2023 RI Preliminary Examinations H1 Physics Paper 2 Solutions

1 **(a)**

$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$g = 4\pi^2 \frac{L}{T^2} = 4\pi^2 \left(\frac{0.850}{\left(\frac{36.9}{20}\right)^2}\right) = 9.858 = 9.86 \text{ m s}^{-2}$$

(b)

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

$$\frac{\Delta g}{9.858} = 2\left(\frac{0.2}{36.9}\right) + \left(\frac{0.001}{0.850}\right)$$

$$\Delta g = 0.118 = 0.1 \text{ m s}^{-2}$$

g = (9.9 ± 0.1) m s^{-2}

2 **(a)** To hit the coconut horizontally, vertical component of the velocity = 0.
Initial vertical velocity = 20 sin θ.

Using $v^2 = u^2 + 2as$, and setting v to 0 m s^{-1} and s = 18.0 – 2.2 = 15.8 m:

$0 = (20\sin\theta)^2 - 2(9.81)(15.8)$

$\sin\theta = 0.880 \Rightarrow \theta = 61.7°$

(b) By $v = u + at$,

$0 = 20\,(0.880) - 9.81 \times t$

$t = 1.79$ s

(c) Horizontal displacement = 20 × cos(61.7°) × 1.79
= 17.0 m

(d) The downward acceleration will be larger and hence the same initial vertical velocity will be reduced to zero over a shorter vertical displacement.

Hence, θ has to be larger so that the initial vertical velocity is larger. Since initial horizontal velocity is smaller and it will decrease due to the air resistance in the horizontal direction, the horizontal displacement will be lower.

3 **(a)** product of mass and (linear) velocity

(b) **(i)** Since collision is elastic, total kinetic energy is the same before and after collision.

$$\cancel{\frac{1}{2}}(2\cancel{m})u^2 + \cancel{\frac{1}{2}}\cancel{m}u^2 = \cancel{\frac{1}{2}}(2\cancel{m})v_A{}^2 + \cancel{\frac{1}{2}}\cancel{m}v_B{}^2$$

$$3u^2 = 2v_A{}^2 + v_B{}^2 \quad \text{(shown)}$$

(ii) **1.** Let the scattering angle of B be β respectively.
By principle of conservation of linear momentum,
Considering horizontal motion, taking right as positive,

$$2\cancel{m}(u) - \cancel{m}u = 2\cancel{m}v_A\cos\theta \quad (\because \beta = 90°)$$

$u = 2v_{\text{A}}\cos\theta \quad ... \quad (1)$ **OR** $v_{\text{A,x}} = v_{\text{A}}\cos\theta = \dfrac{u}{2} \cdots (1')$

Considering vertical motion, taking up as positive,

$0 = 2\cancel{m}v_{\text{A}}\sin\theta - \cancel{m}v_{\text{B}}\sin\beta$

$v_{\text{B}} = 2v_{\text{A}}\sin\theta \quad ... \quad (2)$ **OR** $v_{\text{A,y}} = v_{\text{A}}\sin\theta = \dfrac{v_{\text{B}}}{2} \cdots (2')$

$(1)^2 + (2)^2$,

$(u)^2 + (v_{\text{B}})^2 = (2v_{\text{A}}\cos\theta)^2 + (2v_{\text{A}}\sin\theta)^2$

$u^2 + v_{\text{B}}^2 = 4v_{\text{A}}^2 \quad ... \quad (3)$

OR By Pythagorean theorem

$v_{\text{A}}^2 = v_{\text{A},x}^2 + v_{\text{A},y}^2$

$v_{\text{A}}^2 = \left(\dfrac{u}{2}\right)^2 + \left(\dfrac{v_{\text{B}}}{2}\right)^2 \quad (\text{from}(1') \text{ and } (2'))$

