Answers to exam-style questions

Topic 1

Where appropriate, 1 ✓ = 1 mark

1 B

2 A

3 D

4 B

5 A

6 D

7 C

8 A

9 C

10 A

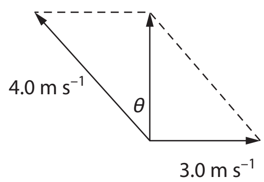
11 Use a smaller heavier ball. ✓
In order to minimise the effect of air resistance. ✓
Let the ball drop from various heights. ✓
In order to draw a graph of height versus time and get the acceleration through the gradient of the graph. ✓
If a stopwatch is to be used measure the time for each height many times and get an average. ✓
In order to get a more accurate value for the time. ✓

12 **a** It will take $\frac{30}{4.0} = 7.5\text{ s}$ to get across. ✓
And he will move $3.0 \times 7.5 = 22.5 \approx 22\text{ m}$ to the right of P. ✓

b Correct diagram. ✓

$\sin\theta = \frac{3.0}{4.0} = 0.75$ ✓

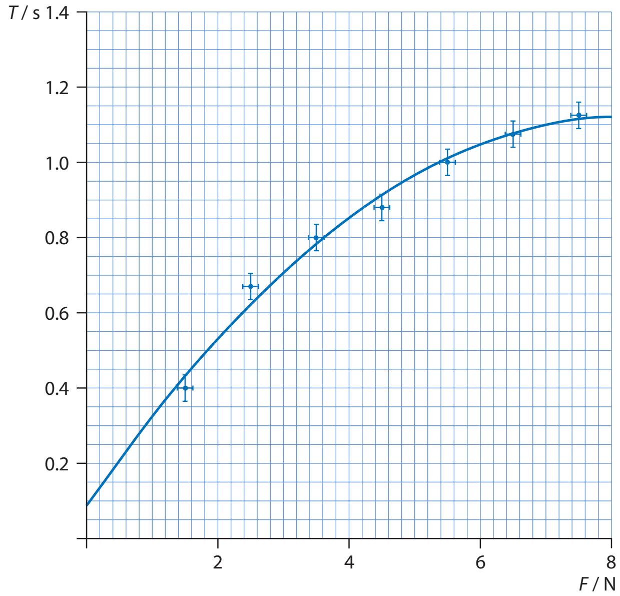
$\theta = \sin^{-1} 0.75 = 48.6°$ ✓



c The woman moves across with a speed of $\sqrt{4.0^2 - 3.0^2} = 2.6458\text{ m s}^{-1}$. ✓

So she will take a time of $\frac{30}{2.6458} = 11.3 \approx 11\text{ s}$, so will be longer than the man. ✓

13 **a** Smooth curve. ✓
Through all the error bars. ✓



b The vertical intercept is about 0.1 s. ✓

c For T to be proportional to F requires a straight line graph through the origin. ✓

And here neither of these conditions are satisfied. ✓

d The uncertainty in T is about ± 0.035 s . ✓

$$\frac{\Delta T^2}{T^2} = 2\frac{\Delta T}{T} \Rightarrow \Delta T^2 = 2T\Delta T \checkmark$$

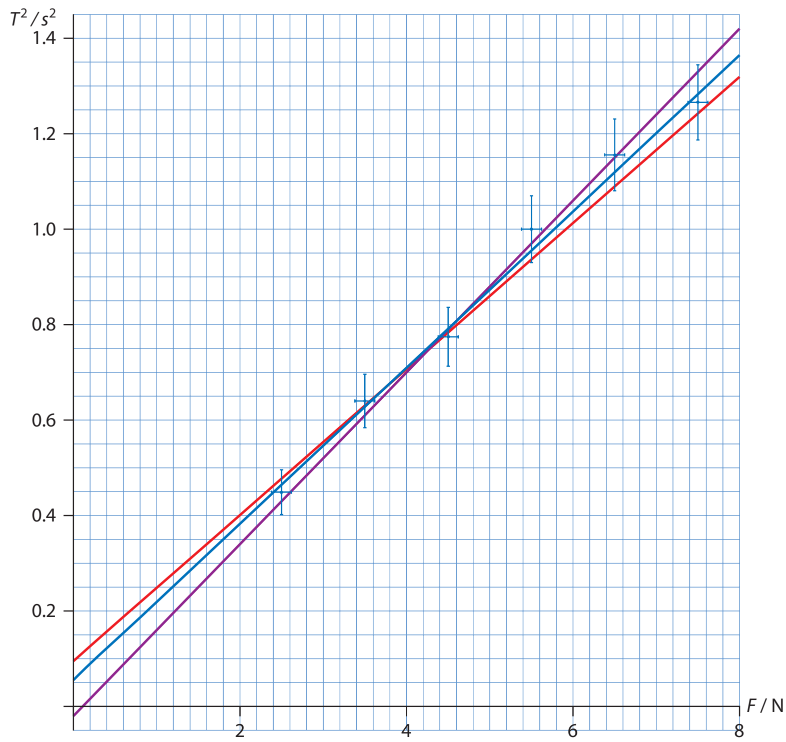
Hence $\Delta T^2 = \pm 2 \times 1.0 \times 0.035 = \pm 0.07 \ \ s^2$ ✓

e Correct plotting of points. ✓

Correct error bars and lines of maximum and minimum slope. ✓

Line of best-fit is straight and within uncertainties passes through origin. ✓

Hence claim is correct. ✓



f Slope of line of best fit $0.164 \ \ s^2\,N^{-1}$. ✓

Max/min slopes $0.153 \ \ s^2\,N^{-1}$ and $0.180 \ \ s^2\,N^{-1}$ so uncertainty is $0.0135 \approx 0.01 \ \ s^2\,N^{-1}$. ✓

So $(0.164 \pm 0.001) \ \ s^2\,N^{-1}$. ✓

Answers to exam-style questions

Topic 10

Where appropriate, 1 ✓ = 1 mark

1 C

2 C

3 C

4 C

5 C

6 C

7 D

8 B

9 C

10 A

11 **a** The potential at the surface is $V = -\frac{GM}{R} = -5.0\times10^{12}\ \text{J kg}^{-1}$. ✓

And so $M = -\frac{VR}{G} = \frac{5.0\times10^{12}\times2.0\times10^{5}}{6.67\times10^{-11}} = 1.5\times10^{28}$ kg. ✓

b The potential energy at launch on the surface of the planet is mV. ✓

And so the total energy at launch is $\frac{1}{2}mv^2 + mV$. ✓

At the escape speed the total energy has to be zero. ✓
And the result follows.

