2024 Y5 H2 Physics Timed Practice Solutions

1 **(a)** **(i)** $T_2 - T_1 = 35.7 - 25.4 = 10.3$ °C

$\Delta(T_2 - T_1) = 0.2$ °C M1

% uncertainty in rise in temperature $= \dfrac{0.2}{10.3} \times 100\ \% = 1.9\ \%$ A1

(ii)

$$c = \frac{IVt}{m(T_2 - T_1)}$$

$$= \frac{(3.80)(12.00)(60.0)}{(0.764)(35.7 - 25.4)}$$

$$= 347.68 \text{ J kg}^{-1}\text{ K}^{-1}$$ M1

$$\frac{\Delta c}{c} = \frac{\Delta I}{I} + \frac{\Delta V}{V} + \frac{\Delta t}{t} + \frac{\Delta m}{m} + \frac{\Delta(T_2 - T_1)}{(T_2 - T_1)}$$ C1

$$\frac{\Delta c}{c} = \frac{0.06}{3.80} + \frac{0.08}{12.00} + \frac{0.1}{60.0} + \frac{0.001}{0.764} + \frac{0.2}{10.3}$$ M1

$$\Delta c = \left(\frac{0.06}{3.80} + \frac{0.08}{12.00} + \frac{0.1}{60.0} + \frac{0.001}{0.764} + \frac{0.2}{10.3}\right) \times 347.68$$

$$\Delta c = 15.59 \simeq 20 \text{ J kg}^{-1}\text{ K}^{-1}$$ A1

> Marker's comments:
> Students are strongly encouraged to show clear substitution and workings.

(iii) $c = 350 \pm 20$ J kg^{-1} K^{-1} B1

> Marker's comments:
> A common mistake is not reporting the actual value of *c* to the same d.p. as its uncertainty, e.g. 348 ± 20.

(iv) The metal block can be heated over a longer period of time such that there is a bigger difference between T_2 and T_1, so that $\dfrac{\Delta(T_2 - T_1)}{(T_2 - T_1)}$ can be reduced. B1

or

Higher current/potential difference to produce a bigger difference between T_2 and T_1.

> Marker's comments:
> Answers which explained ways to reduce the fractional uncertainty of *I*, *V*, *t* or ΔT are accepted. Increasing mass to reduce uncertainty of c is not accepted because the increase in mass will lead to a smaller rise in temperature.

(b) Base units of $F = \text{kg m s}^{-2}$ B1

Base units of $A\rho v^2 = (\text{m}^2)(\text{kg m}^{-3})(\text{m s}^{-1})^2$ B1

$= \text{kg m s}^{-2}$

$=$ base units of F as shown above

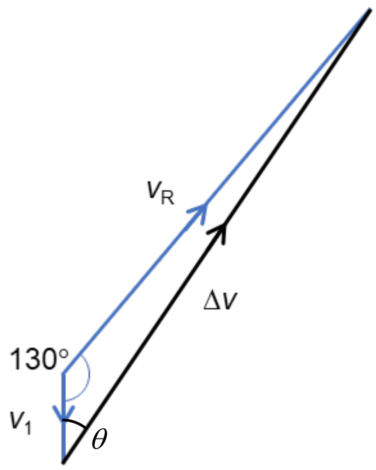
> Marker's comments:
> Students should pay attention to how the workings should be presented for questions that require them to show how units are derived. Students should also take note that $\dfrac{\text{kg m s}^{-2}}{\text{kg m s}^{-2}} = 1$ and not zero.

