Mark scheme for Topic 2

1 We start from $v^2 = 2ad$. When the velocity becomes $2v$ we then have $(2v)^2 = 2ax$, where x is the required distance. Then, $x = \frac{4v^2}{2a} = 4\frac{v^2}{2a} = 4d$. So the required distance from v to $2v$ is $4d - d = 3d$. **C.**

Exam tip: you must work with a formula without time and relate the new distance to the old.

2 When the second ball is released the first is already moving with some velocity. The velocity of the second ball relative to the first is non-zero and so the distance between the balls is increasing, **B**.

3 The kinetic energy right before the explosion is zero. The chemical energy of the explosion provides the extra kinetic energy of the fragments, so kinetic energy increases, i.e. is different.

There is an external force acting, namely gravity, but 'immediately' after the collision means a very small time interval after. Then, $F = \frac{\Delta p}{\Delta t} \Rightarrow \Delta p = F\Delta t = 0$ since $\Delta t \approx 0$. Hence momentum is conserved and so momentum stays the same, **B**.

Exam tip: it is important to realize that even though there is an external force the momentum will not change immediately after the explosion.

4 At launch all 4 balls have the same kinetic (K) and the same potential energy (P). Therefore they will have the same kinetic energy at the ground ($K + P$) and so the same speed.

Exam tip: kinetic energy is a scalar quantity and so the direction of the velocity initially is irrelevant.

5 The initial potential energy of the water is $mg\frac{h}{2}$. The final potential energy is $\frac{m}{2}g\frac{h}{4} + \frac{m}{2}g\frac{h}{4} = \frac{mgh}{4}$. The loss is therefore $\frac{mgh}{2} - \frac{mgh}{4} = \frac{mgh}{4}$, **C**.

6 a i The velocity is zero at the top.

so from $v = u + at$ we get $0 = 20 + (-10)t$, i.e. $t = 2.0\,\text{s}$. **[2]**

Exam tip: it is important to pay attention to the signs.

ii From $s = ut + \frac{1}{2}at^2$ we get $s = 20 \times 2 + \frac{1}{2}(-10)(2^2)$

$s = 20\,\text{m}$

OR

from $s = \left(\frac{u+v}{2}\right)t$,

$s = \left(\frac{20+0}{2}\right) \times 2$.

$= 20\,\text{m}$ **[2]**

iii From $v = u + at$, we get $v = 20 + (-10)(6.0)$

$v = -40\,\text{m}\,\text{s}^{-1}$. **[2]**

iv Using $s = \left(\frac{u+v}{2}\right)t$ again, $s = \left(\frac{20-40}{2}\right) \times 6 = -60\,\text{m}$,

so the height is 60 m.

OR

from $v^2 = u^2 + 2as$ we get $(-40)^2 = (20)^2 + 2(-10)s$

and so $s = -\frac{1600-400}{2 \times 10} = -60\,\text{m}$.

OR

use $s = ut + \frac{1}{2}at^2$ to get $s = 20 \times 6 + \frac{1}{2}(-10)(6^2)$

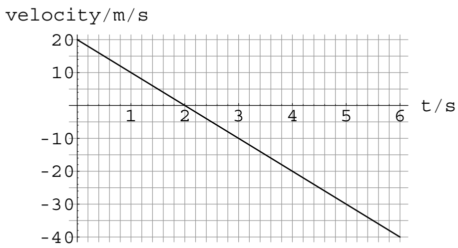
$s = -60\,\text{m}$. **[2]**

v The change in displacement is $-60-0=-60\,\text{m}$ and so the average velocity is $\frac{-60}{6.0}=-10\,\text{m}\,\text{s}^{-1}$.