c $v = \sqrt{-2V} = \sqrt{2\times5.0\times10^{12}}$ ✓
Which equals $v = 3.2\times10^{6}\ \text{m s}^{-1}$. ✓

d The work required is $W = m\Delta V$ with $\Delta V = (-1.2\times10^{12} - (-5.0\times10^{12}) = 3.8\times10^{12}\ \text{J kg}^{-1}$. ✓
And this is $W = 1500\times3.2\times10^{12} = 5.7\times10^{15}$ J. ✓

e The additional energy needed is the kinetic energy: from $\frac{mv^2}{r} = \frac{GMm}{r^2}$ we find $E_K = \frac{1}{2}\frac{GMm}{r} = -\frac{1}{2}mV$ where V is the potential at the position of the probe. ✓

And this is $E_K = -\frac{1}{2}\times1500\times(-1.2\times10^{12}) = 9.0\times10^{14}$ J. ✓

f The potential at the release point is $V_1 = -2.2\times10^{12}\ \text{J kg}^{-1}$ and from conservation of energy

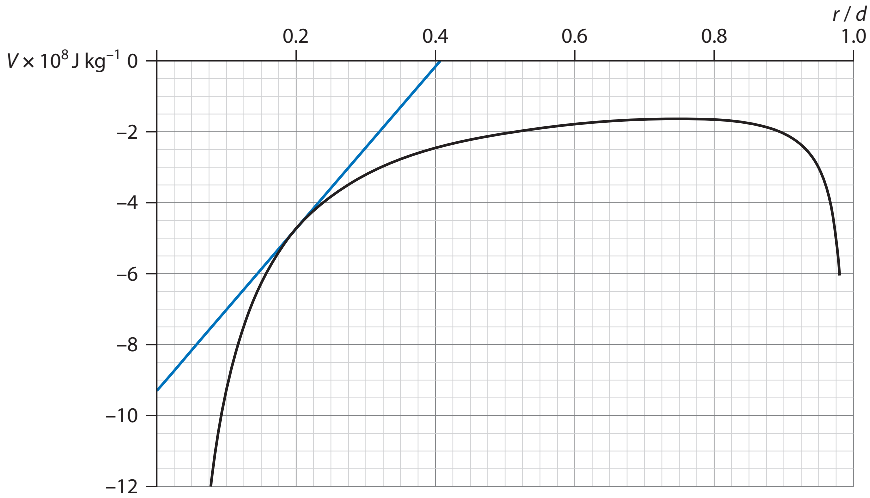
$mV_1 = mV_2 + \frac{1}{2}mv^2$ where is the potential at the surface. ✓

Hence $v = \sqrt{2(V_1 - V_2)} = \sqrt{2(-2.2\times10^{12} - (-5.0\times10^{12})} = 2.4\times10^{6}\ \text{m s}^{-1}$. ✓

12 a The slope of the tangent is gravitational field strength. ✓

Draw a tangent at the point with $\frac{r}{d} = 0.20$. ✓

Evaluate slope to be $g = \frac{0-(-9.2\times 10^8)}{(0.41-0)\times 4.8\times 10^8} \approx 4.7\ \text{N kg}^{-1}$. ✓



b The gravitational potential has zero slope there. ✓
Which implies that the gravitational field strength is zero at that point. ✓

c $g = \frac{GM}{r_1^2} - \frac{Gm}{r_2^2}$ ✓

$0 = \frac{GM}{0.75^2} - \frac{Gm}{0.25^2}$ ✓

Giving $\frac{M}{m} = \frac{0.75^2}{0.25^2} = 9.0$ ✓

13 a $qV_1 + \frac{1}{2}mv^2 = qV_2$ i.e. $q\frac{kQ}{r_1} + \frac{1}{2}mv^2 = q\frac{kQ}{r_2}$ ✓

$2.4\times 10^{-6} \times \frac{8.99\times 10^9 \times 8.8\times 10^{-6}}{0.75} + \frac{1}{2}\times 0.0075\times 3.2^2 = 2.4\times 10^{-6} \times \frac{8.99\times 10^9 \times 8.8\times 10^{-6}}{r_2}$ ✓

$0.2532 + 0.3840 (= 0.6372) = \frac{0.1899}{r_2}$

Hence $r_2 = 0.2980 \approx 0.30$ m. ✓

b The pellet will move radially away from the sphere. ✓
With an increasing speed but a decreasing acceleration. ✓

c The total energy of the pellet is 0.6372 J and far away this will turn into kinetic energy. ✓

Hence $\frac{1}{2}\times 0.075\times v^2 = 0.6372$ J leading to $4.1\ \text{m s}^{-1}$. ✓

14 a $qV = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2qV}{m}}$ ✓

Hence $v = \sqrt{\frac{2\times 1.6\times 10^{-19}\times 29.1}{9.11\times 10^{-31}}} = 3.197\times 10^6 \approx 3.2\times 10^6\ \text{m s}^{-1}$. ✓

b The horizontal distance of 2.0 cm is covered at the constant speed found above. ✓

And so $x = vt \Rightarrow t = \frac{x}{v} = \frac{0.020}{3.197\times 10^6} \approx 6.3\times 10^{-9}$ s. ✓

c The vertical distance covered is $y = \frac{1}{2}at^2 \Rightarrow a = \frac{2y}{t^2} = \frac{2 \times 0.25 \times 10^{-2}}{(6.3 \times 10^{-9})^2} \approx 1.3 \times 10^{14}\ \text{m s}^{-2}$. ✓

And from $qE = ma$ we find $E = \frac{ma}{q} = \frac{9.11 \times 10^{-31} \times 1.3 \times 10^{14}}{1.6 \times 10^{-19}} \approx 740\ \text{N C}^{-1}$. ✓

d The vertical component of velocity at B is $v_y = at = 1.3 \times 10^{14} \times 6.3 \times 10^{-9} \approx 8.2 \times 10^5\ \text{m s}^{-1}$. ✓

Hence $\theta = \tan^{-1}\frac{v_y}{v_x} = \tan^{-1}\frac{8.2 \times 10^5}{3.2 \times 10^6} \approx 14°$. ✓

e The work done is the change in kinetic energy. ✓

Which is $\Delta E_K = \frac{1}{2}mv_y^2 = \frac{1}{2} \times 9.11 \times 10^{-31} \times (8.2 \times 10^5)^2 = 6.3 \times 10^{-17}$ J. ✓

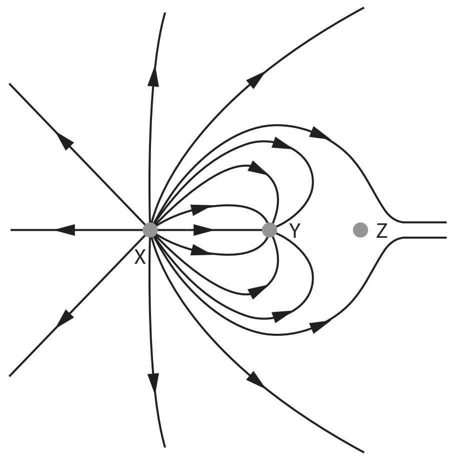
f The work done is also $W = q\Delta V$ and so $\Delta V = \frac{W}{q} = \frac{6.3 \times 10^{-17}}{1.6 \times 10^{-19}} = 394 \approx 390$ V. ✓