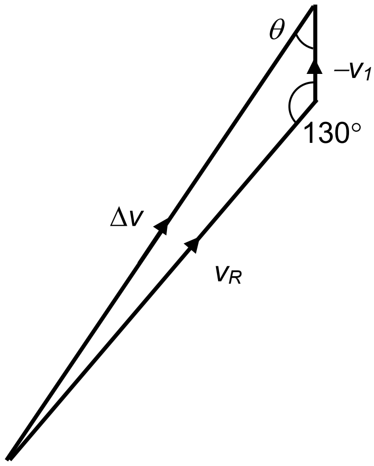
2 **(a)** $v_1^2 = u^2 + 2as$

$v_1^2 = 0 + 2(9.81)(1.10)$ B1

$v_1 = 4.65 \text{ m s}^{-1}$

(b) **(i)** B1





There must be a negative sign for v_1

Marker's comments:
The most common mistake is taking Δv to be the resultant velocity instead of v_R.

(ii) $(\Delta v)^2 = (4.65)^2 + (25.0)^2 - 2(4.65)(25.0)\cos 130°$ M1

$\Delta v = \sqrt{796.0706} = 28.2 \text{ m s}^{-1}$ A1

$\frac{\sin 130°}{\Delta v} = \frac{\sin\theta}{v_R}$

$\sin\theta = \frac{\sin 130°}{28.2147} \times 25 = 0.67876$ A1

$\theta = 42.7°$

Angle from the horizontal = 90° – 42.7° = 47.3°

Marker's comments:
Some students correctly calculated the angle between the arrows without indicating the angle on their diagram but went on to incorrectly state that that angle was to the horizontal/vertical.

(iii) Vertically:

$v_y = u_y + a_y t$

$-25.0\sin 40° = 25.0\sin 40° + (-9.81)t$

$t = 3.276 \text{ s}$ M1

Horizontally:

$s_x = u_x t = 25.0\cos 40° \times 3.276$ M1

$= 62.7 \text{ m}$ A1

Marker's comments:
Many students unnecessarily broke the first step down into two parts and found the time taken to the maximum height and then the time taken back down to the ground before calculating the horizontal range.

(iv) There is air resistance, which acts against the ball's motion. M1

The actual horizontal range of the ball's motion is smaller. A1

Marker's comments:
Many students overexplained this question. Students should use the marks of the question to decide on the length of their answers.

3 **(a)** The rate of change of momentum of a body is proportional to the resultant force acting on it and B1
occurs in the direction of the force. B1

Marker's comments:
Many students reversed the order of the first statement and wrote that the resultant force is proportional to the rate of change of momentum. This suggests the resultant force appears as a result of the change of momentum, which is opposite to reality.
Many students also missed out the second part of the statement of the law.

(b) **(i)**

$$T - mg = ma$$
$$T - 3700(9.81) = 3700(0.39) \quad \text{M1}$$
$$T = 3.77 \times 10^4 \text{ N} \quad \text{A1}$$

(ii) **1.**

$$\left.\begin{aligned} \frac{\Delta m}{\Delta t} &= \frac{\rho \Delta V}{\Delta t} = \frac{\rho(A\Delta x)}{\Delta t} \\ &= \rho A \frac{\Delta x}{\Delta t} \\ &= \rho(\pi r^2)v \\ &= 1.3 \times \pi \times 9.0^2 \times v \end{aligned}\right\} \text{M1}$$
$$= 330v$$

Rate of increase of momentum of air $= 2\dfrac{\Delta m}{\Delta t}(v - 0)$ M1
$= 2 \times 330v^2$

By Newton's 2nd law, this is the force exerted on the air by the rotor.
By Newton's 3rd law, this is the equal to the force exerted by the air on the rotor. B1
$\Rightarrow 2 \times 330v^2 = 150000$
$\Rightarrow v = 15.1 \text{ m s}^{-1}$ A1

Marker's comments:
When the question states explicitly "explain your working", students should make sure they explain clearly how the expressions used in their calculations are derived or how certain quantities can be equated. In this question, the force that acts on the air is equal to the rate of change of momentum of the air $\left(\dfrac{\Delta m}{\Delta t}(v - 0)\right)$ (Newton's second law). However, many students equated it to the force acting on the helicopter without any explanation, hence losing the mark for Newton's third law.

