Exercise 4A

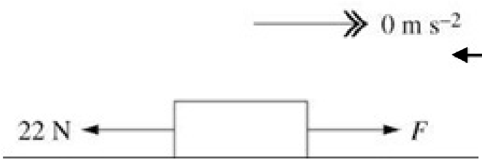
1 Work done $= Fs$
$$= 0.6 \times 4.2$$
$$= 2.52$$
The work done is 2.52 J

2 Work done $= Fs$
$$102 = F \times 12$$
$$F = \frac{102}{12} = 8.5$$
The magnitude of the force is 8.5 N

3 Work done against gravity $= mgh$
$$= 0.35 \times 9.8 \times 7$$
$$= 24.01$$
The work done against gravity is 24.0 J (3 s.f.)

4 Work done against gravity $= mgh$
$$= 15 \times 9.8 \times 4$$
$$= 588$$
The work done against gravity is 588 J

5



No acceleration, so the force pushing the box has the same magnitude as the resistances.

$F = 22$ N

Work done $= Fs$
$$= 22 \times 15$$
$$= 330$$
The work done by the force pushing the box is 330 J

6 Work done by gravity $= mgh$
$$= 0.5 \times 9.8 \times 15$$
$$= 73.5$$
The work done by gravity is 73.5 J

7 Work done $= mgh$

$30 \times 1000 = 80 \times 9.8h$

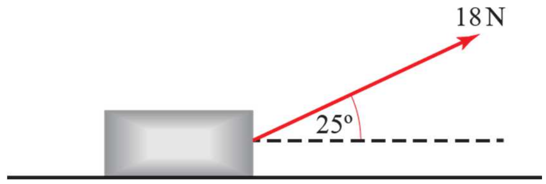
1 kJ = 1000 J

$$h = \frac{30000}{80 \times 9.8}$$

$$h = 38.26\ldots$$

The building is 38.3 m high (3 s.f.)

8 a



Work done = horizontal component of force × distance moved

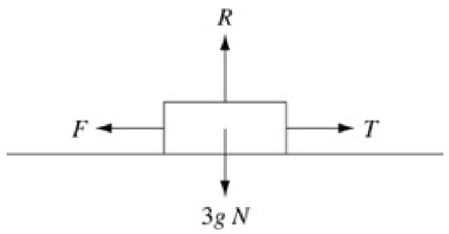
$= 18\cos 25° \times 14$

$= 228.38\ldots$

The work done is 228 J (3 s.f.)

b One assumption made is that there is no frictional force between the sled and the ice.
This is likely to be a valid assumption, due to the low coefficient of friction between sled and ice.

9



Work done $= Ts$

$30 = T \times 4$

$T = 7.5$

Resolving parallel to the plane:

$T - F = 0$

The parcel moves at a constant speed so the acceleration is 0 m s^{-2}

$7.5 - F = 0$

$F = 7.5$

Resolving perpendicular to the plane to find R.

$R = mg$

$R = 3 \times 9.8$

Friction is limiting:

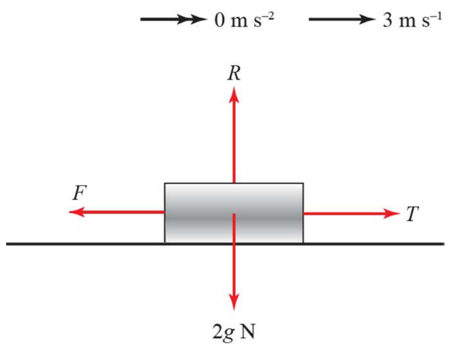
$F = \mu R$

$7.5 = \mu \times 3 \times 9.8$

$$\mu = \frac{7.5}{3 \times 9.8} = 0.2551\ldots$$

The coefficient of friction is 0.255 (3 s.f.)

10



$\mu = 0.55$

Resolving perpendicular to the plane:
$R = 2g$
Friction is limiting:
$F = \mu R$
$F = 0.55 \times 2g$
Resolving parallel to the plane:
$T - F = 0$
$T = 0.55 \times 2g$

$$\begin{aligned}\text{Work done } &= Ts \\ &= 0.55 \times 2g \times (3 \times 2) \\ &= 0.55 \times 2 \times 9.8 \times 6 \\ &= 64.68\end{aligned}$$

Distance moved = speed × time

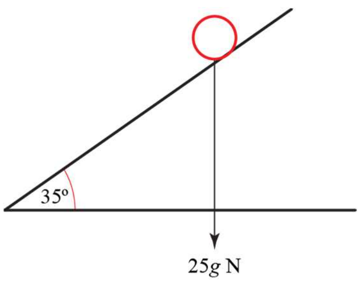
The work done is 64.7 J (3 s.f.)

11 Work done against gravity $= mgh$

$$\begin{aligned}&= 52 \times 9.8 \times 46 \\ &= 23\,441.6\end{aligned}$$

The work done against gravity is 23 400 J (3 s.f.)

12

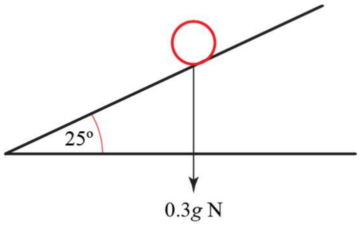


$$\begin{aligned}\text{Work done by gravity } &= mgh \\ &= 25 \times 9.8 \times (2 \sin 35^\circ) \\ &= 281.0\ldots\end{aligned}$$

Vertical distance moved = 2 sin 35°

The work done by gravity is 281 J (3 s.f.)

13



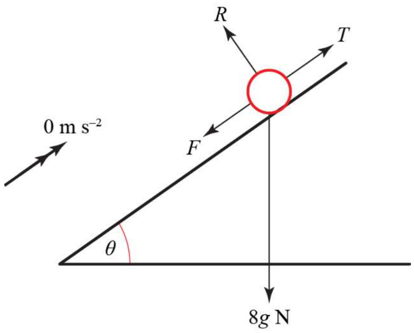
Work done against gravity $= mgh$

$= 0.3 \times 9.8 \times (2\sin 25°)$

$= 2.484\ldots$

The work done against gravity is 2.48 J (3 s.f.)

14



$\mu = 0.3$

a Resolving perpendicular to the plane:

$R = 8g\cos\alpha$

$= 8g \times \dfrac{12}{13}$

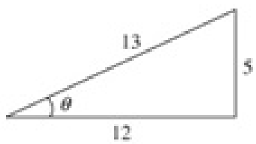
Friction is limiting:

$F = \mu R$

$F = 0.3 \times 8 \times 9.8 \times \dfrac{12}{13}$

$= 21.71\ldots$

The frictional force has magnitude 21.7 N (3 s.f.)



Draw a small right-angled triangle to show information about α. Use exact values for $\sin\alpha$ and $\cos\alpha$.

b Work done against friction $= Fs$

$= 21.71\ldots \times 15$

$= 325.6\ldots$

The work done against friction is 326 J (3 s.f.)

c Work done against gravity $= mgh$

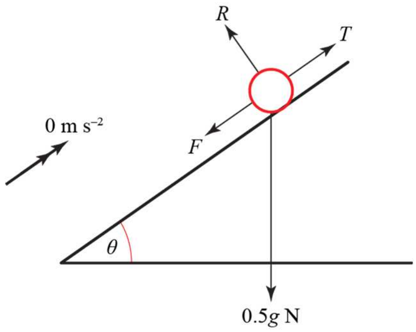
$= 8 \times 9.8 \times (15\sin\alpha)$

$= 8 \times 9.8 \times \left(15 \times \dfrac{5}{13}\right)$

$= 452.3\ldots$

The work done against gravity is 452 J (3 s.f.)

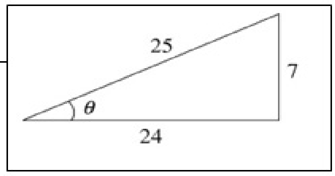
15



Resolving perpendicular to the plane:

$R = 0.5g\cos\theta$

$= 0.5g \times \frac{24}{25}$



Resolving parallel to the plane:

$T = F + 0.5g\sin\theta$

Friction is limiting:

$F = \mu R$

$F = \mu \times 0.5g \times \frac{24}{25}$

$T = \mu \times 0.5g \times \frac{24}{25} + 0.5g \times \frac{7}{25}$

Work done by force $=$ force $\times$ distance moved

$12 = T \times 3$

$T = 4$

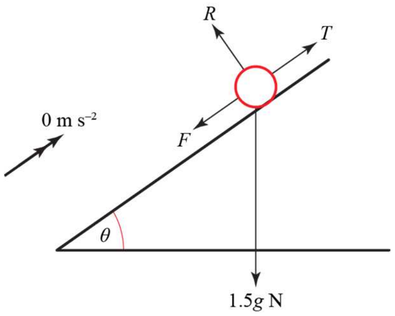
$\therefore\ 4 = \mu \times 0.5g \times \frac{24}{25} + 0.5g \times \frac{7}{25}$

$$\mu = \frac{4 - 0.5 \times 9.8 \times \frac{7}{25}}{0.5 \times 9.8 \times \frac{24}{25}}$$

$\mu = 0.5586\ldots$

The coefficient of friction is 0.559 (3 s.f.)