$u^2 + v_{\text{B}}^2 = 4v_{\text{A}}^2 \quad ... \quad (3)$

From equation in **(b)(i)**, $3u^2 = 2v_{\text{A}}^2 + v_{\text{B}}^2 \quad \Rightarrow v_{\text{A}}^2 = \dfrac{3u^2 - v_{\text{B}}^2}{2} \quad ... \quad (4)$

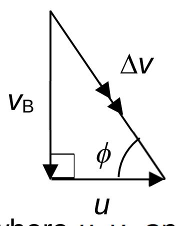
Substituting (4) into (3),

$$u^2 + v_{\text{B}}^2 = 4\left(\frac{3u^2 - v_{\text{B}}^2}{2}\right)$$

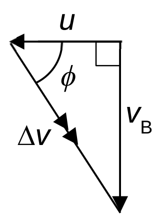
$$= 6u^2 - 2v_{\text{B}}^2$$

$$v_{\text{B}} = \sqrt{\frac{5}{3}}u = \sqrt{\frac{5}{3}}\left(3.5\times10^5\right) = 4.5185\times10^5 = 4.5\times10^5 \text{ m s}^{-1}$$

(b) (ii) 2.



Alternatively,



where u, v_{B} and Δv are the magnitudes of the vectors.

By Pythagorean theorem,

$$\Delta v = \sqrt{u^2 + v_{\text{B}}^2}$$

$$= \sqrt{u^2 + \left(\sqrt{\frac{5}{3}}u\right)^2}$$

$$= \sqrt{\frac{8}{3}}u = \sqrt{\frac{8}{3}}\left(3.5\times10^5\right) = 5.7155\times10^5 = 5.7\times10^5 \text{ m s}^{-1}$$

$$\tan\phi = \frac{v_{\text{B}}}{u}$$

$$\phi = \tan^{-1}\frac{v_{\text{B}}}{u} = \tan^{-1}\sqrt{\frac{5}{3}} = 52^\circ$$

52° <u>below horizontal</u>

$$\begin{aligned}\Delta p &= m\Delta v \\ &= \left(1.7\times10^{-27}\right)\left(5.7155\times10^{5}\right) \\ &= 9.7\times10^{-22}\ \text{kg m s}^{-1}\end{aligned}$$

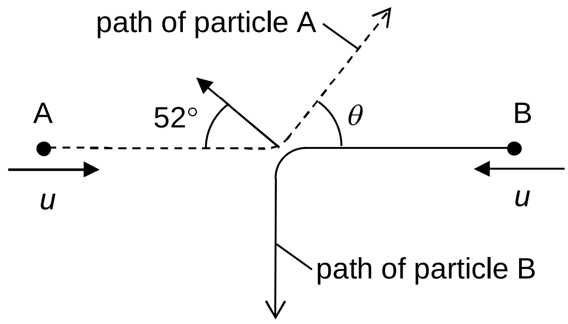
change in momentum is 9.7×10^{-22} kg m s^{-1}

(b) (iii)

$$\begin{aligned}\bar{F} &= \frac{\Delta p}{t} \\ &= \frac{9.7\times10^{-22}}{1.2\times10^{-6}} \\ &= 8.1\times10^{-16}\ \text{N}\end{aligned}$$

by Newton's third law, average force exerted by particle B on particle A is 8.1×10^{-16} N

<u>52° above horizontal</u> (in the opposite direction of change in momentum of particle B).



4 (a) 1. The resultant force acting on the body is zero.

2. The resultant moment/torque on the body about any axis/point is zero.

(b) (i)

$$\begin{aligned}\text{tension in spring} &= (21)(0.015) \\ &= 0.315\ \text{N}\end{aligned}$$

sum of clockwise moments = sum of anticlockwise moments

$$(0.30)(M)(9.81) + (0.50)(21)(0.015) = (0.50)(0.250)(9.81)$$

$$M = 0.363\ \text{kg}$$

(ii) $F + 0.315 = (0.250 + 0.363)\, g$

$F = 5.70$ N

5 (a) The charge is stationary.

