2024 H1 Physics Paper 2 Preliminary Examination Solution (JC Sharing)

1 **(a)** **(i)** Take direction up the slope as positive.

$$v^2 = u^2 + 2as_0$$

$$0 = 7.0^2 + 2(-9.81\sin 30°)s_0$$

$$s_0 = 4.9949 = 4.99 \text{ m}$$

OR

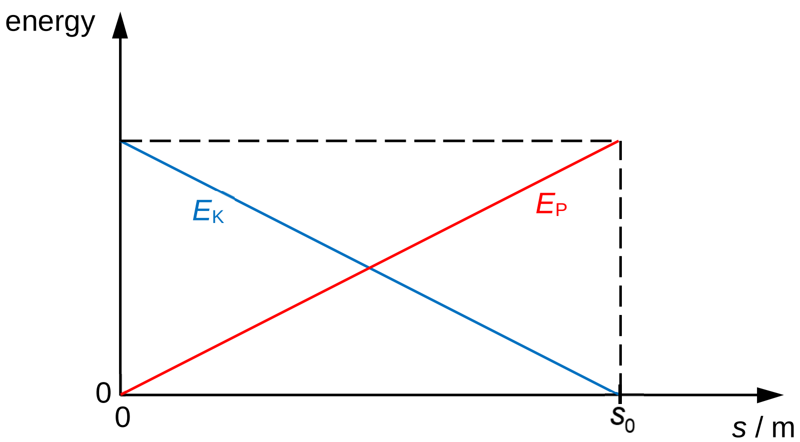
By the principle of conservation of energy,
increase in G.P.E. = decrease in K.E.

$mg(\Delta h) = \frac{1}{2}mv^2 - 0$, where Δh is the max. vertical height from ground

$$\Delta h = \frac{v^2}{2g} = \frac{7.0^2}{2(9.81)}$$

$$s_0 = \frac{\Delta h}{\sin 30°} = \frac{7.0^2}{2(9.81)} \div \sin 30° = 4.9949 = 4.99 \text{ m}$$

(ii)



1. $E_K = \frac{1}{2}mv^2 = \frac{1}{2}m\left(u^2 + 2[-g\sin\theta]s\right)$

$E_K = \frac{1}{2}mu^2 - (mg\sin\theta)s$

Graph of E_K-s is a straight line with negative gradient and vertical intercept $\frac{1}{2}mu^2$.

2. $E_P = mg(\Delta h) = mg(s\sin\theta)$

$E_P = (mg\sin\theta)s$

Graph of E_P-s is a straight line through the origin with positive gradient.

(b) **(i)** $v^2 = u^2 + 2as$

$$v^2 = 14.0^2 + 2\left(-9.81\sin 30°\right)\left(\frac{4.0}{\sin 30°}\right)$$

$$v = 10.841 = 10.8 \text{ m s}^{-1} \quad \text{(shown)}$$

OR

decrease in K.E. = increase in G.P.E.

$$\frac{1}{2}mu^2 - \frac{1}{2}mv^2 = mg\left(\Delta h\right)$$

$$v^2 = u^2 - 2g\left(\Delta h\right) = 14.0^2 - 2\left(9.81\right)\left(4.0\right)$$

$$v = 10.841 = 10.8 \text{ m s}^{-1} \quad \text{(shown)}$$

*Must show non-rounded off value before stating the final answer.

(ii) Take directions to the right and downwards as positive.

Time of flight after the ball leaves the top of the slope to the ground:

$$s_y = u_y t + \tfrac{1}{2}a_y t^2$$

$$-4.0 = \left(10.8\sin 30°\right)t + \frac{1}{2}\left(-9.81\right)t^2$$

$$t = 1.6080 \text{ s or } -0.50713 \text{ s (NA)}$$

Horizontal distance travelled:

$$s_x = u_x t + \tfrac{1}{2}a_x t^2$$

$$= \left(10.8\cos 30°\right)\left(1.6080\right) + 0$$

$$= 15.040 = 15.0 \text{ m}$$

*Correct method and substitution must be shown.
* Wrong root must be rejected.

2 **(a)** The initial total momentum of both balls is not zero.

Since there is no net external force acting on the balls as a system, by the principle of conservation of momentum, the total momentum of both balls must remain unchanged and cannot be zero.

Hence, the balls could not be stationary at the same time.

