 0, the extension decreases, work is done <u>by</u> the fibre, and this work is the area Q. The net work done <u>on</u> the fibre is therefore (P – Q). Note: if the axes are swapped, work done will be area between graph and vertical axis.

8 **D** When the ball is falling vertically with constant speed v, the resultant force acting on it is zero. Therefore, weight W is balanced by the sum of upthrust U and viscous force kv: $W = U + kv$
Note: if velocity is high, the viscous is kv^2.

9 **C** Let the power developed by the locomotive be P.

If its acceleration is a when travelling at speed v, the equation of motion is

pulling force $\dfrac{P}{v}$ – frictional force $= (\text{mass})a$

$$\Rightarrow \frac{P}{10} - 5.0\times10^{4} = \left(3.0\times10^{5}\right)(0.50)$$

$$\Rightarrow P = 2.0\times10^{6}\ \text{W}$$

The speed reaches a maximum when the acceleration decreases to zero:

$$\frac{P}{v_{\text{max}}} - \text{frictional force} = 0$$

$$\Rightarrow \frac{2.0\times10^{6}}{v_{\text{max}}} = 5.0\times10^{4}$$

$$\therefore v_{\text{max}} = \frac{2.0\times10^{6}}{5.0\times10^{4}} = 40\ \text{m s}^{-1}$$

10 **D** The direction of electric field V/x points from left to right within the parallel plates. The electric force $(q)(V/x)$ acts to the right on the charge having displacement x to the right. The work done by this electric force on the charge is $+[(q)(V/x)]\ (x) = +qV$, causing its kinetic energy to increase by qV. Therefore, its electric potential energy decreases by qV, due to conservation of mechanical energy.

11 **B** A & D are equivalent statements and both are wrong.
If the centripetal acceleration of the astronaut and capsule is the same, their centripetal force may not be the same because they may have different mass.

12 **B** The car tends to lose contact at the top of the lump if it’s speed is too high.
The car just loses contact with the lump if the normal contact N just becomes zero.

Applying N2L to car at top of lump:
$F_c = W – N \Rightarrow mv^2/r = mg – 0 \Rightarrow r = v^2/g = 20^2/9.81 = 41$ m

13 **B** The g-field strength at the mid-point between stars X & Y must be zero since both stars have the same mass and they are equidistant from the line PQ. (B)

As we move away from that mid-point, the vertical component of g due to each star continues to cancel each other, leaving only the horizontal component g_x:
$g_x = –2GM \cos\theta / r^2$, where θ is the angle each g-field makes with the line PQ.

Initially, the horizontal component g_x increases as we move away from the mid-point. But when r is too large, g_x decreases to zero. This explains the rise and fall of option B.

14 **C** Applying N2L, $F_R = ma \Rightarrow F_G = m\,(r\omega^2) \Rightarrow GMm/r^2 = mr\omega^2$
$\Rightarrow M = r^3(2\pi/T)^2/G = (2.95\text{x}10^8)^3\ (2\pi/1.89\text{x}24\text{x}60\text{x}60)^2/(6.67\text{x}10^{-11}) = 5.70\text{x}10^{26}$ kg

15 **A** Definition of shm: $a = –\omega^2x$. Hence, the a-vs-t graph has the same shape as the negative x-vs-t graph.

16 **B** Since the amplitude of the driver is constant, the amplitude of the new graph must be same as graph X at low frequency (B or C).

However, with less damping, the new graph must above graph X at all frequencies. (So, C is wrong.)

17 **A** Whether it is the Celsius or Kelvin scale, the temperature difference between ice and boiling point are both 100 °C or K.

18 **C** $Q = m\,c\,\theta \Rightarrow dQ/dt = m\,c\,d\theta/dt \Rightarrow P = m\,c$ (gradient)
$\Rightarrow c = P / m$ (gradient) $\Rightarrow c \propto$ 1/gradient, since P & m are constant

Since Y has the smallest gradient, it has the largest specific heat capacity c.

Note: Option A is wrong because horizontal portions represent boiling points of the 3 liquids.

19 **A** The total number of gas particles remains constant before and after heating.
$\Rightarrow N_{total,\, i} = N_{total,\, f}$
$\Rightarrow p_{1i} V_{1i} / kT_{1i} + p_{2i} V_{2i} / kT_{2i} = p_{1f} V_{1f} / kT_{1f} + p_{2f} V_{2f} / kT_{2f}$
$\Rightarrow p_{1f} [V_{1i} / T_{1i} + V_{2i} / T_{2i}] = p_{1f} [V_{1f} / T_{1f} + V_{2f} / T_{2f}]$
$\Rightarrow (1.00\text{x}10^5)\ [0.40 + 0.20] / 300 = p_{1f}\ [0.40 / 300 + 0.20 / 600]$
$\Rightarrow p_{1f} = 1.2\text{x}10^5$ Pa

20 **D** Malus law: $I = I_o \cos^2\theta \Rightarrow A = A_o \cos\theta$
From wave theory, we know that $I \propto A^2$.
Hence, $I \propto A_o^2 \cos^2\theta$, where $A_o = a$.

