2021 A-Level H2 Physics Suggested Solutions

Paper 1

1 **C** Relate to how heavy a 50 g slotted mass feels (during practical sessions). A handphone is approximately 150 g (around three pieces of 50 g).
$W = mg = (0.150)(9.81) = 1.45\ \text{N} \approx 1.5\ \text{N}$
$150\ \text{cN} = 150 \times 10^{-2}\ \text{N} = 1.5\ \text{N}$

2 **A** Using $F = B I L$
unit on left : kg m s^{-2} (using $F = ma$)
unit on right : (unit of B)(A)(m)

hence unit of B = kg A^{-1} s^{-2}

3 **B** At the top of the projectile, ball has horizontal velocity to the right. Hence air resistance is to the left. It has a weight, vertically downwards. Therefore, resultant force is in the direction indicated by arrow B.

4 **B** Taking right as positive:
relative speed of approach = relative speed of separation
$v - 0 = 0.67v - v_x$
$v_x = -0.33\ v$

5 **A** Common mistake is to choose C. Option C gives the N3L pair of floor and brick. But question is asking for N3L pair of W and that of S.
W is force between brick and Earth.
S is force between brick and floor.

6 **B** When ball is in water,
weight of ball = upthrust + tension
$(0.100)(9.81) = (0.5v)\ \rho_w\ g + (0.75)(0.100)(9.81)$
where ρ_w : density of water (1000 kg m^{-3})
hence $v = 5 \times 10^{-5}\ m^3 = 50\ cm^3$

7 **D** Extra elastic potential energy = area under force-extension graph (hence it is the area the line makes with the vertical axis)
$= ½\ (W_1)(x_1) - ½\ (W_0)(x_0)$
$= ½\ (W_1 x_1 - W_0\ x_0)$

8 **A** Work done against resistive forces in moving 1 km = $f \times d$
= (400)(1000) = 400 000 J

16 % of fuel is converted to work done against resistive forces.
Hence fuel needed is 400 000 / 0.16 = 2500 000 J

Since 1 kg provides 48 MJ, the amount of fuel needed
= 2500 000/ (48×10^6) = 0.052 kg = 52 g

9 **A** $\omega = \frac{v}{r} = \frac{Be}{m}$ hence angular velocity is proportional to B (for constant e and m).

10 **B** Using proportion, 10 m : 6.0 J kg^{-1}
2.5 m : 1.5 J kg^{-1}

Work done = gain in gPE = $m(\Delta\phi)$ = (2)(1.5) = 3.0 J

11 **D** $v = r\omega$

$= (36000000 + 6400000)(\frac{2\pi}{24 \times 3600})$

$= 3083 \text{ m s}^{-1}$

12 **C** Assuming gas is ideal, using $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
where Nm = total mass of gas = (5000)(0.029)

hence

$10^5 = \frac{1}{3}\frac{(5000)(0.029)}{(10)(3)(4)} < c^2 >$

$< c^2 > = 248275$

$\sqrt{< c^2 >} = 498$

13 **D** $Q = mc\,\Delta\theta + ml$
=(5)(4190)(70) + (5)(2260 000)
= 1.28×10^7 J

14 **B** No change in internal energy since there is no heat transferred or work done on gas.

15 **C** For SHM, when velocity is maximum, KE is maximum and PE is minimum.
When velocity is zero, KE is zero and PE is maximum.
Since PE is maximum at 0 and 2 s, only option A and C has velocity zero at 0 and 2 s.
When t = 1s, PE = 0, so KE should be max.
Hence answer is C.

16 **D** $c = f\lambda$
$\lambda = (3.00 \times 10^8) / (5.0 \times 10^{14}) = 6.0 \times 10^{-7}$

$\Delta\phi = \frac{\Delta x}{\lambda}(2\pi)$

$= \frac{1.5 \times 10^{-6}}{6.0 \times 10^{-7}}(2\pi)$

$= 5\pi$

Phase difference of 5π is equivalent to π radian.

17 **B** Malus' law : intensity $\propto \cos^2\theta$

Initially, when middle filter is 45° to X and Y, the intensity of light emerging from Y is non-zero.
When middle filter is 90° to X and Y, the intensity of light emerging from Y is zero (since $\cos^2 90° = 0$) .

18 D

Rayleigh criterion $\theta = \dfrac{\lambda}{b} = \dfrac{620 \times 10^{-9}}{0.50} = 1.24 \times 10^{-6}$

Using

$\theta \approx \dfrac{d}{L}$ where *d*: separation of sources; *L* : distance from source to observer

$$1.24 \times 10^{-6} = \frac{d}{5.7 \times 10^{16}}$$

$$d = 7.1 \times 10^{10}$$

19 D

20 C

$$F_{12} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

$$2.0 = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} \quad ....(1)$$

$$F_{23} = \frac{(2Q_1)Q_2}{4\pi\varepsilon_0 (2r)^2} \quad ....(2)$$

$$(2)/(1) : F_{23} = \frac{2}{4} \times 2 = 1$$

21 B

$$R = \frac{\rho l}{A}$$

$$\frac{R}{l} = \frac{\rho}{A} = G$$

For 4 wires arranged in parallel, the total cross-sectional area = 4 *A*

$$R = \frac{\rho L}{4A}$$

$$= G\frac{L}{4}$$

22 A Both components are in series, hence have same current. The total p.d. across them has to be 3.0 V.
From graph, when current is 0.10 A, the p.d. across both components = 1.0 + 2.0 = 3.0 V.

23 C For lamp to glow more brightly, p.d. across LDR has to be small and p.d. across lamp and thermistor has to be large.
LDR has low resistance in bright light.
Thermistor has high resistance in low temperature.

24 **A** Using right-hand grip rule for the circular coil, the B-field is pointing into paper. Using FLHR, the force on short wire is upwards.