The distance travelled is $20+20+60=100\,\text{m}$ and so the average speed is $\frac{100}{6.0}\approx 17\,\text{m}\,\text{s}^{-1}$. **[2]**

Exam tip: understand that 'average' has a specific meaning.

b **i**



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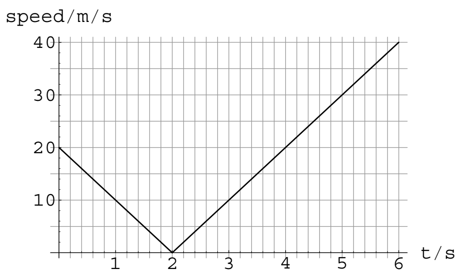

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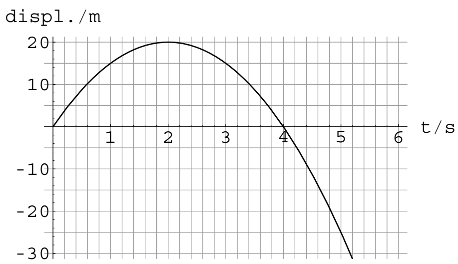
Exam tip: it is important to realize that the question asks for a graph of speed and not velocity.

iii



(This graph continues until $s=-60\,\text{m}$ at $t=6.0\,\text{s}$.) **[1]**

7 **a** $\Delta p = \left(0.20 \times 2.5 - 0.20 \times \underbrace{(-4.0)}_{\text{notice the sign}}\right) = 1.3\ \text{N s}$

upwards. **[2]**

b $F_{\text{net}} = R - mg = \dfrac{\Delta p}{\Delta t} = \dfrac{1.3}{0.14} = 9.3\ \text{N}$.

Hence $R = 2.0 + 9.3 \approx 11\ \text{N}$. **[2]**

Exam tip: the common mistake here is to neglect the weight. Remember that $\dfrac{\Delta p}{\Delta t}$ gives the average net force.

8 **a** **i** The area under the graph from $t = 0$ to $t = 4.5\ \text{s}$ is

$2 \times 3 + \dfrac{1}{2} \times 1.5 \times 3 - \dfrac{1}{2} \times 1 \times 2 = 7.25\ \text{m s}^{-1}$

and represents the change in velocity.

Hence the final velocity is $-9.0 + 7.25 = -1.75 \approx -1.8\ \text{m s}^{-1}$. **[2]**

ii The acceleration of free fall is read off the graph after $t = 4.5\ \text{s}$.

and is $2.0\ \text{m s}^{-2}$. **[2]**

iii At $t = 1.0\ \text{s}$ the acceleration is $3.0\ \text{m s}^{-2}$ and so $F - mg = ma \Rightarrow F = mg + ma$

$F = 250 \times 2.0 + 250 \times 3.0 = 1250 \approx 1.2\ \text{kN}$. **[2]**

iv The area under the graph until $t = 5.0\ \text{s}$ is $7.25 - 0.5 \times 2.0 = 6.25\ \text{m s}^{-1}$

and so the impact velocity is $-9.0 + 6.25 = -2.75 \approx -2.8\ \text{m s}^{-1}$. **[2]**

b The total energy of the landing module at $t = 0$ is
$\dfrac{1}{2}mv^2 + mgh = \dfrac{1}{2} \times 250 \times 9.0^2 + 250 \times 2.0 \times 25 = 22625\ \text{J}$. At $t = 4.5\ \text{s}$ it is
$\dfrac{1}{2}mv^2 = \dfrac{1}{2} \times 250 \times 1.75^2 = 382.8\ \text{J}$. The change in total energy is therefore
$22625 - 382.8 = 22242.2\ \text{J}$.

The power was delivered in 4.5 s and so the average power delivered is
$\dfrac{22281.25}{4.5} = 4942 \approx 4.9\ \text{kW}$. **[2]**

9 **a** The net force on a body is equal to the rate of change of its momentum with time. **[1]**

b In $\Delta t = 1\text{ s}$ the air leaving the blades will move forward a distance *v*. The air that moved is thus enclosed in a cylinder of cross-sectional area πR^2 and height *v* and so its mass is $\rho\pi R^2 v$.

The change in the momentum of this mass is $\Delta p = \rho\pi R^2 v \times v$.