21 **D** Speed of wave = wavelength/period = half-wavelength/half=period = $(x_3\text{-}x_2)/(t_2\text{-}t_1)$

22 **C** Incident waves and reflected waves superpose to produce a stationary wave.

Distance between 2 consecutive nodes (eg 90-30mm) or 2 consecutive antinodes (eg 60-120mm) is equal to half-wavelength. Therefore, λ = 2x60 = 120mm.

23 **B** Applying the double-slit formula, $x = \lambda D/a = (6.0\text{x}10^{-7})(1.50)/(3.0\text{x}10^{-3}) = 0.0003$ m

24 **D** That is how the direction of an electric field is defined.

Note: Electric field strength depends on how close or far apart the field lines are.

25 **A** Do by elimination method – otherwise, there are many lengths, angles & resolutions to deal with.

By symmetry, E-field at S & Q must the same. Hence, options C & D are wrong.

By drawing vectors, E-fields at P & R are in same direction as E-fields at S & Q. So, option B is wrong.

26 **D** $T = 2\pi/\omega$
$I = Q/t = e/T = e\omega/2\pi = (1.60\text{x}10^{-19})(4.1\text{x}10^{16})/(2\pi) = 1.04\text{x}10^{-3}$ A

27 **D** For D, $V_x = (4/6) \times 12 = 8$V.

Options B & C are in reverse bias and hence no current is flowing.

28 **B** In the dark LDR resistance increases. The net resistance of the parallel branch also increases (apply resistors in parallel formula). Therefore, total current I_1 decreases. Since net resistance of the parallel branch increases, pd across the parallel branch also increase, hence driving a higher current.

29 **A** Since the potentials at points X & Y are the same, the potential difference between them is zero and hence no current is driven through the wire.

30 **D** By the principle of conservation of energy, loss in KE = gain in EPE

$\Rightarrow -\Delta KE = \Delta PE = q\,\Delta V$ [since epe = qV]

$\Rightarrow (KE_i - KE_f) = q(E\Delta x)$ [since E=–dV/dx]

$\Rightarrow \frac{1}{2} m (v^2 - v_f^2) = q(Ex)$ [ΔV, and hence Ex, must be positive]

$\Rightarrow v_f^2 = v^2 - 2(2e)Ex/m$ [q = 2e]

$\Rightarrow v_f = \sqrt{(v^2 - 4eEx/m)}$

31 **D** Magnetic flux $\phi = BA$. Hence

$$\text{Unit of } B = \frac{\text{unit of } \phi}{\text{unit of } A} = \text{Wb m}^{-2}$$

32 **C** Magnetic flux density B is independent of the coil position. Hence it remains constant.
Total magnetic flux Φ of the coil is dependent on the number of turns N, the area A of coil and the component of B which is perpendicular to A. Since this component of B is smaller in the new position, Φ decreases.

33 **D**

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P} \Rightarrow \frac{N_P}{600} = \frac{V_P}{9} = \frac{750}{250}$$

$$\therefore N_P = \frac{750}{250} \times 600 = 1800$$

$$\therefore V_P = \frac{750}{250} \times 9 = 27 \text{ V}$$

34 **B** Mean power dissipated is

$$\langle P \rangle = I_{\text{r.m.s.}}^2 R$$

Rearranging,

$$I_{\text{r.m.s.}} = \sqrt{\frac{\langle P \rangle}{R}} = \sqrt{\frac{160}{10}} = 4.0 \text{ A}$$

35 **D** The graphs show the instantaneous power dissipated in the resistor.
Since $P_{instant} = I_{instant}^2 R = (I_o \sin \omega t)^2 R = I_o^2 R \sin^2 \omega t = (\sqrt{2} I)^2 R \sin^2 \omega t = 2 I^2 R \sin^2 \omega t$.

The shape of graphs A & B are wrong because squaring a sinusoidal graph does not produce sharp points at P=0.

36 **C** Wave nature of EM wave: diffraction or interference
Particulate nature of EM wave: photoelectric effect

37 A

$$\Delta E = \frac{hc}{\lambda}$$

$$= \frac{6.63 \times 10^{\ 34} \times 3.0 \times 10^{8}}{633 \times 10^{\ 9}}$$

$$= 3.14 \times 10^{\ 19}$$

$$= 1.96 eV$$

38 D To produce an n-type semiconductor material, silicon is doped with a group 5 element. The fifth electron of the phosphorus atom (for eg) is only loosely bound to it. On an energy band diagram, this electron occupies the donor level that lies within the energy gap, just below the conduction band.