25 **D** Magnetic flux = BA

26 **A**
$$< E > = \frac{\Delta\Phi}{t} = \frac{\Delta(NBA)}{t}$$
$$= \frac{(3000)(1.8)(\pi 0.01^2)}{0.06} - 0$$
$$= 28\,\text{V}$$

27 **B**
$$\frac{V_s}{V_p} = \frac{16}{1.88} = 8.5$$
$$\frac{V_s}{V_p} = \frac{I_p}{I_s}$$
Hence I_s = 0.32 / 8.5 = 0.038 A = 38 mA

28 **B** Longer wavelength corresponds to transition between smaller ΔE.
Hence 590 nm corresponds to transition from n = 3 to 2.
$\Delta E_{3\to1} = \Delta E_{3\to2} + \Delta E_{2\to1}$
$$\frac{hc}{\lambda} = \frac{hc}{590} + \frac{hc}{440}$$
$$\lambda = 252$$

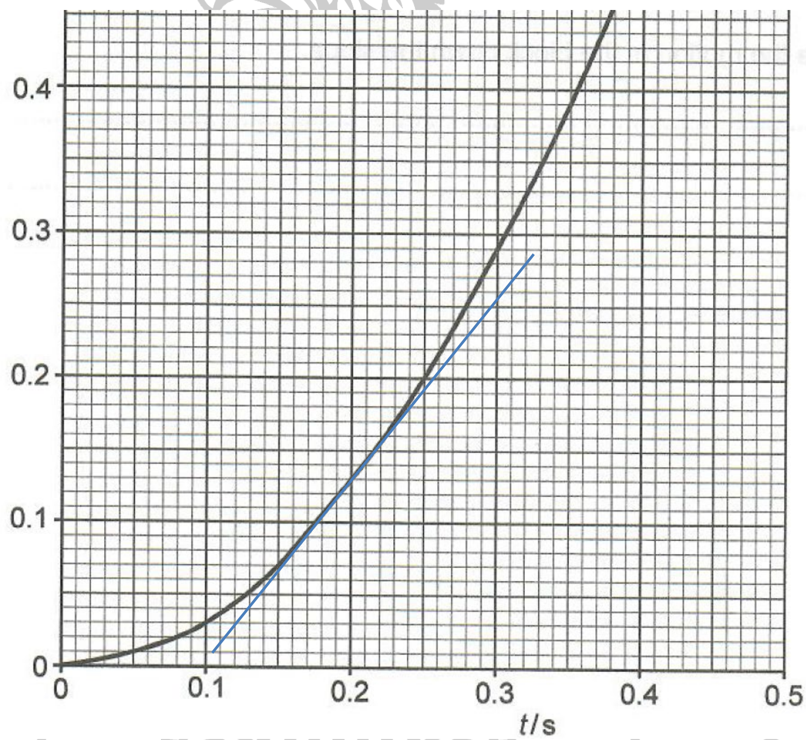
29 **D**
$$\text{intensity} = \frac{P}{A} = \frac{Nhf}{tA}$$

30 **B** Energy released = ($m_{reactants}$ – $mass_{products}$) c^2
= $(136.90709 - 136.90583 - 5.49 \times 10^{-4})(1.66 \times 10^{-27})(3.00 \times 10^8)^2$
$= 1.1 \times 10^{-13}$

2021 A-level H2 Physics Suggested Solutions
Paper 2

1 (a) The block will <u>accelerate uniformly along a straight path</u> down the slope at a rate less than $g = 9.81 \text{ m s}^{-2}$. [1]

(b) (i)



[1]

Using points (0.120, 0.030) and (0.320, 0.280) on the tangent line,

$$\text{speed} = \text{gradient} = \frac{0.280 - 0.030}{0.320 - 0.120} = 1.25 \text{ m s}^{-1}$$ [1]

(ii) $v = u + at$

$1.25 = 0 + a \times 0.20$ [1]

$a = 6.25 \text{ m s}^{-2}$ [1]

2 **(a)** From graph, the momentum of the ball as it makes contact with the surface (at 0.53 s) is 3.20 N s. [1]

$$E_k = \frac{p^2}{2m} = \frac{3.20^2}{2 \times 0.62}$$ [1]
$$= 8.26 \text{ J}$$ [1]

(b) From graph, the ball is in contact with the surface from $t = 0.53$ s to 0.68 s, during which its momentum changes from 3.20 N s to −1.80 N s.

The magnitude of the average force on the ball is equal to the magnitude of the total change in momentum over the total time interval. (This is basically from Newton's 2nd Law.)

$$\langle F \rangle = \left| \frac{\Delta p}{\Delta t} \right| = \left| \frac{-1.80 - 3.20}{0.68 - 0.53} \right| = 33.3 \text{ N}$$ [1] [1]

But note that **this average force represents only the net force on the ball** – not the force the surface acts on the ball! That would be the normal contact force, which is what we are tasked to find.

When in contact with the surface, two forces act on the ball – the normal contact force N upwards, and the weight of the ball mg downwards. (Note that the magnitude of N can vary with time.) However, since $\langle F \rangle$ on the ball is upwards, the average normal contact force $\langle N \rangle$ must be larger than the weight of the ball. [1]

[1]

$$\langle F \rangle = \langle N \rangle - mg$$
$$\langle N \rangle = \langle F \rangle + mg = 33.3 + 0.62(9.81)$$
$$= 39.4 \text{ N}$$

Note: The final answer has to be positive, since it is the magnitude.

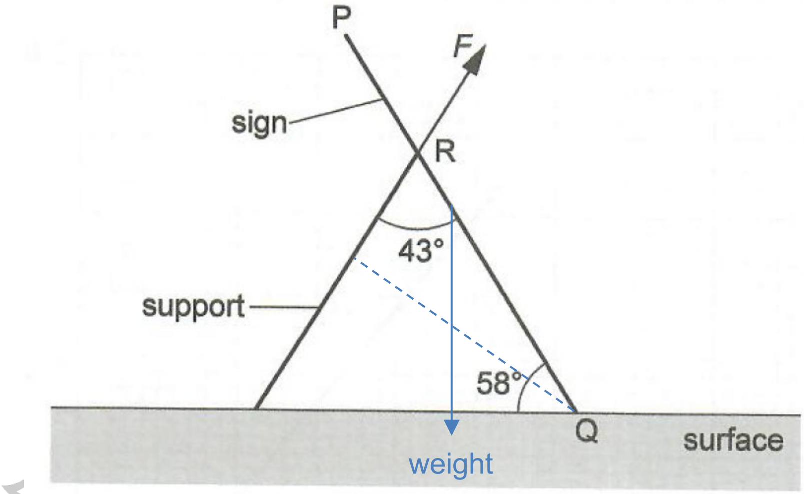
(c) KE after the first rebound $= \frac{1.80^2}{2 \times 0.62} = 2.61$ J

fraction of KE retained after every rebound $= \frac{2.61}{8.26} = 0.316$ [1]

After n-th rebound, the fraction of the initial KE retained is 0.316^n
$0.316^n = 5.0\% = 0.050$ (solved by taking logarithm on both sides) [1]
$n = 2.60 = 3$ (round up, integer number of times of rebounding) [1]

Note: Since the fractional loss of KE is constant for every rebound, the fraction of KE retained is also constant, because (fractional loss) + (fraction retained) = 1.

