Answers to exam-style questions

Topic 2
Where appropriate, 1 ✓ = 1 mark

1 D
2 C
3 C
4 D
5 A
6 D
7 D
8 A
9 C
10 A

11 a i The equation applies to straight line motion with acceleration g. Neither condition is satisfied here. ✓
   ii This equation is the result of energy conservation so it does apply since there are no frictional forces present. ✓

b From \( v = \sqrt{2gh} \) we find \( h = \frac{v^2}{2g} = \frac{4.8^2}{2 \times 9.81} = 1.174 = 1.2 \text{ m}. \) ✓

c i The kinetic energy at B is \( E = \frac{1}{2}mv^2 = \frac{1}{2} \times 25 \times 4.8^2 = 28.8 \text{ J}. \) ✓

The frictional force is \( f = \mu_k N = \mu_k mg = 0.45 \times 25 \times 9.81 = 110.36 \text{ N} \) and so the work done by this force is the change in the kinetic energy of the block, and so \( 110.36 \times d = 28.8 \Rightarrow d = 0.261 = 0.26 \text{ m}. \) ✓

ii The deceleration is \( \frac{f}{\mu} = \frac{110.36}{25} = 4.41 \text{ m} \text{s}^{-2}. \) ✓

and so \( 0 = 4.8 \times 4.41 \times t \) giving 1.1 s for the time. ✓

d The speed at B is independent of the mass. ✓

\( fd = \frac{1}{2}mv^2 \Rightarrow \mu_k mgd = \frac{1}{2}mv^2 \Rightarrow d = \frac{v^2}{2\mu_k}, \) ✓

and so the distance is also independent of the mass. ✓

12 a i \( v_x = v \cos \theta = 22 \times \cos 35^\circ = 18.0 = 18 \text{ m} \text{s}^{-1} \) ✓

\( v_y = v \sin \theta = 22 \times \sin 35^\circ = 12.6 = 13 \text{ m} \text{s}^{-1} \) ✓

ii Graph as shown. ✓
Graph as shown. ✓

b i At maximum height: \( v_y^2 = 0 = u_y^2 - 2gy. \) ✓

\[
y = \frac{u_y^2}{2g}
\]

and so \( y = \frac{12.6^2}{2 \times 9.8} = 8.1 \text{ m} \) ✓

OR

\[
v_y = 0 = v \sin \theta - gt \quad 12.6 - 9.8t = 0
\]

so \( t = 1.29 \text{ s} \) ✓

Hence \( y = 12.6 \times 1.29 - \frac{1}{2} \times 9.8 \times 1.29^2 = 8.1 \text{ m} \) ✓

ii The force is the weight, i.e. \( F = 0.20 \times 9.8 = 1.96 = 2.0 \text{ N}. \) ✓

c i \[
\frac{1}{2}mu^2 + ngh = \frac{1}{2}mv^2
\]
hence \( v = \sqrt{u^2 + 2gh} \) ✓

\[
v = \sqrt{u^2 + 2gh} = \sqrt{22^2 + 2 \times 9.8 \times 32} = 33.3 = 32 \text{ m s}^{-1} \)

\[
ii \quad v^2 = v_x^2 + v_y^2 \Rightarrow v_y = -\sqrt{v_x^2 - v_y^2} = -\sqrt{33.3^2 - 18.0^2} = -28.0 \text{ m s}^{-1}
\]

Now \( v_y = u_y \sin \theta - gt \) so \(-28.0 = 12.6 - 9.8 \times t \) hence \( t = 4.1 \text{ s} \) ✓

d i Smaller height. ✓
Smaller range. ✓
Steeper impact angle. ✓

ii The angle is steeper because the horizontal velocity component tends to become zero. ✓

Whereas the vertical tends to attain terminal speed and so a constant value. ✓

13 a i In 1 second the mass of air that will move down is \( \rho(\pi R^2 v). \) ✓

The change of its momentum in this second is \( \rho(\pi R^2 v)\Delta t = \rho\pi R^2 v^2. \) ✓

And from \( F = \frac{\Delta p}{\Delta t} \) this is the force. ✓
\[ R \pi R^2 v^2 = mg \\\n\begin{align*}
\text{And so } v &= \sqrt{\frac{mg}{\rho \pi R^2}} = \sqrt{\frac{0.30 \times 9.8}{1.2 \times \pi \times 0.25^2}} = 3.53 = 3.5 \text{ m s}^{-1}.
\end{align*}
\]

\[ b \text{ The power is } P = Fv \text{ where } F = \rho \pi R^2 v^2 \text{ is the force pushing down on the air and so } P = \rho \pi R^2 v^2. \]

