Summary of key points

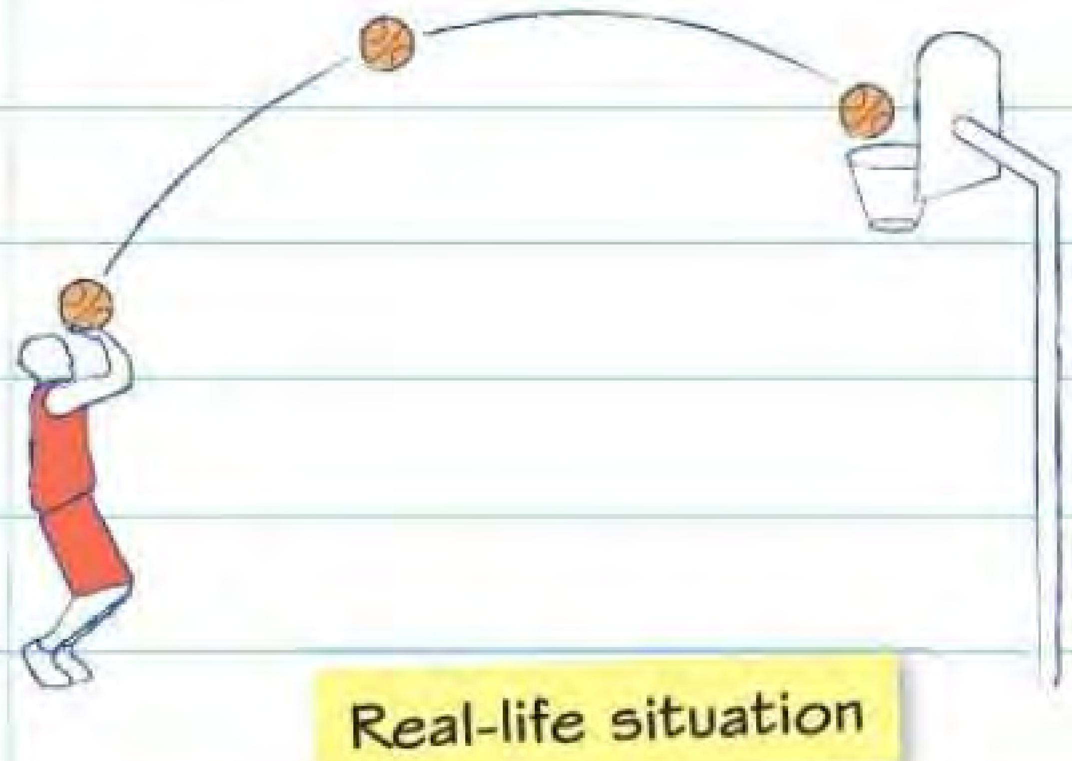
1. Mathematical models can be constructed to simulate real-life situations.
2. Modelling assumptions can be used to simplify your calculations.
3. The base SI units most commonly used in mechanics are:

Quantity	Unit	Symbol
Mass	kilogram	kg
Length/displacement	metre	m
Time	second	s

4. A vector is a quantity which has both magnitude and direction.
5. A scalar quantity has magnitude only.
6. Distance is the magnitude of the displacement vector.
7. Speed is the magnitude of the velocity vector.

