# Force and change in momentum

Worked solutions

**GCSE science calculations**

This topic online

**1** **Higher tier**

A trolley of mass 2.0 kg is pushed along a bench. Its velocity changes by 3.0 m/s in 0.50 s.

Calculate the resultant force on the trolley. (2 marks)

Force = mass x change in velocity ÷ time taken

$$F = \frac{2.0 \times 3.0}{0.50}$$

$$F = 6.0 \div 0.50$$

**12 N**

**2** **Higher tier**

Leah takes a penalty in a five-a-side football match. The ball has a mass of 0.45 kg and starts at rest. It leaves her boot at 24 m/s. Her boot is in contact with the ball for 0.010 s.

Calculate the average force of the boot on the ball. (2 marks)

Force = mass x change in velocity ÷ time taken

$$\Delta v = 24 - 0 = 24 \text{ m/s}$$

$$F = \frac{0.45 \times 24}{0.010}$$

$$F = 10.8 \div 0.010$$

**1080 N**

**3** **Higher tier**

A rowing boat is pushed away from a jetty. The change in momentum of the boat is 36 kg m/s. The push lasts for 0.15 s.

Calculate the average force on the boat. (2 marks)

Force = change in momentum ÷ time taken

$$F = 36 \div 0.15$$

**240 N**


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**4** **Higher tier**

A fielder catches a cricket ball of mass 0.16 kg. The ball is moving at 30 m/s and is brought to rest in 20 ms.

Calculate the average force on the ball. (3 marks)

Convert ms to s: 1 s = 1000 ms

$\Delta t = 20 \div 1000 = 0.020$ s

Force = mass x change in velocity ÷ time taken

$$F = \frac{0.16 \times 30}{0.020}$$

$F = 4.8 \div 0.020$

**240 N**

**5** **Higher tier**

Mohammed hits a golf ball off a tee at a driving range. The ball has a mass of 46 g. It starts at rest and leaves the club at 65 m/s. The club is in contact with the ball for 0.50 ms.

Calculate the average force of the club on the ball. (3 marks)

Convert g to kg: 1 kg = 1000 g

$m = 46 \div 1000 = 0.046$ kg

Convert ms to s: 1 s = 1000 ms

$\Delta t = 0.50 \div 1000 = 0.0005$ s

Force = mass x change in velocity ÷ time taken

$$F = \frac{0.046 \times 65}{0.0005}$$

$F = 2.99 \div 0.0005$

**5980 N**


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**6** **Higher tier**

In a safety test, a car of mass 1500 kg travelling at 54 km/h drives into a crash barrier filled with water. The car is brought to rest in 0.25 s.

1 m/s = 3.6 km/h

Calculate the average force of the barrier on the car. (3 marks)

Convert km/h to m/s: divide by 3.6

$v = 54 \div 3.6 = 15$ m/s

Force = mass x change in velocity ÷ time taken

$$F = \frac{1500 \times 15}{0.25}$$

$F = 22\,500 \div 0.25$

**90 000 N**

**7** **Higher tier**

A gymnast of mass 50 kg jumps off a vaulting box that is 1.8 m high. She lands on a crash mat at 6.0 m/s and is brought to rest. While the mat stops her, the average resultant force on her is 1500 N.

Calculate the time it takes the mat to stop her. (3 marks)

The landing speed is given, so the 1.8 m height is not needed

Force = mass x change in velocity ÷ time taken

$$1500 = \frac{50 \times 6.0}{\Delta t}$$

$1500 \times \Delta t = 300$

$\Delta t = 300 \div 1500$

**0.2 s**


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**8** **Higher tier**

A dynamics trolley of mass 0.80 kg is at rest on a level track. A constant resultant force of 4.0 N acts on it for 1.5 s.