39 A

A: 7p, 7n
B: 9p, 8n✗
C: 5p, 6n✗
D: 6p✗, 7n

40 C

Mass equivalent of photon $= \dfrac{2.13 \times 10^{-13}}{\left(3.0 \times 10^{8}\right)^{2}\left(1.66 \times 10^{-27}\right)} = 0.00143u$

Mass of the nucleus=59.9308u+0.00143u=59.9322u

END

Paper 2 Structured Questions

1 **(a)** **(i)** Since force X = 0 N, force Y must be equal and opposite to the weight of S.

Magnitude = 60.0 N A1
θ = 90° A1

(ii) Resolving forces vertically (taking upwards as positive),

$Y_y + 200\sin 30° - 60 = 0$

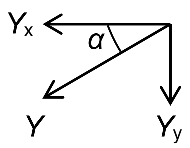
$Y_y = -40.0$ N

Resolving forces horizontally (taking leftwards as positive),

$Y_x - 200\cos 30° = 0$

$Y_x = 173.205$ N

M1



$Y = \sqrt{Y_x^{\,2} + Y_y^{\,2}} = 178$ N A1

$\tan\alpha = \dfrac{Y_y}{Y_x}$

$\alpha = 13.0°$

$\therefore \theta = -13.0°$ OR $\theta = 13.0°$ below the horizontal A1

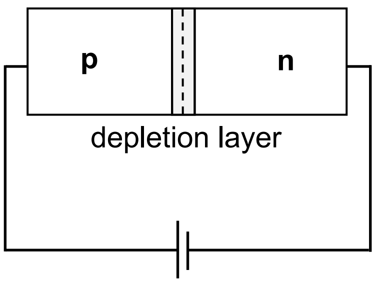
(b) The force X has <u>a horizontal component</u>. B1
If rope B is parallel to the weight, then both Y and weight are vertical and <u>have no horizontal component</u> to cancel out the horizontal component of X. B1

2 **(a)** p-type doping is <u>the addition of impurity atoms</u> of valency 3 to the intrinsic semiconductor, which <u>introduces an acceptor level just above the valence band</u>. B1

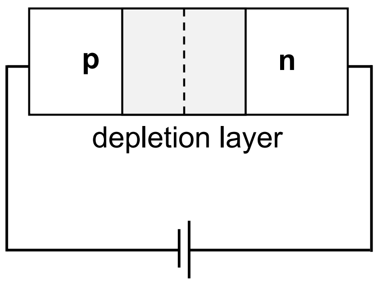
Due to the small energy gap, electrons from the valence band are easily excited to the acceptor level. This results in <u>more holes in the valence band</u>, which serve as the majority charge carriers. B1

Therefore, the conductivity improves due to more holes.

(b)



Forward bias



Reverse bias

When the p side of the p-n junction is at a higher potential compared to the n side, the p-n junction is forward bias. B1
The width of the depletion layer and potential barrier of the junction decreases, allowing the movement of majority charge carriers across the junction (i.e. holes move from p to n side and electrons move from n to p side). B1

When the p side is at a lower potential compared to the n side, the p-n junction is reverse bias.
The width of the depletion layer and potential barrier of the junction increases. B1
This prevents the movement of majority charge carriers.
Hence p-n junction acts as a rectifier as it only allows current to flow in one direction.

3 (a) As the variable resistance increases, the current decreases. B1
Hence, the potential difference across the internal resistance decreases. B1
Since terminal p.d. = e.m.f. – p.d. across internal resistance, terminal potential difference increases. B1

(b) (i)

$$I = \left(\frac{5.0}{4.0 + 0.25 + 3.5}\right) = 0.645 \text{ A}$$ M1

$$V_B = E - Ir$$
$$= 5.0 - 0.645 \times 0.25$$ M1
$$= 4.8 \text{ V}$$ A1

(ii)

$$\text{efficiency} = \frac{IV_B}{IE}$$ (because total power of external load = IV_B) M1

$$= \frac{V_B}{E} = \frac{4.84}{5.0}$$
$$= 0.97 = 97\%$$ A1

(c) (i) V_{PJ} = 1.2 V A1

(ii)

$$V_{PQ} = \left(\frac{3.5}{4.0 + 3.5 + 0.25}\right)(5.0) = 2.25806$$ C1

$$\frac{V_{PQ}}{1.0 \text{ m}} = \frac{V_{PJ}}{l} \Rightarrow l = \frac{V_{PJ}}{V_{PQ}}(1.0 \text{ m}) = \frac{1.2}{2.25806}(1.0 \text{ m}) = 0.53 \text{ m}$$ A1

(iii) <u>p.d. across resistance wire PJ is now larger than e.m.f. of cell C</u>, the potentiometer is no longer balanced. B1
Current will flow through cell C (anticlockwise) so that the p.d. across PJ equals the terminal p.d. of cell C again. B1

4 (a) (i) Faraday's law of electromagnetic induction states that the induced electromotive force (emf) is proportional to the rate of change of magnetic flux linkage. B1
The magnetic flux linkage Φ through the coil is given by $NBA \cos\theta$, where N is the number of turns in the coil, B is the magnetic flux density, A is the area of the coil and θ is the angle between the normal of the coil and B. B1
As the coil rotates about axis PQ, the angle θ changes, inducing an e.m.f. = $-\mathrm{d}\Phi/\mathrm{d}t$ = $NBA\omega \sin\theta$, where $\omega = \mathrm{d}\theta/\mathrm{d}t$. The graph for e.m.f. therefore has a sinusoidal shape. B1
At θ = 0, Φ is at maximum value, but rate of change of flux linkage at this instant is 0, hence the induced e.m.f. is 0. B1
At θ = 90°, rate of change of magnetic flux linkage is maximum, hence, the induced e.m.f. is at its maximum value.

