2023 RI Preliminary Examinations H2 Physics Paper 2 Solutions

1 **(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:

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

$\sin\theta = 0.880$

$\theta = 61.7°$

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

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

$t = 1.79$ s

(c) Horizontal displacement = $20 \times \cos(61.7°) \times 1.79$

$= 17.0$ 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.

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

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

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

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

(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,

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

$$u = 2v_A\cos\theta \quad \ldots \quad (1)$$

Considering vertical motion, taking up as positive,

$$0 = 2\cancel{m}v_A\sin\theta - \cancel{m}v_B\sin\beta$$

$$v_B = 2v_A\sin\theta \quad \ldots \quad (2)$$

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

$$(u)^2 + (v_B)^2 = (2v_A\cos\theta)^2 + (2v_A\sin\theta)^2$$

$$u^2 + {v_B}^2 = 4{v_A}^2 \quad \ldots \quad (3)$$

From equation in **(b)(i)**,

$$3u^2 = 2v_A^{\ 2} + v_B^{\ 2}$$

$$v_A^{\ 2} = \frac{3u^2 - v_B^{\ 2}}{2} \quad \ldots \quad (4)$$

Substituting (4) into (3),

$$\begin{aligned} u^2 + v_B^{\ 2} &= 4v_A^{\ 2} \\ &= 4\left(\frac{3u^2 - v_B^{\ 2}}{2}\right) \\ &= 6u^2 - 2v_B^{\ 2} \\ 3v_B^{\ 2} &= 5u^2 \\ v_B &= \sqrt{\frac{5}{3}}u \\ &= \sqrt{\frac{5}{3}}\left(3.5\times10^5\right) = 4.5185\times10^5 = 4.5\times10^5 \text{ m s}^{-1} \end{aligned}$$

Alternatively,
Let the horizontal and vertical components of the velocity of particle A after collision be $v_{A,x}$ and $v_{A,y}$ respectively, and the vertical (downward) velocity of particle B after collision be v_B.
By principle of conservation of linear momentum,
Considering horizontal motion, taking right as positive,

$$2\cancel{m}(u) - \cancel{m}u = 2\cancel{m}v_{A,x} \quad (\because v_{B,x} = 0)$$

$$u = 2v_{A,x}$$

$$v_{A,x} = \frac{u}{2} \quad \ldots \quad (*)$$

Considering vertical motion, taking up as positive,

$$0 = 2\cancel{m}v_{A,y} - \cancel{m}v_B$$

$$v_B = 2v_{A,y}$$

$$v_{A,y} = \frac{v_B}{2} \quad \ldots \quad (\wedge)$$

By Pythagorean theorem,

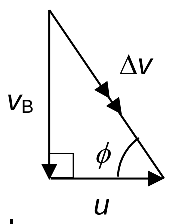
$$v_A^{\ 2} = v_{A,x}^{\ 2} + v_{A,y}^{\ 2}$$

$$v_A^{\ 2} = \left(\frac{u}{2}\right)^2 + \left(\frac{v_B}{2}\right)^2 \quad (\text{from} (*) \text{ and } (\wedge))$$

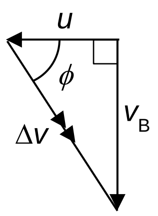
$$u^2 + v_B^{\ 2} = 4v_A^{\ 2}$$

which is identical to equation (3).

(b) (ii) 2.



Alternatively,



where u, v_B and Δv are the magnitudes of the vectors.