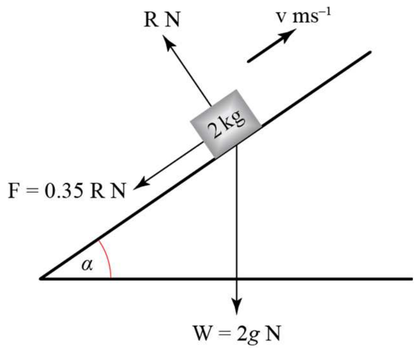
16



$\mu = 0.4$

Resolving perpendicular to the plane:
$R = 1.5g\cos 40°$
Friction is limiting:
$F = \mu R$
$F = 0.4 \times 1.5g\cos 40°$
Resolving parallel to the plane:
$T = F + 1.5g\sin 40°$
$T = 0.4 \times 1.5g\cos 40° + 1.5g\sin 40°$
Work done by $T = T \times s$
$= (0.4 \times 1.5g\cos 40° + 1.5g\sin 40°) \times 8$
$= 111.6\ldots$
The work done by T is 112 J (3 s.f.)

17 $\sin\alpha = \frac{3}{5} \Rightarrow \cos\alpha = \frac{4}{5}$



Work done = force × distance moved in direction of force

a Work done by gravity $E_g = Wh$

Weight, $W = mg = 2g$, $h = 3\sin\alpha = \frac{9}{5}$ m

$E_g = 2g \times \frac{9}{5}$

$E_g = 2 \times 9.8 \times 1.8 = 35.28$

The work done by gravity is 35.3 J (3 s.f.)

b Work done by friction $E_F = Fs$, $s = 3$ m
Normal reaction force, R, can be found by resolving perpendicular to the slope:
$R = 2g\cos\alpha$

$R = \frac{8}{5}g$

So frictional force, $F = \frac{7}{20} \times \frac{8}{5}g = \frac{14}{25}g$

$E_F = \frac{14}{25}g \times 3$

$E_F = 0.56 \times 9.8 \times 3 = 16.464$

The work done by gravity is 16.5 J (3 s.f.)

17 c Work done against these forces = kinetic energy lost

Since kinetic energy = $\frac{1}{2}mv^2$, so here:

$$35.28 + 16.464 = \left(\frac{1}{2} \times 2u^2\right) - \left(\frac{1}{2} \times 2 \times 0^2\right)$$

$$51.744 = u^2$$

$$u = 7.1933...$$

The particle is projected at a speed of 7.19 m s^{-1} (3 s.f.)

Exercise 4B

1 **a** Kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2}\times 0.3\times 15^2 = 33.8$ J (3 s.f.)

b Kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2}\times 3\times 2^2 = 6$ J

c Kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2}\times 0.1\times 100^2 = 500$ J

d Kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2}\times 25\times 4^2 = 200$ J

e Kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2}\times 800\times 20^2 = 160\,000$ J

In order, from the most kinetic energy to the least, will be **e**, **c**, **d**, **a**, **b**

2 **a** Gain of P.E. $= mgh = 1.5\times 9.8\times 3 = 44.1$ J

b Gain of P.E. $= mgh = 55\times 9.8\times 15 = 8085$ J

c Loss of P.E. $= mgh = 75\times 9.8\times 30 = 22\,050$ J

d Loss of P.E. $= mgh = 580\times 9.8\times 6 = 34\,104$ J

3 Decrease in K.E. $= \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$$= \frac{1}{2}\times 1.2\times 12^2 - \frac{1}{2}\times 1.2\times 4^2$$
$$= 76.8$$

The decrease in the particle's K.E. is 76.8 J

4 Increase in K.E. $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$$= \frac{1}{2}\times 900\times 20^2 - \frac{1}{2}\times 900\times 5^2$$
$$= 168\,750$$

The increase in the van's K.E. is 168 750 J

5 Increase in K.E. $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$$6 = \frac{1}{2}\times 0.2\times v^2 - \frac{1}{2}\times 0.2\times 2^2$$
$$6 = 0.1v^2 - 0.4$$
$$v^2 = \frac{6.4}{0.1} = 64$$
$$v = 8 \quad (v > 0)$$

Speed is positive.

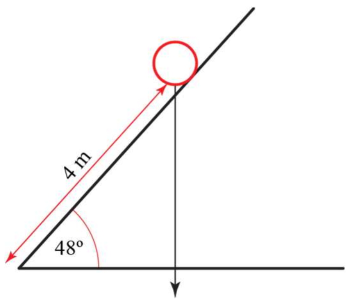
The value of v is 8.

6 Decrease in $\text{K.E.} = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$$100 = \frac{1}{2}\times 45\times 5^2 - \frac{1}{2}\times 45v^2$$
$$100 = 562.5 - 22.5v^2$$
$$v^2 = \frac{462.5}{22.5}$$
$$v = \pm 4.533\ldots$$
$$v = 4.533\ldots \quad (v > 0)$$

The skater's final speed is 4.53 m s^{-1} (3 s.f.)

7 a



$$\text{P.E. lost} = mgh$$
$$= 25\times 9.8\times(4\sin 48°)$$
$$= 728.2\ldots$$

Vertical distance moved is 4 sin 48°.

The P.E. lost by the child is 728 J (3 s.f.)

b You have assumed there to be no air resistance.
This would be valid for low speeds, but not for high speeds.

8 a $s = 2$ m, $a = 9.8$ m s^{-2}, $u = 0$, $v = ?$

$$v^2 = u^2 + 2as$$
$$v^2 = 0 + 2\times 9.8\times 2$$
$$v^2 = 39.2$$

Use $v^2 = u^2 + 2as$ to find the speed of the ball as it hits the water.

$$\text{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2}\times 0.6\times 39.2$$
$$= 11.76$$

The K.E. of the ball as it hits the surface of the water is 11.8 J (3 s.f.)

b $\text{K.E. lost} = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$$= 11.76 - \frac{1}{2}\times 0.6\times 4.8^2$$
$$= 4.848$$

The K.E. lost by the ball is 4.85 J (3 s.f.)

9 $u = 35 \text{ m s}^{-1}$, $a = -1.2 \text{ m s}^{-2}$, $t = 5$ s, $v = ?$

$v = u + at$

Use $v = u + at$ to find the final speed of the lorry.

$v = 35 - 1.2 \times 5$

$v = 29$

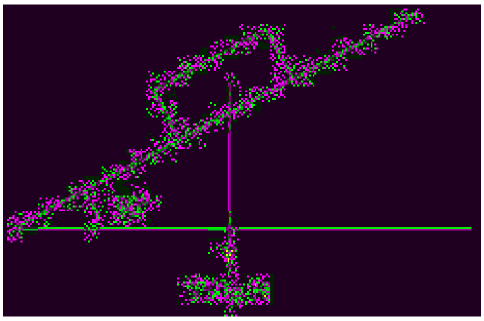
$$\text{Loss of K.E.} = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 2000 \times 35^2 - \frac{1}{2} \times 2000 \times 29^2$$

$$= 384\,000$$

The loss of K.E. of the lorry is 384 000 J

10



a $$\text{Loss of K.E.} = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 750 \times 20^2 - \frac{1}{2} \times 750 \times 15^2$$

$$= 65\,625$$

The loss of K.E of the car is 65 625 J

b $$\text{Gain of P.E.} = mgh$$

$$= 750 \times 9.8 \times (500 \sin 30^\circ)$$

$$= 1\,837\,500$$

The gain of P.E. of the car is 1 837 500 J

11 Increase of P.E. $= mgh$

1 kJ = 1000 J

$$15.7 \times 1000 = 80 \times 9.8h$$

$$h = \frac{15.7 \times 1000}{80 \times 9.8}$$

$$h = 20.02$$

The cliff is 20.0 m high (3 s.f.)

Challenge

a The ball is dropped from the top of a cliff, and falls freely under gravity.
Use the equation $v = u + at$
Using $u = 0$ and $a = g$, you have $v = gt$

$$\text{K.E.} = \tfrac{1}{2}mv^2 = \tfrac{1}{2}\times 1\times(gt)^2 = \frac{g^2t^2}{2} = 48.0t^2$$

$s = ut + \tfrac{1}{2}at^2$. So using $s = h$, $u = 0$ and $a = g$, you have $h = \tfrac{1}{2}gt^2$

$$\text{P.E.} = -mgh = -1\times g\times\left(\tfrac{1}{2}gt^2\right) = -\frac{g^2t^2}{2} = -48.0t^2$$

b Kinetic energy + potential energy $= \dfrac{g^2t^2}{2} + \left(-\dfrac{g^2t^2}{2}\right) = 0$

So kinetic energy + potential energy is constant.

Exercise 4C

1 **a** P.E. lost $= mgh = 0.4 \times 9.8 \times 7$

$= 27.44$

The P.E. lost is 27.4 J (3 s.f.)

b K.E. gained $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= \frac{1}{2} \times 0.4 \times v^2 - 0$

P.E. lost = K.E. gained

$27.44 = \frac{1}{2} \times 0.4 \times v^2$

$v^2 = \frac{27.44}{0.2}$

$v = 11.71\ldots$

The final speed of the particle is 11.7 m s^{-1} (3 s.f.)

2 **a** K.E. gained $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= \frac{1}{2} \times 0.5 \times 12^2 - 0$

$= 36$

The K.E. gained by the stone is 36 J

b P.E. lost = K.E. gained

= 36 J

The P.E. lost by the stone is 36 J

c P.E. lost $= mgh$

$36 = 0.5 \times 9.8 \times h$

$h = \frac{36}{0.5 \times 9.8}$

$h = 7.346\ldots$

The height of the tower is 7.35 m (3 s.f.)