(ii) **1.** Maximum emf = $\dfrac{6.8\times 0.050}{2}$ = 0.17 V B1

2. $T = \dfrac{10.0\times 8.0}{2}$ = 40.0 ms M1

$f = \dfrac{1}{T} = \dfrac{1}{0.040} = 25$ Hz A1

(b) $\omega = 2\pi f = 2\pi \times 25 = 50\pi$ C1

$E_0 = NBA \times \omega$ M1

$0.17 = 120 \times B \times 1.3 \times 10^{-3} \times 50\pi$

$B = 6.94 \times 10^{-3}$ T A1

5 **(a)** The gravitational potential at a point is defined as the work done per unit mass by an external agent in bringing a small mass from infinity to that point.

(b) **(i)** At $r = 4.0 \times 10^8$ m, $\phi = -3.2 \times 10^8$ J kg^{-1}

$\phi = -\dfrac{GM}{r}$

$-3.2\times 10^8 = -\dfrac{6.67\times 10^{-11}\times M}{4.0\times 10^8}$ M1

$M = 1.92 \times 10^{27}$ kg A1

(ii) $E_P = -\dfrac{GMm}{r} = -\dfrac{6.67\times 10^{-11}\times 1.92\times 10^{27}\times 8.93\times 10^{22}}{4.22\times 10^8}$ M1

$= -2.710\times 10^{31}$ J

$E_K = \dfrac{1}{2}mv^2 = \dfrac{1}{2}m(\dfrac{2\pi r}{T})^2 = \dfrac{1}{2}\times 8.93\times 10^{22}\times(\dfrac{2\pi\times 4.22\times 10^8}{1.53\times 10^5})^2$ M1

$= 1.341\times 10^{31}$ J

Total energy = $E_P + E_K = -2.710 \times 10^{31} + 1.341 \times 10^{31} = -1.37 \times 10^{31}$ J A1

Or

$\dfrac{GMm}{r^2} = \dfrac{mv^2}{r}$ M1

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

$E_K = \dfrac{1}{2}mv^2 = \dfrac{GMm}{2r}$

Total energy = $E_P + E_K = -\dfrac{GMm}{r} + \dfrac{GMm}{2r} = -\dfrac{GMm}{2r}$ M1

$= -\dfrac{6.67\times 10^{-11}\times 1.92\times 10^{27}\times 8.93\times 10^{22}}{2\times 4.22\times 10^8}$

$= -1.35\times 10^{31}$ J A1

(c) At $x = 1.4 \times 10^{-15}$ m, $V = 1.02 \times 10^{6}$ J C^{-1}. At $x = 1.0 \times 10^{-10}$ m, $V \approx 0$. C1
By conservation of energy,
Total initial energy = total final energy

$$\frac{1}{2}mv^2 + 0 = 0 + eV$$ M1

$$\frac{1}{2} \times 1.67 \times 10^{-27} \times v^2 = 1.6 \times 10^{-19} \times 1.03 \times 10^{6}$$

$v = 1.4 \times 10^{7}$ m s^{-1} A1

(d) Similarity: the magnitudes of the both potentials are inversely proportional to the distance from the mass or charge. B1
Difference: Gravitational potential is always negative as gravitational force is always attractive. Electric potential can be positive or negative as it depends on whether the charge of the object is positive or negative. B1

6 **(a)** The rate of change of *A* decreases with *t* as the magnitude of the gradient of the curve decreases with *t* B1

(b) **(i)**

$\frac{1}{m}$ / kg^{-1}	A / 10^{-2} m	ln (A / m)
5.00	1.8×10^{-2}	−4.0

A1

(ii) [Plotting of point & drawing of BFL]

(iii)
$$\text{gradient} = \frac{(-2.550)-(-5.450)}{0.20-9.70} = \frac{2.900}{-9.50}$$ M1
$$= -0.305$$ A1

(iv) $A = A_0 e^{-bt/2m} \Rightarrow \ln A = (-bt/2)\left(\frac{1}{m}\right) + \ln A_0$. Hence, if the proposed expression is correct, the graph of ln$A$ vs $1/m$ should be a straight line graph of gradient $-bt/2$ and y-intercept lnA_0. B1

Since the graph obtained is a straight line, it supports the proposed expression. B1