3 (a) [1]



Let the length of PQ be L.

clockwise moment due to F = anticlockwise moment due to weight

$$F \times \frac{2L}{3} \times \sin 43^\circ = \text{weight} \times \frac{L}{2} \times \cos 58^\circ$$ [1]

$$F = \frac{2.3 \times 9.81 \times 3 \times \cos 58^\circ}{4 \times \sin 43^\circ}$$ [1]

$$= 13.1\ \text{N}$$ [1]

(b) Force F has a rightward component and an upward component. Since weight points only vertically down, [1]
force at Q must have a leftward horizontal component to counter the rightward horizontal component of F, so that PQ can be in equilibrium. [1]
Hence, the force at Q cannot be vertical.

4 (a) Consider a small test mass with mass *m*, located a distance *r* from *M*.

Newton's Law of gravitation: gravitational force $F = \frac{GMm}{r^2}$

Gravitational field strength *g* is defined as the gravitational force experienced per unit mass.

$$g = \frac{\text{gravitational force}}{m} = \frac{1}{m}\frac{GMm}{r^2} = \frac{GM}{r^2}$$ [1]

(b) Since the centripetal force is provided by the gravitational force, the centripetal acceleration a_c is equal to *g*.

$$a_c = g,\ \omega^2 r = \frac{GM}{r^2} \Rightarrow r = \left(\frac{GM}{\omega^2}\right)^{\frac{1}{3}}$$ [1]

angular speed of the satellite, $\omega = \frac{2\pi}{110 \times 60} = 9.52 \times 10^{-4}$ rad s^{-1} [1]

Hence,

$$g = \frac{GM}{r^2} = \frac{GM}{\left(\frac{GM}{\omega^2}\right)^{\frac{2}{3}}} = \left(GM\omega^4\right)^{\frac{1}{3}} = (6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (9.52 \times 10^{-4})^4)^{\frac{1}{3}}$$ [1]

$= 6.90$ m s^{-2} [1]

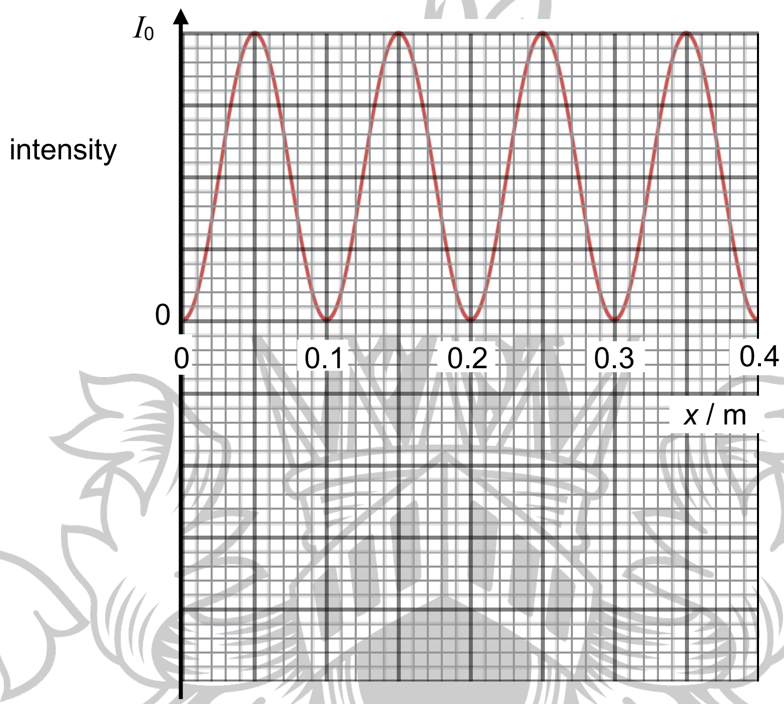
(c) Using the satellite from (b) as a comparison, Earth's angular velocity ω is $\frac{2\pi}{T} = \frac{2\pi}{24(60)(60)} = 7.27 \times 10^{-5}$ rad s^{-1}, which is an order of magnitude smaller than the satellite's $\omega = 9.52 \times 10^{-4}$ rad s^{-1}. Since $a_c = r\omega^2$, the a_c on Earth's surface must be about two orders of magnitude smaller than the satellite's centripetal acceleration $a_c = g = 6.90$ m s^{-2}, due to the ω^2 term and the smaller orbital radius *r* for an object on Earth. [1]

Therefore, the centripetal acceleration a_c of an object moving with the surface of Earth must also be about two orders of magnitude smaller than the gravitational acceleration *g*, which is approximately 9.81 m s^{-2}. [1]

Since $g = a_c + a_{freefall}$, with a_c being negligible, *g* and $a_{freefall}$ are approximately equal. They are exactly equal at the South and North poles, where the radius of circular motion (hence a_c) is zero. [1]

(Note: Earth's radius *r* is approximately 6370 km, and its angular velocity ω is $\frac{2\pi}{T} = \frac{2\pi}{24(60)(60)} = 7.27 \times 10^{-5}$ rad s^{-1}. Hence, $a_c = r\omega^2 = 0.034$ m s^{-2}, which is almost 300 times smaller than $g = 9.81$ m s^{-2}. Hence, $a_c << g$.)