By Pythagorean theorem,

$$\Delta v = \sqrt{u^2 + v_B{}^2}$$
$$= \sqrt{u^2 + \left(\sqrt{\frac{5}{3}}u\right)^2}$$
$$= \sqrt{\frac{8}{3}}u = \sqrt{\frac{8}{3}}\left(3.5\times10^5\right) = 5.7155\times10^5 = 5.7\times10^5 \text{ m s}^{-1}$$

$$\tan\phi = \frac{v_B}{u}$$
$$\phi = \tan^{-1}\frac{v_B}{u} = \tan^{-1}\sqrt{\frac{5}{3}} = 52°$$

52° <u>below horizontal</u>

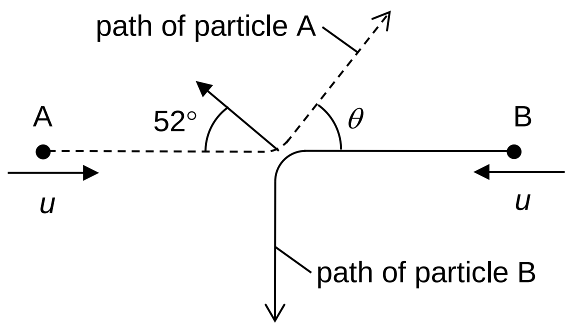
$$\Delta p = m\Delta v$$
$$= \left(1.7\times10^{-27}\right)\left(5.7155\times10^5\right)$$
$$= 9.7\times10^{-22} \text{ kg m s}^{-1}$$

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

(b) (iii)

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

by Newton's third law, average force exerted by particle B on particle A is 8.1×10^{-16} N at <u>52° above horizontal</u> (in the opposite direction of change in momentum of particle B).



3 (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)

$$\text{tension in spring} = (21)(0.015)$$
$$= 0.315 \text{ N}$$

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)

$$\rho_{150g} = \frac{m}{V}$$

$$V = \frac{0.36}{8.9\times10^3}$$

$$U = \rho\frac{0.36}{2\left(8.9\times10^3\right)}(9.81)$$

$$(mg - T)0.50 = (Mg - U)0.50$$

$$(0.250)(9.81)-(21)(0.015)=(0.36)(9.81)-\rho\frac{0.36}{2\left(8.9\times10^3\right)}(9.81)$$

$$\rho = 7.03\times10^3\ \text{kg m}^{-3}$$

(iii) The metre rule is <u>tilted anti-clockwise</u> at an angle from its original position with less than half of <u>block M submerged in the liquid</u>.
OR
The metre rule is <u>tilted</u> at an angle from its original position with <u>less than half of block M submerged in the liquid</u>.

Additional information:

$$mg = Mg - U$$

$$(0.250)(9.81)=(0.36)(9.81)-b\left(7.0266\times10^3\right)\frac{0.36}{\left(8.9\times10^3\right)}(9.81)$$

$$b = 0.387$$

When the rule is balanced, 39% of block M is submerged in liquid.

4 (a) A longitudinal wave is one in which its <u>particles oscillate in a direction parallel to the direction of energy transfer</u>.

(b) (i) 1.

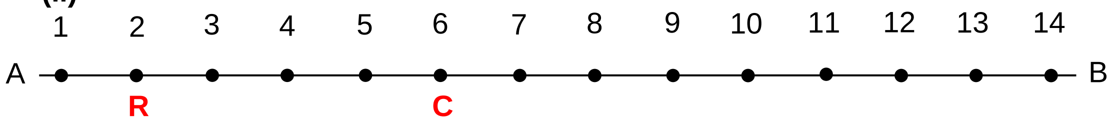
$$\frac{1}{2}\times\text{wavelength} = 0.080\ \text{m}$$

$$\therefore\ \text{wavelength} = 0.160\ \text{m}$$

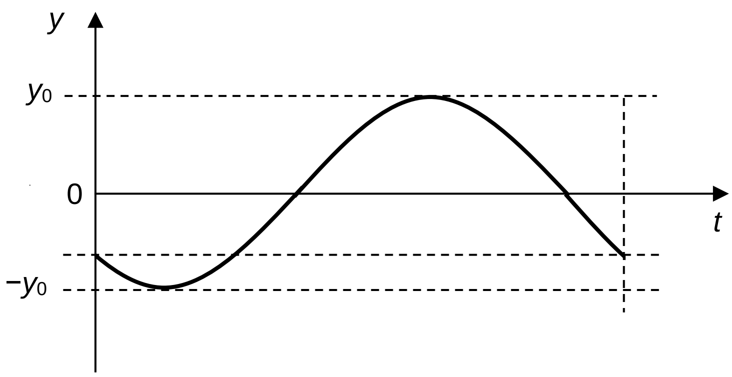
2.