(v) **1.**
$$\text{gradient} = \frac{-bt}{2}$$ M1
$$b = \frac{-2\ (\text{gradient})}{t} = \frac{-2\ (-0.305)}{5.0} = 0.122 \text{ kg s}^{-1}$$ A1

2.
$$y\text{-intercept} = \ln A_0 = -2.500$$ M1
$$A_0 = e^{-2.500} = 8.2 \times 10^{-2} \text{ m}$$ A1

(c) $\dfrac{A}{A_0} = e^{-bt/2m}$

$\ln\left(\dfrac{A}{A_0}\right) = \dfrac{-bt}{2m}$

$\ln\left(\dfrac{1}{2}\right) = \dfrac{-0.122t}{2 \times 500 \times 10^{-3}}$ M1

$t = 5.68$ s A1

(d) Since energy of system, $E \propto A^2$ M1

$\dfrac{E}{E_0} = \left(\dfrac{A}{A_0}\right)^2 = \left(e^{-bt/2m}\right)^2$ A1

$$\left(\frac{E}{E_0}\right) = e^{-bt/m} \Rightarrow \ln\left(\frac{E}{E_0}\right) = \frac{-bt}{m} \Rightarrow \ln\left(\frac{1}{2}\right) = \frac{-bT_{1/2}}{m} \Rightarrow T_{1/2} = \left[\frac{\ln\left(\frac{1}{2}\right)}{b}\right]m$$

Therefore $T_{1/2}$ is directly proportional to m.

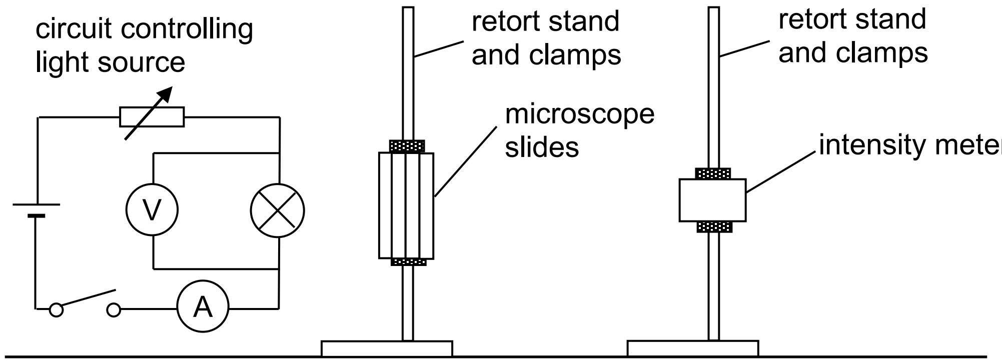
7 **Problem Definition**

Independent variable: total thickness of microscope slides, t

Dependent variable: intensity of emergent light, I

Control variables: intensity of incident light, distance between light source and intensity detector, material of microscope slides

Diagram (2 marks)



1 mark for drawing a circuit that is able to vary the intensity of light.
1 mark for the slides and intensity meter that is clamped properly. [2]

Procedure (6 marks)

1. Set up the apparatus as shown in the diagram.
2. Measure the thickness of the microscope slide(s) used using a pair of Vernier callipers and record the reading as t. [1]
3. Clamp the slide and switch on the light source. Adjust the brightness of the light source by varying the resistance of the variable resistor until a measurable light intensity is detector by the intensity meter. [1]
4. Record the reading on the intensity meter as, I.
5. Increase the thickness of the material, t by increasing the number of microscope slides. [1]
6. Repeat steps 2 – 5 to obtain at least 6 sets of readings.
7. Intensity of light is kept constant by ensuring that the voltmeter and ammeter readings remain constant throughout the experiment. [1]
   Distance between light source and intensity meter is kept constant by not shifting the setup. [1]
   The material of microscope slides is kept constant by using microscope slides that are of the same type and material. [1]
   (1 mark for any correct mention of control variable)

Analysis (1 mark)

Assume that
$I = k\,t^{n}$
where n and k are constants.

Taking lg to both sides, lg I = n lg t + lg k
Plot a graph of lg I against lg t. [1]

Safety Precautions (max 1 mark)

1. Be careful when handling the microscope slides as they are made of glass. Clamp them just enough to hold them together without any air spaces between the slides. Do not clamp them too tightly as they may break. [1]
2. Wear gloves when handling the light source as the bulb may get very hot. [1]

Methods to Ensure Reliability (max 2 marks)

1. For the preliminary reading, ensure that the minimum thickness and maximum thickness of the slides produces an appreciable difference in the intensity readings. If the difference is small, increase range of thickness by using more slides. [1]
2. Conduct the experiment and take readings of the intensity of the light passing out of the material in a dark room. This will ensure that the intensity of the light measured is not affected by stray light. [1]
3. Place a lens between the light source and the slides such that the light source is at the focal point of a lens to produce a parallel beam of light. [1]
4. Ensure that the microscope slides are clamped perpendicularly to the light beam using a protractor. [1]
5. Ensure the microscope slides are clean and dust-free, so as to minimize gaps in between the slides. [1]