15 **a** Field lines are mathematical lines originating and ending in electric charges. ✓
Tangents to these lines give the direction of the electric field at a point. ✓

b They leave from positive charges (or infinity) and end in negative charges (or infinity). ✓
They cannot cross. ✓
Their density is proportional to the electric field strength. ✓

c X is positive and Y is negative. ✓

d **i** The field is zero at a position that may be approximated by Z. ✓



ii The ratio of the distance of Z from X to the distance from Y is about 2.5. ✓

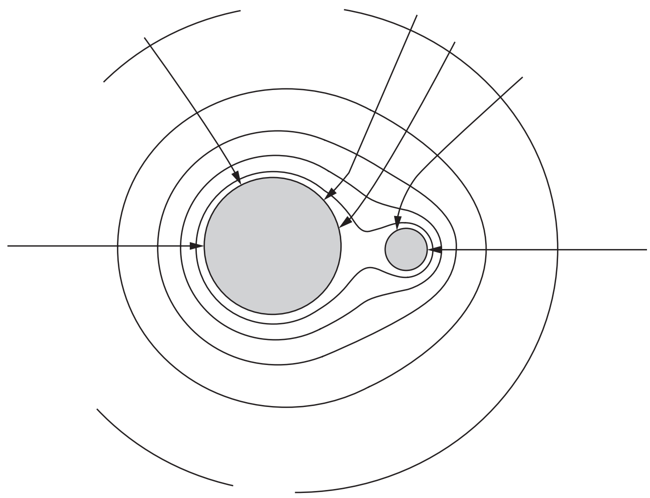
Hence from $0 = \frac{kQ_X}{r_1^2} - \frac{kQ_Y}{r_2^2}$ we find $\frac{Q_X}{Q_Y} = \frac{r_1^2}{r_2^2} = 2.5^2 \approx 6$. ✓

16 a i An equipotential surface is the set of all points that have the same potential. ✓

b i Field lines normal to equipotentials. ✓

And normal to spheres. ✓

(plus symmetrically paced lines one the lower side)



ii The potential difference between A and B is $\Delta V = 2.0 \times 10^6\ \text{J kg}^{-1}$. ✓

And so the work done is $m\Delta V = 1500 \times 2.0 \times 10^6 = 3.0 \times 10^9$ J. ✓

iii $g \approx \dfrac{\Delta V}{\Delta r}$ ✓

$g \approx \dfrac{10^6}{4.0 \times 10^6} = 0.25\ \text{N kg}^{-1}$ ✓

iv From a very large distance away the two bodies look like one point particle. ✓

And the equipotential surfaces of a single particle are spherical. ✓

c The potential; lines shown correspond to two masses so they are defined by $-\dfrac{GM_1}{r_1} - \dfrac{GM_2}{r_2} = \text{constant}$, or just

$-\dfrac{M_1}{r_1} - \dfrac{M_2}{r_2} = \text{constant}$. ✓

Two positive charges or two negative charges would give equipotential lines defined by

$-\dfrac{Q_1}{r_1} - \dfrac{Q_2}{r_2} = \text{constant}$. ✓

And so would be the same as in the gravitational case. ✓

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 $h = \frac{v^2}{2g} = \frac{4.8^2}{2 \times 9.81} = 1.174 \approx 1.2$ m. ✓

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

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

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

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

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

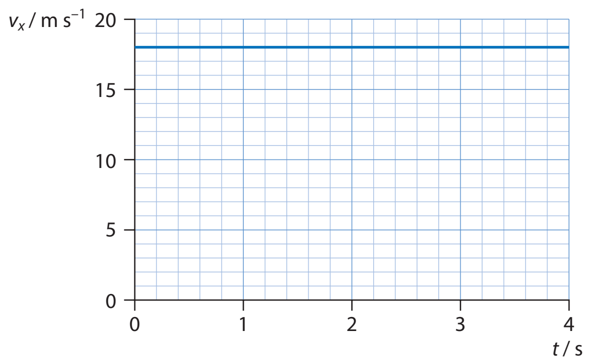
$fd = \frac{1}{2}mv^2 \Rightarrow \mu_K mgd = \frac{1}{2}mv^2 \Rightarrow d = \frac{v^2}{2\mu_K}$, ✓

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

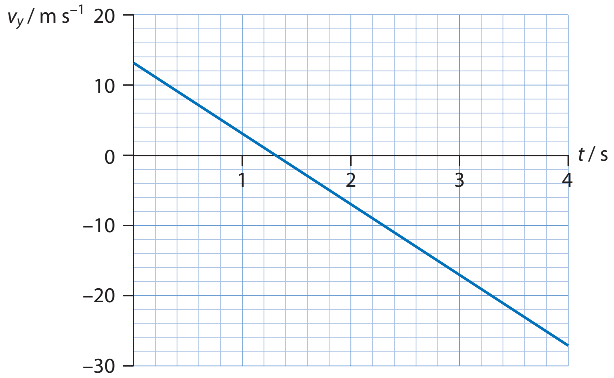
12 a i $v_x = v\cos\theta = 22 \times \cos 35° = 18.0 \approx 18\ \text{m s}^{-1}$ ✓

$v_y = v\sin\theta = 22 \times \sin 35° = 12.6 \approx 13\ \text{m s}^{-1}$ ✓

ii Graph as shown. ✓



Graph as shown. ✓



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

$y = \dfrac{u_y^2}{2g}$ ✓

and so $y = \dfrac{12.6^2}{2 \times 9.8} = 8.1$ m ✓

OR

$v_y = 0 = v\sin\theta - gt$ $12.6 - 9.8t = 0$ ✓

so $t = 1.29$ s ✓

Hence $y = 12.6 \times 1.29 - \dfrac{1}{2} \times 9.8 \times 1.29^2 = 8.1$ m ✓

ii The force is the weight, i.e. $F = 0.20 \times 9.8 = 1.96 \approx 2.0$ N. ✓

c i $\dfrac{1}{2}mu^2 + mgh = \dfrac{1}{2}mv^2$ hence $v = \sqrt{u^2 + 2gh}$ ✓

$v = \sqrt{u^2 + 2gh} = \sqrt{22^2 + 2 \times 9.8 \times 32} = 33.3 \approx 32$ m s^{-1} ✓

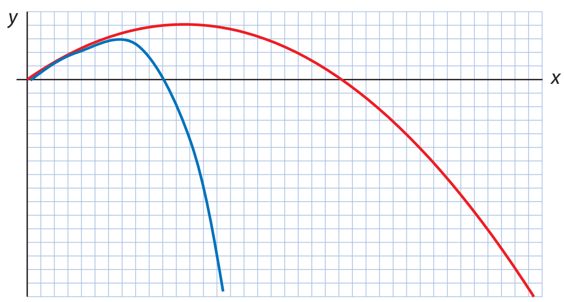
ii $v^2 = v_x^2 + v_y^2 \Rightarrow v_y = -\sqrt{v_x^2 - v_x^2} = -\sqrt{33.3^2 - 18.0^2} = -28.0$ m s^{-1} ✓