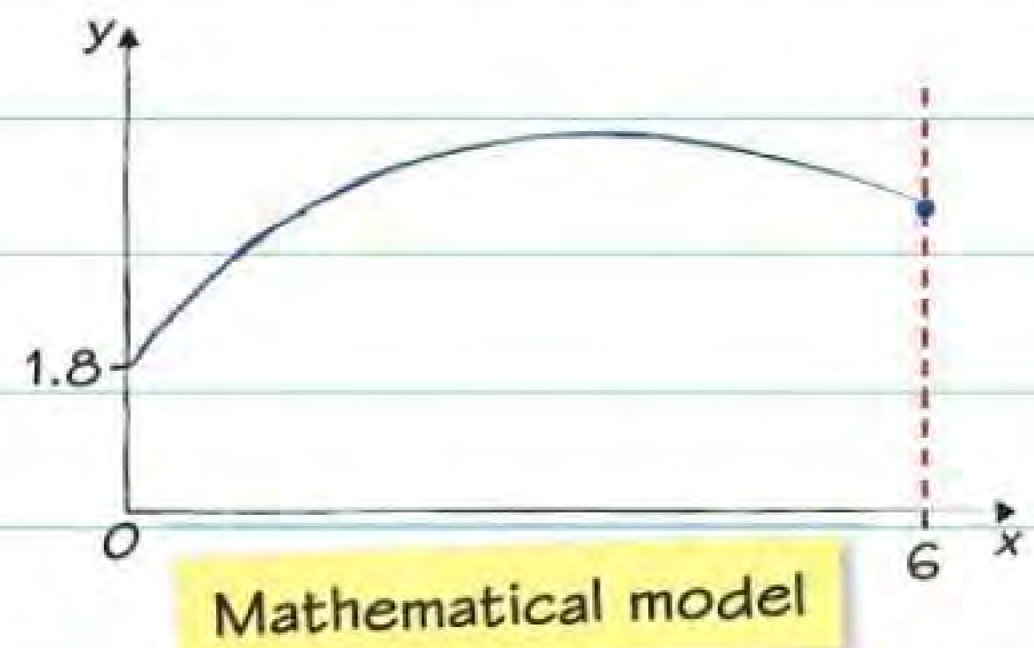
Modelling in mechanics

You can use a model to describe a problem mathematically. The model will make certain **assumptions** about the real-life situation to simplify the calculations. You might need to criticise or refine a model, and you should always interpret the model in the **context** given. This model shows the path of a basketball being thrown towards a hoop:



Real-life situation

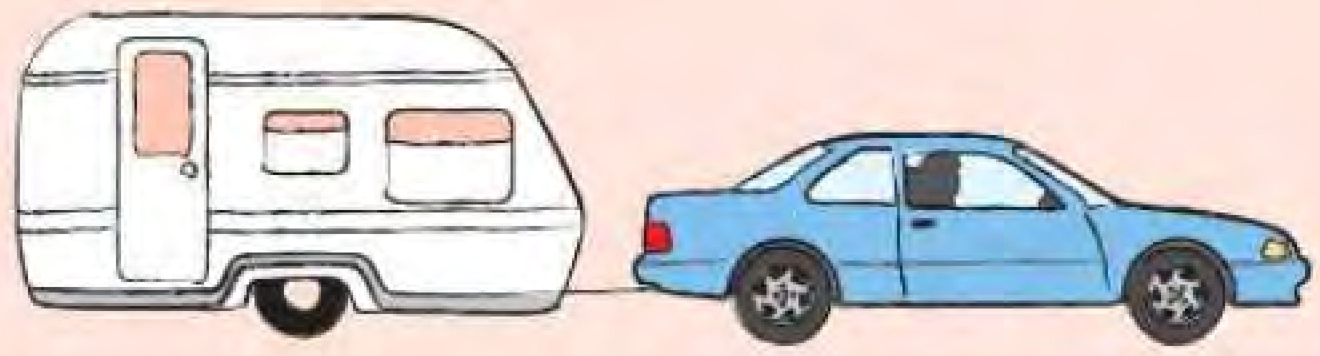
$y = -0.3x^2 + 2.1x + 1.8,\ 0 \leqslant x \leqslant 6$



Mathematical model

The model is only **valid** for certain values of x. The ball leaves the player's hand at $x = 0$ and hits the hoop at $x = 6$.

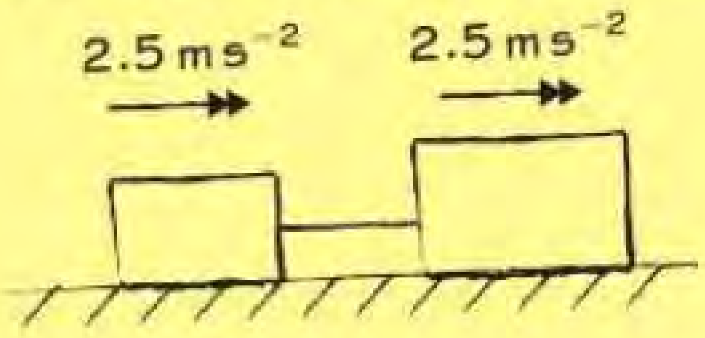
Worked example



The diagram shows a car pulling a caravan. The car is attached to the caravan by a light, inextensible tow-bar. The caravan and car accelerate together at $2.5\,\text{m s}^{-2}$. State how you can use the assumption that the tow-bar is inextensible. **(1 mark)**

The caravan and car will have the same acceleration.