(b) By the principle of conservation of momentum,

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$
$$u_A + u_B = v_A + v_B$$
$$4.0 + (-1.0) = v_A + v_B$$
$$v_A + v_B = 3.0 \qquad \text{----- (1)}$$

Since collision is elastic,

$$u_B - u_A = v_A - v_B$$
$$(-1.0) - 4.0 = v_A - v_B$$
$$v_A - v_B = -5.0 \qquad \text{----- (2)}$$

$$(1) - (2) \qquad 2v_B = 3.0 - (-5.0)$$
$$v_B = 4.0 \text{ m s}^{-1} \text{ (shown)}$$

* Both equations must be solved.

(c) By Newton's second law, the average force on ball B by ball A is

$$F_{net,B} = \frac{\Delta p_B}{\Delta t} = \frac{0.50\left(4.0 - (-1.0)\right)}{0.25} = 10 \text{ N}$$

By Newton's third law, the average force on ball A by ball B has the same magnitude of 10 N.

OR

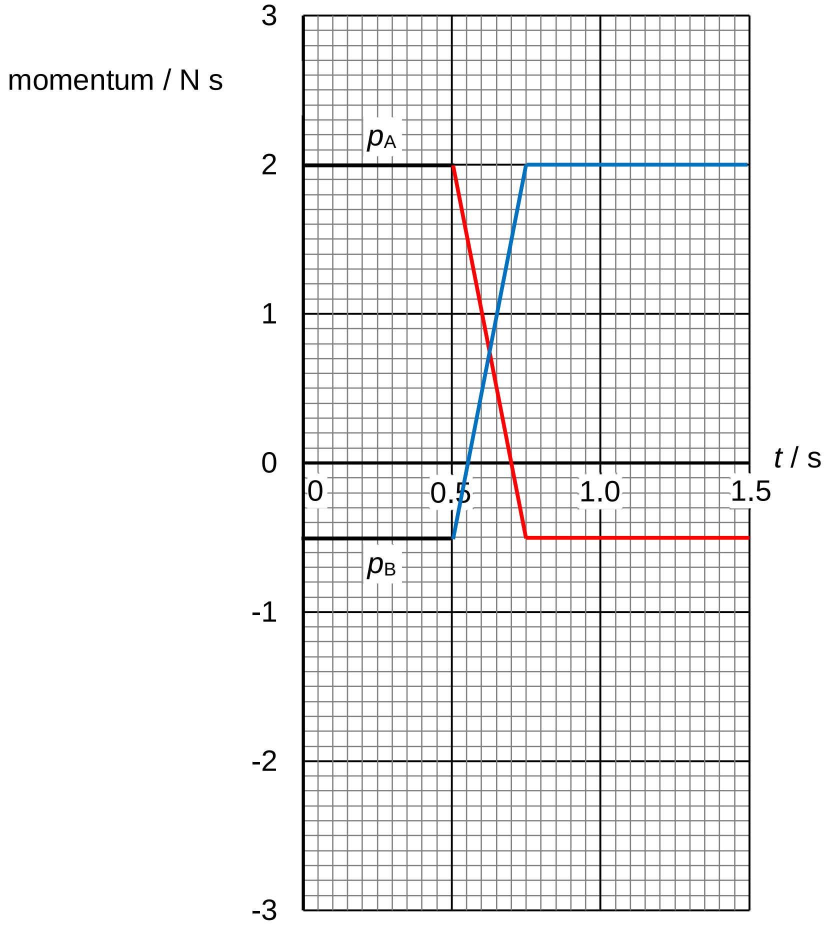
From equation (1) or (2) in part (b), $v_A = -1.0 \text{ m s}^{-1}$.

By Newton's second law, the average force on ball A by ball B is

$$F_{net,A} = \left|\frac{\Delta p_A}{\Delta t}\right| = \left|\frac{0.50\left((-1.0) - 4.0\right)}{0.25}\right| = 10 \text{ N}$$

*Signs for direction of vectors must be coherent and shown.

