Force and Acceleration

Objects with balanced forces (zero resultant force) are either stationary or moving at a steady speed in a straight line.

The speed or direction of something with a resultant force **changes**. It might speed up, slow down or change direction. This means that it accelerates.

The **acceleration** depends on the resultant force and the mass of the object. We would expect a 100 N force to have a bigger effect on a 100 g apple than on a $20\,000$ kg bus.

1 The diagram above shows a 50 kg trolley in a warehouse and a 2 kg skateboard.

(a) Calculate the resultant force on the trolley and also on the skateboard.

(b) Calculate the resultant force on each kilogram for the trolley and the skateboard.

(c) If the trolley and the skateboard were in a race with these forces, which would pull away from the start line more rapidly?

The acceleration of an object in m/s^2 is given by the resultant force per kilogram (in N/kg) on the object.

2 A 200 N force pulls a 25 kg trolley.

(a) Force on each kilogram $=$ ☐ $\div$ ☐ $=$ ☐ newtons

(b) Complete the sentence: The acceleration (in m/s^2) is ☐.

(c) A 4 kg cat uses a 20 N force to speed up. Work out the acceleration using an equation.

force (N)	$=$	mass (kg)	$\times$	acceleration (m/s^2)
20	$=$	4	$\times$	

(d) Work out the acceleration when 80 N of weight pulls a dropped 8 kg sandbag.

(e) Work out the acceleration when 5 N of weight pulls a dropped 0.5 kg lump of cheese.

3 Model cars in a competition need to accelerate at 8 m/s^2.

(a) Complete: The force on each kilogram needs to be ☐ newtons.

(b) Work out the force needed on a 2 kg model using an equation.

force (N)	=	mass (kg)	×	acceleration (m/s^2)
☐	=	2	×	8

(c) Work out the force needed on a 0.4 kg model using an equation.

force (N)	=	mass (kg)	×	acceleration (m/s^2)
☐	=	0.4	×	8

(d) Work out the force needed for a 100 g car. $(1000 \text{ g} = 1 \text{ kg})$

---

4 A bottle in a space station accelerates at 3 m/s^2 when an astronaut pushes it.

(a) What is the force on each kilogram of the bottle?

(b) The astronaut pushed the bottle with a 6 N force. How many 3 N forces is this?

(c) What is the mass of the bottle? (Each 3 N force acts on 1 kg.)

(d) Work out the mass if 45 N causes a 5 m/s^2 acceleration using an equation.

force (N)	=	mass (kg)	×	acceleration (m/s^2)
45	=	☐	×	5

(e) Work out the mass if 63 N causes a 7 m/s^2 acceleration.

---

5 Complete the word equations using **acceleration**, **resultant force** and **mass**.

(a) acceleration $=$ (b) resultant force $=$ (c) mass $=$

---

6 Rewrite your word equations using symbols.
a is the acceleration, F is the resultant force and m is the mass.

(a) $a =$ (b) $F =$ (c) $m =$

7 Use your understanding of force and acceleration (including the equations) to calculate

(a) The resultant force needed to give a 200 kg pony a 2 m/s^2 acceleration.

(b) The acceleration when a $20\,000$ kg bus is driven with a $10\,000$ N resultant force.

(c) The mass of a melon if a 3 N force gives it a 6 m/s^2 acceleration.

---

8 A 1.6 kg computer is pulled with a 4 N force across a desk where there is 1.6 N of friction.

(a) Calculate the resultant force on the computer.

(b) Calculate the acceleration of the computer.

---

9 Calculate the acceleration of

(a) A 40 kg trolley pushed by 100 N against 80 N of friction.

(b) A 60 kg swimmer pushing forward with 200 N against 120 N of drag.

---

10 A 0.3 kg firework needs to accelerate upwards at 80 m/s^2. As it rises there is a combined downwards force of 9 N acting on it from its weight and the drag.

(a) Calculate the resultant force from the acceleration and mass.

(b) Calculate the upwards propulsion force needed to achieve this resultant force.

---

11 A $300\,000$ kg train takes 80 s to get to its top speed of 100 m/s on a flat track. On average, there is a combined friction and air resistance force of 50 kN = $50\,000$ N. Calculate

(a) the acceleration needed. Remember: acceleration $=$ velocity change $\div$ time taken.

(b) the resultant force.

(c) the force required from the engine.