An **inextensible** tow-bar, string or rod only affects **acceleration**. Don't talk about the tension in the tow-bar in your answer.



Motion under gravity

When an object moves freely under gravity, you ignore **air resistance**. This means the acceleration is **constant**. You also model objects as **particles**, so their weight acts at a single point. In your AS exam, you are also assuming that the motion is **vertical**.

Pulleys and strings

Learn these three modelling facts for questions involving pulleys.

1. The pulley is **smooth** – the magnitude of the **tension** in the string will be the same on both sides of the pulley.
2. The string is **inextensible** – the magnitude of the **acceleration** will be the same for both particles.
3. The string is **light** – you can **ignore** the **weight** of the string in any calculations.

Now try this

A block P of mass 0.8 kg is accelerating along a smooth horizontal table top. It is attached to a block Q of mass 0.1 kg by means of a light inextensible string running over a smooth pulley. P and Q are modelled as particles. State how you can use in your calculations the modelling assumptions that:

(a) the table top is smooth Answer
(b) P and Q are modelled as particles Answer
(c) the string is inextensible Answer
(d) the string is light Answer
(e) the pulley is smooth. Answer **(5 marks)**

8.3 Quantities and units

The International System of Units, (abbreviated **SI** from the French, Système international d'unités) is the modern form of the metric system. These **base** SI units are most commonly used in mechanics.

Quantity	**Unit**	**Symbol**
Mass	kilogram	kg
Length/displacement	metre	m
Time	seconds	s