Now $v_y = u_y \sin\theta - gt$ so $-28.0 = 12.6 - 9.8 \times t$ hence $t = 4.1$ 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 $\rho(\pi R^2 v)v = \rho\pi R^2 v^2$. ✓

And from $F = \dfrac{\Delta p}{\Delta t}$ this is the force. ✓

ii $\rho\pi R^2 v^2 = mg$ ✓

And so $v = \sqrt{\dfrac{mg}{\rho\pi R^2}} = \sqrt{\dfrac{0.30\times 9.8}{1.2\times\pi\times 0.25^2}} = 3.53 \approx 3.5\ \text{m s}^{-1}$. ✓

b The power is $P = Fv$ where $F = \rho\pi R^2 v^2$ is the force pushing down on the air and so $P = \rho\pi R^2 v^2$. ✓
So $P = 1.2\times\pi\times 0.25^2\times 3.53^2 = 2.936 \approx 3.0$ W ✓

c i From $F = \rho\pi R^2 v^2$ the force is now 4 times as large, i.e. $4mg$ and so the **net** force on the helicopter is $3mg$. ✓

And so the acceleration is constant at $3g$. Hence $s = \dfrac{1}{2}\times 3g\times t^2 \Rightarrow t = \sqrt{\dfrac{2s}{3g}} \approx 0.90$ s. ✓

ii $v = 3gt = \sqrt{\dfrac{2s}{3g}}$ ✓

$v \approx 26\ \text{m s}^{-1}$ ✓

iii The work done by the rotor is $W = Fd = 4mgd = 4\times 0.30\times 9.8\times 12 = 141$ J. ✓

14 a i The area is the impulse i.e. 2.0×10^3 N s. ✓

ii The average force is found from $\bar{F}\Delta t = 2.0\times 10^3$ N s. ✓

And so $\bar{F} = \dfrac{2.0\times 10^3}{0.20} = 1.0\times 10^4$ N. ✓

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

iii 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 m s^{-1}. ✓

iv $s = \dfrac{1}{2}\bar{a}t^2 = \dfrac{1}{2}\times 1.25\times 10^3\times 0.20^2$ ✓

$s = 25$ m ✓

b i The final speed is $\bar{v} = \bar{a}t = 1.25\times 10^3\times 0.20$, ✓
$\bar{v} = 250\ \text{m s}^{-1}$. ✓

ii The kinetic energy is $E_K = \dfrac{1}{2}mv^2 = \dfrac{1}{2}\times 8.0\times 250^2$ ✓

$E_K = 2.5\times 10^5$ J ✓

iii $P = \dfrac{E_K}{t} = \dfrac{2.5\times 10^5}{0.20}$ ✓

$P = 1.25\times 10^6$ W ✓

15 a i It is zero (because the velocity is constant). ✓

ii $F - mg\sin\theta - f = 0$ ✓

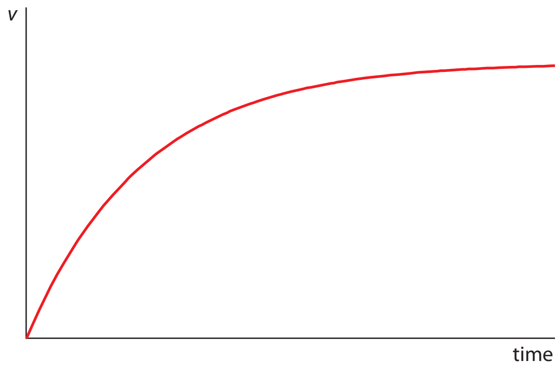
$F = mg\sin\theta + f = 1.4\times 10^4\times\sin 5.0° + 600$ ✓

$F = 1820$ N ✓

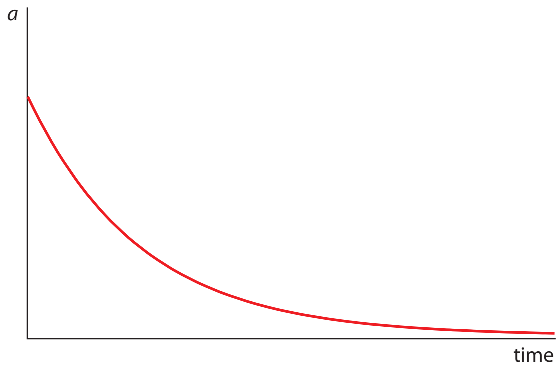
b The power used by the engine in pushing the car is $P = Fv = 1820\times 6.2 = 1.13\times 10^4$ W, ✓
$P = 11.3$ kW. ✓

The efficiency is then $e = \dfrac{11.3}{15} = 0.75$ ✓

c i Initial speed zero. ✓
Terminal speed. ✓



ii Initial acceleration not zero. ✓
And approaching zero. ✓



16 a i The change in momentum is $\Delta p = 0.090 \times (90 - 130)$, ✓
$\Delta p = -3.6$ N s. ✓

ii This is also the negative change in the momentum of the block and so $1.20v = 3.6$ N s giving $v = 3.0$ m s^{-1}. ✓

iii The initial kinetic energy is $E = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.090 \times 130^2 = 422.5$ J. ✓

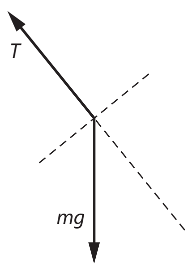
The final kinetic energy is $E = \frac{1}{2} \times 0.090 \times 90^2 + \frac{1}{2} \times 1.20 \times 3.0^2 = 369.9$ J. The change is then $\Delta E = 369.9 - 422.5 = -52.6 \approx -53$ J. ✓

b We have conservation of energy and so $\frac{1}{2} \times m \times 3.0^2 = m \times 9.8 \times h$ and so $h = 0.459$ m. ✓

But $h = L - L\cos\theta$ and so $0.459 = 0.80 \times (1 - \cos\theta)$ ✓

giving $\cos\theta = 0.426$ and so $\theta = 64.77° \approx 65°$ ✓

c i It is not because there is a net force on it. ✓



ii From the diagram, $T - mg\cos\theta = m\frac{v^2}{L}$. ✓

But $v = 0$ and so $T = mg\cos\theta = 1.20 \times 9.8 \times \cos 64.77° = 5.0$ N. ✓