The charge is moving in the direction of the magnetic field.

(b) (i) Out of plane of paper

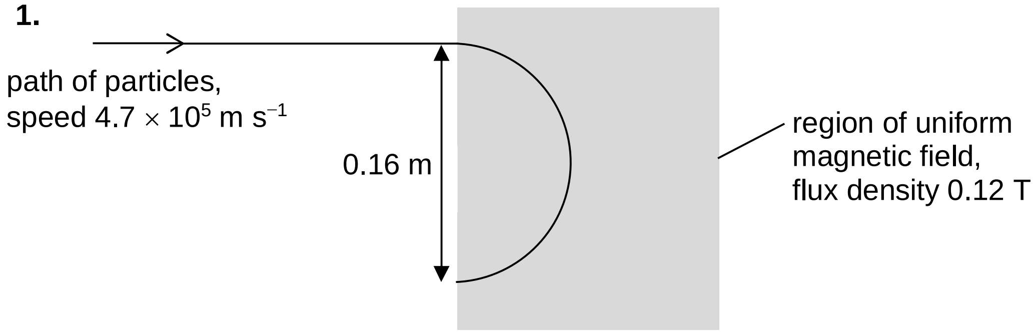
(ii) Magnetic force provides centripetal force

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

$$0.12\times3.2\times10^{-19} = \frac{m\times4.7\times10^{5}}{0.080}$$

$$m = 6.54\times10^{-27}\ \text{kg}$$

(iii) **1.**



2. $Bqv = qE$

$0.12 \times 4.7 \times 10^5 = E$

$E = 5.64 \times 10^4$ N C^{-1}

3. Since the velocity of the other particles are the same, the path is a straight line.

6 **(a)** **(i)** While the speed is constant, the direction of the velocity is changing continuously.
Since velocity is a vector, a change in direction means a change in the quantity. Therefore, the train is accelerating.

(ii) Horizontal distance between rails = $\sqrt{w^2 - E^2}$

$$\tan\theta = \frac{\text{vertical distance}}{\text{horizontal distance}} = \frac{E}{\sqrt{(w^2 - E^2)}}$$

(iii) Vertically,

$$N\sin\theta = mg \qquad -(1)$$

Horizontally, the horizontal component of normal contact force provides the centripetal force,

$$N\cos\theta = \frac{mv^2}{r} \qquad -(2)$$

$$(1)/(2)$$

$$\tan\theta = \frac{v^2}{rg}$$

$$\frac{E}{\sqrt{w^2 - E^2}} = \frac{v^2}{rg}$$

$$v = \left(\frac{Erg}{\sqrt{w^2 - E^2}}\right)^{\frac{1}{2}}$$

(b) **(i)** Passenger trains are lighter/carry a smaller weight.

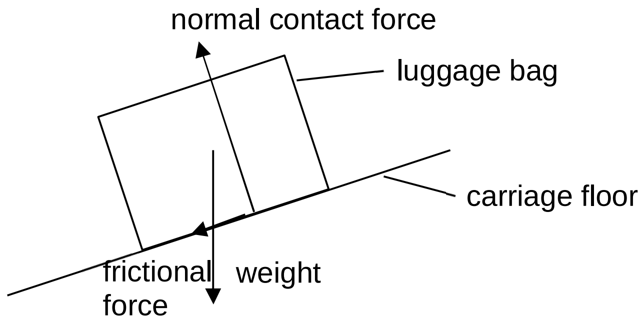
(ii) CD_{max} is 110 mm for 1435 rail gauge.
E_v = 110 + 95 = 205 mm

$$v_0 = \left(\frac{Erg}{\sqrt{w^2 - E^2}}\right)^{0.5}$$

$$= \left(\frac{(205\times10^{-3})(1500)(9.81)}{\sqrt{1435^2 - 205^2}\times10^{-3}}\right)^{0.5}$$

$$= 46.086 = 46.1 \text{ m s}^{-1}$$

(ii) **1.**



2.