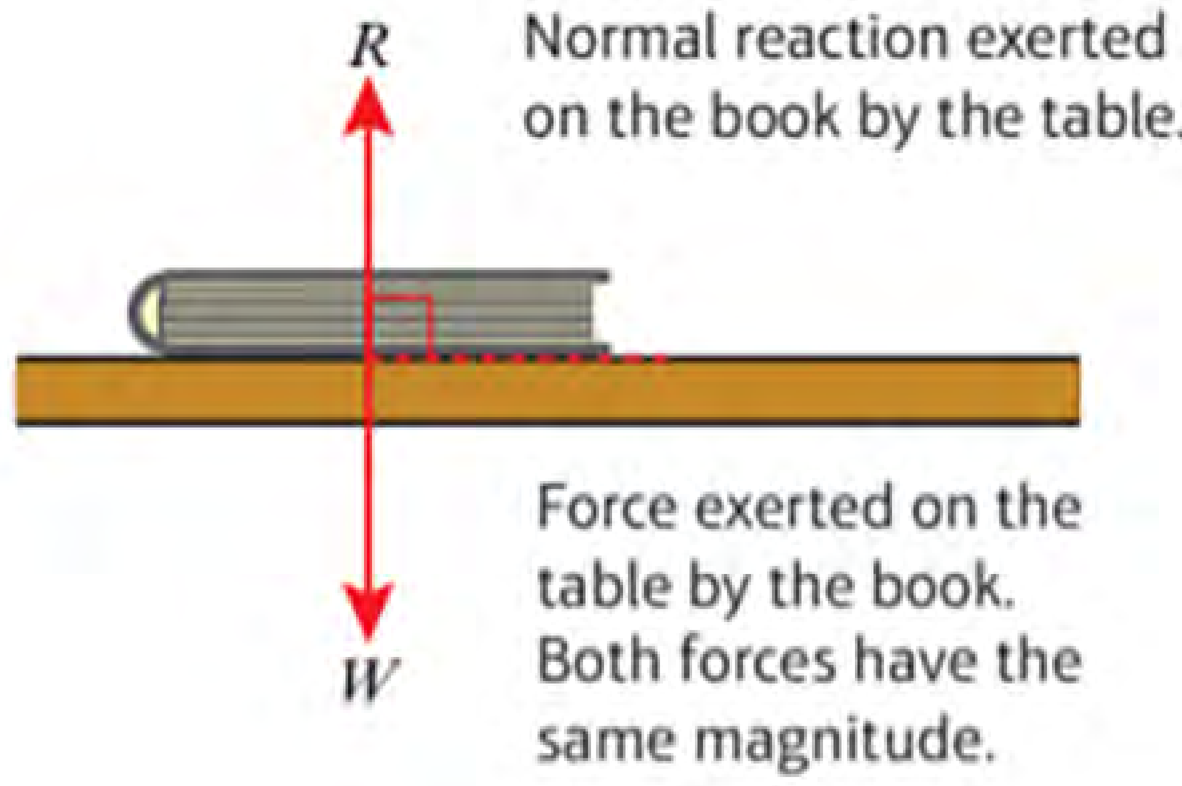
Watch out

A common misconception is that kilograms measure weight not mass. However, **weight** is a **force** which is measured in **newtons (N)**.

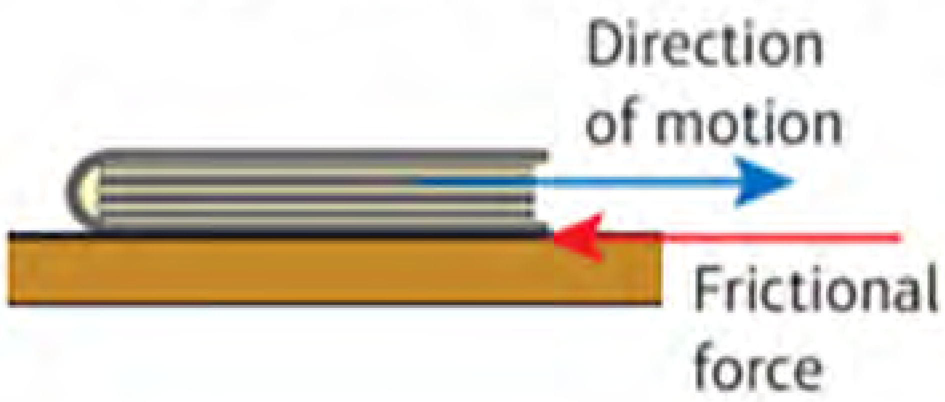
These **derived** units are compound units built from the base units.

Quantity	**Unit**	**Symbol**
Speed/velocity	metres per second	$m\,s^{-1}$
Acceleration	metres per second per second	$m\,s^{-2}$
Weight/force	newton	N (= $kg\,m\,s^{-2}$)

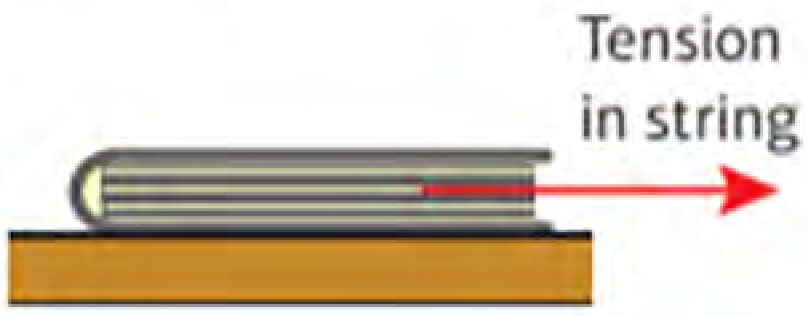
You will encounter a variety of forces in mechanics. These **force diagrams** show some of the most common forces.



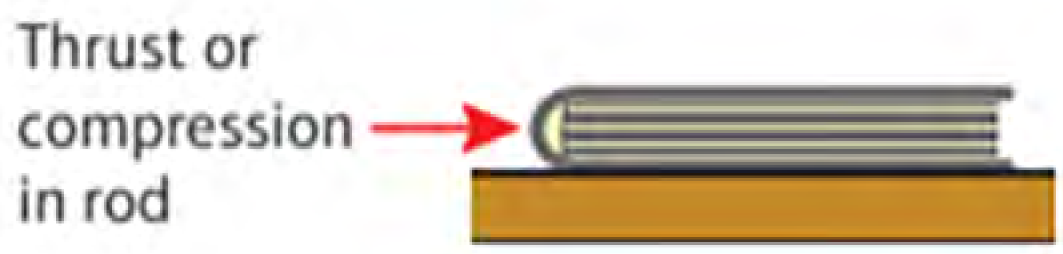
- The **weight** (or gravitational force) of an object acts vertically downwards.
- The **normal reaction** is the force which acts perpendicular to a surface when an object is in contact with the surface. In this example the normal reaction is due to the weight of the book resting on the surface of the table.
- The **friction** is a force which opposes the motion between two rough surfaces.