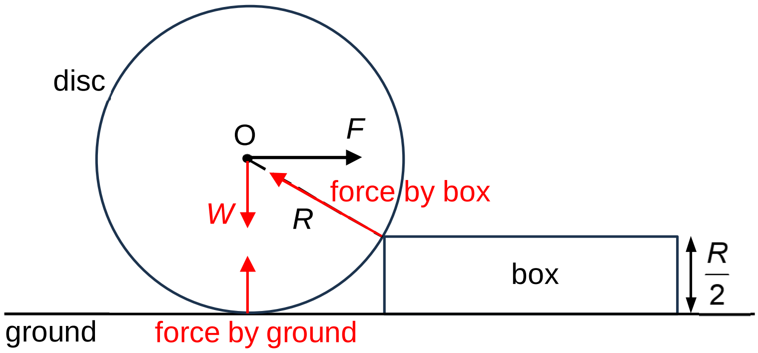
(d)



Balls A and B will exchange velocities and momenta as both balls have the same mass. From (b), $p_{B,f} = (0.50)(4.0) = 2.0$ N s.

Since duration of collision is 0.25 s, constant final momenta to start from 0.75 s to 1.5 s, with lines joining 0.50 s to 0.75 s during the collision.

3 **(a)**



When the disc is just about to rotate, the contact force by the ground just becomes zero.

Perpendicular distance from corner of box to line-of-action of F is $\frac{R}{2}$.

Perpendicular distance from corner of box to line-of-action of W is $\sqrt{R^2 - \left(\frac{R}{2}\right)^2} = \frac{\sqrt{3}}{2}R$.

Applying the principle of moments about the corner of box,

$$F \times \frac{R}{2} = W \times \frac{\sqrt{3}}{2}R$$

$$\frac{F}{W} = \sqrt{3} = 1.7321 = 1.73$$

*Need to state or show understanding that normal contact force is zero.

(b) F acting at O needs to be <u>inclined upwards</u> such that it is at an angle <u>above the horizontal</u> to <u>produce a clockwise moment</u> about the corner to <u>overcome the anticlockwise moment due to the weight</u>.

OR

F acting at O needs to be <u>inclined upwards</u> so that there is an <u>upward vertical component to produce a clockwise moment</u> about the corner to <u>overcome the anticlockwise moment due the weight</u>.

OR

F needs to be <u>shifted upwards above O</u> so that there is a <u>moment arm from the corner of the box to the line-of-action of F</u>, to <u>produce a clockwise moment</u> about the corner to <u>overcome the anticlockwise moment due to the weight</u>.

Note: Increasing the magnitude of the horizontal force F acting at O will not cause any rotation as F has no moment about the corner of the box because the perpendicular distance from the corner to the line-of-action of F is zero.

*Position of F must be such that there is a moment arm from the corner of the box to the line-of-action of F.
*Direction of F must be such as to provide a clockwise moment about the corner of the box to overcome the anticlockwise moment due to the weight.

4 **(a)** **(i)** At the top of the circle,

$$T_T + mg = \frac{m{v_T}^2}{L}$$

For the ball to just complete the vertical circle, the tension T_T at the top of the circle is zero.

$$mg = \frac{m{v_T}^2}{L}$$
$${v_T}^2 = gL$$
$$v_T = \sqrt{gL}$$

*Explains or states clearly that tension at the top is zero.

(ii) By the principle of conservation of energy, as the ball moves from the top to the bottom of the circle, its gravitational potential energy decreases and its kinetic energy increases. This means the speed at the bottom is greater than the speed at the top. Hence $\frac{v_B}{v_T} > 1$.

(iii)
$$\frac{v_B}{v_T} = 3$$
$$v_B = 3v_T$$

As the ball moves from the top to the bottom,
increase in K.E. = decrease in G.P.E.

$$\frac{1}{2}m{v_B}^2 - \frac{1}{2}m{v_T}^2 = mg\left(2L\right)$$
$$\frac{1}{2}m\left(3v_T\right)^2 - \frac{1}{2}m{v_T}^2 = mg\left(2L\right)$$
$$\frac{9}{2}m{v_T}^2 - \frac{1}{2}m{v_T}^2 = 2mgL$$
$$4m{v_T}^2 = 2mgL$$
$$v_T = \sqrt{\frac{1}{2}}\sqrt{gL}$$

As $\sqrt{\frac{1}{2}}\sqrt{gL} < \sqrt{gL}$, where $\sqrt{gL}$ is the value of v_T at which the string just goes slack, the ball will not be able to complete a full circle if $\frac{v_B}{v_T} = 3$. Hence, $\frac{v_B}{v_T} = 3$ is not possible to achieve.

