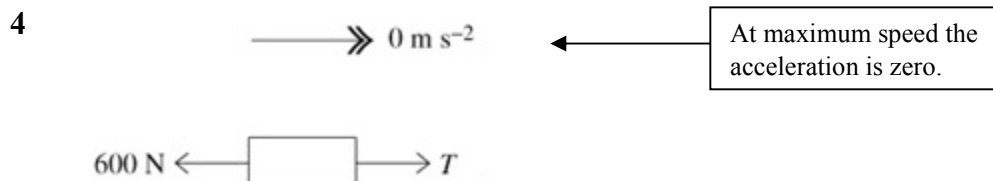


Work, energy and power 2D

1 Power = Fv
 $= 1500 \times 12$
 $= 18\,000$
 The power is 18 kW

2 Power = Fv
 $= 1000 \times 15$
 $= 15\,000$
 The power is 15 000 W (or 15 kW)

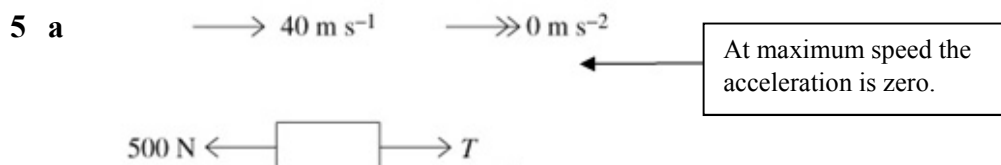
3 Power = Fv
 $5000 = F \times 18$
 $F = \frac{5000}{18}$
 $= 277.7\dots$
 The driving force has magnitude 278 N (3 s.f.)



Resolving horizontally: $T = 600$

Power = Fv
 $15000 = 600v$
 $v = \frac{15000}{600}$
 $= 25$

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



Resolving horizontally: $T = 500$

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 $\longrightarrow \longrightarrow 16 \text{ m s}^{-1}$ $\longrightarrow \longrightarrow 0 \text{ m s}^{-2}$



$$\begin{aligned} \text{Power} &= Fv \\ 8.8 \times 10^3 &= T \times 16 \\ T &= \frac{8800}{16} \\ T &= 550 \end{aligned}$$

Resolving horizontally: $R = T$

$$R = 550$$

The magnitude of the resistance is 550 N

7 a $\longrightarrow 7 \text{ m s}^{-1}$ $\longrightarrow \longrightarrow a \text{ m s}^{-2}$



$$\begin{aligned} \text{Power} &= Fv \\ 9000 &= T \times 7 \\ T &= \frac{9000}{7} \end{aligned}$$

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

Now using $F = ma$:

$$T - 350 = ma$$

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

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

$$a = 1.100\dots$$

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

b $\longrightarrow 15 \text{ m s}^{-1}$ $\longrightarrow \longrightarrow a \text{ m s}^{-2}$



$$\begin{aligned} \text{Power} &= Fv \\ 9000 &= T \times 15 \\ T &= \frac{900}{15} = 600 \end{aligned}$$

Now using $F = ma$:

$$T - 350 = ma$$

$$600 - 350 = 850a$$

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

$$a = 0.2941\dots$$

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

7 c $\longrightarrow v \text{ m s}^{-1}$ $\longrightarrow\!\!\!\!\!\!> v \text{ m s}^{-2}$



Resolving horizontally: $T = 350$

Power = Fv

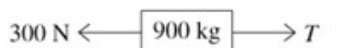
$9000 = 350v$

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

$v = 25.71\dots$

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

8 $\longrightarrow 20 \text{ m s}^{-1}$ $\longrightarrow\!\!\!\!\!\!> 0.3 \text{ m s}^{-2}$



Using $F = ma$:

$T - 300 = 900 \times 0.3$

$T = 900 \times 0.3 + 300$

$= 570$

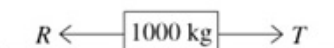
Power = Fv

$= 570 \times 20$

$= 11\,400$

The power development by the engine is $11\,400 \text{ W}$ (or 11.4 kW)

9 $\longrightarrow 24 \text{ m s}^{-1}$ $\longrightarrow\!\!\!\!\!\!> 0.2 \text{ m s}^{-2}$



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 $\longrightarrow v \text{ m s}^{-1} \longrightarrow \gg 0 \text{ m s}^{-2}$