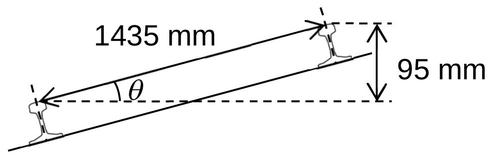
$$\frac{mv^2}{r} = \frac{(19.6)\left(\frac{150000}{60\times60}\right)^2}{1500}$$

$$= 23 \text{ N}$$

3.

$$\sin\theta = \frac{95}{1435}$$

$$\theta = 3.8°$$



4. Vertically, $N\cos\theta = mg + f\sin\theta \quad -(1)$

Horizontally, $N\sin\theta + f\cos\theta = 23$

$\Rightarrow \quad N\sin\theta = 23 - f\cos\theta \quad -(2)$

$(2)/(1)$,

$$\tan\theta = \frac{23 - f\cos\theta}{(19.6)(9.81) + f\sin\theta}$$

$$(19.6)(9.81)\tan\theta + f\sin\theta\tan\theta = 23 - f\cos\theta$$

$f = 10.2$ N $\quad$ ($f = 9.98$ N if $F_c = 22.69$ N is used in the calculation)

Since $f < f_{max}$, luggage will not slide

OR

<u>Faster method</u>

the component of weight parallel to the slope and friction should provide the component of centripetal force that is parallel to the slope.

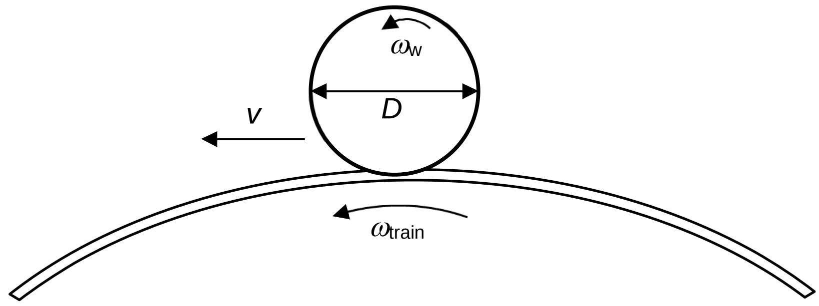
$$mg\sin\theta + f = F_c\cos\theta$$

$$(19.6)(9.81)\sin 3.8° + f = 23\cos 3.8°$$

$$f = 10.2 \text{ N}$$

(c) **(i)** As the circumference of the outer wheel is larger, it will be able to travel a greater distance even though it rotates as the same rate as the inner wheel, allowing both wheels to stay on the track.

(ii)



For a wheel of diameter D and angular velocity of ω_W moving at speed v along a curved rail of radius R,

linear speed at rim of wheel = speed of wheel

$$\left(\frac{D}{2}\right)\times\omega_w = R\times\omega_{train}$$

Since both the inner and outer wheels are rotating with the same angular velocity of ω_W, and both wheels are moving along the curved rails with the same angular velocity ω_{trail},

$$\frac{D_o}{D_i}=\frac{R_{outer}}{R_{inner}}$$

$$\frac{D_o}{1.150}=\frac{200+1.524}{200}$$

$$D_o = 1.1588 = 1.16 \text{ m}$$

(d) **(i)**

- Easier maintenance (of rails)
- Cheaper or easier or faster to build (as there is no need to build tunnels or viaducts)

(ii)

- Allows land surface to be used for other purposes
- Less noise to residents / less noise pollution
- Train operations is not affected by weather conditions (rain or snow)

7 **(a)** **(i)** The resistance of a resistor is the ratio of potential difference across the resistor to the current in it.

