2019 A-Level H2 Physics Suggested Solutions

Paper 1

1 **D**

2 **D**

$$0.01 \times 4.072 = 0.04072 \text{ V}$$
$$= 40.72 \text{ mV}$$
$$40.72 + 10 = 50.72 \text{ mV}$$
$$\approx 0.05 \text{ V (1sf)}$$

3 **D**

let $(t_1 + 1.00)$ s be total time of fall

at t_1, $s = \frac{1}{2}(9.81)(t_1)^2$

at t_1+1.00, $4s = \frac{1}{2}(9.81)(t_1 + 1)^2$

solving the eqns will give

$t_1 = 1.00$ or $-\frac{1}{3}$

time of fall $= 1 + 1 = 2.00$ s

4 **C** Between t_1 and t_2 the gradient of graph is increasing. Eventually the graph becomes linear and thus acceleration tend towards zero.

5 **A** No net force acting on the system (X, Y and container) and thus by principle of conservation of linear momentum, no change in the combined centre of gravity of the system.

6 **B** By conservation of linear momentum,

$$mu + 0 = mv + 2mv$$
$$u = 3v$$
$$\text{KE}_i = \frac{1}{2}m(u)^2 = \frac{1}{2}m(3v)^2 = \frac{1}{2}m(9v^2)$$
$$\text{KE}_f = \frac{1}{2}m(v)^2 + \frac{1}{2}m(2v)^2 = \frac{1}{2}m(5v^2)$$

7 **A** using coordinates (10,14)

$$F = kx$$
$$k = \frac{14}{(\frac{10}{1000})} = 1400$$

at (20,28) the elastic limit of spring is reached

$$\text{work done} = \frac{1}{2}kx^2 = \frac{1}{2}(1400)(\frac{20}{1000})^2 = 0.28 \text{ J}$$

8 **D** As the object moves towards Y, the net force on the object tends to zero and thus the rate of increase in kinetic energy tends to zero. (ie the gradient of KE-distance graph tends to zero)

9 **D**

$$P = \frac{\Delta GPE}{\Delta t} = \frac{1.3 \times 10^9 \times 9.81 \times 2}{60 \times 60 \times 24} = 295000 \text{ J}$$

10 **B**

$$v = R\omega$$

$$\omega = \frac{v}{R}$$

Since v is constant, graph B is correct

11 **D**

$$a_c = \omega^2 r$$

$$\omega = \sqrt{\frac{a_c}{r}} = \sqrt{\frac{20g}{7.0}} = 5.3$$

12 **A**

By CoE

$$E_i = E_f$$

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

$$v = \sqrt{\frac{2GM}{R}}$$

13 **C**

$$\frac{1}{2}m\langle c\rangle^2 = \frac{3}{2}kT$$

$$\langle c\rangle = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{1.25 \times 10^{-20}}{\left(\frac{4 \times 10^{-3}}{6.02 \times 10^{23}}\right)}} = 1374$$

14 **C**

By definition, total internal energy of a gas is the sum of the random distribution of KE and PE associated with the molecules of a system of gas

15 **B**

By 1st Law of thermodynamics

16 **B**

17 **B**

$$T_A = \frac{1}{480} = 2.0833 \times 10^{-3}$$

$$T_B = \frac{1}{482} = 2.0747 \times 10^{-3}$$

$$\frac{0.25}{T_A} = 120$$

$$\frac{0.25}{T_B} = 120.5$$

at $t = 0.25$ s, the 2 waves will meet and interfere destructively

$$\frac{0.75}{T_A} = 360$$

$$\frac{0.75}{T_B} = 361.5$$

at $t = 0.75$ s, the 2 waves will meet and interfere destructively

18 **C** Between consecutive constructive intereferences, the metal sheet is moved by 60 mm.
When the metal sheet is moved by 60 mm, the path difference between the 2 waves detected by the receiver is increased by 120 mm. thus wavelength is 120 mm.

19 **D**
$$n\lambda = d\sin\theta$$
$$\lambda = \frac{3\times10^{8}}{6\times10^{14}} = 5\times10^{-7}$$
$$\theta_3 = \sin^{-1}\left(\frac{5\times10^{-7}}{\frac{10^{-2}}{4\times10^{3}}}\right) = 36.869$$
$$36.869\times2 = 74^\circ$$

20 **C**
$$\theta = \frac{\lambda}{b}$$

21 **B** In uniform electric field, the electric force acting on electron is constant and thus acceleration is constant. By Newton's 2nd Law, rate of increase of velocity is constant.