3

a Increase in K.E. $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= \frac{1}{2} \times 6 \times 5^2 - \frac{1}{2} \times 6 \times 2.5^2$

$= 56.25$

The increase in K.E. of the box is 56.3 J (3 s.f.)

b The work done by the force is 56.3 J

3 **c** $F = ma$

$10 = 6a$

$a = \dfrac{5}{3}$

Substituting into:

$v^2 = u^2 + 2as$

With $u = 2.5\text{ m s}^{-1}$, $v = 5\text{ m s}^{-1}$ and $a = \dfrac{5}{3}\text{ m s}^{-2}$ gives:

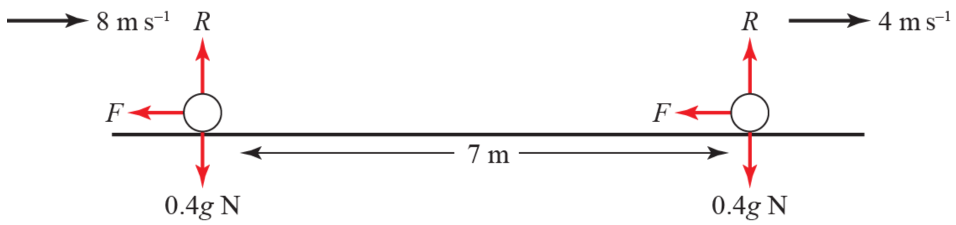
$5^2 = 2.5^2 + 2\left(\dfrac{5}{3}\right)s$

$25 = 6.25 + \dfrac{10}{3}s$

$s = 5.625\text{ m}$

$s = 5.63\text{ m (3 s.f.)}$

4



a K.E. lost $= \dfrac{1}{2}mu^2 - \dfrac{1}{2}mv^2$

$= \dfrac{1}{2}\times 0.4\times 8^2 - \dfrac{1}{2}\times 0.4\times 4^2$

$= 9.6$

The K.E. lost by the particle is 9.6 J

b The work done against friction is 9.6 J ← Work done = change in energy

c Resolving perpendicular to the surface: $R = 0.4g$

Friction is limiting: $F = \mu R$

$F = 0.4g\times\mu$

Work done $= Fs$

$9.6 = 0.4g\times\mu\times 7$

$\mu = \dfrac{9.6}{0.4\times 9.8\times 7} = 0.3498\ldots$

The coefficient of friction is 0.350 (3 s.f.)

5 

$\mu = 0.4$

a K.E. lost $= \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$= \frac{1}{2} \times 3 \times 6^2 - 0$

$= 54$

The kinetic energy lost by the box is 54 J

b The work done against friction is 54 J

c Resolving perpendicular to the floor: $R = 3g$

Friction is limiting: $F = \mu R$

$F = 0.4 \times 3g$

Work done $= Fs$

$54 = 0.4 \times 3g \times s$

$$s = \frac{54}{0.4 \times 3g} = 4.591\ldots$$

The distance AB is 4.59 m (3 s.f.)

6 P.E. lost $= mgh$

$= 0.8 \times 9.8 \times 5$

$= 39.2$

K.E. gained $=$ P.E. lost

$= 39.2$

K.E. gained $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$39.2 = \frac{1}{2} \times 0.8v^2 - 0$

$$v^2 = \frac{39.2 \times 2}{0.8}$$

$v = 9.899\ldots$

The particle hits the ground at a speed of 9.90 m s^{-1} (3 s.f.)

7 K.E. gained $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= \frac{1}{2} \times 0.3 \times 20^2 - 0$

$= 60$

P.E. lost $=$ K.E. gained

$= 60$

P.E. lost $= mgh$

$60 = 0.3 \times 9.8 \times h$

$$h = \frac{60}{0.3 \times 9.8}$$

$h = 20.40\ldots$

The cliff is 20.4 m high (3 s.f.)

8 P.E. gained $= mgh$

$= 0.3 \times 9.8 \times 5$

K.E. lost = initial K.E. − final K.E.

$= \frac{1}{2} \times mu^2 - 2.1$

$= \frac{1}{2} \times 0.3u^2 - 2.1$

K.E. lost = P.E. gained

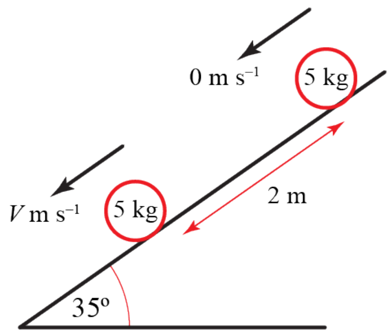
$\frac{1}{2} \times 0.3u^2 - 2.1 = 0.3 \times 9.8 \times 5$

$$u^2 = \frac{0.3 \times 9.8 \times 5 + 2.1}{\frac{1}{2} \times 0.3}$$

$u = 10.58\ldots$

The value of u is 10.6 (3 s.f.)

9



a P.E. lost = mgh

$$= 5 \times 9.8 \times (2 \sin 35°)$$
$$= 56.21\ldots$$

The P.E. lost is 56.2 J (3 s.f.)

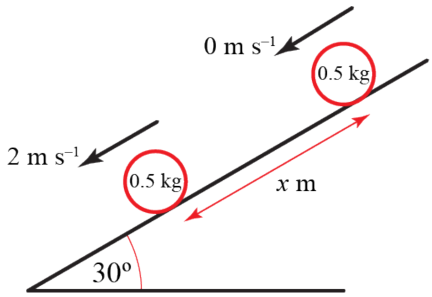
b The K.E. gained is 56.2 J

c K.E. gained $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$$56.21 = \frac{1}{2} \times 5 \times v^2 - 0$$
$$v^2 = \frac{56.21 \times 2}{5}$$
$$v = 4.741\ldots$$

The final speed of the package is 4.74 m s^{-1} (3 s.f.)

10



$$\text{K.E. gained} = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$
$$= \frac{1}{2} \times 0.5 \times 2^2 - 0$$
$$= 1$$

$$\text{P.E. lost} = mgh = 0.5 \times 9.8 \times (x \sin 30°)$$

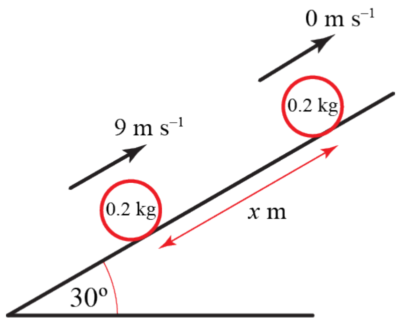
$$\text{P.E. lost} = \text{K.E. gained}$$

$$0.5 \times 9.8 \times (x \sin 30°) = 1$$

$$x = \frac{1}{0.5 \times 9.8 \times \sin 30°}$$
$$= 0.4081\ldots$$

The value of x is 0.408 (3 s.f.)

11



$$\text{K.E. lost} = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$$
$$= \frac{1}{2} \times 0.2 \times 9^2 - 0$$

$$\text{P.E. gained} = mgh$$
$$= 0.2 \times 9.8 \times (x \sin 30°)$$

P.E. gained = K.E. lost

$$0.2 \times 9.8 \times (x \sin 30°) = \frac{1}{2} \times 0.2 \times 9^2$$
$$x = \frac{\frac{1}{2} \times 0.2 \times 9^2}{0.2 \times 9.8 \sin 30°}$$
$$= 8.265\ldots$$

The value of x is 8.27 (3 s.f.)

12 K.E. lost $= \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$$= \frac{1}{2} \times 0.6u^2 - 0$$

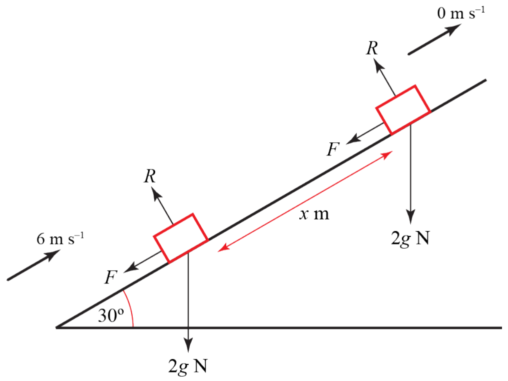
$$\text{P.E. gained} = mgh$$
$$= 0.6 \times 9.8 \times (5 \sin 40°)$$

K.E. lost = P.E. gained

$$\frac{1}{2} \times 0.6u^2 = 0.6 \times 9.8 \times 5 \sin 40°$$
$$u^2 = \frac{0.6 \times 9.8 \times 5 \sin 40°}{\frac{1}{2} \times 0.6}$$
$$u = 7.936\ldots$$

The speed of projection is 7.94 m s^{-1} (3 s.f.)

