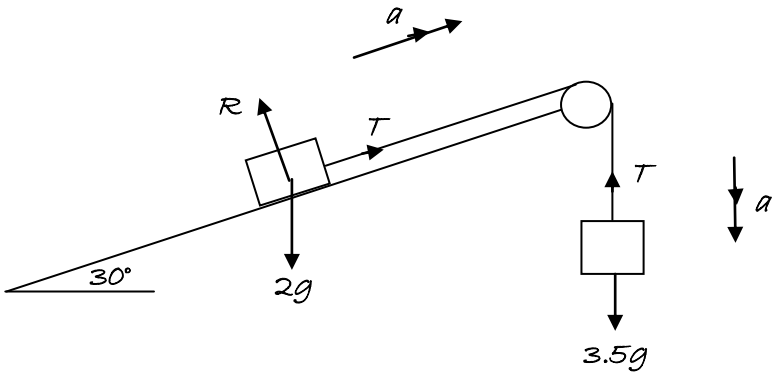
Section 2: Newton's second law

Solutions to Exercise level 2

1.



Considering the 3.5 kg mass downwards: $3.5g - T = 3.5a$

Considering the 2 kg mass up the plane: $T - 2g\sin 30° = 2a$

$T - g = 2a$

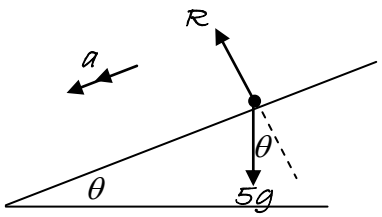
Adding: $2.5g = 5.5a$

$$a = \frac{2.5 \times 9.8}{5.5} = 4.45$$

$T = 2a + g = 18.7$

The acceleration is 4.45 ms^{-2} and the tension in the string is 18.7 N.

2.



Resolving parallel to the plane: $5g\sin\theta = 5a$

$a = 9.8 \times \frac{1}{5} = 1.96$

$u = 7$ $\quad v^2 = u^2 + 2as$

$v = 0$ $\quad 0 = 7^2 - 2 \times 1.96s$

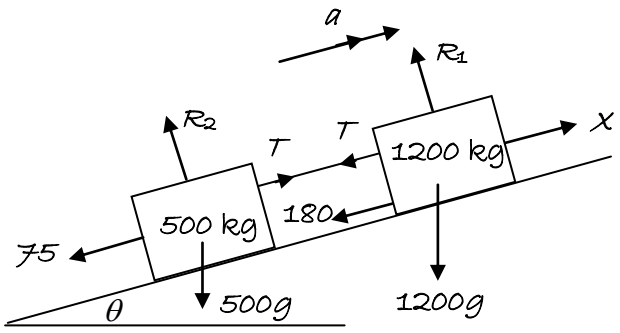
$a = -1.96$ $\quad s = 12.5$

$s = ?$

It moves 12.5 m before coming to rest.

Edexcel A level Maths Forces in 2D 2 Exercise solns

3.



(i) Constant speed, so $a = 0$.

For both car and trailer up the slope:

$$X - 180 - 75 - 1200g\sin\theta - 500g\sin\theta = 0$$

$$X = 255 + 1700 \times 9.8 \times 0.1$$

$$X = 1921$$

For trailer: $T - 75 - 500g\sin\theta = 0$

$$T = 75 + 500 \times 9.8 \times 0.1$$

$$T = 565$$

The tractive force is 1921 N and the tension is 565 N.

(ii) When decelerating at 0.5 ms^{-2}, $a = -0.5$.

For both car and trailer up the slope:

$$X - 180 - 75 - 1200g\sin\theta - 500g\sin\theta = 1700 \times -0.5$$

$$X = 255 + 1700 \times 9.8 \times 0.1 - 850$$

$$X = 1071$$

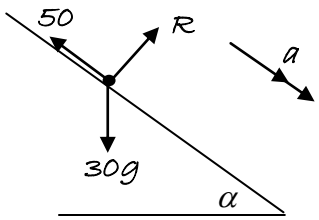
For trailer: $T - 75 - 500g\sin\theta = 500 \times -0.1$

$$T = 75 + 500 \times 9.8 \times 0.1 - 250$$

$$T = 315$$

The tractive force is 1071 N and the tension is 315 N.

4. (i) On slope:



Resolving down the slope: $30g\sin\alpha - 50 = 30a$

$$30a = 30 \times 9.8 \times \tfrac{5}{13} - 50 = \tfrac{820}{13}$$

$$a = \tfrac{82}{39}$$

The acceleration is 2.10 ms^{-2} (3 s.f.)

(ii) $u = 0$ $\quad v^2 = u^2 + 2as$

$a = \frac{82}{39}$ $\quad = 0 + 2 \times \frac{82}{39} \times 5 = \frac{820}{39}$

$s = 5$ $\quad v = 4.59$

$v = ?$

The speed at the end of the slope is 4.59 ms^{-1} (3 s.f.).

(ii) On horizontal section:

$50 = 30a$

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

The deceleration is 1.67 ms^{-2} (3 s.f.)