22 **B**
$$\Delta V = \left(\frac{4}{10}\right)\times1000 = 400\text{ V}$$

23 **C**

24 **D** When R = 0 parallel arrangement is short circuited
minimum V reading when $R = 1.0$
$$V_1 = \frac{1}{1.5}\times12 = 8.0$$

25 **B** By Faraday's Law of EMI,
$$\varepsilon = -\frac{d\Phi}{dt} = \frac{10\times10^{-3}\times2\times10^{-2}}{4} = 5\times10^{-5}$$

26 **C**

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

28 **C**

29 **B**

30 **A**

2019 A Level Paper 2

Suggested Mark Scheme and Detailed Solution

1 **(a)** The resultant force on the object is zero. [B1]
The resultant moment (or torque) on the object about any axis is zero. [B1]

(b) Considering vertical equilibrium:
$T_1 \sin 20° + T_2 \sin 10° = 700$ N ---------(1) [C1]
Considering horizontal equilibrium:
$T_1 \cos 20° = T_2 \cos 10° \Rightarrow T_1 = T_2 \dfrac{\cos 10°}{\cos 20°}$ ------------(2) [M1]
Solving,
T_1 = 1380 N [A1]
T_2 = 1320 N [A1]

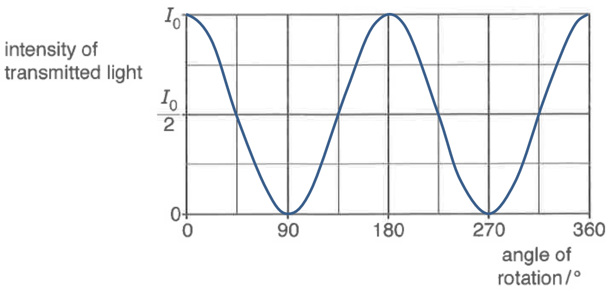
(c) Taking pivot about base of pole.
Angle between support cable and ground $= \tan^{-1}(\dfrac{1.2}{1.6}) = \tan^{-1}(0.75) = A$ [C1]
Considering horizontal components of forces and its moment about the base of pole:
clockwise moment = anti-clockwise moment
$T(\cos A)(1.2) = (150)(\cos 10°)(1.8)$ [M1]
$T = 280$ N [A1]

2 **(a)** **(i)** A transverse wave is one in which its particles oscillate in a direction perpendicular to the direction of energy transfer. [B1]
Electromagnetic wave. [B1]

(ii) Plane polarisation of a wave means that the oscillations of the transverse wave are restricted to a single plane. [B1]

(b) **(i)** Intensity of light emerging from 1st polarising filter
$I' = I_0 \cos^2 30°$ [C1]
Angle between 1st and 2nd transmission axis = 60° − 30° = 30°
Intensity of light emerging from 2nd polarising filter.
$I_T = I' \cos^2 30° = (I_0 \cos^2 30°)(\cos^2 30°)$ [M1]
$= 0.5625 I_0 = 0.563 I_0$ [A1]

(ii) $I_0 = kA^2$ and $I_T = kA_T{}^2 = 0.5625 I_0$
$\dfrac{A_T}{A} = \sqrt{\dfrac{0.5625 I_0}{I_0}}$ [M1]
$= 0.750$ [A1]



[B1] cosine graph
[B1] maximum intensity at 0, 180, 360 deg and 0 and 90 and 270 deg.

(c) **(i)** It is because sound wave is a longitudinal wave, and the particles oscillate in the direction of energy transfer which cannot be polarised. [B1]

(ii)

$$\text{period of sound wave } = T = \frac{1}{f} = \frac{1}{740}\text{ s}$$

$$\text{time base of oscilloscope} = \frac{1}{740} \div 6.8\text{ cm}$$ [M1]

$$= 1.9872 \times 10^{-4}\text{ s cm}^{-1}$$

$$= 0.200\text{ ms cm}^{-1}$$ [A1]

3 **(a)** The electric potential at a point in an electric field is defined as the work done per unit positive charge by an external force in bringing a small test charge from infinity to that point. [B1]