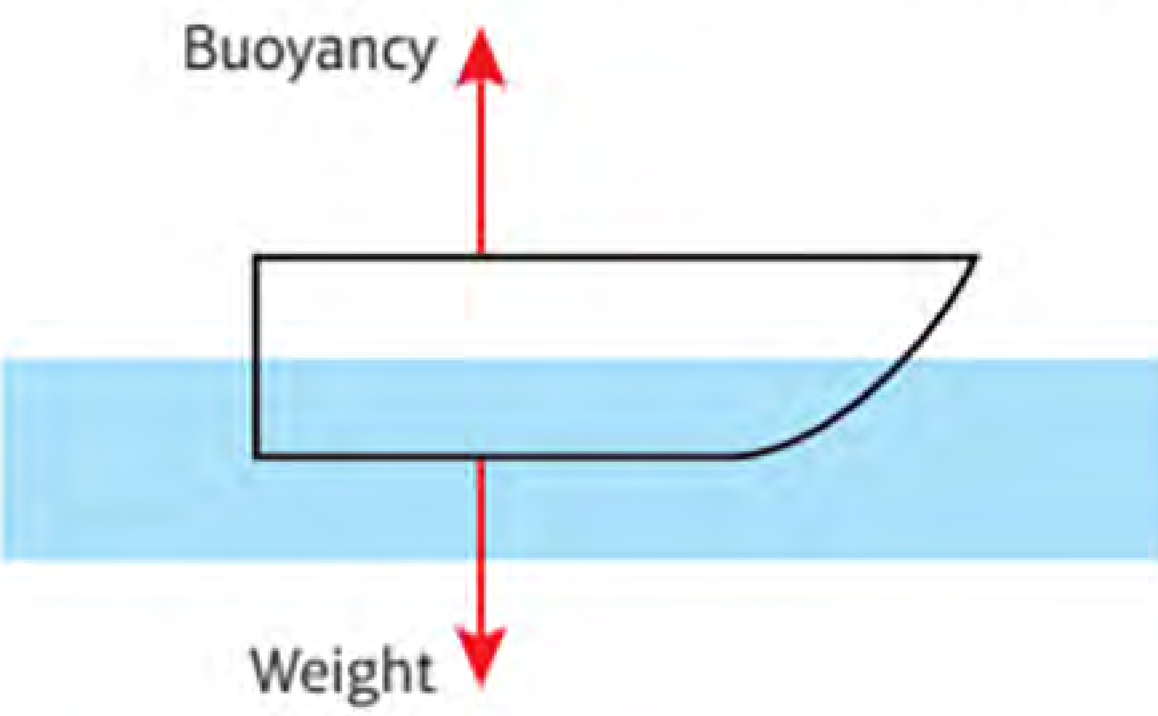
- If an object is being pulled along by a string, the force acting on the object is called the **tension** in the string.



- If an object is being pushed along using a light rod, the force acting on the object is called the **thrust** or **compression** in the rod.



- **Buoyancy** is the upward force on a body that allows it to float or rise when submerged in a liquid. In this example buoyancy acts to keep the boat afloat in the water.



- **Air resistance** opposes motion. In this example the weight of the parachutist acts vertically downwards and the air resistance acts vertically upwards.

Example 3

Write the following quantities in SI units.

a 4 km **b** 0.32 grams **c** 5.1×10^6 km h^{-1}

a 4 km = 4 × 1000 = 4000 m

The SI unit of length is the metre and 1 km = 1000 m.

b 0.32 g = 0.32 ÷ 1000 = 3.2×10^{-4} kg

The SI unit of weight is the kg and 1 kg = 1000 g. The answer is given in standard form.

c 5.1×10^6 km h^{-1} = $5.1 \times 10^6 \times 1000$
= 5.1×10^9 m h^{-1}

The SI unit of speed is m s^{-1}. Convert from km h^{-1} to m h^{-1} by multiplying by 1000.