(iii) The density of air decreases with increasing altitude, reducing the upward force that can be generated by the helicopter. B1

4 **(a)** $m_A u_{A(y)} + m_B u_{B(y)} = m_A v_{A(y)} + m_B v_{B(y)}$

$$0 = (0.250)(15.0 \sin 30^\circ) + (0.600)(-v_B \sin\theta) \quad \text{B1}$$

$$v_B \sin\theta = \frac{(0.250)(15.0 \sin 30^\circ)}{(0.600)} = 3.13 \quad \text{(shown)}$$

Marker's comments:
Some students wrote both terms on the RHS of the equation as positive and ended up with v_B sin(theta) = – 3.13. This could have been easily accounted for by stating the magnitude is +3.13. But instead, many students simply erased away the negative sign which resulted in a mathematical error and losing the mark.

(b) Applying the Principle of Conservation of Linear Momentum in the x-direction:

$$m_A u_{A(x)} + m_B u_{B(x)} = m_A v_{A(x)} + m_B v_{B(x)}$$

$$(0.250)(30.0) + 0 = (0.250)(15.0\cos 30^\circ) + (0.600)(v_B \cos\theta)$$

$$v_B \cos\theta = \frac{(0.250)(30.0) - (0.250)(15.0\cos 30^\circ)}{(0.600)} = 7.087$$ M1

$$\tan\theta = \frac{3.13}{7.09}$$ M1

$$\theta = 23.8^\circ$$

(c) $v_B \sin(23.8^\circ) = 3.13$ A1

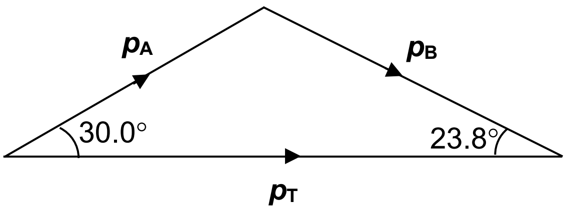
$$v_B = 7.76 \text{ m s}^{-1}$$

Or:

$v_B \cos(23.8^\circ) = 7.08734$

$$v_B = 7.75 \text{ m s}^{-1}$$

(d)



Correct directions B1

Correct labelling of vectors and angles (30.0° and 23.8°) B1

Marker's comments:
This question asks for a diagram that shows the relationship between the total momentum and the momenta of A and B. Hence, a triangle is necessary.

(e) Initial $E_k = \frac{1}{2}(0.250)(30)^2 = 112.5$ J M1

Final total $E_k = \frac{1}{2}(0.250)(15)^2 + \frac{1}{2}(0.600)(7.75)^2 = 46.1$ J M1

Since the final total kinetic energy is less than the initial kinetic energy, the collision is not elastic. A1

Marker's comments:
To justify the collision is inelastic, many students used the relative speed of approach is not equal to relative speed of separation. This is **incorrect,** because the two relative speeds are equal only if it is a **one-dimensional** elastic collision. Recall that the relation was derived from the equation of conservation of KE:

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

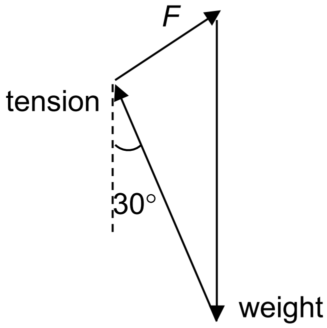
In 2-D collisions, the velocities of the particles in the x-direction do not fully account for the KE of the particles. In fact, for elastic collisions:

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

$$\frac{1}{2}m_1u_{1x}{}^2 + \frac{1}{2}m_1u_{1y}{}^2 + \frac{1}{2}m_2u_{2x}{}^2\ \frac{1}{2}m_2u_{2y}{}^2 = \frac{1}{2}m_1v_{1x}{}^2 + \frac{1}{2}m_1v_{1y}{}^2 + \frac{1}{2}m_2v_{2x}{}^2\ \frac{1}{2}m_2v_{2y}{}^2$$

The presence of the four terms that arise due to velocities in the *y*-direction means that the derivation in the lecture notes is no longer valid. Hence, the only way to answer this question is to compare the kinetic energy before and after collision.