(b) **(i)** Since potential is positive, the charge is thus positive and provided by protons.

$$V = \frac{q}{4\pi\varepsilon_0 r}, \text{ at } r = 6.0\times10^{-10}\text{ m, } V = 130\text{ V}$$ [C1]

$$q = 4\pi\varepsilon_0 rV = 4\pi(8.85\times10^{-12})(6.0\times10^{-10})(130)$$ [M1]

$$= 8.675\times10^{-12} = X(1.6\times10^{-19})$$

$$X = 54.2 = 54 \text{ (integer)}$$ [A1]

(ii) It is because the distance between the single proton and nucleus is large, in the order of 10^{-8} m compared to the size of nucleus which is in the order of 10^{-10} m. They are very far apart. [B1]

(iii)

$$F = \frac{Qq}{4\pi\varepsilon_0 r^2} = \frac{54ee}{4\pi\varepsilon_0(2.0\times10^{-8})^2} = m_p a$$ [C1]

$$a = \frac{54(1.6\times10^{-19})^2}{4\pi\varepsilon_0(2.0\times10^{-8})^2(1.67\times10^{-27})}$$ [M1]

$$= 1.86\times10^{16}\text{ m s}^{-2}$$ [A1]

(iv) The proton experiences repulsion from the nucleus as both are positively charged. By conservation of energy, the decrease in potential energy leads to a corresponding increase in kinetic energy. Potential energy at infinity is zero. [B1] change in potential energy $= U_{\infty} - U_{r} = 0 - \dfrac{Qq}{4\pi\varepsilon_0 r} = 0 - \dfrac{54(1.6\times10^{-19})^2}{4\pi\varepsilon_0(2.0\times10^{-8})}$ [M1]

$= -6.22\times10^{-19}$ J

Hence the change in KE = + 6.22 $\times10^{-19}$ J [A1]

4 (a) (i) Using <u>Flemings Left Hand rule, the magnetic force acts upwards towards plate P. Hence electric force on the proton has to act downwards towards plate Q</u>. Hence plate <u>P has to be positive</u>. [M1] [A1]

(ii) For proton to not deviate, the magnetic force balances the electric force on the proton. $F_m = F_E$ [B1]

KE of proton $= \dfrac{1}{2}m_p v^2 = 64$ eV

$v = \sqrt{\dfrac{2(64)(1.6\times10^{-19})}{(1.67\times10^{-27})}}$ [C1]

$= 110.74\times10^3$ m s^{-1} [C1]

$F_m = F_E$

$Bqv = qE \Rightarrow E = Bv$

$E = (45\times10^3)(110.74\times10^3)$ [M1]

$= 4983$ N C^{-1} [A1]

(ii)

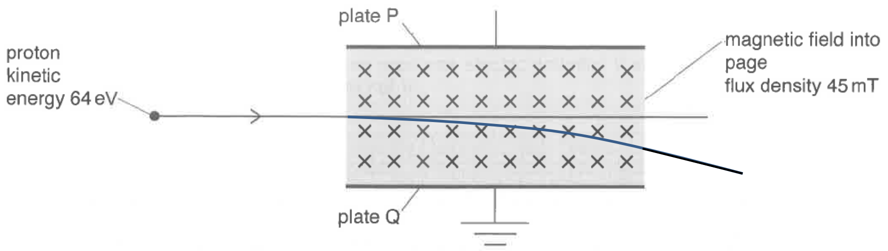


Fig. 4.1

[B1] proton is deflected downwards within the plates (as v↓, F_m↓, $F_E > F_m$)
(note: upon exit, proton moves in a straight line)

(b) $F = B_x I_x L = \dfrac{\mu_0 I_y}{2\pi d} I_x L$ [C1]

$= \dfrac{(4\pi\times10^{-7})(8.4)(5.5)}{2\pi(0.12)} L$ [M1]

$\dfrac{F}{L} = 7.7\times10^{-5}$ N m^{-1} [A1]

The force on wire X acts towards wire Y (towards the right). [A1]

5 (a) The electromotive force (e.m.f.) of a source is defined as the amount of electrical energy that is converted from other forms of energy when the source drives a unit charge around a complete circuit. [B1]

(b) (i) E = 12.0 V [B1]