13



$$\text{K.E. lost} = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$$
$$= \frac{1}{2}\times 2\times 6^2 - 0$$
$$= 36$$

$$\text{P.E. gained} = mgh$$
$$= 2\times 9.8\times (x\sin 30°)$$
$$= 9.8x$$

Resolving perpendicular to the plane: $R = 2g\cos 30°$

Friction is limiting: $F = \mu R$

$$F = \frac{1}{3}\times 2g\cos 30° = \frac{2}{3}g\cos 30°$$

Work done against friction $= Fx = \dfrac{2}{3}gx\cos 30°$

K.E. lost = P.E. gained + work done against friction

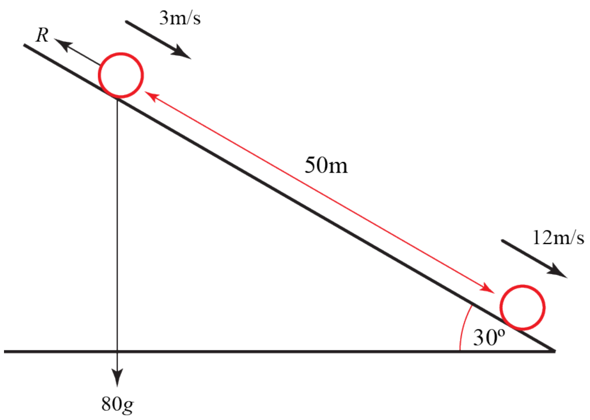
$$\Rightarrow 36 = 9.8x + \frac{2}{3}gx\cos 30°$$

$$36 = 9.8x\left(1+\frac{2}{3}\cos 30°\right)$$

$$x = \frac{36}{9.8\left(1+\frac{2}{3}\cos 30°\right)} = 2.328\ldots$$

The particle moves 2.33 m up the plane (3 s.f.)

14



a Work done by resistive forces on the skier = change in total energy of the skier

Loss in P.E. = mgh

Increase in K.E. = $\frac{1}{2}mv^2 - \frac{1}{2}mu^2$

Total loss of energy = P.E. lost – K.E. gained

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

Force × distance = $mgh + \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$$50R = (80 \times 9.8 \times 50\sin 30°) + \left(\frac{1}{2} \times 80 \times 3^2\right) - \left(\frac{1}{2} \times 80 \times 12^2\right)$$

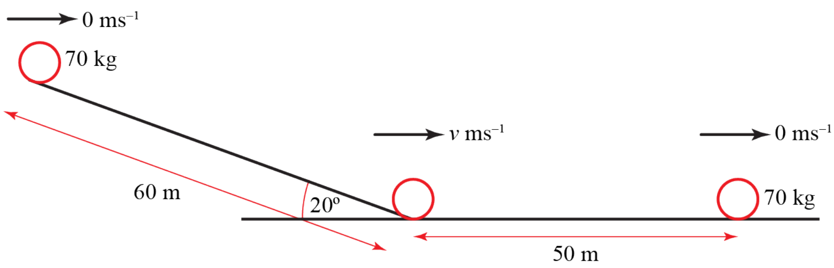
$$50R = 14\ 200$$

$$R = 284$$

The value of R is 284.

b The resistive force may not be constant, and could depend on speed, for example.

15



Consider energy changes from start to end – do not divide the motion into two parts.

Change in K.E. $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$$= 0 - 0$$

Loss of P.E. = mgh

$$= 70 \times 9.8 \times (60\sin 20°)$$

Work done against resistance $= Fs$

$$= R \times (60 + 50)$$

$$= 110R$$

Work done against resistance = loss of P.E.

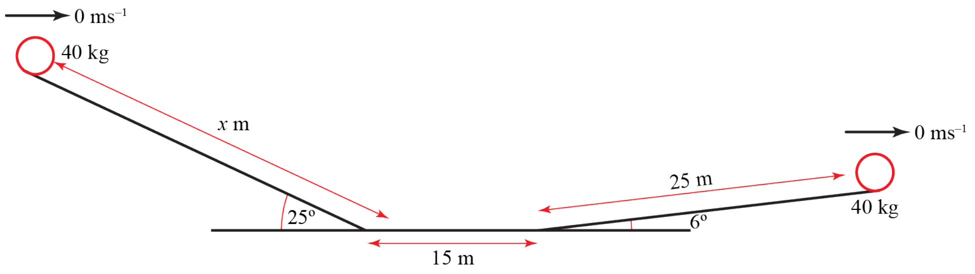
$$110R = 70 \times 9.8 \times (60\sin 20°)$$

$$R = \frac{70 \times 9.8 \times 60\sin 20°}{110}$$

$$R = 127.9\ldots$$

The value of R is 128 (3 s.f.)

16



Consider energy changes from start to end – do not divide the motion into three parts.

Loss of P.E. $= mgh$

$$= 40 \times 9.8 \times (x \sin 25° - 25 \sin 6°)$$

Change in K.E. $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$$= 0 - 0$$

Work done against resistance $= Fs$

$$= 18 \times (x + 15 + 25)$$

$$= 18 \times (x + 40)$$

Work done against resistance = loss of P.E.

$$18x + 18 \times 40 = 40 \times 9.8 \times x \sin 25° - 40 \times 9.8 \times 25 \sin 6°$$

$$(40 \times 9.8 \sin 25° - 18)x = 18 \times 40 + 40 \times 9.8 \times 25 \sin 6°$$

$$x = \frac{18 \times 40 + 40 \times 9.8 \times 25 \sin 6°}{40 \times 9.8 \sin 25° - 18}$$

$$x = 11.81\ldots$$

The girl travels 11.8 m down the slope.

Challenge

Let the mass of a hydrogen molecule $= m$
So the mass of an oxygen molecule $= 8m$

Consider the average kinetic energy of the oxygen molecules:
$\frac{1}{2}mv^2 = \frac{1}{2} \times 8m \times 400^2 = \frac{3}{2}kT$

Consider the average kinetic energy of the hydrogen molecules:
Average K.E. $= \frac{3}{2}kT = \frac{1}{2} \times 8m \times 400^2 = \frac{1}{2}mv^2$

So $\frac{1}{2} \times 8m \times 400^2 = \frac{1}{2}mv^2$

$$8 \times 400^2 = v^2$$

$$v = \sqrt{1\,280\,000}$$

$$= 1131.3\ldots$$

The average speed of the hydrogen molecules is 1130 m s^{-1}

Exercise 4D

1

$$\text{Power} = Fv$$
$$= 1500 \times 12$$
$$= 18\ 000$$

The power is 18 kW

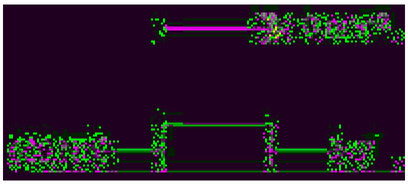
2
$$\text{Power} = Fv$$
$$= 1000 \times 15$$
$$= 15\ 000$$

The power is 15 000 W (or 15 kW)

3
$$\text{Power} = Fv$$
$$5000 = F \times 18$$
$$F = \frac{5000}{18}$$
$$= 277.7\ldots$$

The driving force has magnitude 278 N (3 s.f.)

4



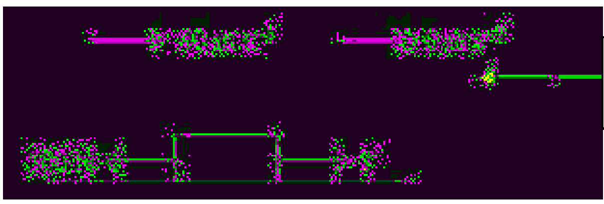
At maximum speed the acceleration is zero.

Resolving horizontally: $T = 600$

$$\text{Power} = Fv$$
$$15\,000 = 600v$$
$$v = \frac{15\,000}{600}$$
$$= 25$$

The maximum speed is 25 m s^{-1}

5 a



At maximum speed the acceleration is zero.

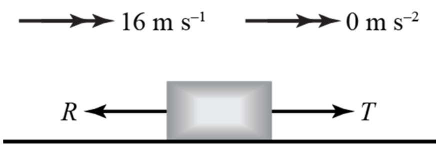
Resolving horizontally: $T = 500$

$$\text{Power} = Fv$$
$$= 500 \times 40$$
$$= 20\,000$$

The power is 20 000 W (or 20 kW)

b The resistance to motion of the car would typically be expected to increase with speed but it would be reasonable to assume a constant resistive force if the car maintained the same speed and the gradient and surface of the road stayed the same.

6



Power $= Fv$

$8.8 \times 10^3 = T \times 16$

$T = \frac{8800}{16}$

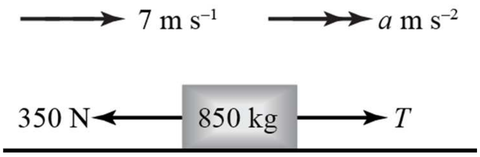
$T = 550$

Resolving horizontally: $R = T$

$R = 550$

The magnitude of the resistance is 550 N

7 a



Power $= Fv$

$9000 = T \times 7$

$T = \frac{9000}{7}$

Now using $F = ma$:

$T - 350 = ma$

$\frac{9000}{7} - 350 = 850a$

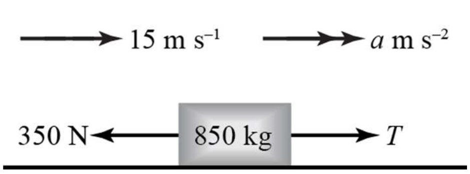
$a = \frac{\frac{9000}{7} - 350}{850}$

$a = 1.100\ldots$

The acceleration is 1.10 m s^{-2} (3 s.f.)

First find the tractive force produced by the engine and then use $F = ma$ to find the acceleration.