5 (a) (i)

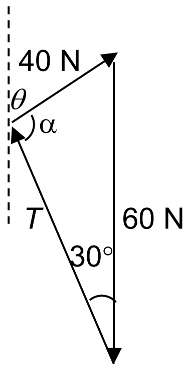


M1

A closed polygon (triangle) (with arrows clockwise) shows that resultant force is zero. A1

Marker's comments:
This question requires students to explain with reference to the diagram sketched. Hence, students who mentioned that the forces pass through a common point (indicating no net torque) are not given credit.

(ii) Using sine rule:



$$\frac{\sin\alpha}{60} = \frac{\sin 30°}{40}$$

$\alpha = 48.6°$ or $131.4°$ M1

(From vector triangle in **(i)**, α is more than 90°)

$\theta = 180° - 30° - 131.4° = 18.6°$ A1

Marker's comments:
Many students failed to notice that the angle α is more than 90°.
A few students attempted to draw a scaled diagram when solving this question. Obtaining an accurate answer from drawing a scaled diagram requires a large diagram and accurate drawing. It may be difficult to fulfil these conditions when examiners expect students to answer using calculations and insufficient space is provided for answers.

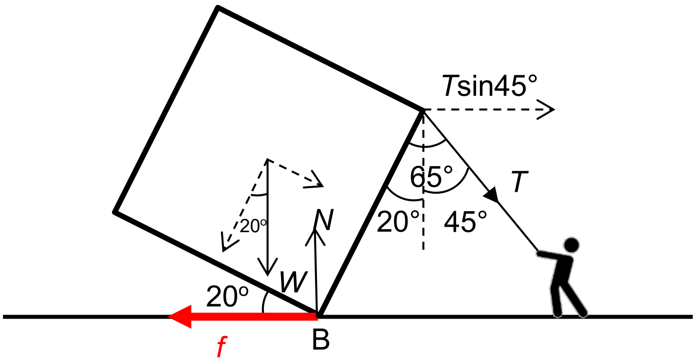
(iii) Consider vertical forces:
$T \cos 30° + 40 \cos 18.6° = 60$
$T = 25.5$ N B1

Marker's comments:
A few students attempted to draw a scaled diagram when solving this question.

(b) Considering the free body diagram of the ball, tension in upper cord is the sum of the tension in the lower cord and weight of the ball. M1
The tension in the upper cord is larger and it will break first. A1

Marker's comments:
Some students only mentioned that the tension in the lower cord is due to the applied force.
A more accurate relationship would be $T_{upper} = T_{lower} + W$.
Hence, $T_{lower} = T_{upper} - W$.

6 **(a)**



Taking moments about B,

Moment due to $W = \left(W\cos 20°\right)\left(\frac{L}{2}\right) - \left(W\sin 20°\right)\left(\frac{L}{2}\right)$ M1

$= (50)(9.81)\left(\frac{3.0}{2}\right)\left(\cos 20° - \sin 20°\right)$ M1

$= 440$ N m (anticlockwise) A1

Marker's comments:
This question is the same as Forces tutorial question D10 and it is disappointing that most students are unable to do this part. The common mistakes are using W sin 20° only or W cos 20° only in calculating the moment, and making errors in calculating the perpendicular distance between W and point B.

(b) By principle of moments, taking moments about B,
anticlockwise moment = clockwise moment

$440 = (T\sin 65°)(3.0)$ M1

$T = 162$ N A1

(c) **(i)** (draw frictional force f pointing to the left, parallel to the floor.) B1
The tension T has a horizontal component acting to the right. In order to maintain translational equilibrium, there needs to be a force acting to the left. B1
Since the weight and normal contact force are both vertical, the only force that can oppose the tension's horizontal component is the frictional force. B1
Hence, frictional force must be acting to the left.