5 (a) wavelength $= \dfrac{v}{f} = \dfrac{340}{1700} = 0.200$ m

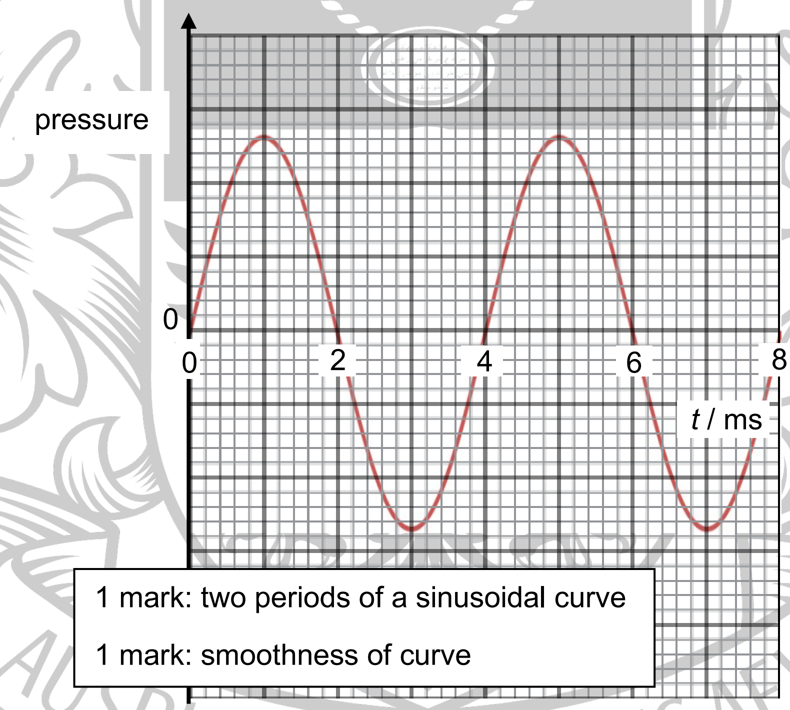


1 mark: only positive values

1 mark: location of nodes and antinodes

1 mark: 4 periods (as deduced from the wavelength, with distance between consecutive nodes (or antinodes) being half a wavelength)

(b) period $T = 1/f = 1/250 = 4.00$ ms

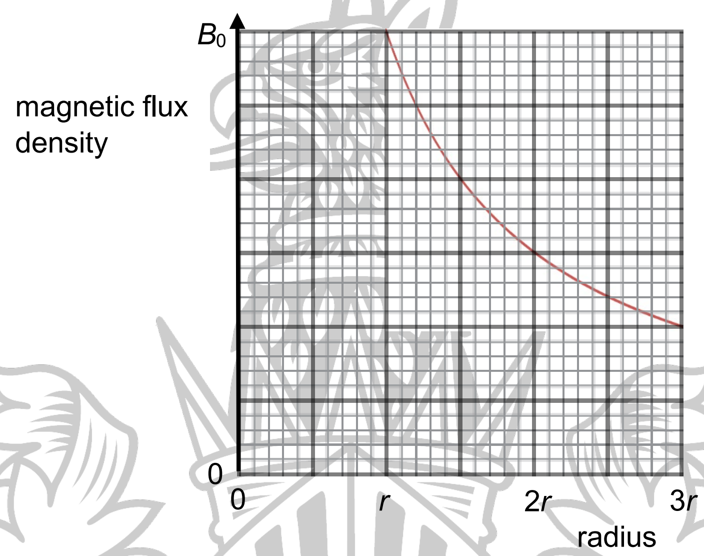


1 mark: two periods of a sinusoidal curve

1 mark: smoothness of curve

Note: The curve should be two periods of a sinusoidal curve. The phase angle and the amplitude of the curve do not matter.

(c) $B = \frac{\mu_0 N I}{2r} \propto \frac{1}{r}$



2 marks: values of B at r, $2r$ and $3r$ (B_0, $B_0/2$, $B_0/3$)

1 mark: smoothness of curve

6 (a) (i) Potential difference across R $=$ potential difference across lamp

$$= 0.30 \times 5.0$$
$$= 1.5 \text{ V}$$ [1]

Potential difference across R $=$ potential difference across lamp

$$= 0.30 \times 5.0$$
$$= 1.5 \text{ V}$$ [1]

Potential difference across the 3.0 Ω resistor $= 6.0 - 1.5 = 4.5 \text{ V}$

Current flowing through the 3.0 Ω resistor $= \dfrac{4.5}{3.0} = 1.5 \text{ A}$

Hence, current flowing through R is 1.5 – 0.30 = 1.2 A. [1]

Resistance of $R = \dfrac{1.5}{1.2} = 1.25 \approx \mathbf{1.3\ \Omega}$

Alternatively:

Potential difference across the 3.0 Ω resistor $= 6.0 - 1.5 = 4.5 \text{ V}$ [1]

Let the effective resistance of R and the lamp be R_{eff}. Then

$$\frac{R_{eff}}{3} = \frac{1.5}{4.5} \quad \Rightarrow \quad R_{eff} = 1.0\ \Omega$$ [1]

Hence, $\dfrac{5 \times R}{5 + R} = 1.0$

$$R = \mathbf{1.3\ \Omega}$$ [1]

(ii) The ratio of the power dissipated by the 3.0 Ω, R and the lamp is:

$1.5^2 \times 3.0 : 1.2^2 \times 1.25 : 0.3^2 \times 5.0$ [1]

$= 6.75 : 1.8 : .45$

$= 15 : 4 : 1$ [1]

Hence, the energy transferred in the lamp is

$$\frac{1}{15 + 4 + 1} \times 120 = \mathbf{6.0\ J}$$ [1]

(iii) At the beginning, the <u>temperature of the filament is at its lowest (room temperature), which results in a large current as the resistance is low</u> as well. [1]

As the current flows through the lamp, the <u>temperature of the filament lamp will increase</u>, which will cause the <u>resistance of the filament to increase, resulting in a decrease in current.</u> [1]

Hence, the current is the greatest when the current is first switched on as the temperature and resistance of the filament is the lowest at the start.

(b) Since X and Y are connected in series, the current flowing through is the same. [1]

$$I_x = I_y$$

Since $I = nAve$

$$\Rightarrow \quad n_x A_x v_x e = n_y A_y v_y e$$

$$\frac{n_y}{n_x} = \frac{A_x}{A_y}\frac{v_x}{v_y} = \frac{\pi r^2}{\pi (2r)^2}\frac{3v}{v}$$ [1]

$$= \frac{3}{4} = 0.75$$ [1]

7 (a) Some of the alpha particles were observed to be scattered at large angles. [1]
This shows that they encountered a positive charge that is concentrated into a very small volume known as the nucleus so that the coulomb repulsion is very large. [1]

Since the α particles are back scattered, the positive charge they collided with must also have a much larger mass, otherwise it would be the positive charges that were pushed away rather than the alpha particles scattered backward. [1]
Hence, the mass of the atom is also largely concentrated within the nucleus. [1]

(b) For minimum separation, all the kinetic energy of the α particle is converted into electric potential energy. We are essentially finding the distance of closest approach.