7 b



Power $= Fv$

$9000 = T \times 15$

$T = \frac{900}{15} = 600$

Now using $F = ma$:

$T - 350 = ma$

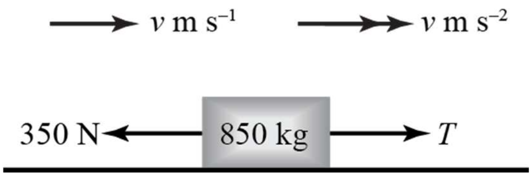
$600 - 350 = 850a$

$a = \frac{250}{850}$

$a = 0.2941\ldots$

The acceleration is 0.294 m s^{-2} (3 s.f.)

c



Resolving horizontally: $T = 350$

Power $= Fv$

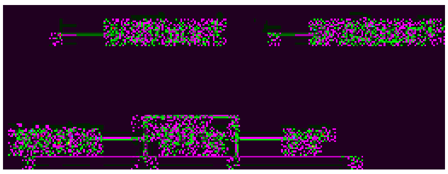
$9000 = 350v$

$v = \frac{9000}{350}$

$v = 25.71\ldots$

The maximum speed is 25.7 m s^{-1} (3 s.f.)

8



Using $F = ma$:

$T - 300 = 900 \times 0.3$

$T = 900 \times 0.3 + 300$

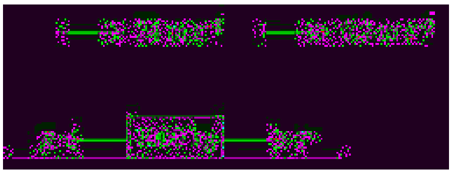
$= 570$

Power $= Fv$

$= 570 \times 20$

$= 11\,400$

The power development by the engine is 11 400 W (or 11.4 kW)

9 

Power $= Fv$

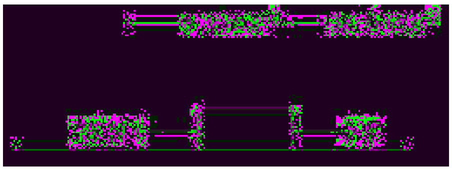
$12\,000 = T \times 24$

$$T = \frac{12\,000}{24} = 500$$

Using $F = ma$:

$$T - R = 1000 \times 0.2$$
$$500 - R = 200$$
$$R = 500 - 200$$
$$R = 300$$

The value of R is 300.

10 

Resolving horizontally:

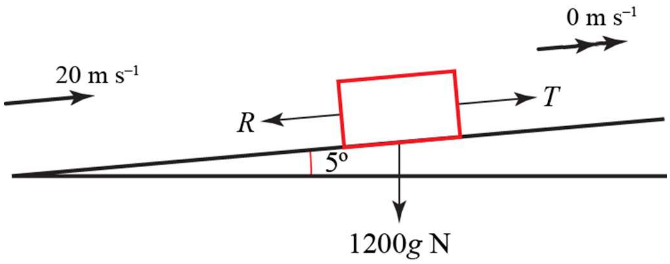
$$T = 28$$

Power $= Fv$

$$280 = 28v$$
$$v = 10$$

The cyclist's maximum speed is 10 m s^{-1}

11 a



Power $= Fv$

$24\,000 = T \times 20$

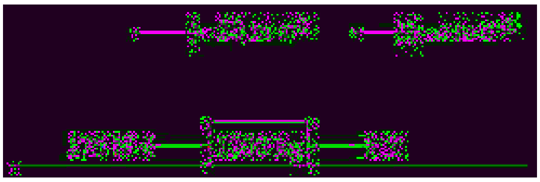
$$T = \frac{24\,000}{20} = 1200$$

Resolving parallel to the slope:

$$T = R + 1200g \sin 5°$$
$$1200 = R + 1200g \sin 5°$$
$$R = 1200 - 1200g \sin 5°$$
$$R = 175.04\ldots$$

The value of R is 175 (3 s.f.)

11 b



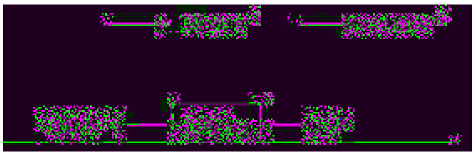
From part **a**, $T = 1200$ N
Using $F = ma$:
$1200 - 175 = 1200a$

$$a = \frac{1200 - 175}{1200}$$

$$a = 0.8541\ldots$$

The initial acceleration of the van is 0.854 m s^{-2} (3 s.f.)

12 a



Power $= Fv$
$26000 = T \times 18$

$$T = \frac{26000}{18}$$

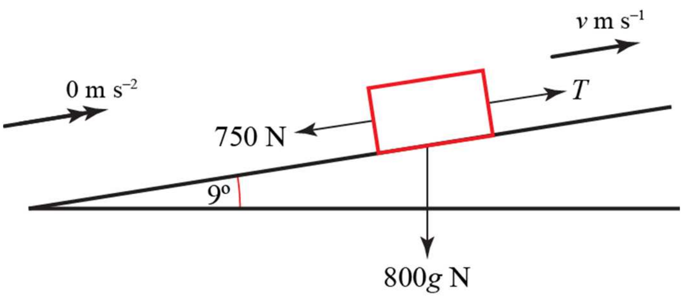
Using $F = ma$:
$T - 750 = 800a$

$$800a = \frac{26000}{18} - 750$$

$$a = 0.8680\ldots$$

The acceleration is 0.868 m s^{-2} (3 s.f.)

b



Resolving parallel to the slope:
$T = 750 + 800g\sin 9°$
Power $= Fv$
$26000 = T \times v$

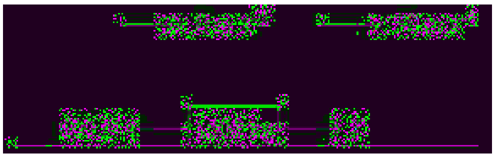
$$26000 = (750 + 800 \times 9.8\sin 9°)v$$

$$v = \frac{26000}{(750 + 800 \times 9.8\sin 9°)}$$

$$v = 13.15\ldots$$

The maximum speed is 13.2 m s^{-1} (3 s.f.)

13 a



Resolving horizontally: $T = 600$

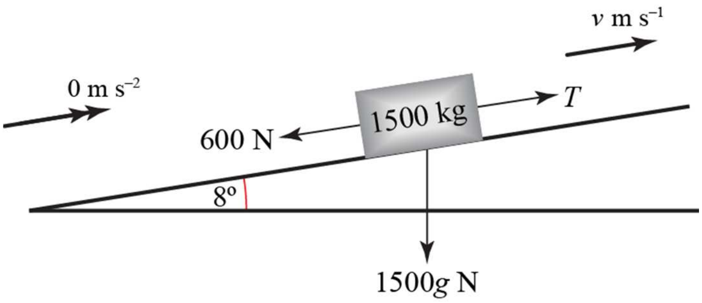
Power $= Fv$

$$= 600 \times 30$$

$$= 18000$$

The power is 18 000 W (or 18 kW)

b



Resolving parallel to the slope:

$T = 600 + 1500g \sin 8°$

Power $= Fv$

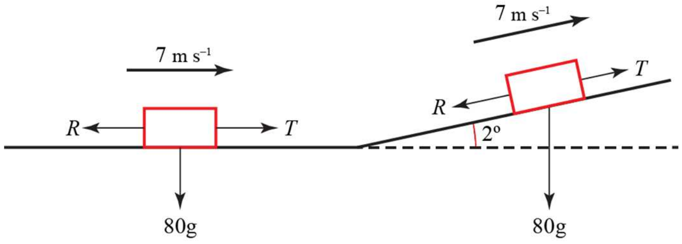
$18000 = (600 + 1500g \sin 8°)v$

$$v = \frac{18000}{(600 + 1500g \sin 8°)}$$

$$= 6.803\ldots$$

The maximum speed is 6.80 m s^{-1} (3 s.f.)

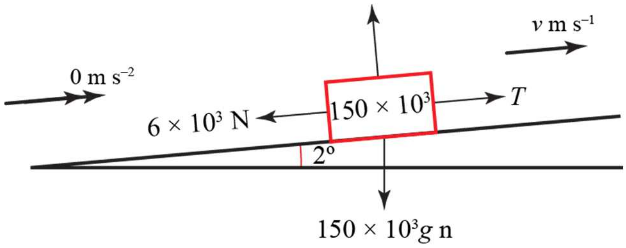
14



Consider the cyclist on level ground:
Power $= Tv$
Power $= 7T$
Since the velocity is constant, resolving horizontally:
$T = R$
So power $= 7R$

Consider the cyclist cycling uphill:
Power $= Tv$
Power $= 7T$
Since the velocity is constant, resolving parallel to the plane:
$T = R + 80g\sin 2°$
So power $= 7T = 7(R + 80g\sin 2°) = 7R + 560g\sin 2°$
Therefore, the increase in power required is:
$(7R + 560g\sin 2°) - 7R = 560g\sin 2°$
$= 191.5\ldots$
The increase in power required is 192 W (3 s.f.)