$T = 5.0$ N. ✓

Answers to exam-style questions

Topic 3

Where appropriate, 1 ✓ = 1 mark

1 A

2 B

3 C

4 D

5 B

6 A

7 B

8 A

9 D (the question should have specified equal moles for each gas)

10 A

11 a Use $pV = nRT \Rightarrow V = \frac{nRT}{p}$ ✓

To find $V = \frac{1.0 \times 8.31 \times 273}{1.0 \times 10^5} = 2.27 \times 10^{-2}\,\text{m}^3$ ✓

b i There are $N_A = 6.02 \times 10^{23}$ molecules. ✓

So to each molecule corresponds a volume $\frac{2.27 \times 10^{-2}}{6.02 \times 10^{23}} = 3.77 \times 10^{-26}\ \text{m}^3$. ✓

ii Assuming a cube of this volume the side is $\sqrt[3]{3.77 \times 10^{-26}} = 3.35 \times 10^{-9}$ m, which is therefore an estimate of the separation of the molecules. ✓

This separation is much larger than the diameter of the helium atom and so the ideal gas approximation is good. ✓

c One mole of lead has a mass of 0.207 kg and a volume of $V = \frac{m}{\rho} = \frac{0.207}{11.3 \times 10^3} = 1.83 \times 10^{-5}\ \text{m}^3$. ✓

To each molecule corresponds a volume $\frac{1.83 \times 10^{-5}}{6.02 \times 10^{23}} = 3.04 \times 10^{-29}\ \text{m}^3$. ✓

Assuming a cube of this volume the side is $\sqrt[3]{3.04 \times 10^{-29}} = 3.12 \times 10^{-10}$ m which is therefore an estimate of the separation of the molecules. ✓

d The ratio is then $\frac{3.35 \times 10^{-9}}{3.12 \times 10^{-10}}$, ✓

≈ 10 . ✓

12 a Specific heat capacity is the amount of energy required to change the temperature of a 1 kg of a substance by 1 K. ✓

b One mole of any substance contains the same number of molecules; to raise the temperature by 1 K the internal energy will increase by the same amount and so the same heart must be provided. ✓

One kg of different substances contains different numbers of molecules and so different amounts of energy are required to increase the temperature by 1 K. ✓

c From $\frac{\Delta Q}{\Delta t} = \frac{\Delta m}{\Delta t} c\Delta T$ we find $600 = \frac{\Delta m}{\Delta t} \times 990 \times (40 - 20)$. ✓

So that $\frac{\Delta m}{\Delta t} = 3.0 \times 10^{-2}\ \text{kg s}^{-1}$. ✓

d Then $\frac{\Delta V}{\Delta t} = \rho \frac{\Delta V}{\Delta t} = 1.25 \times 3.0 \times 10^{-2} = 3.8 \times 10^{-2}\ \text{m}^3\,\text{s}^{-1}$. ✓

e The energy required is $Q = mL = 180 \times 2200 = 3.96 \times 10^5$ J. ✓

$t = \frac{3.96 \times 10^5}{750} = 528\,\text{s} = 8.8$ min. ✓

13 a i The graph is a curve. ✓

If there was no air resistance the acceleration would have been constant and the velocity – time graph a straight line. ✓

ii We must estimate the area under the graph by counting squares with one small square equal in area to 0.5 m. ✓

There about 370 small squares so the height is about 185 m. ✓

iii Applying $mgh = \frac{1}{2}mv^2$ gives $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 185}$, ✓

$v = 60.2 \approx 60\ \text{m s}^{-1}$. ✓

b The impact speed is about 18.1 m s^{-1} implying a loss of mechanical energy of $\frac{1}{2} \times 8.0(60.2^2 - 18.1^2) = 1.32 \times 10^4$ J. ✓

Assuming all of this goes into heating the ball and that this amount of energy warms the entire body uniformly. ✓

$mc\Delta T = 1.32 \times 10^4$, ✓

and so $\Delta T = \frac{1.32 \times 10^4}{8.0 \times 320} \approx 5$ K. ✓

14 a The internal energy is the sum of the total random kinetic energy of the molecules and the intermolecular potential energy of the molecules of tungsten. ✓

b The tungsten loses heat $0.050 \times 132 \times (T - 31)$. ✓

This heat is absorbed by the water and the calorimeter:

$0.300 \times 4200 \times (31 - 22) + 0.120 \times 900 \times (31 - 22) = 1.23 \times 10^4$ J ✓

Hence $0.050 \times 132 \times (T - 31) = 1.23 \times 10^4$ or $T - 31 = \frac{1.23 \times 10^4}{0.050 \times 132} = 1864$ and finally $T = 1895 \approx 1900\,°\text{C}$. ✓

c The calculated temperature is $T = \frac{Q}{m_W c_W} + 31$ where Q is the heat that went into the water and calorimeter.

The actual Q would have been higher because some was transferred into the air during the move of the metal into the water. ✓

Hence the calculated value is smaller than the actual temperature. ✓

15 a The internal energy is the sum of the total random kinetic energy of the molecules and the intermolecular potential energy of the molecules of the substance. ✓

b During melting energy is supplied to the substance melting increasing its internal energy but not its temperature. ✓

Hence the student's statement is false. ✓

c The liquid is losing heat to the surroundings because the container is not insulated. ✓

When the rate of heat loss is equal to the rate at which energy is being provided the temperature will remain constant. ✓

d The rate of heat loss is equal to the rate at which energy was being provided when the heater was on i.e. 35 W. ✓

Since $\frac{\Delta Q}{\Delta t} = mc\frac{\Delta T}{\Delta t}$ we have that $35 = 0.240 \times c \times \frac{3.1}{60}$. ✓

And so $c = \frac{35 \times 60}{0.240 \times 3.1} = 2.8 \times 10^3$ J kg^{-1} K^{-1}. ✓

16 a $pV = nRT \Rightarrow n = \frac{pV}{RT}$ to find $n = \frac{250 \times 10^3 \times 1.50 \times 10^{-2}}{8.31 \times 273} = 1.653$. ✓

So that $N_1 = nN_A = 1.653 \times 6.02 \times 10^{23} = 9.95 \times 10^{23} \approx 1.0 \times 10^{24}$ molecules. ✓

b As the tyre rolls on the road the rubber lining of the tyre expands and contracts generating thermal energy that heats the air in the tyre. ✓

The volume will increase.