Loss in kinetic energy = Gain in electric potential energy

$$5.59 \times 1.6 \times 10^{-13} - 0 = \frac{(2e)(79e)}{4\pi\varepsilon_o r} - 0$$ [1]

$$= \frac{2 \times 79 \times (1.6 \times 10^{-19})^2}{4\pi(8.85 \times 10^{-12})r}$$ [1]

r = **4.07 × 10⁻¹⁴ m** [1]

(c) $^{222}_{86}\text{Rn} \rightarrow \, ^{218}_{84}\text{Po} + \, ^{4}_{2}\text{He}$

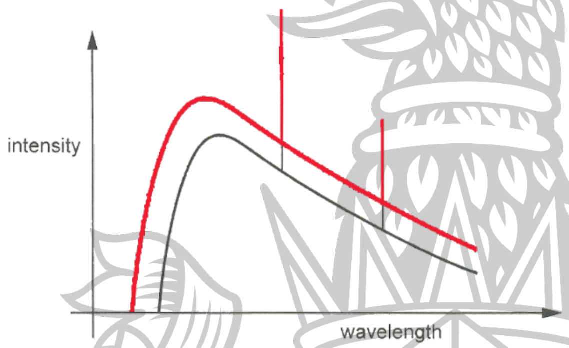
Let the binding energy per nucleon of polonium be E.
Polonium has 222 – 4 = 218 nucleons. [1]

Total binding energy of products = $(4)(7.08) + (218)E$
Total binding energy of reactant (radon) = $(222)(7.69)$ [1]

E_K released $= \text{BE}_{\text{products}} - \text{BE}_{\text{reactants}}$ [1]
$6.62 = (4)(7.08) + (218)E - (222)(7.69)$ [1]
$E = 7.73$ MeV

8 **(a)** It is evacuated to prevent electrons from the electron beam colliding with the gas molecules in the tube, which would reduce the efficiency of X-ray production as scattered electrons may either lose too much energy during the collisions to produce X-rays, or they may not even hit the metal target. [1]

(b) [1] [1] [1]



1. Higher intensity for all wavelengths (including the characteristic peaks)
2. λ_{min} is lower (shifts left)
3. The characteristic X-ray peaks remain at the same positions.

Note: the peak of maximum intensity should shift left to a shorter wavelength.

(c) **(i)**

$$\text{Number of electrons used in one image} = \frac{Q}{e} = \frac{0.12 \times 1.1}{1.6 \times 10^{-19}} = 8.25 \times 10^{17}$$ [1]

$$\text{Thermal energy produced} = 0.99 \times 8.25 \times 10^{17} \times \left(65 \times 1.6 \times 10^{-16}\right) = 8494.2 \approx \mathbf{8500\ J}$$ [1]

(ii)

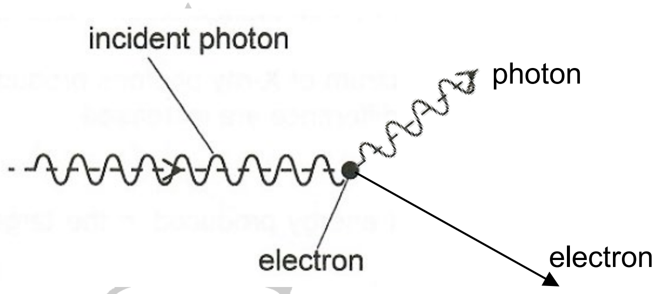
$$\text{Thermal energy} = mc\Delta\theta$$

$$8500 = 0.012 \times 130 \times \Delta\theta$$ [1]

$$\Delta\theta = 5445 \approx \mathbf{5400\ ^\circ C}$$ [1]

(iii) This is to prevent any part of the target from being exposed to the electron beam for a prolonged period (e.g. 1.1 s), which may cause the target to be heated beyond its melting point and start to melt. [1]

(d) (i)



[Note: the directions of the photon and the electron must not contradict momentum conservation in the horizontal and the vertical directions.]

(ii) The photon lost some energy to the electron in the scattering process. Since energy of a photon $E = hc/\lambda$, the wavelength of the photon increases. [1]

(iii) After Compton scattering, the photons move in stray directions. [1]
This will blur the X-ray image produced, resulting in more noise and poorer contrast. [1]

(e) $$\frac{\text{attenuation of X-rays in bone}}{\text{attenuation of X-rays in soft tissue}} = \frac{14^3}{7^3} = 8$$ [1]

(f)
$$I = I_o e^{-\mu x}$$
$$\frac{1}{2} I_o = I_o e^{-\mu x_{1/2}}$$ [1]
$$\mu x_{1/2} = \ln 2$$
$$x_{1/2} = \frac{\ln 2}{\mu}$$ [1]

(g) If detectors are more sensitive, an image of the same contrast can be obtained with reduced X-ray exposure time. The patient will be subjected to less amounts of harmful radiation. [1]

(h) Barium has high atomic number (Z = 56), so X-rays passing through the digestive system will be strongly attenuated by the presence of the barium solution in the system. [1]
On the other hand, the X-ray passing through the neighbouring soft tissue, which has a lower atomic number, will suffer little attenuation.
This allows an image of good contrast to be produced. [1]

(i) Many X-ray images are taken around the body of the patient during a CT scan, compared to a single X-ray. [1]
This results in much greater exposure to harmful radiation for the patient. [1]

2021 A-Level H2 Physics Paper 3 Section A
Suggested Solutions

1 (a) (i) $a = g\sin 40°$

$= 9.81\sin 40°$ [1]

$= 6.31 \text{ m s}^{-2}$ [1]

(ii) $v^2 = u^2 + 2as$

$= 0 + 2(6.31)(0.56)$ [1]

$v = 2.66 \text{ m s}^{-1}$ [1]

(b) (i) $F_c = \frac{mv^2}{r}$

$= \frac{(0.072)(2.66)^2}{0.12}$ [1]

$= 1.35 \text{ N}$ [1]

(ii) $F_c = N + mg$

$N = 1.35 - (0.072)(9.81)$ [1]

$= 0.644 \text{ N}$ [1]

Direction : downwards [1]

2 (a) Gravitational potential at infinity is zero. [1]
Gravitational force is attractive in nature. [1]

To bring a mass from infinity to a point in the gravitational field, the direction of the external force is opposite to the direction of displacement of the mass. This results in negative work done by the external force and hence negative gravitational potential. [1]

(b) (i) $\phi = -\frac{GM}{r}$

$= -\frac{(6.67\times10^{-11})(6.2\times10^{23})}{\left(\frac{6.8\times10^{6}}{2}\right)}$

$= -1.22\times10^{7} \text{ J kg}^{-1}$ [1]

(ii) $KE_i + GPE_i = \frac{1}{2}mv^2 + m\phi$

$= \frac{1}{2}(2.8)(3.8\times10^{3})^2 + (2.8)(-1.22\times10^{7})$ [1]

$= -1.39\times10^{7} \text{ J}$ [1]

Since total initial energy on the surface of planet is less than zero, the rock returns to planet. (Or, to escape, total energy must be ≥ 0.) [1]

3 **(a)** The internal energy of an ideal gas is the <u>sum of the kinetic energies</u> of the molecules due to their <u>random motion</u>. [1] [1]

Note: An ideal gas has no potential energy as the molecules do not experience intermolecular forces except during collisions.