(b) Considering forces along the radial direction,
$$T\sin\theta = mr\omega^2$$

Since $r = L\sin\theta$,
$$T\sin\theta = m\left(L\sin\theta\right)\omega^2$$
$$T = mL\omega^2$$
Since m and L are constants, $T \propto \omega^2$. Hence when the angular velocity is doubled, the tension in the string is $4T$.

5 **(a)** Newton's law of gravitation states that two point masses attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

(b) **(i)** Gravitational force provides the centripetal force on the satellite.

$$\frac{GM_E m}{r^2} = \frac{mv^2}{r}, \quad \text{where } m \text{ is the mass of the satellite}$$

$$v = \sqrt{\frac{GM_E}{r}} \quad \text{(shown)}$$

(ii)

$$\begin{aligned} E_{total} &= \Delta E_K + \Delta E_P \\ &= \left(\frac{1}{2}mv^2 - 0\right) + 7.67\times10^{10} \\ &= \frac{1}{2}m\frac{GM_E}{r} + 7.67\times10^{10} \\ &= \frac{1}{2}(1600)\frac{\left(6.67\times10^{-11}\right)\left(6.0\times10^{24}\right)}{\left(6.4\times10^{6} + 2.1\times10^{7}\right)} + 7.67\times10^{10} \\ &= 1.17\times10^{10} + 7.67\times10^{10} \\ &= 8.84\times10^{10}\ \text{J} \end{aligned}$$

6 **(a)** **(i)** Effective resistance of Q and LDR,

$$R_{eff} = \left(\frac{1}{R_Q} + \frac{1}{R_{LDR}}\right)^{-1}$$
$$= \left(\frac{1}{6.0} + \frac{1}{8.0}\right)^{-1}$$
$$= 3.4286 \text{ k}\Omega$$

$$I_{A_1} = \frac{E}{R_T}$$
$$= \frac{9.0}{(3.4286 + 4.0) \times 10^3}$$
$$= 1.2115 \times 10^{-3} \; = 1.21 \times 10^{-3} \text{ A}$$

(ii) Potential difference across Q and LDR,

$$V_{eff} = \frac{R_{eff}}{R_{eff} + R_P} \times E$$
$$= \left(\frac{3.4286}{3.4286 + 4.0}\right) \times 9.0$$
$$= 4.1539 \text{ V}$$

$$I_{A_2} = \frac{V_{LDR}}{R_{LDR}}$$
$$= \frac{4.1539}{8.0 \times 10^3}$$
$$= 5.1924 \times 10^{-4} \; = 5.19 \times 10^{-4} \text{ A}$$

(b) **(i)** Resistance of the LDR increases when light intensity is lowered. The effective resistance of Q and the LDR increases.

Since the potential difference across P and Q is the same at 9.0 V, by the potential divider principle, the potential difference across Q is a larger proportion of the 9.0 V. Hence the potential difference across Q increases.

OR

Resistance of the LDR increases when light intensity is lowered. The overall resistance of the circuit increases.

Current from the battery decreases. As the resistance of P is the same, the potential difference across P decreases. Since the potential difference across P and Q remains the same at 9.0 V, this means the potential difference across Q increases.

*Must mention / imply total e.m.f. is still 9.0 V or same as before change.

(ii) Since the potential difference across Q increases, the current through Q increases for the same resistance of Q.

Total current in the circuit is the sum of the current through Q and the LDR. Since the total current from the battery decreases due to overall increase in resistance, and the current in Q increases, this means the current through the LDR decreases. Hence the current reading on ammeter A_2 decreases.

7 **(a)** $Q = It$

$= (0.24)(5.0 \times 60)$

$= 72 \text{ C}$

$N = \dfrac{Q}{e}$

$= \dfrac{72}{1.60 \times 10^{-19}}$

$= 4.5 \times 10^{20}$

(b) $\varepsilon = Ir + V_R$

$V_R = \varepsilon - Ir$

$= 1.5 - (0.24)(0.25)$

$= 1.5 - 0.060$

$= 1.44 \text{ V}$

(c) $R = \dfrac{V}{I}$

$= \dfrac{1.44}{0.24}$

$= 6.0\ \Omega$

(d) $E = IVt$

$= (0.24)(1.44)(5.0 \times 60)$

$= 104 \text{ J}$

Note: $E = I^2Rt$ or $E = \dfrac{V^2}{R}t$ will give the same answer.

8 **(a)** In a nuclear fusion reaction, two low nucleon number (OR lighter) nuclei combine into a high nucleon number (OR heavier) nucleus.