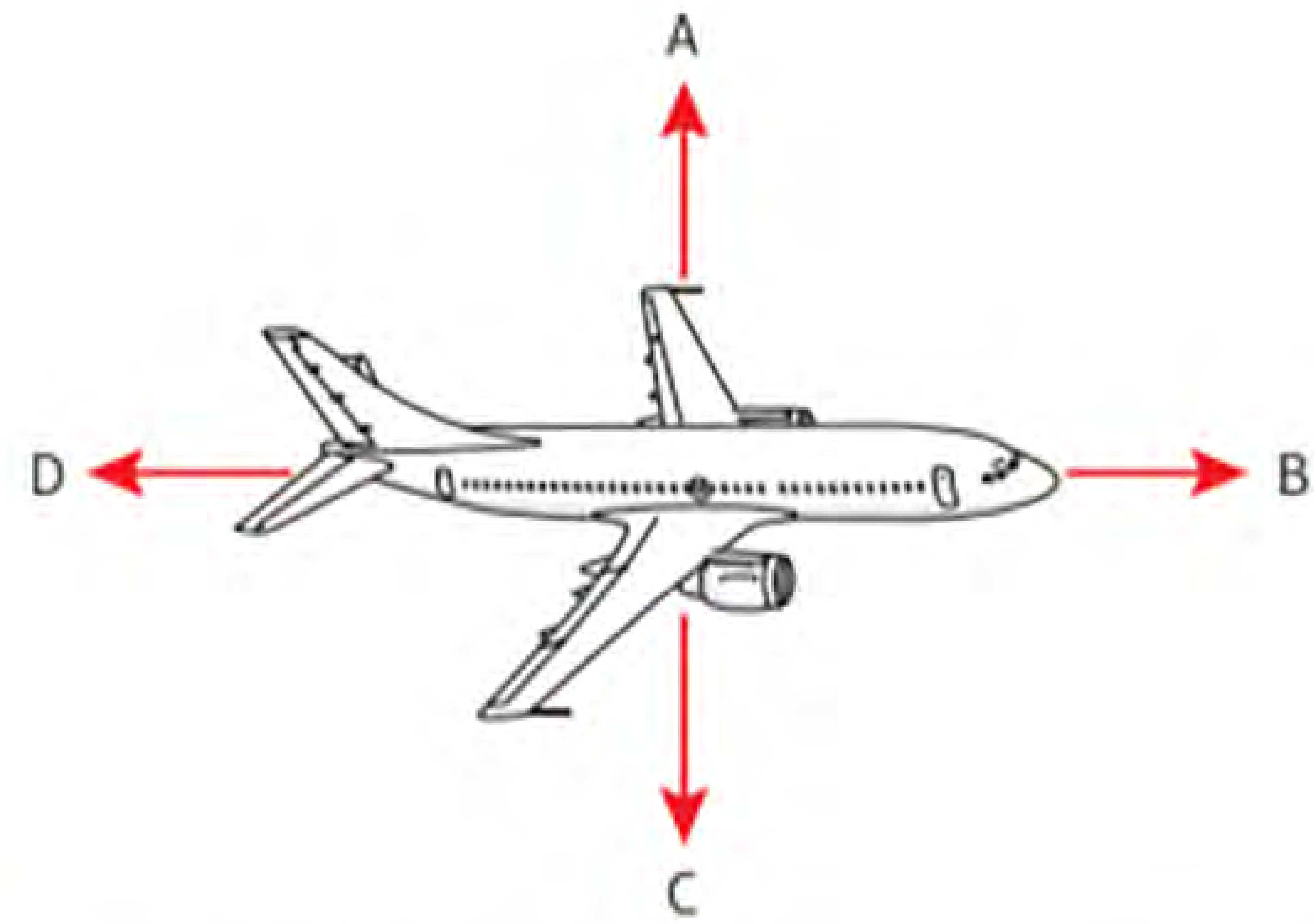
$5.1 \times 10^9 \div (60 \times 60) = 1.42 \times 10^6$ m s^{-1}

Convert from m h^{-1} to m s^{-1} by dividing by 60 × 60. The answer is given in standard form to 3 s.f.