Resolving horizontally:

$$T = 28$$

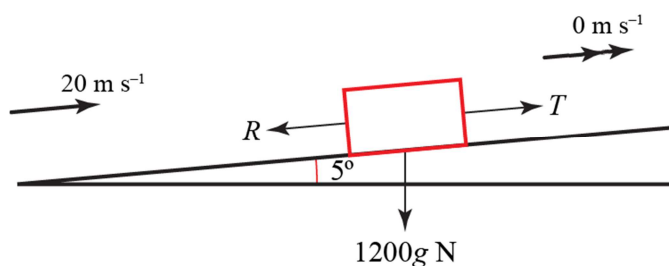
$$\text{Power} = Fv$$

$$280 = 28v$$

$$v = 10$$

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

11 a



$$\text{Power} = Fv$$

$$24000 = T \times 20$$

$$T = \frac{24000}{20} = 1200$$

Resolving parallel to the slope:

$$T = R + 1200g \sin 5^\circ$$

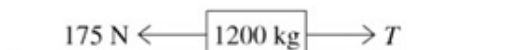
$$1200 = R + 1200g \sin 5^\circ$$

$$R = 1200 - 1200g \sin 5^\circ$$

$$R = 175.04\dots$$

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

b $\longrightarrow 20 \text{ m s}^{-1} \longrightarrow \gg a \text{ m s}^{-2}$



From part a, $T = 1200 \text{ N}$

Using $F = ma$:

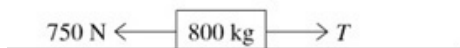
$$1200 - 175 = 1200a$$

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

$$a = 0.8541\dots$$

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

12 a $\longrightarrow 18 \text{ m s}^{-1}$ $\longrightarrow a \text{ m s}^{-2}$



$$\text{Power} = Fv$$

$$26000 = T \times 18$$

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

Using $F = ma$:

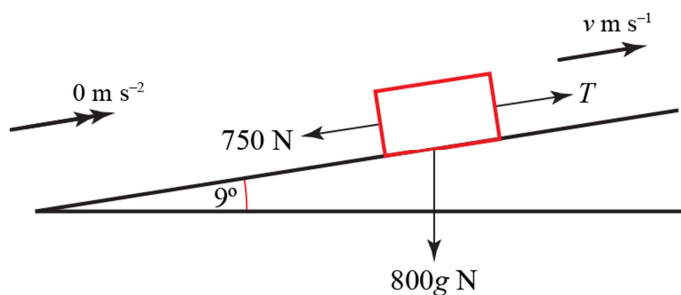
$$T - 750 = 800a$$

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

$$a = 0.8680\dots$$

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

b



Resolving parallel to the slope:

$$T = 750 + 800g \sin 9^\circ$$

$$\text{Power} = Fv$$

$$26000 = T \times v$$

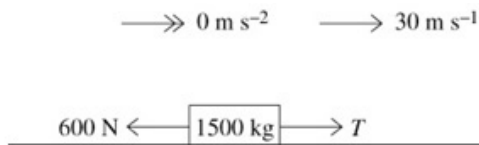
$$26000 = (750 + 800 \times 9.8 \sin 9^\circ)v$$

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

$$v = 13.15\dots$$

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

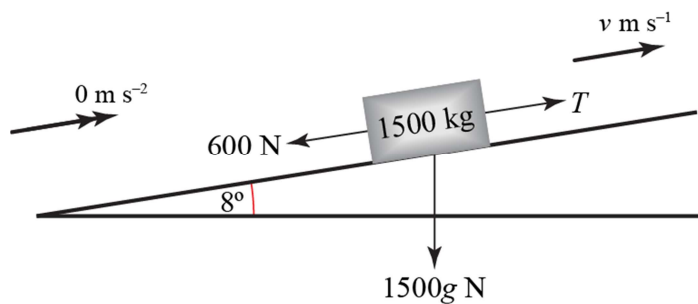
13 a

Resolving horizontally: $T = 600$

$$\begin{aligned} \text{Power} &= Fv \\ &= 600 \times 30 \\ &= 18000 \end{aligned}$$

The power is 18 000 W (or 18 kW)

b



Resolving parallel to the slope:

$$T = 600 + 1500g \sin 8^\circ$$

Power = Fv

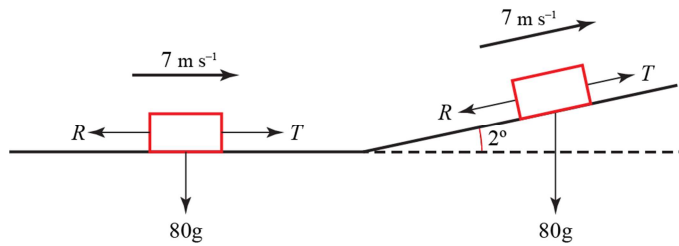
$$18000 = (600 + 1500g \sin 8^\circ)v$$

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

$$= 6.803\dots$$

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

14



Consider the cyclist on level ground:

$$\text{Power} = Tv$$

$$\text{Power} = 7T$$

Since the velocity is constant, resolving horizontally:

$$T = R$$

$$\text{So power} = 7R$$

Consider the cyclist cycling uphill:

$$\text{Power} = Tv$$

$$\text{Power} = 7T$$

Since the velocity is constant, resolving parallel to the plane:

$$T = R + 80g \sin 2^\circ$$

$$\text{So power} = 7T = 7(R + 80g \sin 2^\circ) = 7R + 560g \sin 2^\circ$$

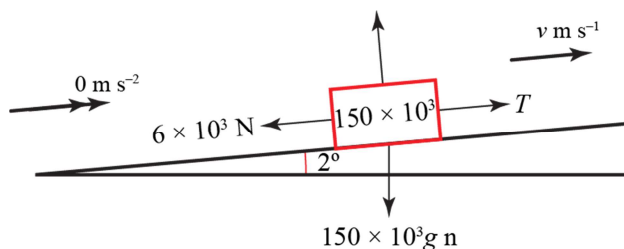
Therefore, the increase in power required is:

$$(7R + 560g \sin 2^\circ) - 7R = 560g \sin 2^\circ$$

$$= 191.5\dots$$

The increase in power required is 192 W (3 s.f.)

15 a



Resolving parallel to the slope:

$$T = (6 \times 10^3) + (150 \times 10^3 g \sin 2^\circ)$$

Power = Fv

$$350 \times 10^3 = (6 \times 10^3 + 150 \times 10^3 g \sin 2^\circ) \times v$$

$$v = \frac{350}{(6 + 150 \times 9.8 \sin 2^\circ)}$$

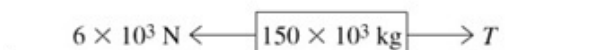
$$= 6.107 \dots$$

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

$$\longrightarrow 6.107 \text{ m s}^{-1} \longrightarrow \gg a \text{ m s}^{-2}$$



Power = Fv

$$350 \times 10^3 = T \times 6.107$$

$$T = \frac{350 \times 10^3}{6.107}$$

Using $F = ma$:

$$T - 6 \times 10^3 = 150 \times 10^3 \times a$$

$$\frac{350 \times 10^3}{6.107} - 6 \times 10^3 = 150 \times 10^3 \times a$$

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

$$a = 0.3420 \dots$$

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

16 $\longrightarrow \longrightarrow 0 \text{ m s}^{-2}$ $\longrightarrow v \text{ m s}^{-1}$



$$\text{Power} = 10 \text{ kW} = 10\,000 \text{ W}$$

$$\text{Power} = Tv$$

$$10\,000 = Tv$$

$$T = \frac{10\,000}{v}$$

When the velocity is maximum, the acceleration = 0 m s^{-2}

Therefore the resultant force is 0 N. Resolving horizontally:

$$T = 150 + 3v$$

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

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

Rearranging:

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

Using the quadratic formula:

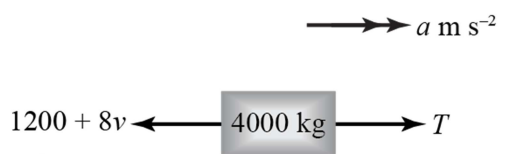
$$v = \frac{-150 \pm \sqrt{150^2 - 4 \times 3 \times (-10\,000)}}{6}$$

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

$$\text{Since } v > 0, v = \frac{-150 + \sqrt{142\,500}}{6} = 37.91\dots$$

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

17 a



$$\text{Power} = 28 \text{ kW} = 28\,000 \text{ W}$$

$$\text{Power} = Tv$$

$$28\,000 = Tv$$

$$T = \frac{28\,000}{v}$$

Resolving horizontally and using $F = ma$:

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

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

$$2800 - (1200 + 80) = 4000a$$

$$1520 = 4000a$$

$$\text{So } a = \frac{1520}{4000} = 0.38 \text{ m s}^{-2}$$

b Using $P = Fv$, when the van is travelling at speed w :

$$28\,000 = Tw$$

$$T = \frac{28\,000}{w}$$

$$\text{Resistive force} = 1200 + 8w$$

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:

$$w = \frac{-50 \pm \sqrt{50^2 - 4 \times 1 \times (-3500)}}{2} = \frac{-50 \pm \sqrt{16\,500}}{2}$$

$$\text{Since } w > 0, w = \frac{-50 + \sqrt{16\,500}}{2} = 39.22\dots$$

The value of w is 39.2 (3 s.f.)