(b) **(i)** Since initial and final gas has the same number of moles of particles,

$$\left(\frac{pV}{RT}\right)_1 = \left(\frac{pV}{RT}\right)_2$$

$$\frac{\left(1.0\times10^5\right)\left(3.2\times10^{-3}\right)}{12+273.15} = \frac{\left(1.0\times10^5\right)\left(3.6\times10^{-3}\right)}{T_2}$$ [1]

$$T_2 = 320.79 \text{ K}$$
$$= 47.6\ ^\circ\text{C}$$ [1]

(ii) Work done by gas against atmosphere $= p\Delta V$

$$= \left(1.0\times10^5\right)\left(3.6-3.2\right)\times10^{-3}$$ [1]
$$= 40 \text{ J}$$ [1]

(c) **(i)** $\Delta U = W + Q = -40 + 101 = 61$ J [1]

(ii)

$$N = \frac{pV}{kT} = \frac{\left(1.0\times10^5\right)\left(3.2\times10^{-3}\right)}{\left(1.38\times10^{-23}\right)\left(12+273.15\right)} = 8.132\times10^{22}$$ [1]

$$\frac{\Delta U}{N} = \frac{61}{8.132\times10^{22}}$$ [1]
$$= 7.50\times10^{-22} \text{ J}$$ [1]

4 **(a)** **(i)**

$$x_0 = \frac{-0.250-\left(-1.250\right)}{2} = 0.500 \text{ cm}$$ [1]

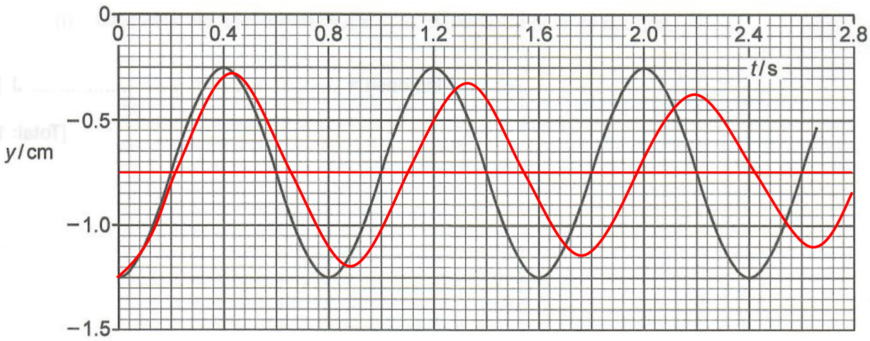
(ii)

$$\omega = \frac{2\pi}{T}$$
$$= \frac{2\pi}{0.80}$$ [1]
$$= 7.85 \text{ rad s}^{-1}$$ [1]

(iii)

$$v_0 = \omega x_0$$
$$= \left(7.85\right)\left(0.50\right)$$ [1]
$$= 3.93 \text{ cm s}^{-1}$$ [1]

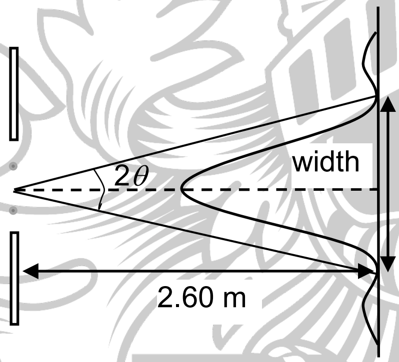
(b) (ii)



Decreasing amplitude. [1]
Longer but <u>constant</u> period. [1]
3 complete oscillations. [1]

5 (a) Diffraction is the <u>bending (or spreading) of waves</u> [1]
after <u>passing through an aperture</u> or <u>round an obstacle</u>. [1]

(b) (i)



$$\sin\theta = \frac{\lambda}{b}$$

$$\theta = \sin^{-1}\left(\frac{590\times10^{-9}}{0.100\times10^{3}}\right)$$ [1]

using arc length, $s = r\alpha$ where $\alpha = 2\theta$

$$\text{width} = (2.60)(2\theta)$$ [1]

$$= 0.0307 \text{ m}$$ [1]

(ii) 1st minimum of single-slit diffraction pattern: $\sin\theta = \frac{\lambda}{b}$.

nth-order maximum of double-slit diffraction pattern: $\sin\theta_n = \frac{n\lambda}{a}$

Hence, the maximum nth-order fringes on one side of central maximum of single-slit diffraction pattern is

$$\frac{n\lambda}{a} < \frac{\lambda}{b}$$

$$n < \frac{a}{b}$$

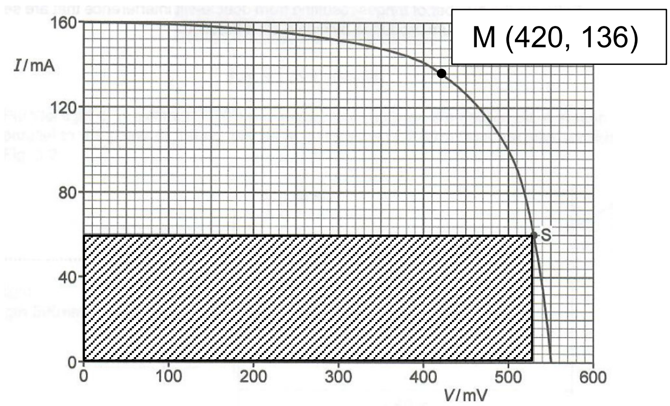
$$= \frac{1.40\times10^{-3}}{0.100\times10^{3}}$$ [1]

$$= 14$$ [1]

Total number of bright fringes seen = 13 + 13 + 1 = 27. [1]

Note: Since the 14th-order of the double-slit pattern falls exactly on the 1st minimum of the single slit pattern, it will not be seen.