Paper 3 Structured Questions

1 **(a)** **(i)** There is no variation in the horizontal component of the velocity as there is no acceleration in this direction. [A1]

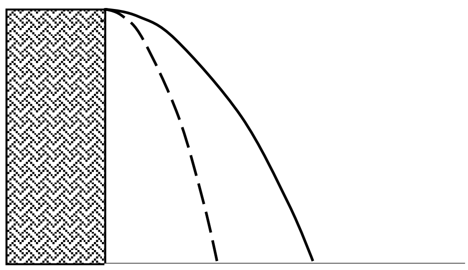
(ii) The vertical component of the velocity increases from zero at a constant rate in the downward direction.

(b) **(i)** It will gradually decrease, and approaches zero asymptotically. [A1]

(Teacher's note: if air resistance is $-kv$, then $\frac{dv}{dt} = -\frac{k}{m}v$, which has exactly the same form as the equation for radioactive decay $\frac{dN}{dt} = -\lambda N$. Hence, v will decrease exponentially: $v = v_o e^{-kt/m}$)

(ii) The vertical component of the velocity increases from zero with time, but at a decreasing rate, and [A1]
approaches a final value known as the terminal velocity asymptotically. [A1]

(c)



See dashed line. The trajectory must start horizontally at the point of projection. [A2]

2 **(a)** **(i)** The radian is the angle subtended by an arc of length equal to its radius. [A2]

(ii) In SHM, the angular frequency is the rate of change of the phase (or phase angle) of the motion with respect to time. [A1]

(b) **(i)** Total energy = max. potential energy

$= mgh$

$= 0.120 \times 9.81 \times 0.40 \times 10^{-2}$ [M1]

$= 4.7 \times 10^{-3}$ J [A1]

(ii) $\frac{1}{2}m\omega^2A^2 = 4.7\times10^{-3}$ [M1]

$\therefore \omega = \frac{1}{0.080}\sqrt{\frac{2(4.7\times10^{-3})}{0.120}}$ [C1]

$= 2\pi f$ [M1]

$\therefore f = 0.56$ Hz [A1]

3 **(a)** The First Law of Thermodynamics states that the internal energy of a system depends only on its state; the increase in the internal energy of a system is equal to the sum of the work done on the system and the heat supplied to the system. [A1] [A1]

(b) **(i)** *Using* $pV = nRT$

$n = \frac{pV}{RT} = \frac{2.4\times10^5\times5.0\times10^{-4}}{8.31\times290}$ [M1]

$= 0.050$ mol [A1]

(ii) **1.** *Using* $W = p\Delta V$

$W = 2.4\times10^5\times(14.4-5.0)\times10^{-4}$ [M1]

$= 226$ J [A1]

(question asked for magnitude)

2. Since the system returns to its original state, $\Delta U = 0$ J [A1]

(iii)

change	work done/J	heating supplied to gas/J	increase in internal energy/J
$X\rightarrow Y$	**–226**	+ 570	**+ 344**
$Y\rightarrow Z$	+ 540	0	**+ 540**
$Z\rightarrow X$	0	**–884**	**–884**

[A1] for each row.

4 **(a)** The *principle of superposition* states that when two waves of the same kind meet at a point in space, the resultant displacement at that point is given by the vector sum of the displacements due to each of the waves at that point. [B1] [B1]

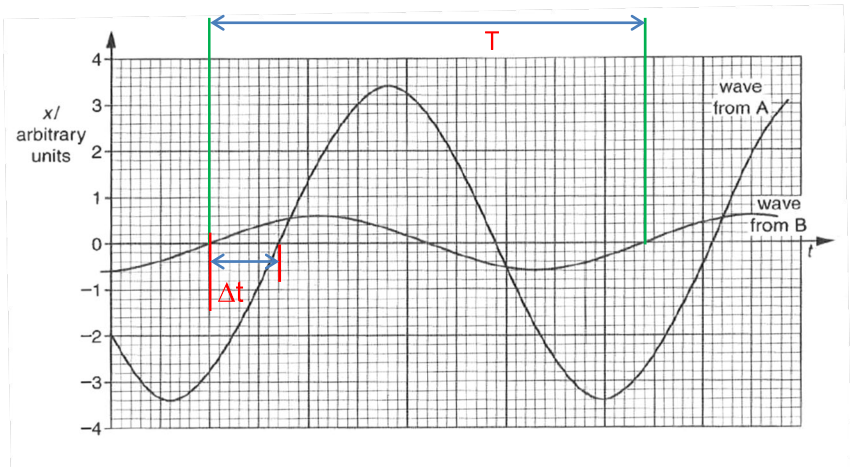


Fig. 4.2

(i)

$$\Delta t = 7 \text{ small squares}$$

$$T = 44 \text{ small squares}$$

$$\text{Phase difference } = \frac{\Delta t}{T}(360°) = \frac{7}{44}(360°)$$

$$= 57°$$ [A1]