So \[ P = 1.2 \times \pi \times 0.25^2 \times 3.53^2 = 2.936 = 3.0 \text{ W} \]

\[ c \]
\[ i \text{ From } F = \rho \pi R^2 v^2 \text{ the force is now 4 times as large, i.e. } 4mg \text{ and so the net force on the helicopter is } 3mg. \]

And so the acceleration is constant at \( 3g \). Hence \[ s = \frac{1}{2} \times 3g \times t^2 \Rightarrow t = \sqrt{\frac{2v}{3g}} = 0.90 \text{ s}. \]

\[ ii \]
\[ \nu = 3gt = \left( \frac{2v}{3g} \right) \]

\[ \nu = 26 \text{ m s}^{-1} \]

\[ iii \text{ The work done by the rotor is } W = Fd = 4mgd = 4 \times 0.30 \times 9.8 \times 12 = 141 \text{ J}. \]

14 \[ a \]
\[ i \text{ The area is the impulse i.e. } 2.0 \times 10^3 \text{ N} \cdot \text{s}. \]

\[ ii \text{ The average force is found from } \bar{F} \Delta t = 2.0 \times 10^3 \text{ N} \cdot \text{s}. \]

And so \[ \bar{F} = \frac{2.0 \times 10^3}{0.20} = 1.0 \times 10^4 \text{ N}. \]

Hence the average acceleration is \( \bar{a} = \frac{1.0 \times 10^4}{8.0} = 1.25 \times 10^3 \text{ m s}^{-2}. \)

\[ iii \text{ The final speed is } \bar{v} = \bar{a}t = 1.25 \times 10^3 \times 0.20 = 250 \text{ m s}^{-1}. \]

And so the average speed is \( 125 \text{ m s}^{-1}. \)

\[ iv \]
\[ s = \frac{1}{2} \bar{a}t^2 = \frac{1}{2} \times 1.25 \times 10^3 \times 0.20^2 \]

\[ s = 25 \text{ m} \]

15 \[ a \]
\[ i \text{ It is zero (because the velocity is constant).} \]

\[ ii \]
\[ F - mg \sin \theta - f = 0 \]

\[ F = mg \sin \theta + f = 1.4 \times 10^3 \times \sin 5.0^\circ + 600 \]

\[ F = 1820 \text{ N} \]

\[ b \]

The power used by the engine in pushing the car is \( P = Fv = 1820 \times 6.2 = 1.13 \times 10^4 \text{ W}, \]

\( P = 11.3 \text{ kW}. \)

The efficiency is then \( e = \frac{11.3}{15} = 0.75 \)
16 a i The change in momentum is \( \Delta p = 0.090 \times (90 - 130) \), \( \checkmark \)
\( \Delta p = -3.6 \text{ Ns} \). \( \checkmark \)
ii This is also the negative change in the momentum of the block and so \( 1.20v = 3.6 \text{ Ns} \)
giving \( v = 3.0 \text{ m s}^{-1} \). \( \checkmark \)
iii The initial kinetic energy is \( E = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.090 \times 130^2 = 422.5 \text{ J} \). \( \checkmark \)
The final kinetic energy is \( E = \frac{1}{2} \times 0.090 \times 90^2 + \frac{1}{2} \times 1.20 \times 3.0^2 = 369.9 \text{ J} \). The change is then
\( \Delta E = 369.9 - 422.5 = -52.6 = -53 \text{ J} \). \( \checkmark \)
b We have conservation of energy and so \( \frac{1}{2}m \times 3.0^2 = m \times 9.8 \times h \) and so \( h = 0.459 \text{ m} \). \( \checkmark \)
But \( h = L - L \cos \theta \) and so \( 0.459 = 0.80 \times (1 - \cos \theta) \) \( \checkmark \)
giving \( \cos \theta = 0.426 \) and so \( \theta = 64.77^\circ = 65^\circ \) \( \checkmark \)
c i It is not because there is a net force on it. \( \checkmark \)
ii From the diagram, \( T - mg \cos \theta = m \frac{v^2}{L} \). \( \checkmark \)
But \( v = 0 \) and so \( T = mg \cos \theta = 1.20 \times 9.8 \times \cos 64.77^\circ = 5.0 \text{ N} \). \( \checkmark \)
\( T = 5.0 \text{ N} \). \( \checkmark \)