6 **(a)**



(i) Rectangular drawn and area shaded accurately. [2]

(ii) Estimate point M where the area of rectangle ($I \times V$) is the largest. [1]

(b) **(i)** At I = 100 mA, V = 500 mV, [1]

$$R = \frac{V}{I} = \frac{500 \times 10^{-3}}{100 \times 10^{-3}} = 5.0\ \Omega$$ [1]

(ii) $P = I^2 R$

$= \left(100 \times 10^{-3}\right)^2 (5.0)$ [1]

$= 0.050$ W [1]

(iii) From graph, e.m.f. of solar cell = 550 mV (when there is no current). [1]

$V = E - Ir$

$$r = \frac{(550 - 500) \times 10^{-3}}{100 \times 10^{-3}} = 0.50\ \Omega$$ [1]

7 **(a)** Similarity:

Both electrical potential and gravitational potential are inversely proportional to the distance from the point charge and point mass. Or, both are defined in terms of work done by an external agent or force. Or, both are scalars. [1]

Difference:

Electrical potential produced by a point charge can be positive or negative depending on the charge, but gravitational potential produced by a point mass is always negative. [1]

(b) **(i)** The potential between the two charges is the addition of the individual potential produced by each charge. Since potential is positive nearer to A and negative nearer to B, it shows that charge A is positive and charge B is negative. Hence the charges have opposite signs. [1]

(ii) Total potential due to charge A and charge B is zero at x = 9.0 cm.

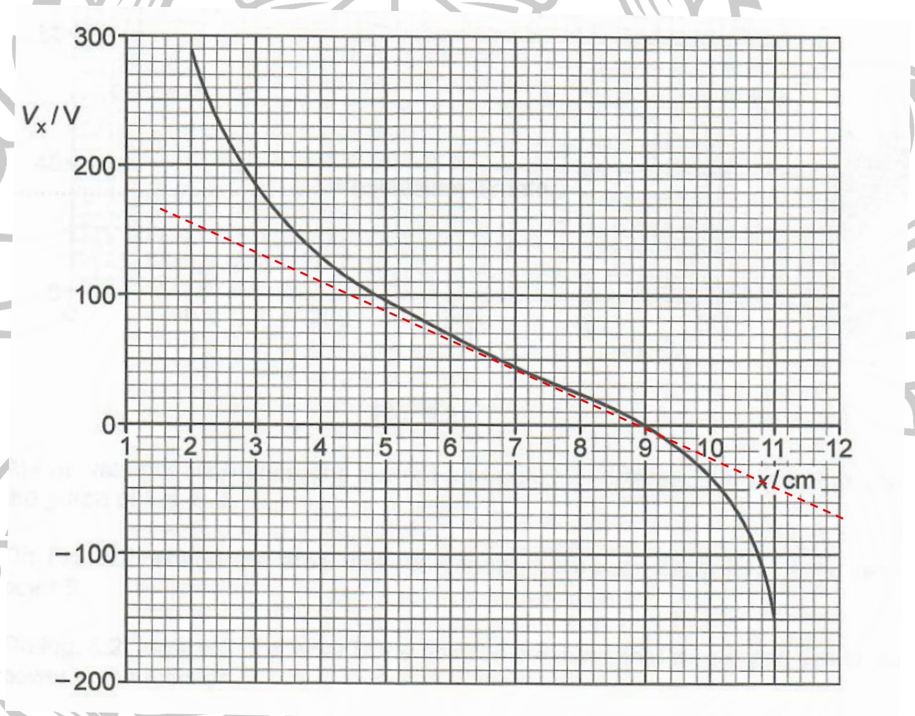
$$V_A + V_B = 0$$ [1]

$$\frac{Q_A}{4\pi\varepsilon_0(0.090)} = -\frac{Q_B}{4\pi\varepsilon_0(0.120-0.090)}$$ [1]

$$\left|\frac{Q_A}{Q_B}\right| = \frac{0.090}{0.030}$$

$$= 3.0$$ [1]

(iii)



Drawing tangent and reading coordinates correctly. [1]

Electric field strength = −gradient of V-x graph

$$= -\frac{160-(-60)}{(1.8-11.6)\times 10^{-2}}$$ [1]

$= 2240$ N C^{-1} (accept 2100-2200 N C^{-1}) [1]

2021 A-Level H2 Physics Suggested Solutions, Paper 3 Section B

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

(b) **(i)** Since the velocity of the proton is perpendicular to the uniform magnetic field, the magnetic force on the proton is always perpendicular to its velocity [1] and it has a constant magnitude. [1] Hence, the proton moves in a circular arc.

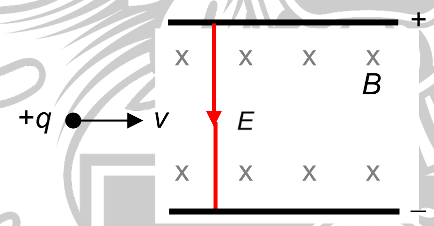
(ii) Since the magnetic force provides the centripetal force for the circular motion of the proton, $Bqv = \frac{mv^2}{r}$

$$B = \frac{mv}{rq}$$

$$= \frac{1.67\times10^{-27}\left(6.2\times10^{5}\right)}{7.6\times10^{-2}\left(1.60\times10^{-19}\right)} \quad [1]$$

$$= 0.085 \text{ T} \quad [1]$$

(c) **(i)**



Deduce direction of B- field.