$$\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = \frac{343}{0.160} = 2144 \approx 2140\ \text{Hz}$$

(ii)



(iii)



(iv) $I = \frac{P}{4\pi r^2}$

$\therefore \frac{I_2}{I_1} = \frac{P/4\pi r_2^2}{P/4\pi r_1^2} = \frac{r_1^2}{r_2^2} = \frac{(1/2)I}{I}$

$r_2^2 = 2r_1^2 \Rightarrow r_2 = \sqrt{2}\, r_1 = \sqrt{2} \times 0.25 = 0.35355$ m

$\therefore$ distance moved by detector $= 0.35355 - 0.25 = 0.10355 \approx 0.10$ m

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

(b) **(i)** $V_X = E - Ir$

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

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

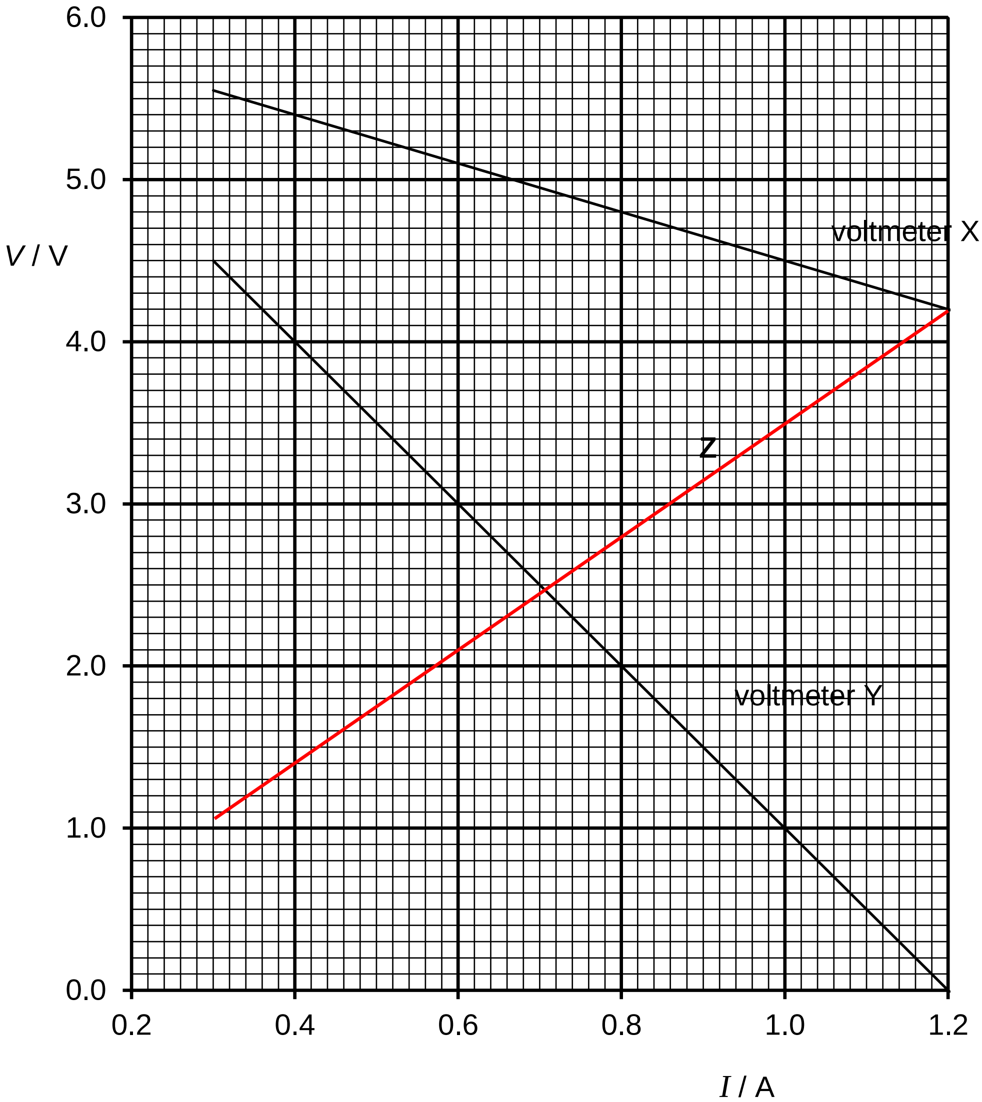
$R_S = \frac{p.d.}{I} = \frac{1.40}{0.40} = 3.5\,\Omega$ (shown)