(Teacher's note: Slit A is nearer to point P, so wave from A arrives at P first and leads in phase by 303°)

(ii) In arbitrary units, amplitudes of waves are:
$A_A = 3.4$ units and $A_B = 0.6$ units

For a bright fringe, waves arrive in phase, thus the amplitudes add up
$= 3.4 + 0.6 = 4.0$ units

For a dark fringe, waves arrives 180° out of phase, thus the amplitude [B1]
$= 3.4 - 0.6 = 2.8$ units

$$I = kA^2$$

$$\frac{I_{dark}}{I_{bright}} = \left(\frac{A_{dark}}{A_{bright}}\right)^2$$

$$= \left(\frac{2.8}{4.0}\right)^2$$ [C1]

$$= 0.49$$ [A1]

5 **(a)** $E_{MAX} = hf - \Phi = hf - hf_0$

$$= h(f - f_0) = h\left(\frac{c}{\lambda} - \frac{c}{\lambda_0}\right) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$ [A1]

(b) **(i)** Extrapolate the line backwards until it cuts the horizontal axis.

The *x*-intercept is $\dfrac{1}{\lambda_0}$.

Read to get: $\dfrac{1}{\lambda_0} = 2.33 \times 10^6 \text{ m}^{-1}$, [M1]

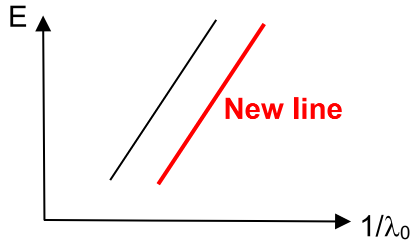
$\therefore \lambda_0 = 4.29 \times 10^{-7} \text{ m}$ [A1]

(ii) The gradient of the line is $= ch$. [B1]

$$h = \frac{1}{3.0 \times 10^8} \frac{(3.00 - 1.00) \times 10^{-19}}{(3.80 - 2.80) \times 10^6}$$ [M1]

$= 6.67 \times 10^{-34} \text{ Js} \approx 6.7 \times 10^{-34} \text{ Js}$ [A1]

(c)



[A1]

6 **(a)** **(i)** A field of force <u>is a region in space where a body experiences a force</u> due to the <u>presence of others of a similar type without physical contact between them</u>. [B1] [B1]

(*need to answer with regard to general case and not specifically gravitational field, electric field etc.)

(ii) If a <u>charged particle is moving at an angle (i.e. non-parallel) to the magnetic field</u>, there will be a <u>force acting on the moving charge at right angles to both its velocity and the magnetic field</u>. [B1] [B1]
If the <u>charged particle has mass m and exists in a gravitational field of field strength g</u>, then <u>gravitational force (F = mg) will act on the charged particle in the direction of the field.</u> [B1] [B1]

(b) **(i)** The two spheres are conducting. Inside them, the mobile charges will move and distribute themselves such that the electric field becomes zero. [B1]

(ii) **1.** Radius of sphere A = 4.0 cm
Radius of sphere B = 2.0 cm } [B1]

2. The charges have <u>opposite signs</u>. This is because if the signs are the same, there <u>will be a position between the spheres where the fields will cancel out vectorially and the net electric field will be zero (null point). Since there is no null point seen in the graph,</u> the charges must be of opposite signs. [B1] [B1]

(iii) **1.** Energy gain by the nucleus = Work done by electric force

$$= \int F\ dx$$
$$= \int qE\ dx$$
$$= q\int E\ dx$$ [B1]

(where $\int E\ dx$ = area under E-x graph)

Counting number of squares under E-x graph for x = 16.0 cm to x = 21.0 cm: ≈30 squares. [B1]

Charge of nucleus = 3e = 3(1.6 x 10^{-19}) C [B1]

Energy gain by the nucleus

$$= q\int E\, dx$$
$$= (3)(1.6\times10^{-19})(30)(0.5\times10^{-2})(0.4\times10^{-5})$$ [C1]
$$= 2.88\times10^{-15}\ \text{J}$$ [A1]

Teacher's note: The question should have been phrased as "Estimate the <u>**kinetic**</u> energy gained…."

