Newton's third law of motion

Newton's third law of motion states that:

> If a body A exerts a force on a body B, then B exerts a force on A in the opposite direction with the same magnitude.

Perhaps the most simple example would be to consider a person standing on the floor.

The diagram shows the normal reaction force (R) of the floor acting on the person (modelled as a particle) in red and the equal force of the person acting on the floor, in black, in the opposite direction. In the diagram the forces are not aligned so that the beginning and end of each can be seen.
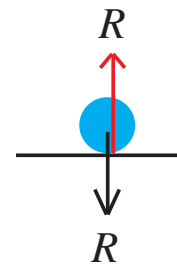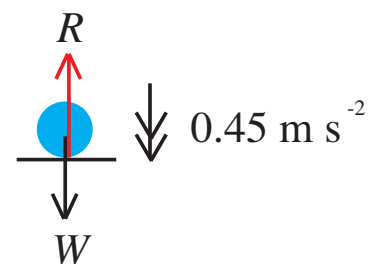
Worked Example 1.

A person of mass 85 kg is standing in a lift which is accelerating downwards at 0.45 m s^{-2}. Draw a diagram to show the forces acting on the person and calculate the force the person exerts on the floor of the lift.

Solution

The weight of the person is 85 g, where g is the acceleration due to gravity. The resultant force is W − R and using Newton's second law gives:

$$\begin{aligned} F &= ma \\ W - R &= 85 \times 0.45 \\ R &= W - 85 \times 0.45 \\ &= 85 \times 9.81 - 85 \times 0.45 = 795.6 \text{ N} = 800 \text{ N (2 d.p.)} \end{aligned}$$

Therefore, using Newton's third law the force the person exerts on the floor of the lift is equal to the force of the floor acting on the person, i.e. R, which equals 800 N.

Worked Example 2.

A large car, of mass 1500 kg, begins to tow a smaller car, of mass 1000 kg, that has broken down. The cars are connected by a tow bar and travel along a straight horizontal road. A horizontal driving force of D N acts on the large car, which is traveling with a constant acceleration of 1.8 m s^{-2}. Given that as the vehicles are moving slowly the air resistance is negligible, draw a diagram to show the forces acting on each of the cars, clearly indicating any forces of the same magnitude and find the driving force D.
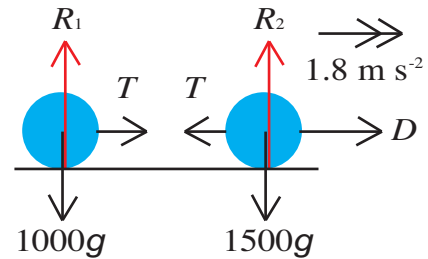
Solution

As can be seen in the diagram, Newton's third law applies in the tow bar, with respect to the tension T. It also applies between the ground and each car.

$$
\begin{aligned}
F &= ma \\
D &= 2500 \times 1.8 \\
D &= 4500 \text{ N} \quad \text{(2 d.p.)}
\end{aligned}
$$
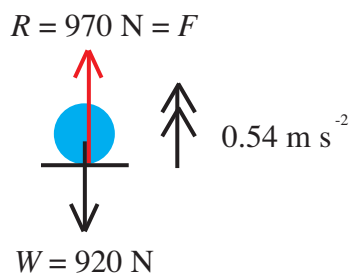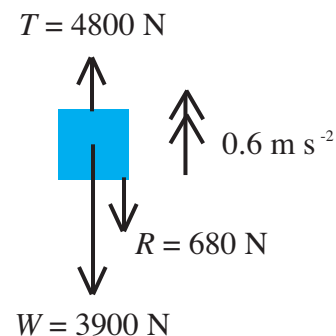

Exercises

1. A person of mass 94 kg is standing in a lift which is accelerating upwards at 0.54 m s^{-2}. Draw a diagram to show the forces acting on the person and calculate the force, F, the person exerts on the floor of the lift.

2. A person of mass 65 kg is standing in a lift of mass 400 kg, which is accelerating upwards at 0.6 m s^{-2}. Draw a diagram to show the forces acting on the lift and calculate their respective values.

3. An engine, of mass 3500 kg, tows two carriages, each of mass 600 kg on a set of straight horizontal rails. Given that the engine has a horizontal driving force of D N and that as they are moving slowly the air resistance is negligible, draw a diagram to show the forces acting on the engine and both carriages, clearly indicating any forces of the same magnitude.

4. A tug boat, of mass 8000 kg, is towing a smaller boat, of mass 2000 kg. Given that the tug boat has a horizontal driving force of D N and that they are accelerating at 1.2 m s^{-2}, draw a diagram to show the forces acting on both boats and calculate the driving force
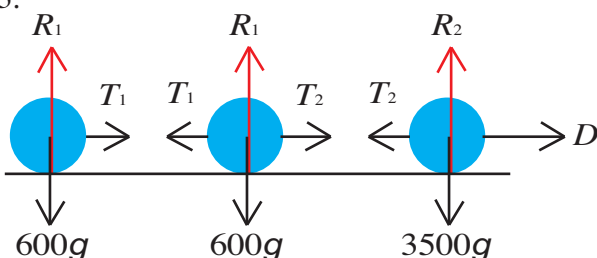
Answers (All to 2 s.f.)

1.

$R = 970 \text{ N} = F$

$W = 920 \text{ N}$

2.

$T = 4800 \text{ N}$

$R = 680 \text{ N}$

$W = 3900 \text{ N}$

3.

$600g$ $600g$ $3500g$

4.

$2000g$ $8000g$