(c) 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 $I = \frac{\text{e.m.f.}}{R}$.

(d) When V_X = 5.25 V, I = 0.50 A. V_Y = 3.50 V

$P = IV$ = (0.50)(3.50) = 1.75 W

(e) **(i)**



(ii) 0.70 A (intersection of graph Z and voltmeter Y)

6 **(a)** The charge is stationary.
The charge is moving parallel to the direction of the magnetic field.

(b) **(i)** $v_{\perp} = 4.7 \times 10^{5} \times \sin 20° = 1.61 \times 10^{5}\ \text{m s}^{-1}$

(ii) Magnetic force provides centripetal force

$$Bqv_{\perp} = \frac{m(v_{\perp})^2}{r}$$

$$0.12 \times 3.2 \times 10^{-19} = \frac{m \times 1.6075 \times 10^{5}}{\frac{1}{2} \times 0.056}$$

$$m = 6.69 \times 10^{-27}\ \text{kg}$$

(iii) $T = \dfrac{2\pi r}{v_{\perp}} = \dfrac{\pi \times 0.056}{1.6075 \times 10^{5}} = 1.0944 \times 10^{-6}\ \text{s}$

$x = v\cos 20° \times T$

$= 4.7 \times 10^5 \times \cos 20° \times 1.0944 \times 10^{-6}$

$= 0.483$ m

(iv) Electrons will travel in a helical path with smaller radius.
Electrons will travel in a helical path with smaller period.
Electrons will travel in a helical path with smaller x.
Direction of rotation of the helical path of the electrons will be opposite to that of the particles.
Additional Information:

$$Bqv_\perp = \frac{m(v_\perp)^2}{r}$$

$$r = \frac{mv_\perp}{Bq}$$

Mass of electron is 9.11×10^{-31} kg and charge is -1.60×10^{-19} C. Hence, r_e will be much smaller.

Time $\left(T = \frac{2\pi r}{v_\perp}\right)$ taken for the electrons to complete one revolution in the helix will also be much smaller and x will be smaller.

7 (a) (i)

$$\langle V^2 \rangle = \frac{(25.0 \times 1.0)}{4.0} = 6.25$$

$$V_{rms} = 2.50 \text{ V}$$

(ii)

$$\langle P \rangle = \frac{V_{rms}{}^2}{R} = \frac{2.50^2}{8.0} = 0.781 \text{ W}$$

(b) (i) Since average power is the same,
V_{rms} of sinusoidal function = V_{rms} of original source = 2.50 V
$V_0 = 2 \times 2.50 = 5.00$ V
Or