15 a



Resolving parallel to the slope:

$T = (6\times10^3) + (150\times10^3 g\sin 2°)$

Power $= Fv$

$350\times10^3 = (6\times10^3 + 150\times10^3 g\sin 2°)\times v$

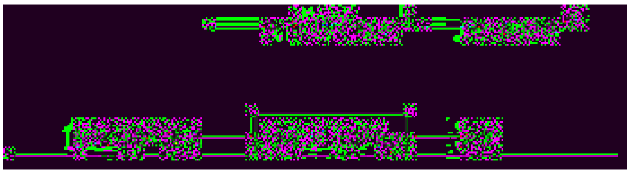
$$v = \frac{350}{(6+150\times9.8\sin 2°)}$$

$$= 6.107\ldots$$

The maximum speed is 6.11 m s^{-1}

1 tonne = 10^3 kg. When tonnes, kilonewtons and kilowatts are used the 10^3 will cancel, leaving easier numbers.

b



Power $= Fv$

$350\times10^3 = T\times6.107$

$$T = \frac{350\times10^3}{6.107}$$

Using $F = ma$:

$$T - 6\times10^3 = 150\times10^3\times a$$

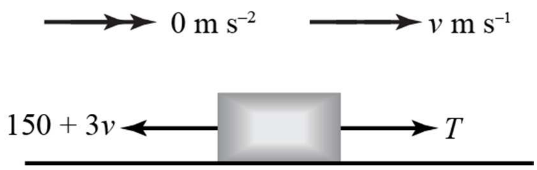
$$\frac{350\times10^3}{6.107} - 6\times10^3 = 150\times10^3\times a$$

$$150a = \frac{350}{6.107} - 6$$

$$a = 0.3420\ldots$$

The initial acceleration is 0.342 m s^{-2} (3 s.f.)

16



Power $= 10\text{ kW} = 10\,000\text{ W}$
Power $= Tv$
$10\,000 = Tv$
$T = \dfrac{10\,000}{v}$
When the velocity is maximum, the acceleration = 0 m s^{-2}
Therefore the resultant force is 0 N. Resolving horizontally:

$T = 150 + 3v$

So $\dfrac{10\,000}{v} = 150 + 3v$

$10\,000 = 150v + 3v^2$

Rearranging:

$$3v^2 + 150v - 10\,000 = 0$$

Using the quadratic formula:

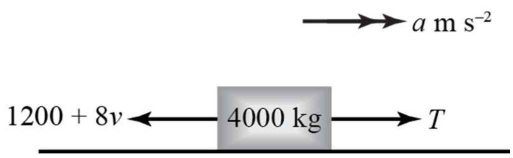
$$v = \frac{-150 \pm \sqrt{150^2 - 4\times 3\times(-10\,000)}}{6}$$

$$v = \frac{-150 \pm \sqrt{142\,500}}{6}$$

Since $v > 0$, $v = \dfrac{-150 + \sqrt{142\,500}}{6} = 37.91\ldots$

The maximum value of v is 37.9 m s^{-1} (3 s.f.)

17 a



Power $= 28\text{ kW} = 28\,000\text{ W}$
Power $= Tv$
$28\,000 = Tv$
$$T = \frac{28\,000}{v}$$
Resolving horizontally and using $F = ma$:

$$\frac{28\,000}{v} - (1200 + 8v) = 4000a$$

When $v = 10\text{ m s}^{-1}$:

$$2800 - (1200 + 80) = 4000a$$
$$1520 = 4000a$$
So $a = \dfrac{1520}{4000} = 0.38\text{ m s}^{-2}$

b Using $P = Fv$, when the car is travelling at speed w:
$28\,000 = Tw$
$$T = \frac{28\,000}{w}$$
Resistive force = $1200 + 8w$
As in part **a**, resolving horizontally and using $F = ma$:

$$\frac{28\,000}{w} - (1200 + 8w) = 4000a$$

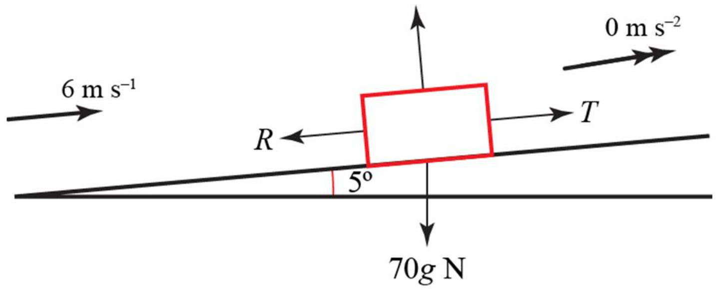
When $v = w\text{ m s}^{-1}$, $a = -0.2\text{ m s}^{-2}$:

$$\frac{28\,000}{w} - (1200 + 8w) = 4000 \times (-0.2)$$
$$28\,000 - 1200w - 8w^2 = -800w$$
$$8w^2 + 400w - 28\,000 = 0$$
$$w^2 + 50w - 3500 = 0$$

Using the quadratic formula:
$$w = \frac{-50 \pm \sqrt{50^2 - 4 \times 1 \times (-3500)}}{2} = \frac{-50 \pm \sqrt{16\,500}}{2}$$
Since $w > 0$, $w = \dfrac{-50 + \sqrt{16500}}{2} = 39.22\ldots$
The value of w is 39.2 (3 s.f.)

Chapter Review

1



Power = Fv

$480 = T \times 6$

$T = \frac{480}{6} = 80$

Resolving parallel to the slope:

$T = R + 70g\sin 5°$

$80 = R + 70 \times 9.8\sin 5°$

$R = 80 - 70 \times 9.8\sin 5°$

$R = 20.21\ldots$

The magnitude of the resistance is 20.2 N (3 s.f.)

2 **a** P.E. gained by water and bucket $= mgh$

$= 12 \times 9.8 \times 25$

$= 2940$

Initial K.E. = final K.E. = 0

Work done by the boy = P.E. gained by bucket

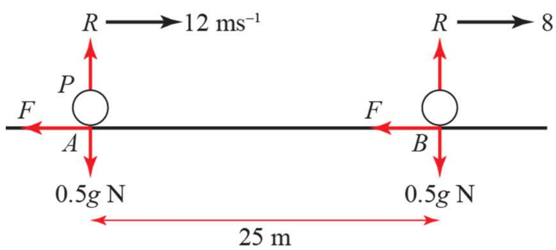
= 2940 J

b Average rate of working $= \frac{\text{work done}}{\text{time taken}} = \frac{2940}{30}$

$= 98$

The average rate of working of the boy is 98 J s^{-1} (or 98 W)

3



a K.E. lost by particle $= \frac{1}{2} \times 0.5 \times 12^2 - \frac{1}{2} \times 0.5 \times 8^2$

$= 20$

Work done by friction = K.E. lost by particle

$\therefore$ Work done by friction = 20 J

3 b Resolving vertically: $R = 0.5g$

Friction is limiting:

$F = \mu R = \mu \times 0.5g$

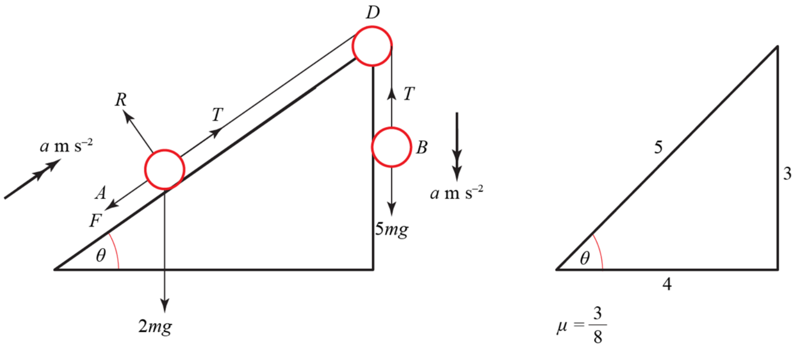
Work done by friction $= F \times s$

$$20 = \mu \times 0.5g \times 25$$

$$\mu = \frac{20}{0.5g \times 25} = 0.1632\ldots$$

The coefficient of friction is 0.163 (3 s.f.)

4



a Resolving perpendicular to the plane for A:

$R = 2mg\cos\theta$

Friction is limiting:

$F = \mu R$

$F = \frac{3}{8} \times 2mg\cos\theta$

$= \frac{3}{8} \times 2mg \times \frac{4}{5}$

$= \frac{3}{5}mg$

$F = ma$ for A: $T - (F + 2mg\sin\theta) = 2ma$

$$T - \left(\tfrac{3}{5}mg + 2mg \times \tfrac{3}{5}\right) = 2ma$$

$$T - \frac{9mg}{5} = 2ma \quad (1)$$

$F = ma$ for B: $5mg - T = 5ma \quad (2)$

(1) + (2): $5mg - \dfrac{9mg}{5} = 7ma$

$$\frac{16mg}{5} = 7ma$$

$$a = \frac{16g}{35} = \frac{16 \times 9.8}{35}$$

$$a = 4.48$$

The initial acceleration of A is 4.48 m s^{-2}

4 **b** For the first 1 m A travels

The motion must be considered in two parts, before and after the string breaks. The friction force acting on A is the same throughout the motion.

$u = 0$

$a = 4.48 \text{ m s}^{-2}$

$s = 1 \text{ m}$

$v = ?$

$$v^2 = u^2 + 2as$$
$$v^2 = 2 \times 4.48 \times 1$$
$$v^2 = 8.96$$

After string breaks:

Loss of K.E. (of A) $= \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$= \frac{1}{2} \times 2m \times 8.96 - 0$

$= 8.96m$

Gain of P.E. (of A) $= mgh$

$= 2mg \times (x \sin\theta)$

$= 2mg \times x \times \frac{3}{5}$

$= \dfrac{6mgx}{5}$

where x is the distance moved up the plane.

