Section 3: Connected objects

Section test

Throughout this test, take $g = 9.8\ \text{ms}^{-2}$.

1. A brick of mass 2 kg falls through water with an acceleration of 2 ms^{-2}. Find the total force of the resistance.

2. A 1000 kg crate is being lowered into a ship's hold with an acceleration of 2 ms^{-2}. Find the tension in the rope.

3. A man of mass 80 kg is standing in a lift, which is accelerating upwards with an acceleration of 0.6 ms^{-2}. What is the size of the force between the man and the lift floor?

4. A light string passes over a smooth pulley and is connected to a mass of 5 kg on one end and a mass of 7 kg on the other end. The system is allowed to move freely.
   What is the acceleration of the system?
   What is the tension in the string?

5. An empty bottle of mass 3 kg is released from a submarine and rises with an acceleration of 0.7 ms^{-2}. If the water causes a resistance of 0.5 N, find the size of the buoyancy force causing the bottle to rise.

6. A mass of 3 kg lies on a smooth table and it is connected to another mass of 7 kg hanging vertically by a light inextensible string which passes over a smooth pulley. What is the acceleration of the system?

7. A car of mass 800 kg is pulling a trailer of mass 200 kg. Each of the car and the trailer experience a resistance of 200 N. The car and trailer are accelerating at 1.3 ms^{-2}.
   What is the driving force of the car?
   What is the tension in the tow bar between the car and trailer?

8. A rope is passed over a smooth beam. Two children, the heavier of which has mass 60 kg, hang onto the rope, one on either end, so that the heavier one descends with an acceleration of 2 ms^{-2}. What is the mass of the lighter child to the nearest kilogram?

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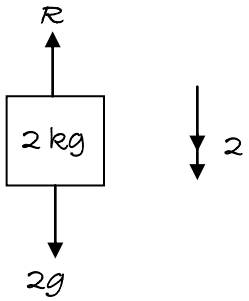
Solutions to section test

1.



$F = ma$

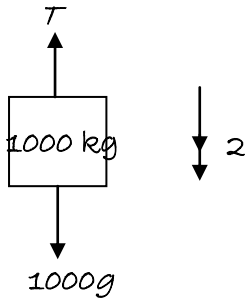
$2g - R = 2 \times 2$

$2 \times 9.8 - 4 = R$

$15.6 = R$

The resistance is 15.6 N.

2.



$F = ma$

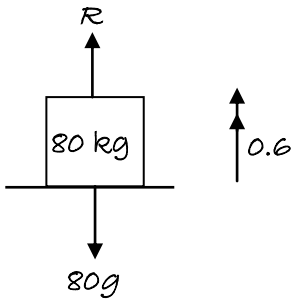
$1000g - T = 1000 \times 2$

$1000 \times 9.8 - 2000 = T$

$7800 = T$

The tension is 7800 N.

3.



$F = ma$

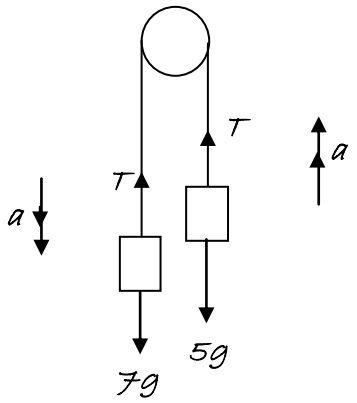
$R - 80g = 80 \times 0.6$

$R = 80 \times 9.8 + 48$

$R = 832$

The force is 832 N.

4.



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Considering the 5 kg mass: $T - 5g = 5a$ (1)

Considering the 7 kg mass: $7g - T = 7a$ (2)

Adding: $2g = 12a$

$$a = \frac{2 \times 9.8}{12} = 1.63$$

The acceleration of the system is 1.63 ms^{-2} (3 s.f.)