And so will the pressure and temperature. ✓

c $p = \frac{nRT}{V} = \frac{1.653 \times 8.31 \times (273 + 35)}{1.60 \times 10^{-2}} = 2.64 \times 10^5$ Pa ≈ 260 kPa. ✓

d i Assuming the volume and temperature stay the same we must have that $\frac{p_1}{n_1} = \frac{p_2}{n_2}$ and so $\frac{250}{1.653} = \frac{230}{n_2}$ giving $n_2 = 1.52$. The number of molecules is then $N_2 = 1.52 \times 6.02 \times 10^{23} = 9.15 \times 10^{23}$. ✓

The number of molecules that left is therefore $N_1 - N_2 = 9.95 \times 10^{23} - 9.15 \times 10^{23} = 8.0 \times 10^{22}$. ✓

The rate of loss is then $\frac{8.0 \times 10^{22}}{8 \times 60 \times 60} = 2.8 \times 10^{18}$ s^{-1}. ✓

ii The number of moles lost is $1.65 - 1.52 = 0.13$ ✓

And so the lost mass of air is $0.13 \times 29 = 3.8$ g. ✓

Answers to exam-style questions

Topic 4

Where appropriate, 1 ✓ = 1 mark

1 A

2 C

3 B

4 A

5 D

6 D

7 D

8 C

9 B

10 A

11 **a** In a longitudinal wave the displacement is along the direction of energy transfer (DOET) ✓
whereas in a transverse wave it is at right angles to the DOET. ✓

b **i** The amplitude is 4.0 mm. ✓

ii The wavelength is 0.20 m. ✓

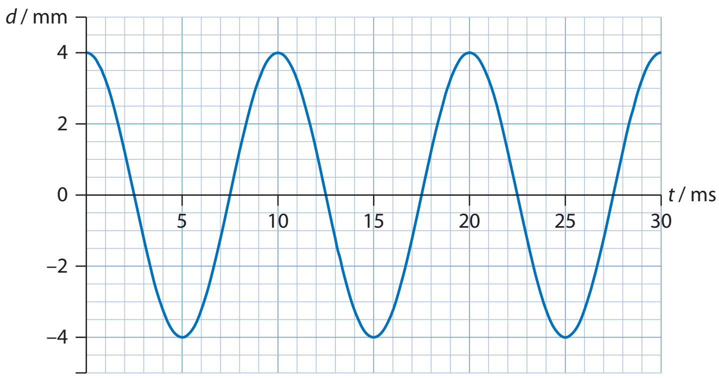
iii The period is 10 s and so the frequency is $f = \frac{1}{T} = \frac{1}{10} = 0.10$ Hz. ✓

c The speed is $v = \lambda f = 0.20 \times 0.10$. ✓

$v = 0.020 \text{ m s}^{-1}$ ✓

d Particle P has zero displacement at t = 10 s. ✓
A short time later the displacement becomes positive (we look at the second graph). ✓
To make the displacement of the point at 0.20 m positive a short time after 10 s the first graph must be shifted to the right, so the wave moves to the right. ✓

e At t = 10 s point Q has displacement 4.0 mm. ✓
Hence we must have the following graph. ✓



f **i** The wavelength of the first harmonic is $4L$, ✓
and so $4L = 0.20 \Rightarrow L = 0.050$ m. ✓

ii Standing waves do not transfer energy; travelling waves do. ✓
Standing waves have variable amplitude; travelling waves have a constant amplitude. ✓

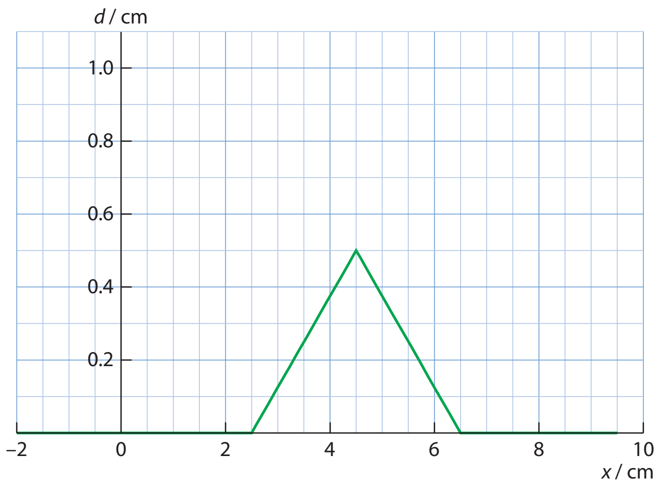
iii It is the speed of one of the travelling waves, ✓
making up the standing wave. ✓

12 a When two waves (of the same type) meet, ✓
the resultant displacement is the algebraic sum of the individual displacements. ✓

b The speed of the black pulse is the same as that of the grey pulse since the medium is the same. ✓

c i The centres of the pulses are separated by a distance of 5.0 cm. The relative speed of the pulses is 30 m s^{-1} and so will completely overlap at a time of $\frac{5.0}{30} = 0.167 \approx 0.17$ s. ✓

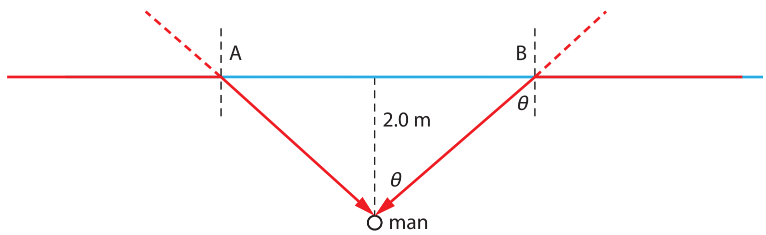
ii In 0.167 s each pulse will move a distance of 2.5 m, ✓
and so the resulting pulse has the shape of the following graph. ✓



d i The pulses have the same shape after the collision. ✓
So no energy is lost (the collision of the pulses is elastic). ✓

ii The energy carried by a pulse is proportional to the (square of the) height of the pulse. ✓
The pulse is short during overlap. ✓
But the string is moving vertically during overlap and so makes up for the apparently missing energy. ✓

13 a The diagram shows how rays of light coming in parallel to the water surface will refract. ✓



So the rays that can enter the man's eyes lie within a circle of diameter AB. ✓

b From the diagram above and Snell's law $1.00 \times \sin 90° = 1.33 \times \sin\theta$ so that $\theta = 48.8°$. ✓
Hence $R = 2.0 \tan\theta = 2.0 \times \tan 48.8° = 2.28 \approx 2.3$ m. ✓

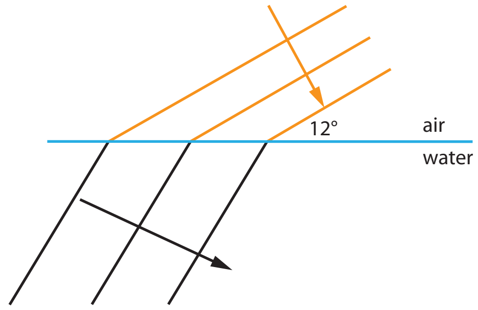
c The angle θ will be the same. ✓
But since the depth is greater so will the radius. ✓

d i Snell's law says that $\frac{\sin 12°}{340} = \frac{\sin\theta}{1500}$ ✓
so that $\theta = 66.5° \approx 67°$. ✓

ii Three wavefronts as shown:

Rays bending away from normal. ✓

Wavelength greater. ✓



iii The sound tends to move parallel to the surface of the water, ✓
and not to penetrate deeper into the water where a swimmer might be. ✓