Calculate the velocity of the trolley at the end of the 1.5 s. (3 marks)

Force = mass x change in velocity ÷ time taken

$$4.0 = \frac{0.80 \times \Delta v}{1.5}$$

$$4.0 \times 1.5 = 0.80 \times \Delta v$$

$$6.0 = 0.80 \times \Delta v$$

$$\Delta v = 6.0 \div 0.80 = 7.5 \text{ m/s}$$

It started at rest, so final velocity = change in velocity

**7.5 m/s**

**9** **Higher tier**

A railway wagon rolls into the buffers at the end of a siding at 2.0 m/s. The buffers bring it to rest in 1.6 s with an average force of 25 000 N.

Calculate the mass of the wagon. (3 marks)

Force = mass x change in velocity ÷ time taken

$$25\,000 = \frac{m \times 2.0}{1.6}$$

$$25\,000 \times 1.6 = m \times 2.0$$

$$40\,000 = m \times 2.0$$

$$m = 40\,000 \div 2.0$$

**20 000 kg**


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**10** **Higher tier**

Kwame throws a tennis ball of mass 0.060 kg at a brick wall. The ball hits the wall at 12 m/s and bounces straight back at 8.0 m/s. The ball is in contact with the wall for 15 ms.

Calculate the average force of the wall on the ball. Show your working. (4 marks)

The ball changes direction. Take away from the wall as positive, so the velocity changes from -12 m/s to +8.0 m/s

$\Delta v = 8.0 - (-12)$

$\Delta v = 20 \text{ m/s}$

Convert ms to s: 1 s = 1000 ms

$\Delta t = 15 \div 1000 = 0.015 \text{ s}$

Force = mass x change in velocity ÷ time taken

$$F = \frac{0.060 \times 20}{0.015}$$

$F = 1.2 \div 0.015$

**80 N**


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**11** **Higher tier**

Engineers test a cycle helmet with a model head. The cyclist and bike together have a mass of 85 kg. The model head has a mass of 4.5 kg.

In each test the model head hits the ground at 6.0 m/s and is brought to rest.

- Without a helmet the head stops in 3.0 ms.
- With the helmet the head stops in 12 ms.

a. Calculate the average force on the head without a helmet.

b. Calculate the average force on the head with the helmet.

c. How many times smaller is the force with the helmet? Show your working.

(5 marks)

Only the head is stopped, so use m = 4.5 kg, not 85 kg

a)

Convert ms to s: 1 s = 1000 ms

$\Delta t = 3.0 \div 1000 = 0.003$ s

Force = mass x change in velocity ÷ time taken

$$F = \frac{4.5 \times 6.0}{0.003}$$

$F = 27 \div 0.003$

**9000 N**

b)

$\Delta t = 12 \div 1000 = 0.012$ s

$$F = \frac{4.5 \times 6.0}{0.012}$$

$F = 27 \div 0.012$

**2250 N**

c)

$9000 \div 2250 = 4$

**4 times smaller**


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**12** **Higher tier**

Isla drops a basketball of mass 620 g from rest. It falls 1.6 m to the floor. Air resistance can be ignored and the acceleration of the ball as it falls is 9.8 $m/s^2$.

The ball bounces straight back up at 4.2 m/s. It is in contact with the floor for 18 ms.

a. Calculate the speed of the ball just before it hits the floor.

b. Calculate the average force of the floor on the ball. Give your answer to 2 significant figures. Show your working.

(5 marks)

a)

$v^2 - u^2 = 2as$, starting from rest so $u = 0$

$v^2 - 0^2 = 2 \times 9.8 \times 1.6$

$v^2 = 31.36$

Take the square root

$v = \sqrt{31.36}$

**5.6 m/s**

b)

The ball changes direction. Take upwards as positive, so the velocity changes from -5.6 m/s to +4.2 m/s

$\Delta v = 4.2 - (-5.6) = 9.8$ m/s

Convert g to kg and ms to s

$m = 620 \div 1000 = 0.62$ kg

$\Delta t = 18 \div 1000 = 0.018$ s

Force = mass x change in velocity ÷ time taken

$$F = \frac{0.62 \times 9.8}{0.018}$$

$F = 337.55...$ N

**340 N**


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