Marker's comments:
Friction acts parallel to the surface. A common mistake is to omit the normal contact force acting and apply the concept that for three forces acting on a body in equilibrium, the line of action of the three forces must acts through a single point. Students should avoid using vague words such as "counteracts", "overcomes" or "account for".

(ii) To maintain translational equilibrium,

$f = T\sin 45°$

$= 162\sin 45°$

$= 115$ N B1

7 **(a)** $k = \dfrac{F}{x} = \dfrac{2.50}{0.200}$ M1

$= 12.5\ \text{N m}^{-1}$ A1

Marker's comments:
Many students forgot to convert 20.0 cm to 0.200 m.

(b) $W =$ area under the $F - x$ graph

$\therefore W = \dfrac{1}{2}Fx = \dfrac{1}{2} \times 2.50 \times 0.200$ M1

$= 0.250\ \text{J}$ A1

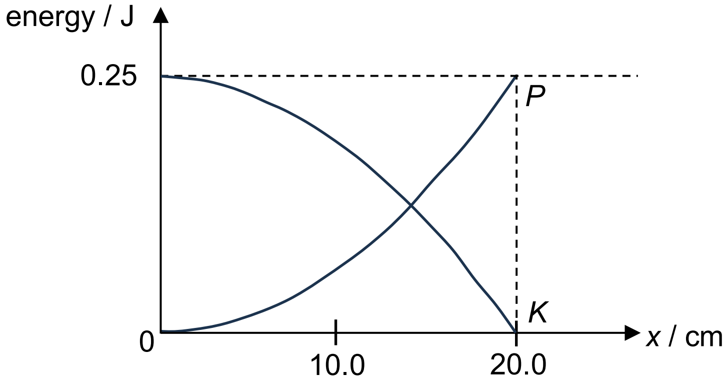
Marker's comments:
A small number of students incorrectly quoted the equation as *W* = *Fx.*

(c) **(i)** When $x = 0.100$ m, $\text{EPE} = \dfrac{1}{2}kx^2 = \dfrac{1}{2} \times 12.5 \times (0.100)^2 = 0.0625\ \text{J}$ M1

When $x = 0.100$ m, $\text{KE} = 0.250 - 0.0625 = 0.188\ \text{J}$ A1

Marker's comments:
Many students failed to understand the question and gave their final answer as 0.0625 J.

(ii)



B1: <u>correct shapes</u> of graphs
B1: <u>sum of *P* and *K* is a constant value</u> (0.250 J) for all *x* values up to *x* = 0.200 m

Marker's comments:
Few students drew the graphs correctly, with more mistakes in the kinetic energy graph than the potential energy graph. Many students incorrectly drew straight lines for the kinetic energy graph, failing to apply the concept that total energy is conserved.

8 **(a)** horizontal force on sphere causes centripetal acceleration
or
horizontal component of tension provides the centripetal force required for sphere to move in horizontal circle — B1
weight of sphere is (now) equal to vertical component of tension — B1
horizontal and vertical components (of tension) (now) combine to give greater tension (in spring), so greater extension of spring — B1

Alternative answer
Initial tension is equal to weight of sphere. ($T = W$) — B1
Vertical component of final tension is equal to weight of sphere ($T' \cos 27° = W$) — B1
greater tension in spring so greater extension of spring — B1

Marker's comments:
Many students did not account for weight when explaining despite the question asking to explain with reference to the 'forces' acting on the sphere. Merely stating that there is a horizontal component and a vertical component of tension or that there has to be a centripetal force as the sphere is moving in a circle without mentioning weight is insufficient. Some students wrongly wrote that centripetal force is another force acting. This is incorrect as centripetal force is just another name for the resultant force towards the centre of the circular path.