Correct direction of the E- field. [1]

(ii) Net force on charge is zero: $F_E = F_B \Rightarrow qE = Bqv$

$$E = Bv$$

$$= 0.085148\left(6.2\times10^{5}\right) \quad [1]$$

$$= 5.3\times10^{5}\ \text{Vm}^{-1} \quad [1]$$

(d) **(i)** Since the magnetic flux density *B* varies sinusoidally with time,

$$B_{rms} = \frac{B_0}{\sqrt{2}} = \frac{6.4\times10^{-3}}{\sqrt{2}} = 4.5 \text{ mT} \quad [1]$$

(ii) The times at which the emf induced in S is zero are (any two of):
1.0, 4.0, 7.0, 10.0, 13.0 ms (1 d.p.) [1]

(e) $B_0 = 6.4 \times 10^{-3}$ T [1]
$T = 6.0 \times 10^{-3}$ s [1]

$$\varepsilon = -\frac{d\Phi}{dt} = -NB_0A\frac{d}{dt}\sin(\omega t + \theta) = -NB_0A\omega\cos(\omega t + \theta),$$

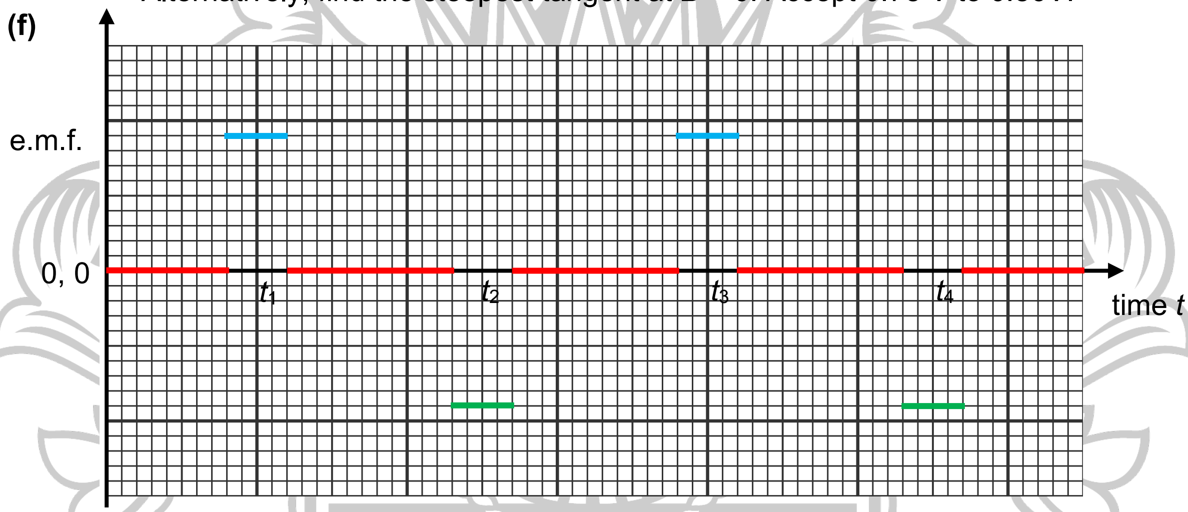
$$\varepsilon_{max} = NB_0A\omega$$

$$= (270)(6.4\times10^{-3})\left(\pi\left(\frac{2.4\times10^{-2}}{2}\right)^2\right)\left(\frac{2\pi}{6.0\times10^{-3}}\right) \quad [1]$$

$$= 0.82\text{V} \quad [1]$$

Alternatively, find the steepest tangent at B = 0. Accept 0.78 V to 0.86V.

(f)



Emf is **zero** during times when flux is constant – shown by the **red** lines [1]

Emf is **positive** and **constant** during times when flux is decreasing uniformly with time – shown by the **blue** lines [1]

Emf is **negative** and **constant** during te times when flux is increasing uniformly with time – shown by the **green** lines [1]

Magnitude and duration of **blue** and **green** lines are the same [1]

9 **(a)** **(i)** 1. Photoelectrons are emitted from the surface of a metal only if the frequency of the light incident on the metal is higher than a certain minimum or threshold value. [1]

2. The maximum kinetic energy of the photoelectrons is dependent only on the frequency, but not on the intensity of the incident light. [1]

(ii) Emission spectrum is produced when an atom de-excite by releasing energy as a photon. [1]

The energy of the emitted photon is given by difference in energies between two energy-levels in the atom ($\frac{hc}{\lambda} = E_{higher} - E_{lower}$). [1]

Since only certain wavelengths are present ($\lambda = \frac{hc}{E_{higher} - E_{lower}}$), it means that discrete energy levels exist in the atom. [1]

(b) (i)

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

$$= \frac{6.63\times10^{-34}\times3.00\times10^{8}}{340\times10^{-9}} = 5.85\times10^{-19}\text{ J}$$ [1]

$$= \frac{5.85\times10^{-19}}{1.60\times10^{-19}}\text{ eV}$$ [1]

$$= 3.66\text{ eV}$$ [1]

(ii) De-excitation between the two lowest levels gives rise to photons of energy −3.4 −(−13.6) = 10.2 eV, which is higher than 3.66 eV of a photon of purple light. [1]

This means that the wavelengths of photons due to transitions to the −13.6 eV level are shorter than 340 nm, which are non-visible since they correspond to uv light. Thus, a visible line spectrum cannot result from transitions to the −13.6 eV energy level. [1]

(c) (i) Decay constant λ = probability of decay per unit time. Hence, probability of decay in time Δt is given by $\lambda\Delta t$.

$$\therefore \lambda.\Delta t = \frac{\ln 2}{53\text{ days}}\times 1\text{ day} = 0.0131$$ [1]

(ii)

$$N_0 = \frac{\text{mass of sample}}{\text{molar mass}}\times\text{Avogadro number}$$

$$= \left(\frac{5.7\times10^{-12}}{7.0\times10^{-3}}\right)\times6.02\times10^{23} = 4.902\times10^{14}$$ [1]

$$N = N_0e^{-\lambda t}$$

$$= 4.902\times10^{14}\times e^{-0.0131(120)}$$ [1]

$$= 1.02\times10^{14}$$ [1]

(iii) By emitting a γ-ray photon, a radioactive beryllium nucleus only loses energy but its composition remains unchanged. Hence, the number of beryllium nuclei is a constant. [1] [1]

(d) From $E = \dfrac{hc}{\lambda}$,

$$p = \frac{h}{\lambda} = \frac{E}{c}$$

$$= \frac{0.48 \times 10^{6} \times 1.60 \times 10^{-19}}{3.00 \times 10^{8}}$$ [1]

$$= 2.56 \times 10^{-22} \text{ N s}$$ [1]

Since $|p_{Be}| = |p_{\gamma}|$,

$$m_{Be} v_{Be} = 2.56 \times 10^{-22}$$

$$v_{Be} = \frac{2.56 \times 10^{-22}}{7 \times 1.66 \times 10^{-27}}$$ [1]

$$= 2.2 \times 10^{4} \text{ m s}^{-1}$$ [1]