The equivalent resistance of S and T in parallel is

$$R_{eq} = \frac{1}{\frac{1}{200}+\frac{1}{300}} = 120\ \Omega$$ [B1] [B1]

When the switch is closed, by the potential divider principle

$$\frac{V}{E} = \frac{R_{eq}}{R_{eq}+r} = \frac{120}{120+r} \quad \rightarrow \quad r = 13.3\ \ \Omega$$ [M1] [A1]

(ii) $E = i\left(R_{eq}+r\right) \Rightarrow i = \dfrac{12.0}{120+13.3} = 0.0900\ \text{A}$ [M1]

$\therefore$ energy dissipated in the power supply in 5.0 mins is

$Pt = i^2 r\, t = 0.0900^2 \times 13.3 \times 5.0 \times 60 = 32.4\ \text{J}$ [A1]

(iii) The voltmeter reading will decrease. [A1]
Reason: after the switch is closed, a current will flow and the heat dissipated in T causes its temperature to increase. This will decrease the resistance of T and the equivalent resistance across the parallel combination of S and T will decrease. [B1] The current drawn from the source will increase and the terminal p.d. across the source which is the voltmeter reading, given by $V = E - ir$, will decrease. [B1]

6 (a) Since there are no black holes and neutron stars (or very massive bodies) in the solar system, gravitational waves are thus not observed from a source in the solar system. [A1]

(b) (i) max fractional change in length = 1.18×10^{-21}

$\therefore$ max change in length = $1.18 \times 10^{-21} \times 4.0 \times 10^{3} = 4.7 \times 10^{-18}$ m [A1]

(ii) Since the maximum change in the length of the tubes is ~10^{-18} m, which is much smaller than the wavelength ~10^{-6} m of the laser light used, the change in amplitude of the resultant wave received at the photo detector based on a path difference of ~10^{-18} m is too small to be detected accurately. [B1]

Hence the effective path difference between the light beams has to be increased by reflecting the light as many times as it is necessary to increase the amplitude of the resultant wave received at the photo detector for it to be detected accurately. [A1]

(iii) Since the two beams of light are π radians out of phase in the absence of gravitational waves, they will interfere destructively to produce a zero amplitude at the detector. [B1] [B1]

(c) (i) Power $P = \dfrac{N}{t}\left(\dfrac{ch}{\lambda}\right) \Rightarrow \dfrac{N}{t} = \dfrac{P}{\left(\dfrac{ch}{\lambda}\right)}$ [M1] [B1]

$$\therefore \frac{N}{t} = \frac{100}{\left(\dfrac{3.00\times10^{8}\times6.63\times10^{-34}}{1064\times10^{-9}}\right)} = 5.35\times10^{20}\ \text{s}^{-1}$$ [A1]

(ii) Force $F = \dfrac{\Delta p}{\Delta t} = \dfrac{N}{t}\Delta p$ [M1]

For total reflection of each photon, $\Delta p = 2p$, but $p = \dfrac{h}{\lambda}$ [B1]

$$\therefore F = \frac{N}{t} \times 2\left(\frac{h}{\lambda}\right) = 5.35 \times 10^{20} \times 2\left(\frac{6.63 \times 10^{-34}}{1064 \times 10^{-9}}\right) = 6.67 \times 10^{-7} \text{ N}$$ [A1]

(iii) If some of the photons are absorbed, then the momentum change per photon is $-p$ and not $-2p$, hence the force on the mirror will be smaller. [A1]

(d) (i) Using $E = \Delta mc^2$,

where Δm = change in mass of the black holes after the collision [M1]

$$\therefore \text{ Energy released} = (29 + 36 - 62) \times 2.0 \times 10^{30} \times (3.00 \times 10^{8})^2$$
$$= 5.4 \times 10^{47} \text{ J}$$ [A1]

(ii) Intensity $I = \dfrac{P}{4\pi r^2}$ [M1]

where $r = 1.39 \times 10^{9} \times 9.5 \times 10^{15} = 1.235 \times 10^{25}$ m [C1]

$$\therefore I = \frac{5.4 \times 10^{47}}{20 \times 10^{-3} \times 4\pi (1.235 \times 10^{25})^2} = 0.0141 \text{ Wm}^{-2}$$ [C1] [A1]

(e) (i) Time interval between the two peaks = (2.4 × 0.01) / 2 = 0.012 s [A1]