14 a Light in which the electric field oscillates on only one plane. ✓

b The intensity transmitted through the first polariser will be 160 W m^{-2}. ✓
The intensity through the second will be $160\cos^2\theta$ W m^{-2} and through the third $160\cos^4\theta$ W m^{-2}. ✓
Hence $160\cos^4\theta = 10$ giving $\theta = 60°$. ✓

c Let the intensities of the polarised and unpolarised components be I_P, I_U respectively: at maximum transmitted intensity the polariser's axis will be parallel to the polarised light's electric field and the transmitted intensity will then be $I_P + \frac{I_U}{2}$; at minimum intensity the polarised component will not be transmitted and so the intensity will be $\frac{I_U}{2}$. ✓

We have that $\frac{I_P + \frac{I_U}{2}}{\frac{I_U}{2}} = 7$ and so $\frac{I_P}{I_U} = 3$. ✓

The required fraction is then $\frac{3}{4}$. ✓

d The wall is vertical and so the reflected light is partially polarised. ✓
In a direction that is parallel to the wall, i.e. vertical. ✓
And so a polariser with a horizontal transmission axis will cut off the reflected glare. ✓

15 a Light leaving each of the slits diffracts at each slit, ✓
and so light from each slit will arrive at the middle of the screen. ✓

b With both slits open light arrives at the middle of the screen in phase and so the amplitude is twice the amplitude due to one slit. ✓
The intensity is proportional to the amplitude squared. ✓
So with one slit open the amplitude will be half and the intensity one quarter, i.e. 1 W m^{-2}. ✓

c The intensity of the side maxima is not the same as that of the central maximum. ✓

d The separation of the maxima on the screen is 0.60 cm and the separation is given by $s = \frac{\lambda D}{d}$ and so $\lambda = \frac{sd}{D}$. ✓

Hence $\lambda = \frac{0.60\times10^{-2}\times0.39\times10^{-3}}{3.2} = 7.3\times10^{-7}$ m. ✓

e Blue light has a smaller wavelength than red light. ✓
Hence the separation of the maxima will be less. ✓

16 a A standing wave is formed when two identical travelling waves moving in opposite directions. ✓

Meet and superpose. ✓

b i The travelling wave from the source reflects off the water surface. ✓

The reflected wave superposes with the incoming wave creating a standing wave in the tube. ✓

ii The standing wave will have a wavelength equal to $\frac{4L}{n}$ where L is the length of the air column and n is an odd integer. ✓

So for a given wavelength λ this will happen only when $L = \frac{\lambda n}{4}$, i.e. for specific values of the air column length. ✓

iii The difference in air column lengths is half a wavelength (explained in the next part) and so the next length is 37 cm. ✓

iv The difference in air column lengths is $\frac{\lambda n}{4} - \frac{\lambda(n-2)}{4} = \frac{\lambda}{2}$, i.e. half a wavelength and the wavelength is $\lambda = 2 \times 0.12 = 0.24$ m. ✓

So $v = f\lambda = 1400 \times 0.24 = 336 \approx 340\ \mathrm{m\,s^{-1}}$. ✓

Answers to exam-style questions

Topic 6

Where appropriate, 1 ✓ = 1 mark

1 A

2 C

3 B

4 C

5 C

6 B

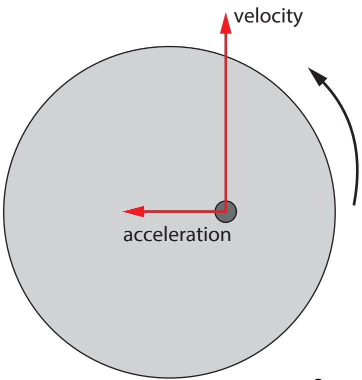
7 D

8 D

9 C

10 A

11 a Velocity arrow. ✓
Acceleration arrow. ✓



b The angular speed is $\omega = \dfrac{2\pi}{1.40} = 4.488 \approx 4.5\ \text{rad s}^{-1}$. ✓

The linear speed is $v = \omega r = 4.488 \times 0.22 = 0.987 \approx 0.99\ \text{m s}^{-1}$. ✓

c At maximum distance the frictional force will be the largest possible, i.e. $f_{max} = \mu_s N = \mu_s mg (= 0.434\ \text{N})$. ✓

$\mu_s mg = m\dfrac{v^2}{r} = m\dfrac{\omega^2 r^2}{r}$, hence $r = \dfrac{\mu_s g}{\omega^2}$ ✓

$r = \dfrac{0.82 \times 9.8}{4.488^2} = 0.399 \approx 0.40\ \text{m}$ ✓

d i Using $r = \dfrac{\mu_s g}{\omega^2}$ we find $\omega = \sqrt{\dfrac{\mu_s g}{r}}$ ✓

$\omega = \sqrt{\dfrac{0.82 \times 9.8}{0.22}} = 6.0\ \text{rad s}^{-1}$ ✓

ii The static frictional force can no longer supply the larger centripetal force required. ✓
The body will then slide and the static frictional force is now replaced by the even smaller sliding frictional force; hence the disc will slide off the rotating platform. ✓

12 a From energy conservation: $\frac{1}{2}mv^2 = mgL$ so $v = \sqrt{2gL}$, ✓

$v = \sqrt{2 \times 9.8 \times 2.0} = 6.26 \approx 6.3\ \text{m s}^{-1}$. ✓

b $a = \frac{v^2}{L} = \frac{6.26^2}{2.0} = 19.6 \approx 20\ \text{m s}^{-2}$. ✓

c Weight vertically downwards. ✓
Larger arrow for tension upwards. ✓

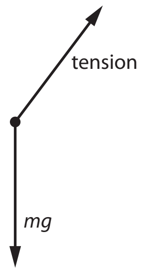
d i A particle is in equilibrium if it moves with constant velocity. ✓
This particle moves on a circle and so cannot be in equilibrium. ✓

ii $T - mg = \frac{mv^2}{L}$ ✓

$T = \frac{mv^2}{L} + mg = \frac{5.0 \times 6.26^2}{2.0} + 5.0 \times 9.8 = 147 \approx 150\ \text{N}$ ✓

(or better: $T = \frac{mv^2}{L} + mg = \frac{m \times 2gL}{L} + mg = 3mg = 3 \times 5.0 \times 9.8 = 147 \approx 150\ \text{N}$)

13 a Correct arrows for tension. ✓
Correct arrow for weight. ✓



b A particle is in equilibrium if it moves with constant velocity. ✓
This particle moves on a circle and so cannot be in equilibrium. ✓

c i The vertical component of the tension equals the weight and so $T\cos\theta = mg$, i.e. $T = \frac{mg}{\cos\theta}$. ✓

The horizontal component of the tension is $T\sin\theta$ and $T\sin\theta = m\frac{v^2}{r} = m\frac{v^2}{L\sin\theta}$ ✓