(i) **1.** $V_X = E - Ir$

From graph of V against I, gradient = – r

$$r = -\text{ gradient} = -\left(\frac{5.40-4.20}{0.40-1.20}\right)$$

$$= 1.5\ \Omega$$

OR

Using substitution of point

4.80 = 6.0 – 0.80 r

r = 1.5 Ω

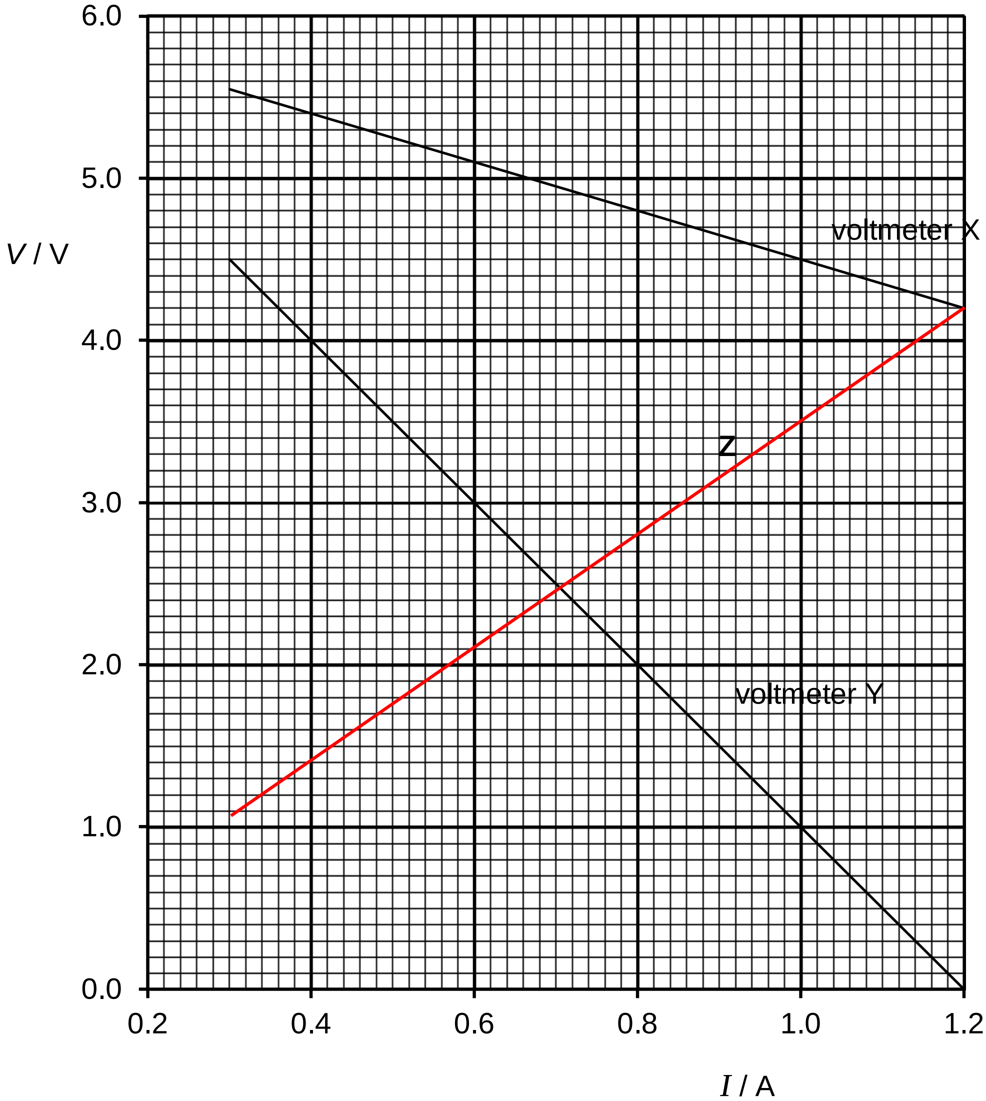
2. When I = 0.40 A, p.d. across fixed resistor = $V_X - V_Y$ = 5.40 – 4.00 = 1.40 V

$$R_S = \frac{p.d.}{I} = \frac{1.40}{0.40} = 3.5\Omega \quad \text{(shown)}$$

(iii) There is a maximum value of the resistance in the circuit, and from the given electromotive force of 6.0 V, there will be a minimum current from $I = \dfrac{\text{e.m.f.}}{R}$.