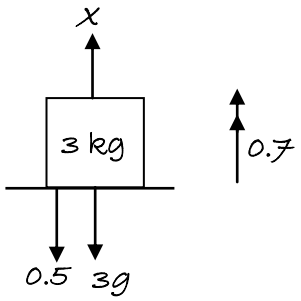
(1) gives $T = 5g + 5a$

$$= (5 \times 9.8) + 5\left(\frac{2 \times 9.8}{12}\right)$$

$$= 57.2$$

The tension in the string is 57.2 N (3 s.f.)

5.



$F = ma$

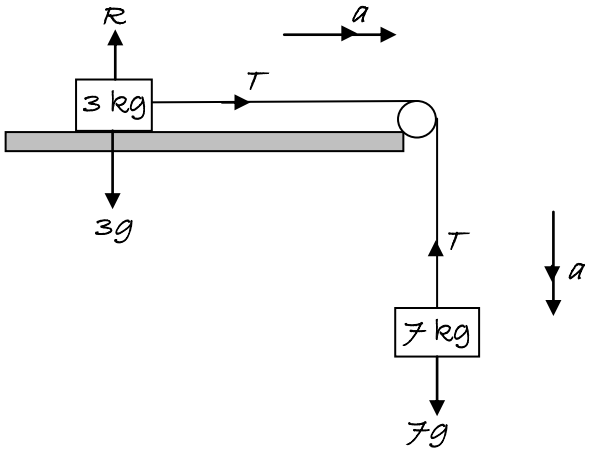
$X - 0.5 - 3g = 3 \times 0.7$

$X = 0.5 + 3 \times 9.8 + 2.1$

$X = 32$

The buoyancy force is 32 N.

6.



For 3 kg mass: $T = 3a$ (1)

For 7 kg mass: $7g - T = 7a$ (2)

Substituting (1) into (2): $7g - 3a = 7a$

$7g = 10a$

$$a = \frac{7 \times 9.8}{10} = 6.86$$

The acceleration of the system is 6.86 ms^{-2}.

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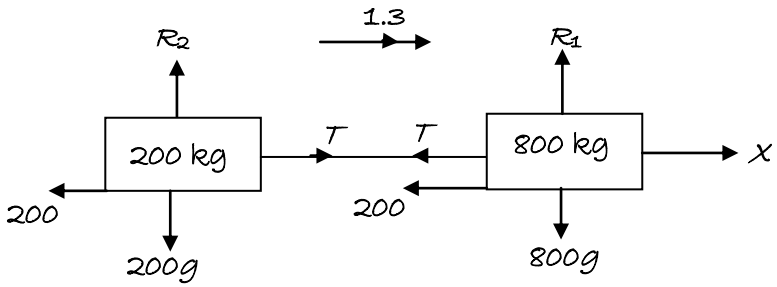
7.



Considering the system as a whole:

$$X - 200 - 200 = 1000 \times 1.3$$

$$X - 400 = 1300$$

$$X = 1700$$

The driving force of the car is 1700 N.

Considering the trailer only:

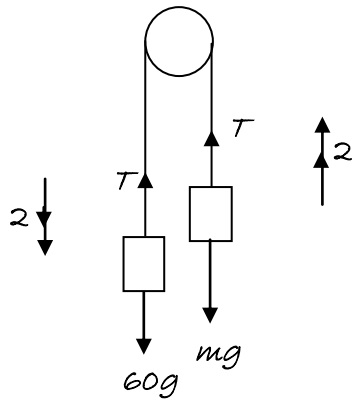
$$T - 200 = 200 \times 1.3$$

$$T - 200 = 260$$

$$T = 460$$

The tension in the towbar is 460 N.

8.



Considering the heavier child: $60g - T = 60 \times 2$

$$60 \times 9.8 = T + 120$$

$$T = 588 - 120 = 468$$

Considering the lighter child: $T - mg = 2m$

$$468 - 9.8m = 2m$$

$$468 = 11.8m$$

$$m = 40 \text{ kg (to nearest kilogram)}$$