(b) **(i)**

$$r = L\sin\theta$$
$$= 21.0\sin 27° \quad \text{M1}$$
$$= 9.5338$$
$$= 9.5 \text{ cm } (\text{shown})$$

(ii) Consider vertical forces,

$$T\cos\theta = mg$$
$$T = \frac{mg}{\cos\theta} \quad \text{M1}$$
$$= \frac{0.29(9.81)}{\cos 27°}$$
$$= 3.19 \text{ N} \quad \text{A1}$$

Marker's comments:
Many students mistook length of spring in Fig. 8.1 as extension and determined the spring constant first before calculating tension in spring in Fig. 8.2. A few thought that the tension asked is the tension in Fig. 8.1. The entire part **(b)** is related to Fig. 8.2. Some students are confused between the sine and cosine functions.

(c) **(i)** By Newton's second law,

$$F_{\text{net}} = ma$$
$$F_c = ma_c$$
$$T\sin\theta = ma_c$$
$$a_c = \frac{T\sin\theta}{m}$$
$$= \frac{3.1929\sin 27°}{0.29} \quad \text{M1}$$
$$= 4.9984$$
$$= 5.00 \text{ m s}^{-2} \quad \text{A1}$$

Marker's comments:
Some students equated $T\sin\theta$ to a_c (without m) which is incorrect.

(ii)

$$a_c = r\omega^2$$
$$a_c = r\left(\frac{2\pi}{T}\right)^2$$
$$T = 2\pi\sqrt{\frac{r}{a_c}}$$
$$= 2\pi\sqrt{\frac{9.5338\times10^{-2}}{4.9984}}$$
$$= 0.868 \text{ s}$$

or

$$a_c = \frac{v^2}{r}$$
$$a_c = \frac{\left(\frac{2\pi r}{T}\right)^2}{r}$$
$$a_c = \frac{4\pi^2 r}{T^2}$$
$$T = 2\pi\sqrt{\frac{r}{a_c}} \qquad \text{M1}$$
$$= 2\pi\sqrt{\frac{9.5338\times10^{-2}}{4.9984}}$$
$$= 0.868 \text{ s} \qquad \text{A1}$$

Marker's comments: Some students forgot to convert the unit of radius of circle from cm to m or made mistakes in recalling the formulae.

9 **(a)** Since platform and counter-weight have the same angular velocity,

$$\omega_A = \omega_B$$
$$\left.\begin{aligned}\frac{u_A}{r_A} &= \frac{u_B}{r_B}\\ \frac{u_A}{u_B} &= \frac{8.4}{3.0}\end{aligned}\right\} \qquad \text{B1}$$
$$\frac{u_A}{u_B} = 2.8$$

Marker's comments: A significant number of students are not able to show the understanding that the counter-weight and platform have the same angular velocity as they are connected to the same beam.

(b) **(i)** loss in $GPE_{platform}$ = gain in $KE_{platform}$ + gain in $KE_{counter\text{-}weight}$ + gain in $GPE_{counter\text{-}weight}$ C1

$(2000)(9.81)(2\times8.4) = ½ (3000) (u_B^2) + ½ (2000)u_A^2 + (3000)(9.81)(2\times3.0)$ M1

$u_A = 11.3 \text{ m s}^{-1}$ A1

Marker's comments: Only a minority of students are able to apply the concept of conservation of energy correctly. Many are not aware that the platform also gains GPE beside KE in this case.

(ii)

$$F_c = \frac{m_A u_A^{\,2}}{r_A} = \frac{(2000)(11.334)^2}{8.4} \qquad \text{M1}$$
$$= 3.06\times10^4 \text{ N} \qquad \text{A1}$$

Marker's comments: Many students may not have enough time to attempt this question properly as this question just required the student to recall the formula for centripetal force.

(iii)

$$N - mg = m\frac{v^2}{r}$$
$$N - 70\times9.81 = 70\times\frac{11.334^2}{8.4} \qquad \text{M1}$$
$$N = 1.76\times10^3 \text{ N} \qquad \text{A1}$$

Marker's comments: There are students who are confused about the mass to be used in the calculation, even though this question is on a passenger who is on the platform.