(iv) When V_X = 5.25 V, I = 0.50 A. V_Y = 3.50 V
$P = IV$ = (0.50)(3.50) = 1.75 W

(v) **1.**



2. 0.70 A (accept 0.71 A) (intersection of graph Z and voltmeter Y)

(b) **(i)** At 25 ºC, resistance of thermistor = 300 Ω
Hence, total resistance = 300 + 200 = 500 Ω

$$I = \frac{12}{500} = 24.0 \text{ mA}$$

(ii) pd across thermistor = $\left(\dfrac{300}{300+200}\right)(12)$
= 7.20 V

(iii) As temperature increases, resistance of thermistor decreases. The total resistance decreases and current in the circuit increases causing the pd across the resistor to increase. Since the pd across both is still at 12 V, pd across thermistor decreases.
OR As temperature increases, resistance of thermistor decreases
Voltage of thermistor, $V_{th} = 12 \times \dfrac{R_{th}}{R_{th} + R}$
Denominator decreases less slowly than numerator, therefore V_{th} decreases

(iv) **1.** $P_1 = \dfrac{V^2}{R} = \dfrac{12^2}{300} = 0.480\,\text{W}$ at 25 ºC

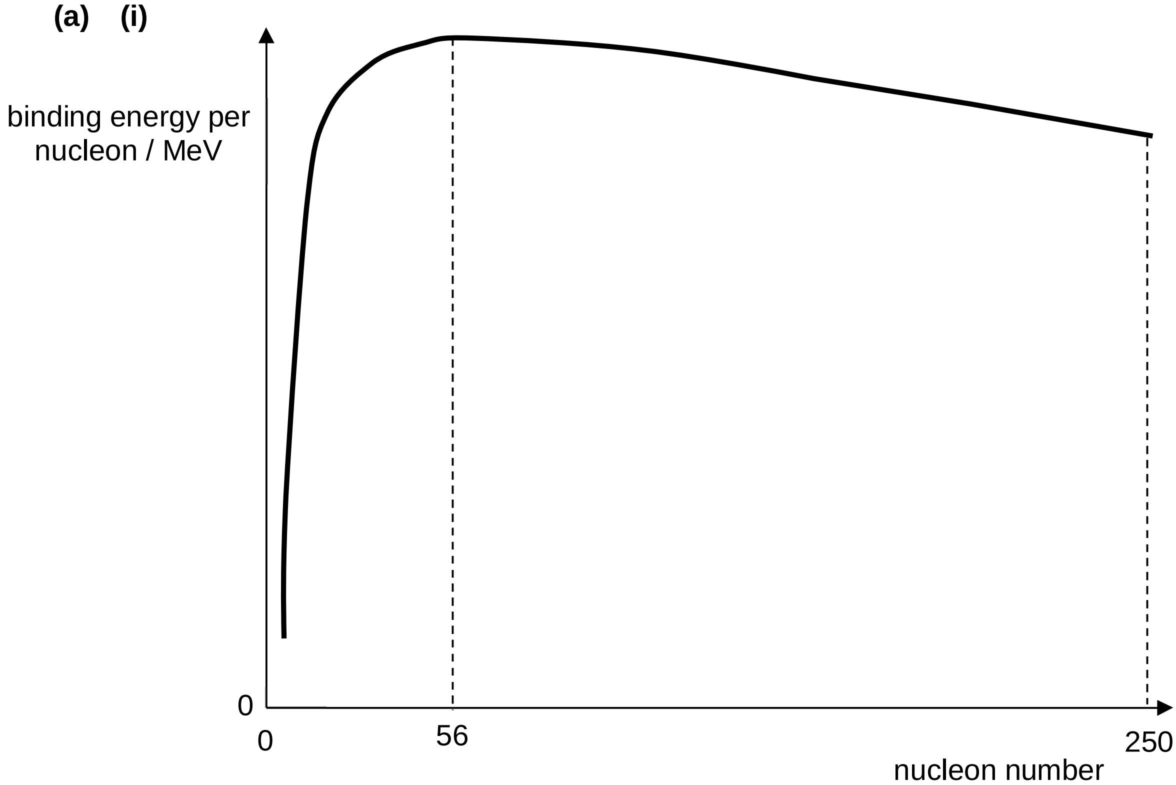
$P_2 = \dfrac{V^2}{R} = \dfrac{12^2}{55} = 2.62\,\text{W}$ at 45 ºC