(ii) speed $v = \dfrac{\text{distance}}{\text{time}} = \dfrac{3002 \times 10^{3}}{0.012} = 2.50 \times 10^{8} \text{ m s}^{-1}$ [A1]

(iii) Gravitational waves travel more slowly in a medium that is denser than free space. [A1]

(f) 1. As the gravitational waves travel solely through free space, there will be less energy loss and the signal will be stronger and hence easier to detect. [A1]

2. Since the detectors are in space, they will be isolated from other bodies and thus there will be much less external disturbances (or noise). [A1]

Paper 3

1 **(a)** **(i)** If air resistance is negligible, using $v^2 = u^2 + 2as$

$0 = 160^2 + 2 \times (-9.81) \times s$ [1]

$s = 1305$ m [1]

Since the greatest height of the object is less than 1305 m, air resistance is not negligible. [1]

(ii) By conservation of energy, energy lost =

$$\frac{1}{2}mv^2 - mgh = \frac{1}{2}\left(0.92\times10^{-3}\right)\left(160^2\right) - \left(0.92\times10^{-3}\right)(9.81)(1100)$$ [1]

$$= 1.85 \text{ J}$$ [1]

(b) $F = ma$

$3.4 \times 10^{-3} + 0.92 \times 10^{-3} \times 9.81 = 0.92 \times 10^{-3} \times a$

$a = 13.5$ m s^{-2}

(c) $F_A = k\,v^2$

v	F_A	k
90	1.10×10^{-3}	1.36×10^{-7}
120	1.90×10^{-3}	1.32×10^{-7}
160	3.40×10^{-3}	1.33×10^{-7}

Since the value of k for the three values of v are similar, F_A is proportional to the square of v.

Reading off correct values from graph [1]
Correct calculation for 3 values of k [1]
Correct conclusion [1]

2 **(a)** Gravitational force provides centripetal force. [1]

$$\frac{GMm}{(R+h)^2} = \frac{mv_s^2}{R+h}$$ [1]

$$v_s = \sqrt{\frac{GM}{R+h}}$$ [1]

(b) Total energy of the rock at infinity is zero. [1]
By conservation of energy,

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

$$V = \sqrt{\frac{2GM}{R+h}}$$ [1]

(c) v_s is the velocity required for an object to move in circular orbit at height of h. Since my answer in **(b)** is greater in value than my answer in **(a)**, the rock will travel off into space. [1] [1]

Note: The answers in (a) and (b) are insufficient for us to decide if the rock will travel off into space. While the speed calculated in (b) is larger than that required for circular motion calculated in (a), the rock may travel in an elliptical orbit. It is only because we know that the total energy of the rock is zero that we know the rock is not bounded to the Earth and will travel off into space.

3 **(a)** **(i)**

$$\frac{V_A}{T_A} = \frac{V_B}{T_B}$$

$$\frac{2.8 \times 10^3}{315} = \frac{7.6 \times 10^3}{T_B}$$ [1]

$$T_B = 855 \text{ K}$$ [1]

(ii) Work done = $3.5 \times 10^5 \times (7.6 \times 10^3 - 2.8 \times 10^3) \times 10^{-6}$ [1]
= 1680 J [1]

(b)

From point B to point C	0 J	[1]
From point C to point A	–2520 J	[1]
From point A to point B	2520 J	[1]

4 **(a)** **(i)** Taking downwards to be positive
At equilibrium, $Mg = \rho AgL$ [1]
where L is length of the tube that is submerged at equilibrium
At displacement x, the resultant force $F = Mg - \rho Ag(L+x)$ [1]
$F = Mg - \rho AgL - \rho Agx$
$F = \rho AgL - \rho AgL - \rho Agx$
$F = -\rho Agx$ [1]

(ii) Using $F = ma$ [1]
$-\rho Agx = Ma$ [1]

$$a = -\left(\frac{\rho Ag}{M}\right)x$$

(b) $a = -\omega^2 x$

$$\omega^2 = \frac{\rho Ag}{M}$$ [1]

$$4\pi^2 f^2 = \frac{\rho Ag}{M}$$ [1]