Work done by friction $= \dfrac{3mg}{5} \times x$

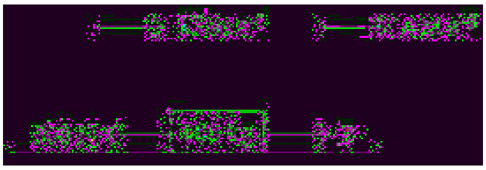
Work–energy principle:

$$\frac{3mgx}{5} + \frac{6mgx}{5} = 8.96m$$
$$\frac{9gx}{5} = 8.96$$
$$x = \frac{8.96 \times 5}{9 \times 9.8}$$
$$x = 0.5079\ldots$$

Total distance moved $= 1 + 0.5079\ldots$

$= 1.51$

The total distance moved by A before it first comes to rest is 1.51 m (3 s.f.)

5 a 

Power = Fv

$16\,000 = T \times 15$

$$T = \frac{16\,000}{15}$$

Ensure units are consistent.

Using $F = ma$:

$$T - 500 = 800a$$

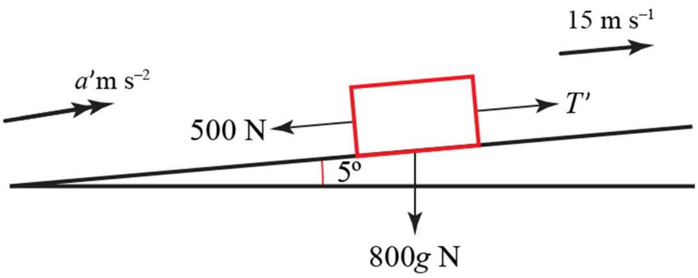
$$\frac{16\,000}{15} - 500 = 800a$$

$$a = \frac{\frac{16\,000}{15} - 500}{800}$$

$$a = 0.7083\ldots$$

The acceleration is 0.708 m s^{-2}

b



Power = Fv

$24\,000 = T' \times 15$

$$T' = \frac{24\,000}{15}$$

Resolving parallel to the slope and using $F = ma$:

$$T' - 500 - 800g\sin 5° = 800a'$$

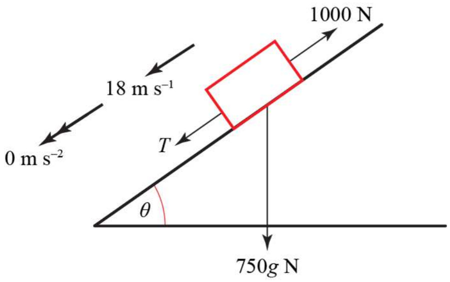
$$\frac{24\,000}{15} - 500 - 800 \times 9.8\sin 5° = 800a'$$

$$800a' = 416.698\ldots$$

$$a' = 0.5208\ldots$$

The new acceleration is 0.521 m s^{-2} (3 s.f.)

6 a



$\tan\theta = \frac{1}{20}$ so $\theta = 2.8624°$

Resolving parallel to the slope:

$T + 750g\sin\theta = 1000$

$T = 1000 - 750 \times 9.8\sin 2.8624°$

$T = 632.95$

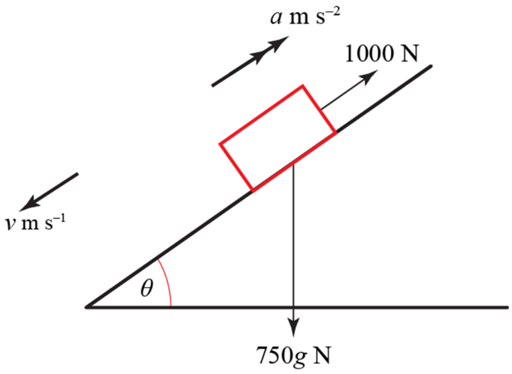
$\text{Power} = Fv$

$= 632.95 \times 18$

$= 11393.2\ldots$

The rate of working of the car's engine is 11.4 kW (3 s.f.)

b



The tractive force is zero.

Resolving parallel to the slope and using $F = ma$:

$1000 - 750 \times 9.8 \times \sin\theta = 750a$

$$a = \frac{1000 - 750 \times 9.8\sin 2.8624°}{750}$$

$a = 0.8439$

Consider motion down the slope:

$a = -0.8439\text{ m s}^{-2}$, $u = 18\text{ m s}^{-1}$, $v = 0\text{ m s}^{-1}$, $t = ?$

$v = u + at$

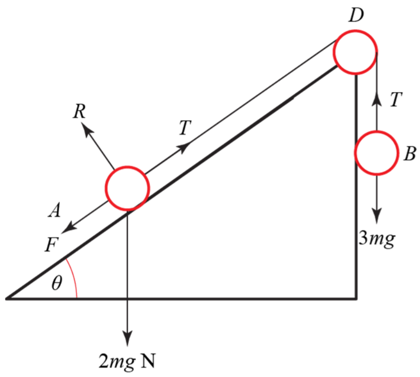
$0 = 18 - 0.8439 \times t$

$$t = \frac{18}{0.8439}$$

$t = 21.32\ldots$

The value of t is 21.3 (3 s.f.)

7



a P.E. gained by A $= mgh$

$= 2mg \times (s \times \sin\theta)$

$= 2mg \times s \times \frac{3}{5}$

$= \dfrac{6mgs}{5}$

P.E. lost by B $= mgh$

$= 3mgs$

$\therefore$ P.E. lost by system $= 3mgs - \dfrac{6mgs}{5} = \dfrac{9mgs}{5}$

7 b Consider A:

Find the frictional force and use the work–energy principle.

Resolving perpendicular to the slope:

$$R = 2mg\cos\theta$$
$$= 2mg \times \tfrac{4}{5}$$
$$= \frac{8mg}{5}$$

Friction is limiting:

$$F = \mu R$$
$$= \frac{1}{4} \times \frac{8mg}{5}$$
$$= \frac{2mg}{5}$$

Work done against friction $= Fs$

$$= \frac{2mgs}{5}$$

K.E. gained by A and B $= \tfrac{1}{2}(2m)v^2 + \tfrac{1}{2}(3m)v^2$

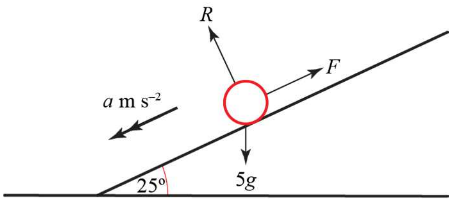
$$= \frac{5mv^2}{2}$$

Work–energy principle:

K.E. gained + work done against friction = P.E. lost

$$\frac{5mv^2}{2} + \frac{2mgs}{5} = \frac{9mgs}{5}$$
$$\frac{5mv^2}{2} = \frac{7mgs}{5}$$
$$v^2 = \frac{2 \times 7mgs}{5 \times 5m}$$
$$v^2 = \frac{14gs}{25}$$

8 a



Resolving parallel to the slope and using $F = ma$:

$$5g\sin 25° - F = 5a$$

Friction is limiting:

$$F = \mu R$$
$$F = 0.3 \times 5g\cos 25°$$

So $5g\sin 25° - 5\times 0.3\times g\cos 25° = 5a$

$$a = g(\sin 25° - 0.3\cos 25°)$$

Consider the motion down the slope.

$u = 0$ and $t = 2$

$$\begin{aligned} v &= u + at \\ &= 0 + 2g(\sin 25° - 0.3\cos 25°) \\ &= 2g(\sin 25° - 0.3\cos 25°) \\ &= 2.9542\ldots \end{aligned}$$

After it has been moving for 2 s the parcel has speed 2.95 m s^{-1} (3 s.f.)

b In 2 s the parcel slides a distance s m down the sloping platform.

$$\begin{aligned} \text{Loss of P.E.} &= mgh \\ &= mg\times s\sin 25° \\ &= 5g\times s\sin 25° \end{aligned}$$

$u = 0$, $v = 2.954$ m s^{-1}, $t = 2$ s

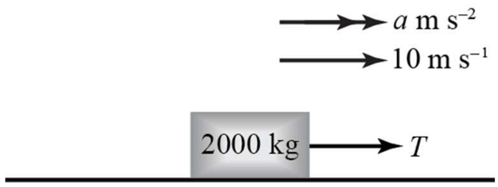
Using $s = \dfrac{u+v}{2}\times t$

$$s = \frac{0 + 2.954}{2}\times 2 = 2.954$$

$$\begin{aligned} \text{So, loss of P.E.} &= 5g\times 2.954\times\sin 25° \\ &= 5\times 9.8\times 2.954\times\sin 25° \\ &= 61.17\ldots \end{aligned}$$

During the 2 s, the parcel loses 61.2 J of potential energy (3 s.f.)

9



Power = 4000 W
Power = $Tv = 10T$

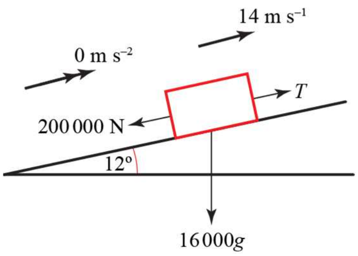
So $T = \dfrac{4000}{10} = 400$ N

Using $F = ma$:

$$T = 2000 \times a$$
$$400 = 2000a$$

So $a = \dfrac{400}{2000} = 0.2$ m s^{-2}

10



Resolving parallel to the slope:

$T = 200000 + 16000g\sin 12°$

$T = 232600.5\cdots$

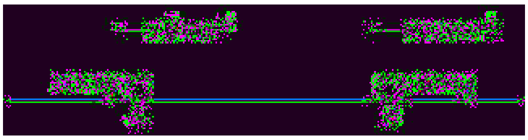
Work done in 10 s = force × distance moved

$= 232\ 600\ldots \times (14 \times 10)$

$= 32\ 564\ 000$ (3 s.f.)