2. At x = 25.0 cm, E = 3.0 x 10^5 V m^{-1}

$F_{net} = qE = ma$

$$a = \frac{qE}{m}$$
$$= \frac{3(1.6\times10^{-19})(3.0\times10^{5})}{7(1.66\times10^{-27})}$$ [M1]
$$= 1.24\times10^{13}\ \text{ms}^{-2}$$ [A1]

3. Acceleration is proportional to E. Throughout the motion, the Lithium nucleus accelerates towards sphere B. From x = 4.0 cm, the acceleration decreases from a maximum value to a minimum value at x = 19.0 cm. After x = 19.0 cm, the acceleration increases until it reaches a maximum value again at x = 28.0 cm. [B1] [B1] [B1]

7 **(a)** **(i)** The resistance of a <u>wire</u> is defined as the <u>*ratio* of the potential difference across it to the current flowing through it.</u> [B1]

(ii) It is the constant of proportionality ρ in the equation $R = \rho\frac{l}{A}$, where R is the resistance of the wire, A is the cross sectional area and l is the length of the wire. [B1]
It is a measure of how well the material conducts electricity. [B1]

(b) **(i)** Since $V = IR = E - Ir$, rearranging

$$R = \frac{E}{I} - r$$ [B1]
$$= \frac{6.0}{1.2} - 0.10 = 4.9\ \Omega$$ [B1]

(ii) $R = \rho \frac{l}{A} \Rightarrow l = \frac{RA}{\rho} = 81.5 \text{ m}$ [M1] [M1]

$N = \frac{81.5}{\pi(0.22)} = 118 \text{ turns}$ [M1] [A1]

(c) $B = (0.72)(4\pi \times 10^{-7})\frac{(118)(1.2)}{0.11}$ [B1]

$= 1.16 \times 10^{-3} \text{ T}$

$= 1.2 \text{ mT}$

(d) **(i)** Gain in kinetic energy = loss in electric potential energy

$\frac{p^2}{2m} = eV$ [M1]

$p = \sqrt{2meV}$

$= \sqrt{2(9.11 \times 10^{-31})(1.6 \times 10^{-19})(250)}$ [C1]

$= 8.5 \times 10^{-24} \text{ Ns}$ [A1]

(ii) The magnetic force provides for the centripetal force required to keep the electron in circular motion. [B1]

$F_c = Bqv = \frac{mv^2}{r}$

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

$= \frac{p}{Be}$

$= \frac{8.54 \times 10^{-24}}{(1.2 \times 10^{-3})(1.6 \times 10^{-19})}$ [C1]

$= 4.4 \times 10^{-2} \text{ m}$ [A1]

(e) The velocity component perpendicular to the magnetic field will result in a magnetic force acting on the electron in a direction that is always perpendicular to its motion. [B1]
This force will act as the centripetal force on the electron, causing it to perform uniform circular motion in a plane that is normal to the page. [B1]
The velocity component parallel to the magnetic field will not result in any magnetic force, but it causes the electron to move at a constant speed along the magnetic field lines. [B1]
The resultant path of the electron is a helix. [B1]

8 **(a)** **(i)** <u>Radioactive decay is the process whereby less stable nuclei transform into a more stable nuclei</u> with the <u>emission of alpha particles, beta particles and/or gamma radiation</u>. [B1] [B1]

(ii) It is impossible to predict when a particular atom will decay. However, the probability per unit time that a given atom will decay is constant. [B1]

(iii) The probability of radioactive decay of an atom is <u>unaffected by external factors (environmental conditions) such as temperature, pressure or chemical composition.</u> [B1]

(b) **(i)**

$\lambda = \dfrac{\ln 2}{t_{1/2}}$ (decay constant) [M1]

$= \dfrac{\ln 2}{(86.4)(365 \times 24 \times 60 \times 60)}$ [M1]

$= 2.54 \times 10^{-10}\ \text{s}^{-1}$ [A1]

Energy of each α particle $= (5.48 \times 10^{6})(1.6 \times 10^{-19})$ J [C1]

To produce power of 2400 W, the required activity A

$= \dfrac{2400}{(5.48 \times 10^{6})(1.6 \times 10^{-19})}$

$= 2.73 \times 10^{15}$ Bq [C1]

$A = \lambda N$

$N = \dfrac{A}{\lambda}$ [B1]

Mass of plutonium required $= N \times$ mass of 1 plutonium nuclei

$= N(238u)$

$= \dfrac{A}{\lambda}(238u)$ [C1]

$= \dfrac{2.73 \times 10^{15}}{2.54 \times 10^{-10}}(238 \times 1.66 \times 10^{-27})$ [C1]

$= 4.27$ kg [A1]

(c) **(i)**

$\text{Efficiency} = \dfrac{\text{output power}}{\text{input power}} \times 100\%$

$= \dfrac{160}{2400} \times 100\%$

$= 6.7\ \%$ [A1]

(ii) Since

$A = A_0 e^{-\lambda t}$ and $P \propto A$,

$P = P_0 e^{-\lambda t}$ [C1]

$= (160)\ e^{-(\frac{\ln 2}{86.4})(3.2)}$ [A1]

$= 156$ W

(d) **(i)** Due to the very long half life of plutonium-238, the decay rate stays fairly constant over the serveral years of flight and thus the power supply is rather constant. [B1] [B1]

(ii) Beta particles are emitted with a wide range of energy. While the most energetic beta particles have energy close to that of alpha particles, their average energy is significantly less. Hence if a beta source such as strontium is used, the efficiency will be much lower. [B1] [B1]