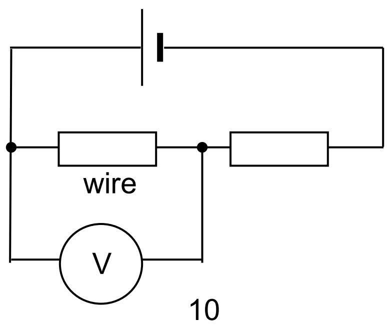
$$4\pi^2 f^2 = \frac{1.2 \times 10^3 \times 5.3 \times 10^{-4} \times 9.81}{0.130}$$ [1]

$$f = 1.10 \text{ Hz}$$ [1]

5 **(a)** $F = kx$
$27 = 1.9 \times 10^4 \times x$ [1]
$x = 1.5 \times 10^{-3}$ m [1]

(b) Change of resistance = $\dfrac{\rho \Delta x}{A} = \dfrac{1.2 \times 10^{-8} \times 1.5 \times 10^{-3}}{2.0 \times 10^{-7}}$ [1]
$= 2.4 \times 10^{-4}\ \Omega$ [1]

(c) [2]



6 (a) (i)

$$B = \mu_0 nI = 4\pi \times 10^{-7} \times \frac{900}{0.46} \times 2.4$$ [1]

$= 5.90 \times 10^{-3}$ T [1]

(ii) The flux pattern of the magnetic field in a solenoid is uniform and the magnitude of the magnetic flux density would be the same within the solenoid. [1]
Hence, the magnitude of the magnetic flux density at the ends of the solenoid will be half of that at the centre. [1]

(b) (i) Faraday's law of electromagnetic induction states that the <u>induced e.m.f. is proportional</u> to the <u>rate of change of magnetic flux linkage</u>. [1] [1]

(ii)

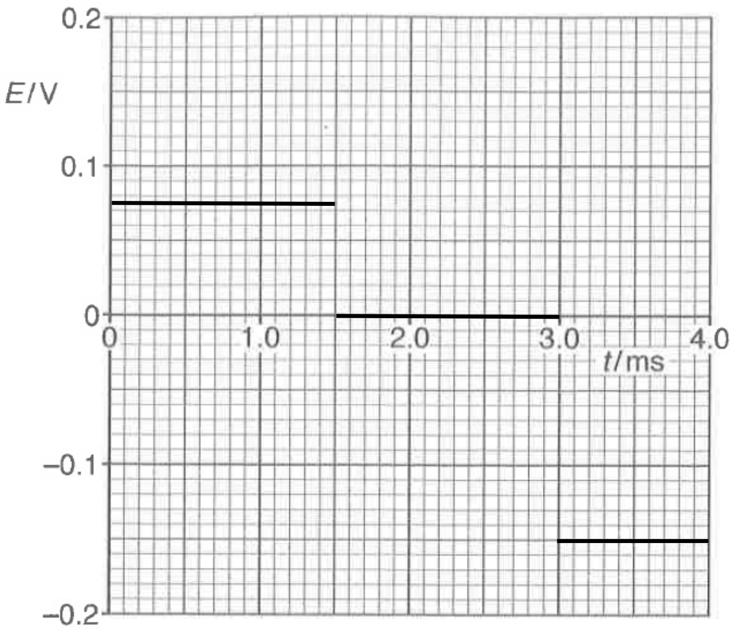
$$\text{e.m.f.} = \frac{\Delta\Phi}{\Delta t} = \frac{95 \times 5.90 \times 10^{-3} \times \pi \times \left(0.8 \times 10^{-2}\right)^2}{1.50 \times 10^{-3}}$$ [1]

$= 0.0751$ V [1]

(iii)

$$B_4 = \mu_0 nI = 4\pi \times 10^{-7} \times \frac{900}{0.46} \times 3.2 = 7.868 \times 10^{-3} \text{ T}$$

$$\text{e.m.f.}_{3-4} = \frac{\Delta\Phi}{\Delta t} = \frac{95 \times 7.868 \times 10^{-3} \times \pi \times \left(0.8 \times 10^{-2}\right)^2}{1.00 \times 10^{-3}} = 0.150 \text{ V}$$



7 (a) It is the <u>value of a steady direct current</u> that can produce the <u>same average power dissipation in the same resistive load</u>. [1] [1]

(b) (i)

$$V_{rms} = \frac{V_o}{\sqrt{2}} = \frac{24}{\sqrt{2}} = 17.0 \text{ V}$$ [1]