(iv) $u = \sqrt{\frac{820}{39}}$ $\quad v^2 = u^2 + 2as$

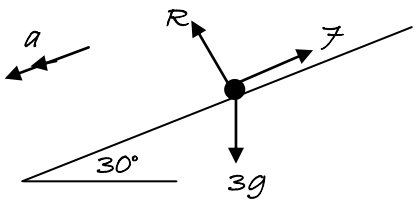
$s = 5$ $\quad v^2 = \frac{820}{39} - 2 \times \frac{5}{3} \times 5$

$a = -\frac{5}{3}$ $\quad v = 2.09$

$v = ?$

The speed is 2.09 ms^{-1} (3 s.f.)

5. (i)



Down the roof: $3g \sin 30° - 7 = 3a$

$3 \times 9.8 \times 0.5 - 7 = 3a$

$a = \frac{7.7}{3} = 2.57$

The acceleration is 2.57 ms^{-2}.

(ii) $v^2 = u^2 + 2as$

$v^2 = 0 + 2 \times \frac{7.7}{3} \times 2$

$v = 3.20$

The velocity at the edge of the roof is 3.20 ms^{-1}.

(iii) The vertical component of the velocity is $v \sin 30°$.
Vertically (taking downwards to be positive):

$$s = ut + \tfrac{1}{2}at^2$$

$$3.5 = \tfrac{1}{2}vt + \tfrac{1}{2} \times 9.8t^2$$

$$9.8t^2 + vt - 7 = 0$$

$$t = \frac{-v \pm \sqrt{v^2 + 4 \times 9.8 \times 7}}{2 \times 9.8} = 0.697$$

Time taken = 0.697 seconds (3 s.f.)

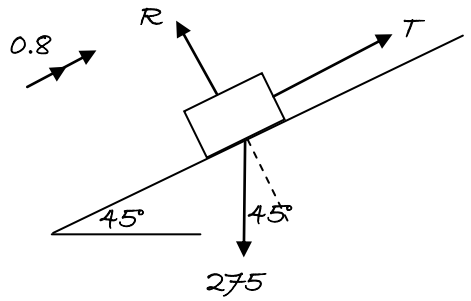
(iv) The horizontal component of the velocity is $v\cos 30°$

Horizontal distance travelled $= v\cos 30° \times t$

$= 1.94$

Horizontal distance travelled = 1.94 m.

6. Mass of crate $= \frac{275}{g}$



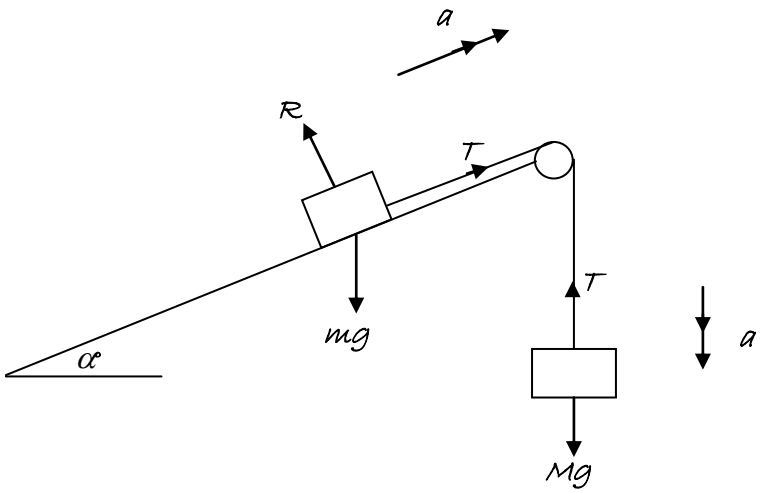
Resolving parallel to the slope:

$$T - 275\sin 45° = \frac{275}{9.8} \times 0.8$$

$$T = 217$$

The tension is 217 N (3 s.f.)

7.



(i) In equilibrium, $a = 0$.

For the mass M vertically: $Mg - T = 0$

For the mass m up the plane: $T - mg\sin\alpha = 0$

Adding: $Mg - mg\sin\alpha = 0$

$$\sin\alpha = \frac{M}{m}$$

(ii) When accelerating, $a = 0.5$.

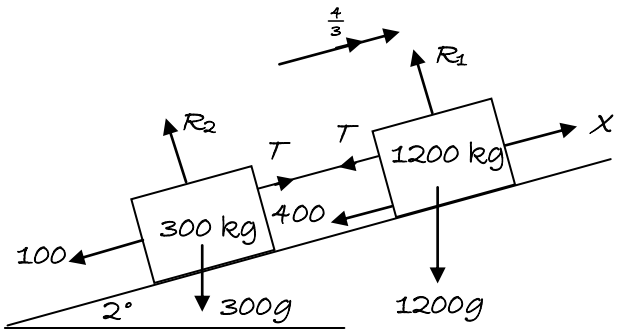
For the mass M vertically: $Mg - T = \frac{1}{2}M$