The work done in 10s is 32 600 000 J (or 32 600 kJ) (3 s.f.)

11



a K.E. gained $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$$= \tfrac{1}{2}\times 0.3\times 12^2 - \tfrac{1}{2}\times 0.3\times 6^2$$

$$= 16.2$$

The K.E. gained is 16.2 J

b The work done by the force is 16.2 J

c Work done = Fs

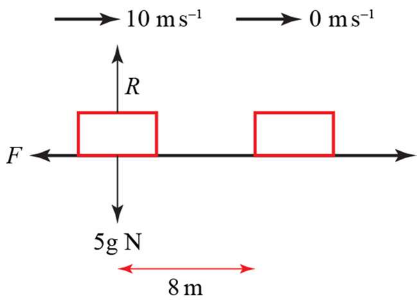
$$16.2 = F \times 4$$

$$F = \frac{16.2}{4}$$

$$F = 4.05$$

The force has magnitude 4.05 N

12



a K.E. lost $= \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$$= \tfrac{1}{2}\times 5\times 10^2 - 0$$

$$= 250$$

The K.E. lost is 250 J

b Work done against friction = 250 J

Work done = Fs

$$250 = F\times 8$$

$$F = \frac{250}{8}$$

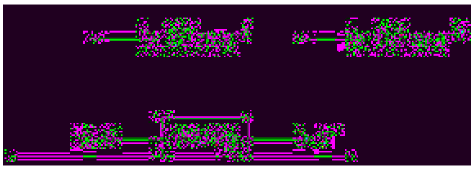
Resolving perpendicular to the slope: $R = 5g$

Friction is limiting: $F = \mu R$

$$\frac{250}{8} = \mu\times 5g$$

$$\mu = \frac{250}{8\times 5g}$$

The coefficient of friction is 0.638 (3 s.f.)

13 

a Power = Fv

$15\,000 = T \times 20$

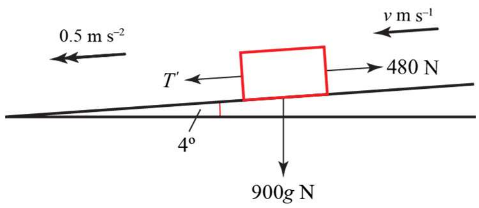
$$T = \frac{15\,000}{20} = 750$$

Using $F = ma$:

$$T - R = 900 \times 0.3$$
$$750 - R = 270$$
$$R = 750 - 270$$
$$R = 480$$

The magnitude of the resistance is 480 N

b



Resolving along the slope and using $F = ma$:

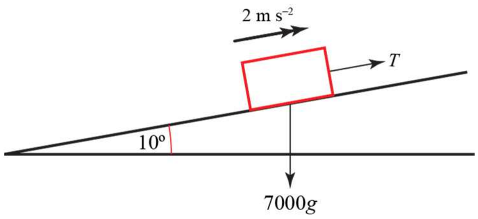
$$T' + 900g\sin 4° - 480 = 900 \times 0.5$$
$$T' = 450 + 480 - 900g\sin 4°$$

Power = Fv

$$8000 = (450 + 480 - 900g\sin 4°)v$$
$$v = \frac{8000}{(450 + 480 - 900g\sin 4°)}$$
$$v = 25.41\ldots$$

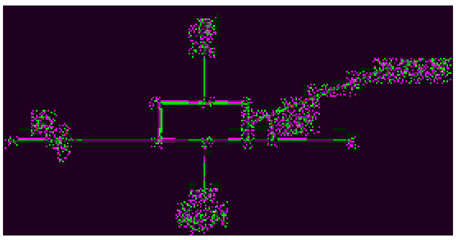
The speed of the car is 25.4 m s^{-1} (3 s.f.)

14



Power = Fv
Power = 4000 W
$T = \frac{4000}{v}$
Resolving along the slope and using $F = ma$:
$\frac{4000}{v} - 7000g\sin 10° = 7000 \times 2$
$\frac{4000}{v} = 25912$
So $v = \frac{4000}{25912} = 0.154\ldots$
The speed of the bus is 0.15 m s^{-1} (2 s.f.)

15



$\mu = \frac{3}{8}$

a Resolving perpendicular to the floor:
$R + 75\sin 15° = 4g$
$R = 4g - 75\sin 15°$
Friction is limiting:
$F = \mu R$
$F = \frac{3}{8} \times (4 \times 9.8 - 75\sin 15°)$
$F = 7.420\ldots$
The magnitude of the frictional force is 7.42 N (3 s.f.)

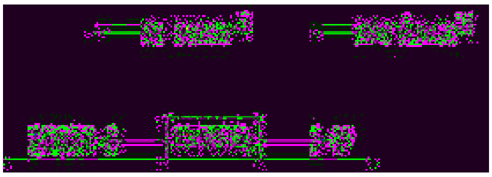
b Work done $= Fs$
$= 75\cos 15° \times 6$
$= 434.66\ldots$
The work done is 435 J (3 s.f.)

15 c Using the work–energy principle:
K.E. gained = work done by tension – work done against friction

$$\tfrac{1}{2}\times 4v^2 = 434.66 - 7.420\times 6$$
$$v^2 = \tfrac{1}{2}(434.66 - 7.420\times 6)$$
$$v = 13.96\ldots$$

The block is moving at 14.0 m s^{-1} (3 s.f.)

16 a



At maximum speed, $a = 0$
Resolving along the road and using $F = ma$:

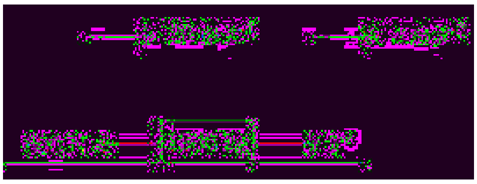
$$T - 600 = 0$$
$$T = 600$$

Power $= Fv$

$$20\,000 = 600v$$
$$v = \frac{20\,000}{600}$$
$$v = 33.33$$

The lorry's maximum speed is 33.3 m s^{-1} (3 s.f.)

b



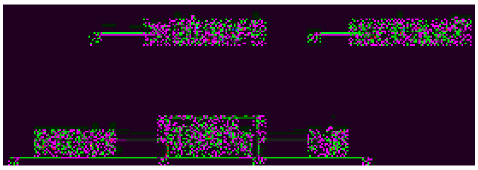
Power $= Fv$

$$20\,000 = T'\times 20$$
$$T' = 1000$$

Using $F = ma$:

$$T' - 600 = 1800a$$
$$1000 - 600 = 1800a$$
$$a = \frac{400}{1800}$$
$$a = 0.2222\ldots$$

The acceleration of the lorry is 0.222 m s^{-2} (3 s.f.)

17 

a Resolving along the road: $T = 600$

Power $= Fv$

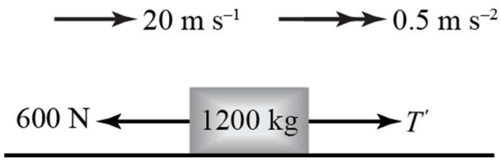
$$= 600 \times 20$$

$$= 12\,000 \text{ W}$$

$$= 12 \text{ kW}$$

The power is 12 kW

b



$$F = ma$$

$$T' - 600 = 1200 \times 0.5$$

$$T' = 600 + 600$$

$$T' = 1200$$

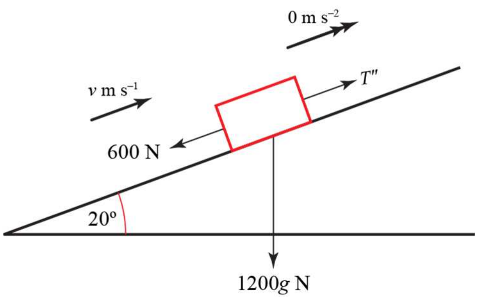
$$\text{Power} = F \times v$$

$$= 1200 \times 20$$

$$= 24\,000$$

The new rate of working is 24 kW

c



Resolving along the slope:

$$T'' = 600 + 1200g \sin 20°$$

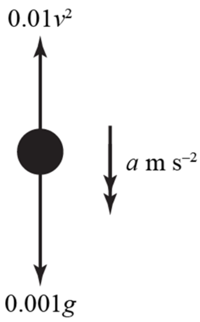
Power $= Fv$

$$50\,000 = (600 + 1200g \sin 20°)v$$

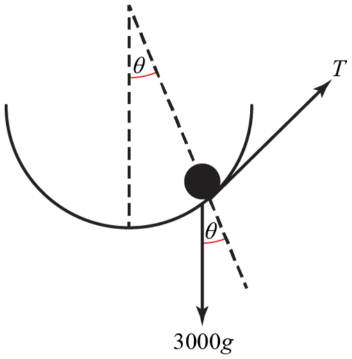
$$v = \frac{50\,000}{(600 + 1200g \sin 20°)}$$

$$v = 10.82\ldots$$

The value of v is 10.8 (3.s.f.)



Challenge



a Car is moving with constant speed in a direction along the tangent to the cylinder. Resolving along the path of the car:

$$T = 3000g\sin\theta$$

Power = Tv
Power $= 3000g\sin\theta \times 20 = 60\,000g\sin\theta = 588000\sin\theta$ W

b When $\theta = 0°$, there is no force to act against, so no power is required.
When $\theta = 90°$, maximum power is needed.