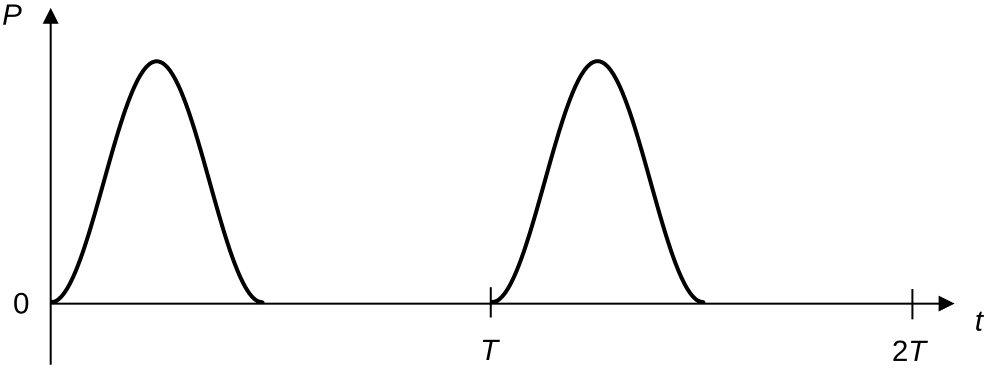
For ½-wave rectified sinusoidal function, $V_{rms} = \frac{V_0}{2}$

$$\langle P \rangle = \frac{V_{rms}{}^2}{R}$$

$$0.781 = \frac{(V_0 / 2)^2}{8}$$

$$V_0 = 5.00 \text{ V}$$

(ii)



8 **(a)** **(i)** While the speed is constant, <u>the direction of the velocity is changing continuously.</u>
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,

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

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

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

$$(1)/(2)$$

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

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

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

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

(ii) CD_{max} is 110 mm for 1435 rail gauge.

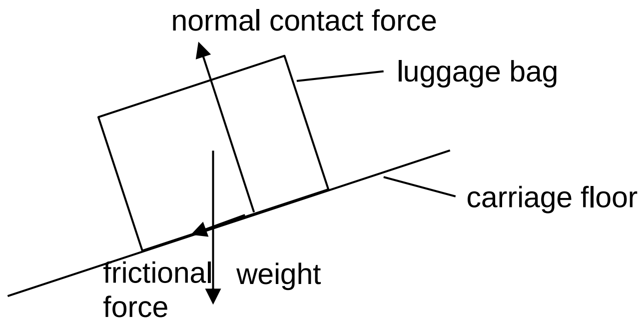
E_v = 110 + 95 = 205 mm

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

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

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

(ii) **1.**

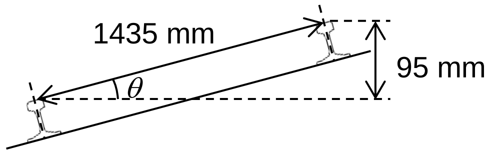


2.

$$\frac{mv^2}{r} = \frac{(19.6)\left(\frac{150000}{60\times 60}\right)^2}{1500}$$
$= 23$ 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

Faster method

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

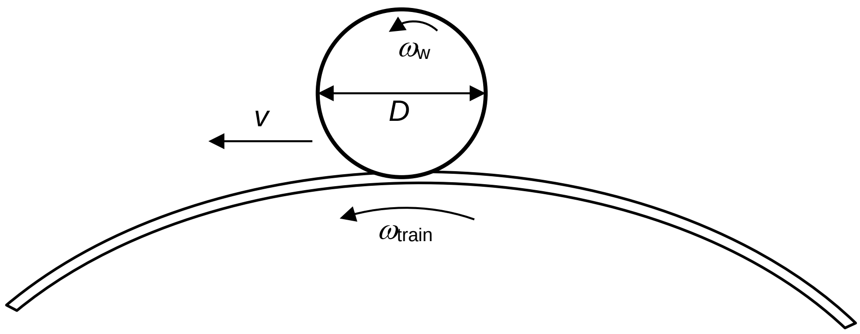
$mg\sin\theta + f = F_c\cos\theta$

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

$f = 10.2$ 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

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

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},

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

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

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

(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)