Hence the force on the air is $F = \dfrac{\Delta p}{\Delta t} = \rho\pi R^2 v^2$. By Newton's third law, this is the force on the cart, directed to the right. **[3]**

Exam tip: the force just calculated is the force on the air. You must use Newton's third law to claim that this is the force on the cart.

10 **a** The component of the weight down the incline is $mg\sin\theta$. The net force **down** the incline is then $mg\sin\theta + f$ and this must equal *F* since speed is constant.

So $F = mg\sin\theta + f = 1.2\times10^4 \times \sin 4.0^\circ + 600 = 1437\text{ N}$.

The power is therefore $P = Fv = 1437\times12 = 17\text{ kW}$. **[3]**

Exam tip: the power consists of two parts: $600\times12 = 7.2\text{ kW}$ which is the power 'against friction' and $1.2\times10^4\times\sin 4.0^\circ\times12 = 10\text{ kW}$ which is the power 'against gravity' for a total of 17 kW.

b Now $F - mg\sin\theta + f = ma \Rightarrow F = 1.2\times10^4\times\sin 4.0^\circ + 600 + 1.2\times10^3\times2.0 = 3837\text{ N}$.

After 5.0 s the speed is $v = 0 + 2.0\times5.0 = 10\text{ m s}^{-1}$ and so the power then is $P = Fv = 3837\times10 \approx 38\text{ kW}$. **[2]**

11 **a** Impulse of a force is defined as the product of the (average) force times the time interval for which the force acts. **[1]**

b **i** The impulse is the area under the curve. The area under the curve is about 40 squares each,

of area $0.5 \times 5.0 = 2.5$ N s

for a total area of $40 \times 2.5 = 100$ N s . **[2]**

ii The impulse is equal to the change of momentum.

and so $mv - 0 = 100$ N s , giving $v = 200$ m s^{-1}. **[2]**

c The velocity is zero initially and then increases at an increasing rate (increasing acceleration until about 1.25 s),

after which the velocity still increases but at a decreasing rate. **[2]**

d The kinetic energy of the particle is $\frac{1}{2}mv^2 = \frac{1}{2} \times 0.50 \times 200^2 = 1.0 \times 10^4$ J

and so the power is $P = \frac{1.0 \times 10^4}{5.0} = 2.0$ kW . **[2]**

e **i** The average force obeys $F\Delta t = 100$ N s , and so $F = 20$ N.

The average acceleration is then $a = \frac{F}{m} = \frac{20}{0.50} = 40$ m s^{-2}. **[2]**

ii The distance travelled is then $s = \frac{1}{2}at^2 = \frac{1}{2}40 \times 5.0^2$

$s = 500$ m **[2]**

12 **a** The direction of velocity is constantly changing,

and acceleration is the rate of change of velocity. **[2]**

Exam tip: it is important to refer to the definition of acceleration and not just say that the direction is changing.

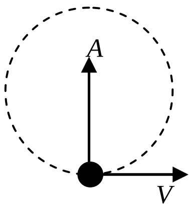
b **i** $v = \frac{2\pi R}{T} = \frac{2\pi \times 25}{48} = 3.3\ \text{m s}^{-1}$. **[1]**

ii The acceleration is $\frac{v^2}{R} = \frac{3.3^2}{25} = 0.44\ \text{m s}^{-2}$ and so the net force on the body is

$m\frac{v^2}{R} = 12 \times 0.44 = 5.2\ \text{N}$

Directed towards the centre of the circle. **[2]**

c **i** **[1]**



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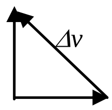

[1]

d The change in velocity from A to B is shown to the right; the angle to the vertical is $\tan^{-1}\frac{3.3}{3.3} = 45^\circ$.

It has magnitude $\sqrt{3.3^2 + 3.3^2} = 4.7\ \text{m s}^{-1}$

and so the average acceleration from A to B is $\frac{4.7}{12} = 0.39\ \text{m s}^{-2}$. **[3]**

Exam tip: 'average' acceleration has a specific meaning – do not add the accelerations at A and B and divide by 2.