2. $\text{power} = \dfrac{\text{energy}}{\text{time}}$. Hence,

$E = Pt = (\dfrac{0.48 + 2.62}{2})(10 \times 60)$
$= 930$ J

(v) Since power does not vary linearly with resistance (which varies linearly with temperature and time), this method will not yield an accurate value of power dissipated when resistance changes. Method assumes linearity between power and resistance.

8 (a) (i)



(ii) In nuclear fusion, the <u>product nuclide has greater binding energy per nucleon</u> than the two lighter nuclides that fused to form it.
Hence, there is an <u>increase in the total binding energy</u> and a <u>release of energy</u>.

(b) (i) Nucleon number, Charge, Mass-energy, Momentum

(ii) Energy released $= (4 \times 7.0739) - (2 \times 1.1123) + (3 \times 2.8273) = 17.5891$ MeV
Total kinetic energy of products E_k = 17.5891 + 0.024 + 0.016 = 17.6291 MeV
By conservation of momentum

$$m_\alpha v_\alpha = m_n v_n$$

$$\frac{v_n}{v_\alpha} = \frac{m_\alpha}{m_n}$$

$$\frac{E_{k,\,n}}{E_{k,\,\alpha}} = \frac{m_n}{m_\alpha}\left(\frac{m_\alpha}{m_n}\right)^2 = \frac{m_\alpha}{m_n}$$

$$\frac{E_{k,\,n}}{E_{k,\,total}} = \frac{m_\alpha}{m_n + m_\alpha}$$

$$E_{k,\,n} = \frac{m_\alpha}{m_n + m_\alpha} \times E_k$$

$$= \frac{4.0026}{4.0026 + 1.0087} \times 17.6291 = 14.1 \text{ MeV}$$

(c) (i) It is impossible to predict which nucleus will decay next.
Or: It is impossible to predict when a nucleus will decay.

(ii) The <u>probability of decay of a nucleus is unaffected by any external factors</u> such as temperature, pressure or chemical composition.

(d) (i) Alpha particles <u>have a range of a few centimeters</u> in air.

(ii) True count-rate:

$$t = 0 \quad C_0 = 6659 - 18 = 6641$$

$$t = 6.0 \quad C = 1051 - 18 = 1033$$

$$\frac{C}{C_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1033}{6641} = \left(\frac{1}{2}\right)^n$$

$$n = 2.68456$$

$$6.0 = n \times t_{1/2}$$

$$t_{1/2} = 2.235 \text{ hr}$$

(iii) At t = 0, measure the count-rate $C_{0,\,0}$ with the detector next to the source and the count rate $C_{o,\,20}$ with the detector 20 cm from the source.
Repeat at t = 6 hours to obtain $C_{6,\,0}$ and $C_{6,\,20}$.
Calculate the count rate for alpha decay using

$$t = 0, \quad C_{0,\alpha} = C_{0,0} - C_{0,20} - 2(C_{background})$$

$$t = 6.0, \quad C_\alpha = C_{6,0} - C_{6,20} - 2(C_{background})$$

Repeat the calculations in **(ii)**.