For the mass m up the plane: $T - mg\sin\alpha = \frac{1}{2}m$

Adding: $Mg - mg\sin\alpha = \frac{1}{2}(M + m)$

$$\sin\alpha = \frac{2Mg - M - m}{2mg}$$

8. (i)



For the car and the trailer:

$$X - 400 - 100 - 1200g\sin 2° - 300g\sin 2° = 1500 \times \tfrac{4}{3}$$

$$X = 500 + 1500 \times 9.8\sin 2° + 2000$$

$$X = 3013$$

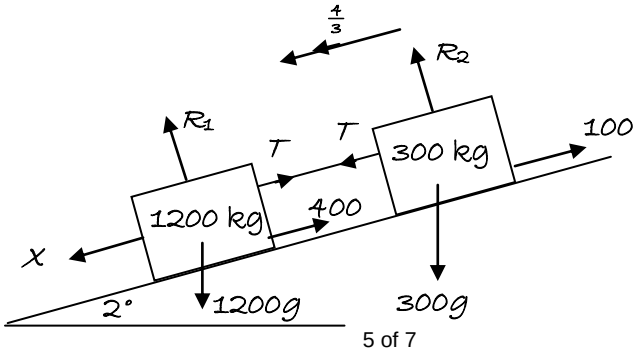
For trailer: $T - 100 - 300g\sin 2° = 300 \times \frac{4}{3}$

$$T = 100 + 300 \times 9.8\sin 2° + 400$$

$$T = 603$$

The tractive force is 3010 N (3 s.f.) and the tension is 603 N (3 s.f.).

(ii)



For the car and the trailer:

$$X - 400 - 100 + 1200g\sin 2° + 300g\sin 2° = 1500 \times \tfrac{1}{3}$$

$$X = 500 - 1500 \times 9.8\sin 2° + 2000$$

$$X = 1987$$

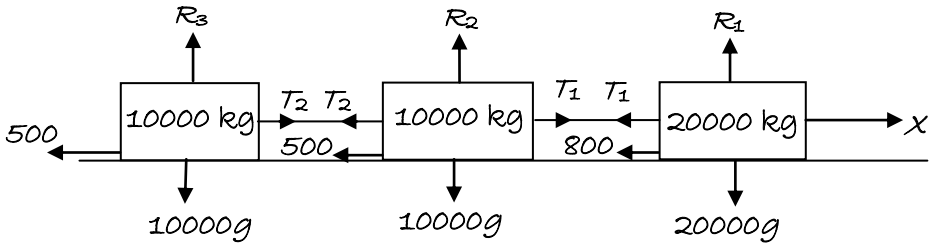
For trailer: $T - 100 + 300g\sin 2° = 300 \times \tfrac{1}{3}$

$$T = 100 - 300 \times 9.8\sin 2° + 400$$

$$T = 397$$

The tractive force is 1990 N (3 s.f.) and the tension is 397 N (3 s.f.).

9.



(i) For whole train: $X - 800 - 500 - 500 = 0$

$$X = 1800$$

The driving force is 1800 N.

(ii) For engine: $X - T_1 - 800 = 0$

$$1800 - T_1 - 800 = 0$$

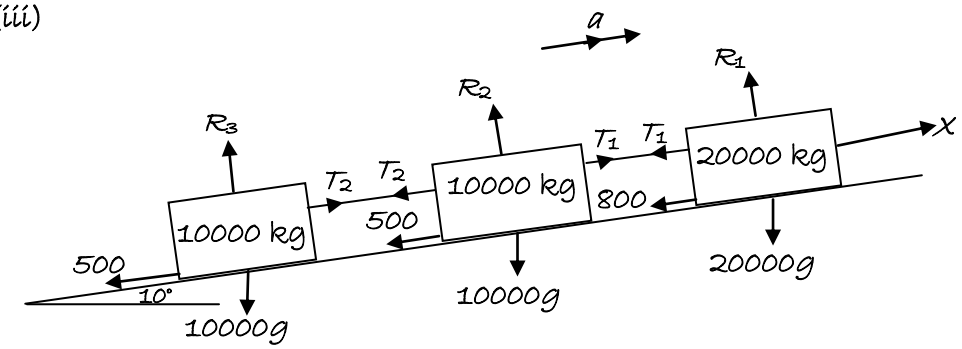
$$T_1 = 1000$$

For second truck: $T_2 - 500 = 0$

$$T_2 = 500$$

The force in the first coupling is 1000 N and the force in the second coupling is 500 N.

(iii)



For whole train: $1800 - 1800 - 40000g\sin 10° = 40000a$

$$a = -g\sin 10° = -1.70$$

The deceleration is 1.70 ms^{-2}.

For the engine: $1800 - T_1 - 800 - 20000g\sin 10° = 20000a$

$$T_1 = 1000 - 20000g\sin 10° - 20000 \times -g\sin 10°$$

$$T_1 = 1000$$

For second truck: $T_2 - 500 - 10000g\sin 10° = 10000a$

$$T_2 = 500 + 1000g\sin 10° + 10000 \times -g\sin 10°$$

$$T_2 = 500$$

The tensions in the couplings are 1000 N and 500 N, as before.