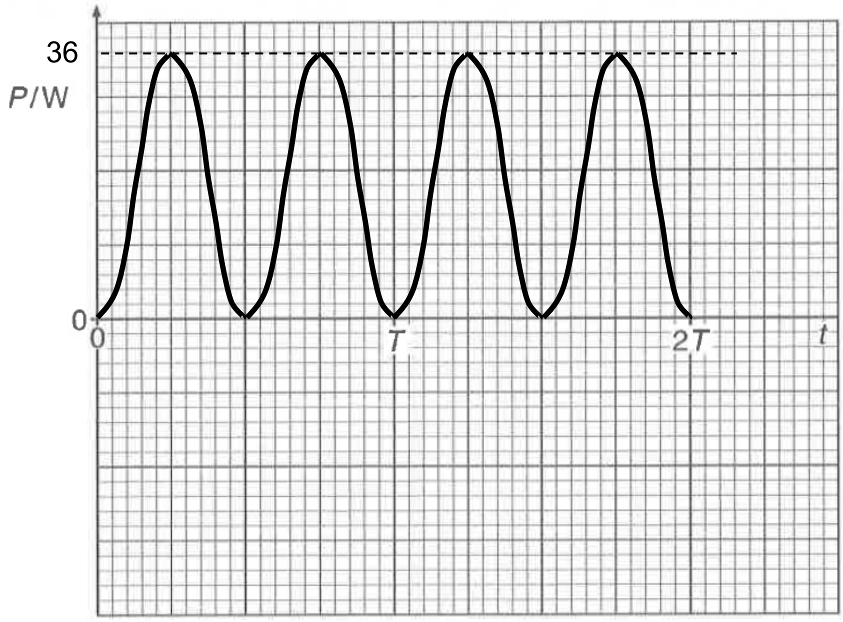
(ii) $\omega = 440$
$2\pi f = 440$
$f = 70.0$ Hz [1]

(c) **(i)** mean power = $\dfrac{V_{rms}^{\ 2}}{R} = \dfrac{17.0^2}{16}$ [1]

$= 18.1$ W [1]

(ii) peak power = $\dfrac{V_0^{\ 2}}{R} = \dfrac{24.0^2}{16} = 36.0$ W [1]

[2]



8 **(a)** **(i)** A photon is a quantum of electromagnetic energy. [1]
Each photon has an energy *hf* where *f* is the frequency. [1]

(ii) Light waves are coherent if they have a constant phase difference. [1]

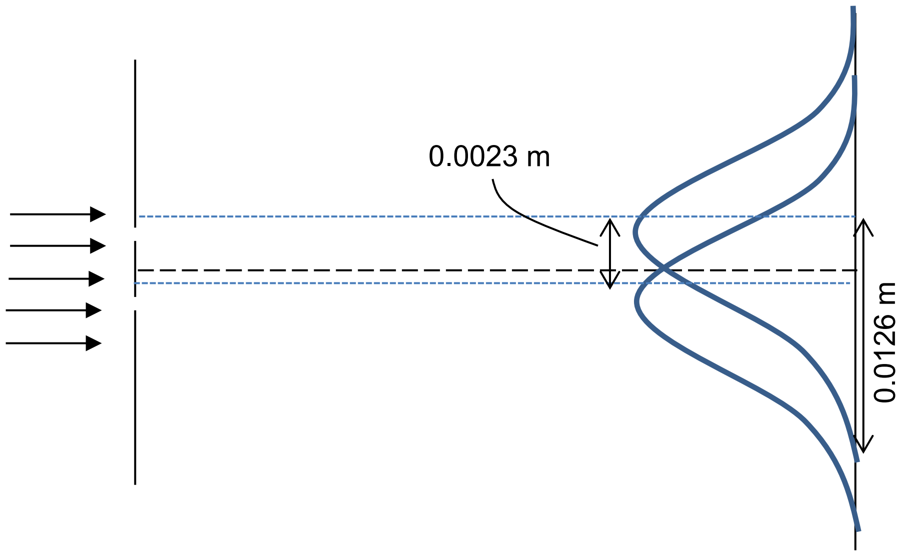
(b) **(i)** Angular position of first minimum $= \dfrac{\lambda}{b} = \dfrac{5.90 \times 10^{-7}}{0.15 \times 10^{-3}} = 0.00393$ [2]

Hence, half-width of central maximum $= 3.2 \times 0.00393 = 0.0126$ m [1]

Full width $0.0126 \times 2 = \mathbf{0.025\ m}$ [1]

(ii) The images of two point sources are considered just resolved if the centre of the central maximum of one of the images coincides with the first minimum of the central maximum of the other image. [2]

(iii)



From **(b)(i)**, the first minimum of the diffraction pattern of the upper slit is 0.0126 m from the centre of its pattern, and this is further than the position of the central peak of the diffraction pattern of the lower slit, which is only 0.0023 m away.
Hence, the two diffraction patterns will not appear as separate.