Or, as given in notes:

Nuclear fusion occurs when two light nuclei combine to form a nucleus of greater mass.

*Reject 'smaller' or 'larger' nuclei.

(b)

$$E_{k,\min} = \frac{1}{2}mv^2$$

$$\left(0.30\times10^{6}\right)\left(1.60\times10^{-19}\right) = \frac{1}{2}\left(1.67\times10^{-27}\right)v^2$$

$$v = 7.58\times10^{6}\ \text{m s}^{-1}$$

*The same speed is obtained If use m = 1.007825u from Fig. 8.1.

(c) **(i)** ${}^{0}_{1}X$

Particle X is a positron.

(ii) Since deuteron ${}^{2}_{1}H$ is more readily found, it suggests that reaction (2) is more probable than reaction (1) and that ${}^{2}_{1}H$ is <u>more stable</u> than ${}^{2}_{2}He$.
Hence, reaction (2) <u>releases more energy</u> than (1).

*Accept ${}^{2}_{2}He$ decays faster / has a shorter half-life than ${}^{2}_{1}H$.

(d) Energy released,

$$E = \Delta mc^2$$
$$= (\text{mass of reactants} - \text{mass of products})c^2$$
$$= (2\times1.007825 - 2.014102 - 0.000549)\left(1.66\times10^{-27}\right)\times\left(3.00\times10^{8}\right)^2$$
$$= 1.4925\times10^{-13} = 1.49\times10^{-13}\ \text{J}$$

(e) Nuclear fission reaction of heavy nuclei requires much less energy to trigger (initiate) and can occur at a lower (room) temperature, while the nuclear fusion reaction of light nuclei requires an extremely high temperature to trigger.

*Accept fission requires less energy OR can occur at a lower temperature.

9 **(a)** **(i)** The resistance of a wire is defined as the ratio of the potential difference across the wire to the current flowing through it.

(ii) Resistivity ρ is the constant of proportionality in the equation $R = \rho \dfrac{l}{A}$, where R is the resistance of the wire, A is the cross sectional area and l is the length of the wire.
OR
The resistivity of the material of a wire can be found from $\rho = \dfrac{RA}{l}$, where R is the resistance of the wire, A is the cross sectional area and l is the length of the wire.

It is a measure of how well the material conducts electricity and it is independent of the physical dimensions (shape, size, volume, mass, length, area, etc) of the wire.

(b) **(i)**

$$\begin{aligned}
R_{total} &= \frac{\varepsilon}{I} \\
&= \frac{6.0}{1.2} \\
&= 5.0\ \Omega \\
R_{total} &= R_{coil} + 0.10 \\
R_{coil} &= \frac{6.0}{1.2} - 0.10 \\
&= 5.0 - 0.10 \\
&= 4.9\ \Omega \text{ (shown)}
\end{aligned}$$

(ii)

$$\begin{aligned}
R_{\text{1-turn}} &= \rho \frac{L}{A} \\
&= \left(1.7 \times 10^{-8}\right) \frac{2\pi\left(\dfrac{22.0 \times 10^{-2}}{2}\right)}{\pi\left(\dfrac{0.60 \times 10^{-3}}{2}\right)^2} \\
&= 0.04156\ \Omega
\end{aligned}$$

$$\begin{aligned}
N &= \frac{R_{coil}}{R_{1-turn}} \\
&= \frac{4.9}{0.04156} \\
&= 118
\end{aligned}$$

(c)

$$\begin{aligned}
B &= 9.05 \times 10^{-7} \frac{NI}{r} \\
&= 9.05 \times 10^{-7} \frac{(118)(1.2)}{(0.110)} \\
&= 0.00116 \\
&= 1.16\ \text{mT}
\end{aligned}$$

(d) (i) From $E_K = \dfrac{p^2}{2m}$ and $E_K = q\Delta V$ (from the definition of p.d. *V*=*W*/*q*, where work done causes an increase in K.E.), we have

$$\begin{aligned} p &= \sqrt{2mE_K} \\ &= \sqrt{2mq\Delta V} \\ &= \sqrt{2\left(9.11\times10^{-31}\right)\left(1.60\times10^{-19}\right)(250)} \\ &= 8.54\times10^{-24}\ \text{N s} \end{aligned}$$

(ii) Since the magnetic force provides for the centripetal force,

$$\begin{aligned} F_B &= F_C \\ Bqv &= \frac{mv^2}{r} \\ r &= \frac{mv}{Bq} \\ &= \frac{p}{Bq} \\ &= \frac{\left(8.54\times10^{-24}\right)}{(0.00116)\left(1.60\times10^{-19}\right)} \\ &= 0.0460\ \text{m} \end{aligned}$$

(e) The component of the velocity parallel to the magnetic field causes the electron to move at a constant speed in the direction of the magnetic field.