Combining gives the answer $v = \sqrt{\frac{gL\sin^2\theta}{\cos\theta}}$.

ii The angular and linear speeds are related by $v = \omega r = \omega L\sin\theta$. ✓

So $\omega = \frac{\sqrt{\frac{gL\sin^2\theta}{\cos\theta}}}{L\sin\theta}$. ✓

Which is the answer $\omega = \sqrt{\frac{g}{L\cos\theta}}$.

d i $v = \sqrt{\frac{9.8 \times 0.45 \times \sin^2 60°}{\cos 60°}} = 2.57 \approx 2.6\ \text{m s}^{-1}$ ✓

ii $\theta = \sqrt{\frac{9.8}{0.45 \times \cos 60°}} = 6.5997 \approx 6.6\ \text{rad s}^{-1}$ ✓

e i The air resistance force will reduce the speed of the ball. ✓

ii A graph of $\frac{\sin^2\theta}{\cos\theta}$ shows that because the speed decreases, the angle will also decrease. ✓

iii The cosine of the angle will increase and hence the angular speed will decrease. ✓
(**Note:** These questions are best answered by considering the total energy of the ball:

$$E=\frac{1}{2}mv^2+mgh=\frac{1}{2}m\frac{gL\sin^2\theta}{\cos\theta}+mgL(1-\cos\theta)=\frac{1}{2}mgL\left(\frac{\sin^2\theta+2\cos\theta-2\cos^2\theta}{\cos\theta}\right)$$

The air resistance will reduce the total energy; graphing the total energy as a function of angle θ shows that for the energy to decrease the angle must decrease.)

14 **a** Measuring distances from the top of the sphere and using energy conservation shows that:

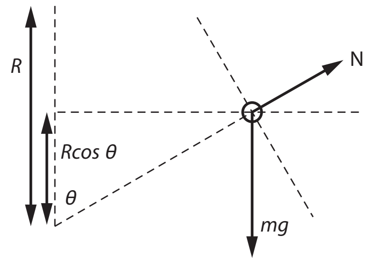
$0=\frac{1}{2}mv^2-mgh$ where h is the vertical distance the marble falls. ✓

From trigonometry: $h=R(1-\cos\theta)$. ✓ (see diagram that follows in **b**)

And so $0=\frac{1}{2}mv^2-mgR(1-\cos\theta)$. ✓

Manipulating gives $v=\sqrt{2gR(1-\cos\theta)}$.

b The forces on the marble are the weight mg and the normal reaction force N:



Taking components of the weight gives $mg\cos\theta-N=\frac{mv^2}{R}$. ✓

Hence $N=mg\cos\theta-\frac{mv^2}{R}$. ✓

Substituting the expression for the speed from above gives $N=mg\cos\theta-2mgR(1-\cos\theta)$. ✓
And the result $N=mg(3\cos\theta-2)$ follows.

c The marble will lose contact when $N\to 0$, i.e. when $\cos\theta=\frac{2}{3}$ or $\theta\approx 48°$. ✓

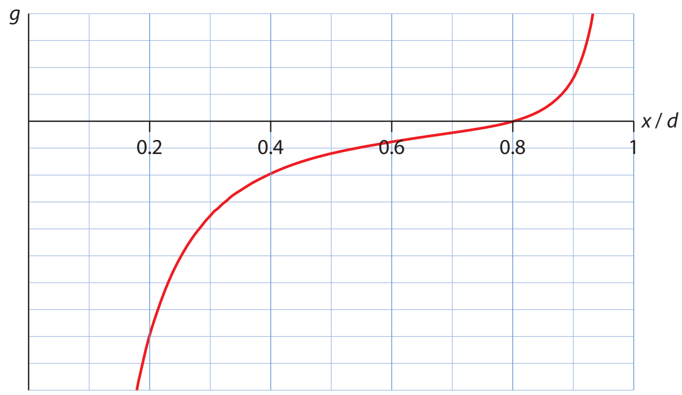
15 **a** Calling this distance x we have that:

$\frac{G16M}{x^2}=\frac{GM}{(d-x)^2}$ ✓

$16(d-x)^2=x^2$ or $4(d-x)=\pm x$ ✓

Only the plus sign gives a positive distance and so $x=\frac{4d}{5}$. ✓

b Correct sign. ✓
Correct intersection. ✓
(The negative of this graph is also acceptable)

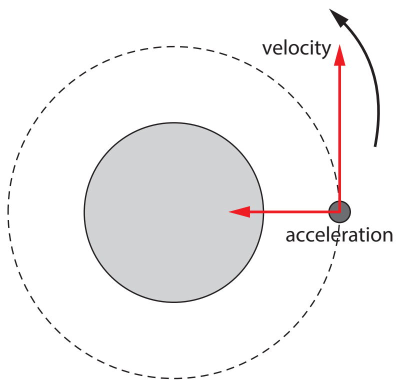


c i The force is zero. ✓

ii The force from the larger mass will be larger because the particle will be closer to it. ✓
Hence the net force will be directed towards the large mass. ✓

d It will move to the left. ✓
With increasing speed and increasing acceleration. ✓

16 a i Velocity arrow. ✓
Acceleration arrow. ✓



ii Acceleration is the rate of change of the velocity vector. ✓
Here the velocity vector is changing because its direction is so we have acceleration. ✓

b The force on the satellite is $\frac{GMm}{r^2} = m\frac{v^2}{r}$ i.e. $\frac{GM}{r} = v^2$. ✓

Using $v = \omega r$, ✓

gives $\frac{GM}{r} = \omega^2 r^2$. ✓

From which the result $\omega^2 r^3 = GM$ follows.

c i Since r decreases, from $\omega^2 r^3 = GM$ the angular speed will increase. ✓

ii From $\frac{GM}{r} = v^2$, as r decrease v increases. ✓

d i Using $\omega^2 r^3 = GM$ we find $M = \frac{\omega^2 r^3}{G}$ ✓

And so $M = \frac{(5.31\times 10^{-5})^2 \times (2.38\times 10^8)^3}{6.67\times 10^{-11}} = 5.70\times 10^{26}$ kg. ✓

ii Again using $\omega^2 r^3 = GM$ we find $\omega_T^2 r_T^3 = \omega_E^2 r_E^3$. ✓

Hence $\omega_T = \omega_E\sqrt{\frac{r_E^3}{r_T^3}} = 5.31\times 10^{-5} \times \sqrt{\left(\frac{2.38\times 10^8}{1.22\times 10^9}\right)^3} = 4.58\times 10^{-6}\ \text{rad s}^{-1}$ ✓

Hence $T = \frac{2\pi}{\omega_T} = \frac{2\pi}{4.58\times 10^{-6}} = 1.37\times 10^6\ \text{s} = \frac{1.37\times 10^6}{24\times 3600}\ \text{d} = 15.856 \approx 15.9\ \text{d}$ ✓