Note: this question is erroneous because the above explanation is not Rayleigh criterion at all even though it is also based on the width of the central maximum of each pattern. Rayleigh criterion is about whether the images of **two light sources** at close proximity can be resolved after their light passes through the **same** aperture, while in this case we have **one light source** passing through **two apertures** instead.

(iv) $\Delta x = \dfrac{\lambda D}{a} = \dfrac{5.90 \times 10^{-7} \times 3.2}{0.0023}$ [1]

$= 8.2 \times 10^{-4}$ m [1]

(v) Number of fringes $= \dfrac{0.0252}{8.2 \times 10^{-4}} \approx 30$ [1]

(c) **(i)** Slit separation $d = \dfrac{10^{-3}}{750} = 1.33 \times 10^{-6}$ m [1]

$d \sin\theta_1 = \lambda \Rightarrow \theta_1 = \sin^{-1}\left(\dfrac{5.90 \times 10^{-7}}{1.33 \times 10^{-6}}\right) = 26°$ [1]

$d \sin\theta_2 = 2\lambda \Rightarrow \theta_2 = \sin^{-1}\left(\dfrac{2 \times 5.90 \times 10^{-7}}{1.33 \times 10^{-6}}\right) = 62°$ [1]

(ii) The central bright spot will not be along the normal to the plane of the grating. [1]
There will be more bright spots on one side of the central spot than the other side. [1]

9 **(a)** *Radioactive decay* is the spontaneous disintegration of atomic nuclei into another species through emissions of alpha or beta particles or the de-excitation of nuclei to lower energy states through the emission of gamma radiations.

Nuclear fission is the disintegration of a heavy nuclide into more stable medium-sized nuclides.

Nuclear fusion is a nuclear reaction in which two or more lighter nuclei combine to form a heavier nuclide.

(b) **(i)** Mass difference

$=(14.003074+4.002604-16.999130-1.007825)\times1.66\times10^{-27}$ [1]

$=-2.1198\times10^{-30}$ kg [1]

Hence, the associated energy

$=-2.1198\times10^{-30}\text{ kg}\times(3.00\times10^{8})^{2}$ [1]

$=-\mathbf{1.91\times10^{-13}}$ **J** [1]

(ii) From **(b)(i)**, there is an energy deficit of 1.91×10^{-13} J in the reaction. Since this is more than the kinetic energy of the alpha particle, the reaction will not take place or else the total mass-energy will not be conserved. [1] [1]

(c) **(i)** $E=1.16\times1.6\times10^{-13}=1.856\times10^{-13}$ J [1]

$E=\dfrac{hc}{\lambda}$ [1]

$1.856\times10^{-13}=\dfrac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$

$\lambda=\mathbf{1.07\times10^{-12}}$ **m** [1]

(ii) $p=\dfrac{h}{\lambda}=\dfrac{6.63\times10^{-34}}{1.07\times10^{-12}}=\mathbf{6.20\times10^{-22}}$ **kg m s^{-1}**

(d) **(i)** Since the nucleus was stationary initially, the initial momentum is zero. By principle of conservation of momentum, the total momentum of the daughter nucleus and the gamma ray photon is zero too. [1]

Hence, [1]

$E_k=\dfrac{p^2}{2m}$ [1]

$=\dfrac{(6.20\times10^{-22})^2}{2\times60\times1.66\times10^{-27}}$ [1]

$=\mathbf{1.93\times10^{-18}}$ **J**

Note: the marks for this part seems generous because the use of $E_k=p^2/2m$ shortens the workings.

(ii) Since $\dfrac{1.93\times10^{-18}}{1.856\times10^{-13}}\approx1.0\times10^{-5}$, the energy of the daughter nucleus is negligible compared to the energy of the γ-ray photon. [1]