The component of the velocity perpendicular to the magnetic field causes the electron to experience a magnetic force that is always perpendicular to this component.

This magnetic force provides for the centripetal force to cause the electron to move is a uniform circular motion in a plane that is perpendicular to the magnetic field.

As a result of both motions, the electron moves along a helical path (or forms a helix) in the direction of the magnetic field.

(f) (i) Since electric field points from high to low potential, the electric force on the electron acts toward the left.

(ii) Since the magnitude and direction of the electric force on the electron remain constant throughout its motion, the electron moves along a parabolic path.

10 **(a)** **(i)** The electric field strength at a point is defined as the electric force exerted per unit positive charge placed at that point.

(ii) Six horizontal lines that are equally-spaced (drawn using a ruler).
Lines touching both plates normally and with arrows pointing towards the right.

(iii) **1.**

$$E = \left| -\frac{dV}{dx} \right| = \frac{24}{12 \times 10^{-3}} = 2000 \text{ V m}^{-1}$$

2.

$$F = qE = \left(1.60 \times 10^{-19}\right)\left(2000\right) = 3.2 \times 10^{-16} \text{ N}$$

3. Since the electric force on the electron is opposite to the displacement of the electron, the work done by the force on the electron is negative.

$$W = Fd = -\left(3.2 \times 10^{-16}\right)\left(12 \times 10^{-3}\right) = -3.84 \times 10^{-18} \text{ J}$$

* Do not award A1 if answer is positive.

4. By the principle of conservation of energy,

$$\frac{1}{2}mu^2 + W = \frac{1}{2}mv^2$$

$$v^2 = u^2 + \frac{2}{m}W$$

$$v = \sqrt{\left(4.5 \times 10^6\right)^2 + \frac{2}{\left(9.11 \times 10^{-31}\right)}\left(-3.84 \times 10^{-18}\right)}$$

$$= \sqrt{1.18197 \times 10^{13}}$$

$$= 3.44 \times 10^6 \text{ m s}^{-1}$$

(b) **(i)** Between the plates, the magnitude and direction of the electric force on the electron remain constant. Since the initial velocity is not parallel to the acceleration, the electron moves in a parabolic path that curves upwards.

Beyond the plates, no force acts on the electron, and hence the electron moves in a straight line.

(ii) **1.**

$$F_E = ma_y$$

$$a_y = \frac{F_E}{m} = \frac{3.2 \times 10^{-16}}{9.11 \times 10^{-31}} = 3.51 \times 10^{14} \text{ m s}^{-2}$$

2. $v_x = u_x = 4.5\times10^6 \text{ m s}^{-1}$

$$
\begin{aligned}
t &= \frac{s_x}{v_x} \\
&= \frac{24\times10^{-3}}{4.5\times10^6} \\
&= 5.33\times10^{-9} \text{ s}
\end{aligned}
$$

$$
\begin{aligned}
v_y &= u_y + a_y t \\
&= 0 + \left(3.51\times10^{14}\right)\left(5.33\times10^{-9}\right) \\
&= 1.87\times10^6 \text{ m s}^{-1}
\end{aligned}
$$

$$
\begin{aligned}
v &= \sqrt{v_x^{\ 2} + v_y^{\ 2}} \\
&= \sqrt{\left(4.5\times10^6\right)^2 + \left(1.87\times10^6\right)^2} \\
&= \sqrt{2.3754\times10^{13}} \\
&= 4.87\times10^6 \text{ m s}^{-1}
\end{aligned}
$$

3.

$$
\begin{aligned}
\tan\theta &= \frac{v_y}{v_x} \\
\theta &= \tan^{-1}\left(\frac{v_y}{v_x}\right) \\
&= \tan^{-1}\left(\frac{1.87\times10^6}{4.5\times10^6}\right) \\
&= 22.6^\circ \qquad \text{(above the horizontal)}
\end{aligned}
$$