Example 4

The force diagram shows an aircraft in flight.

Write down the names of the four forces shown on the diagram.



A upward thrust — Also known as 'lift', this is the upward force that keeps the aircraft up in the air.

B forward thrust — Also known as 'thrust', this is the force that propels the aircraft forward.

C weight — This is the gravitational force acting downwards on the aircraft.

D air resistance — Also known as 'drag', this is the force that acts in the opposite direction to the forward thrust.

Exercise 8C

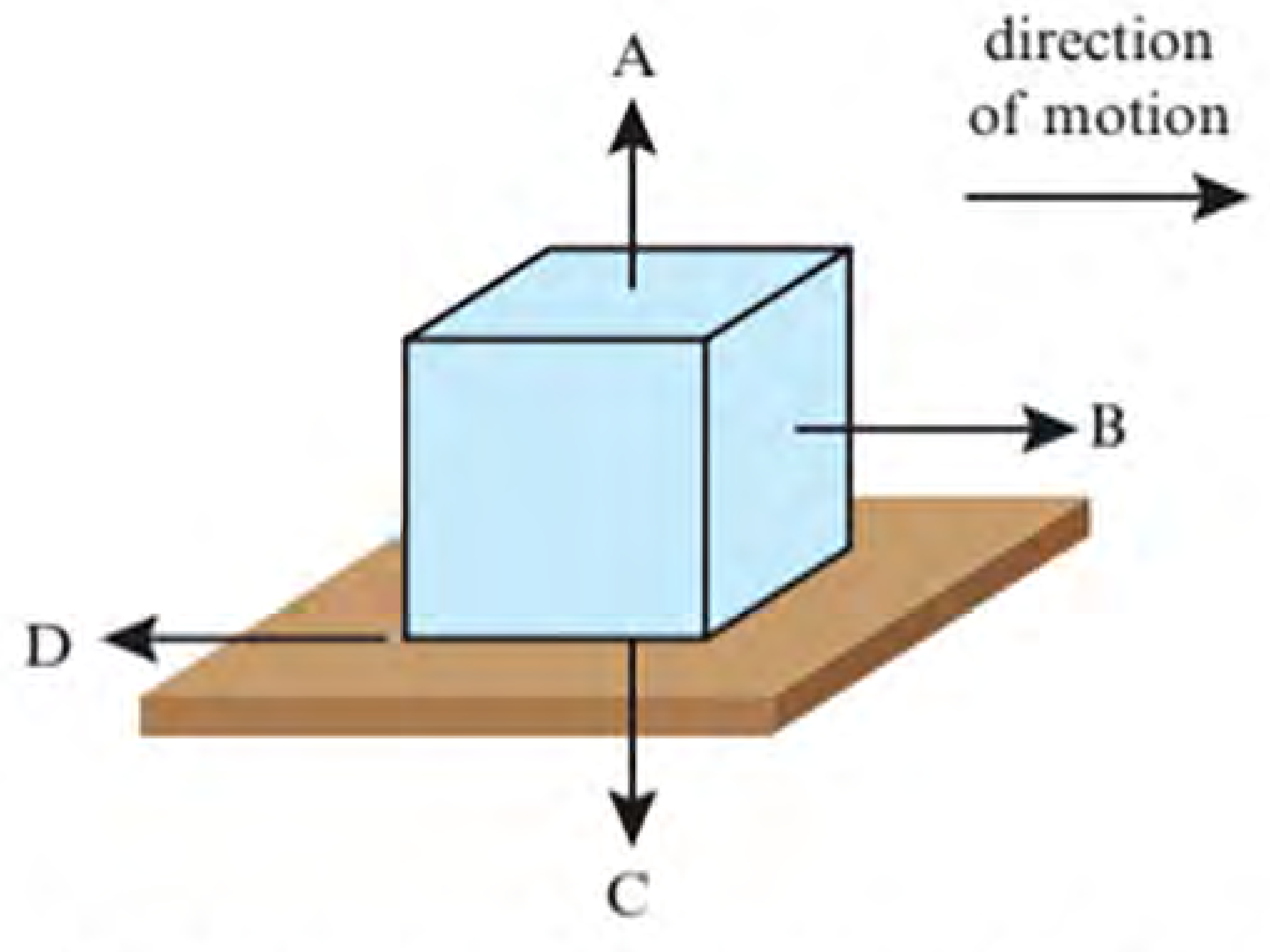
1 Convert to SI units:

a $65\ \text{km h}^{-1}$ b $15\ \text{g cm}^{-2}$ c 30 cm per minute

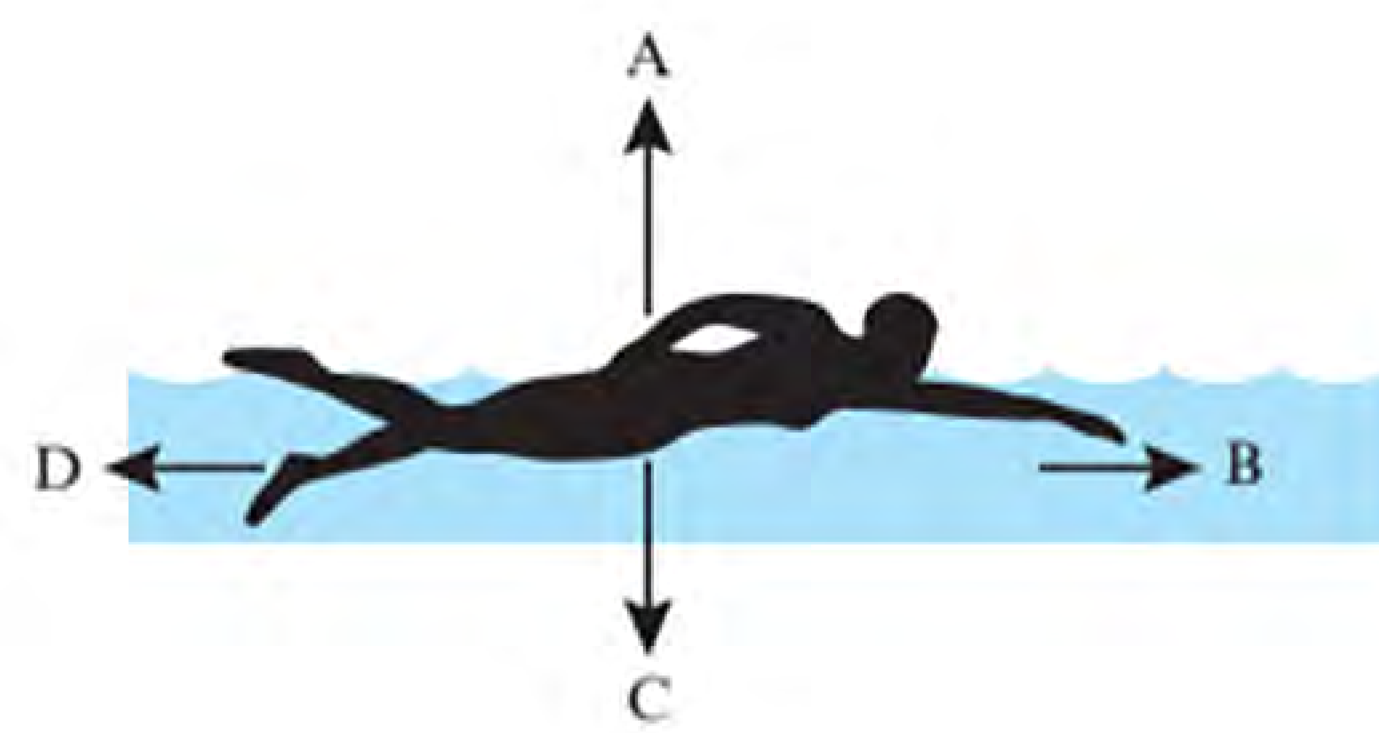
d $24\ \text{g m}^{-3}$ e $4.5 \times 10^{-2}\ \text{g cm}^{-3}$ f $6.3 \times 10^{-3}\ \text{kg cm}^{-2}$

2 Write down the names of the forces shown in each of these diagrams.

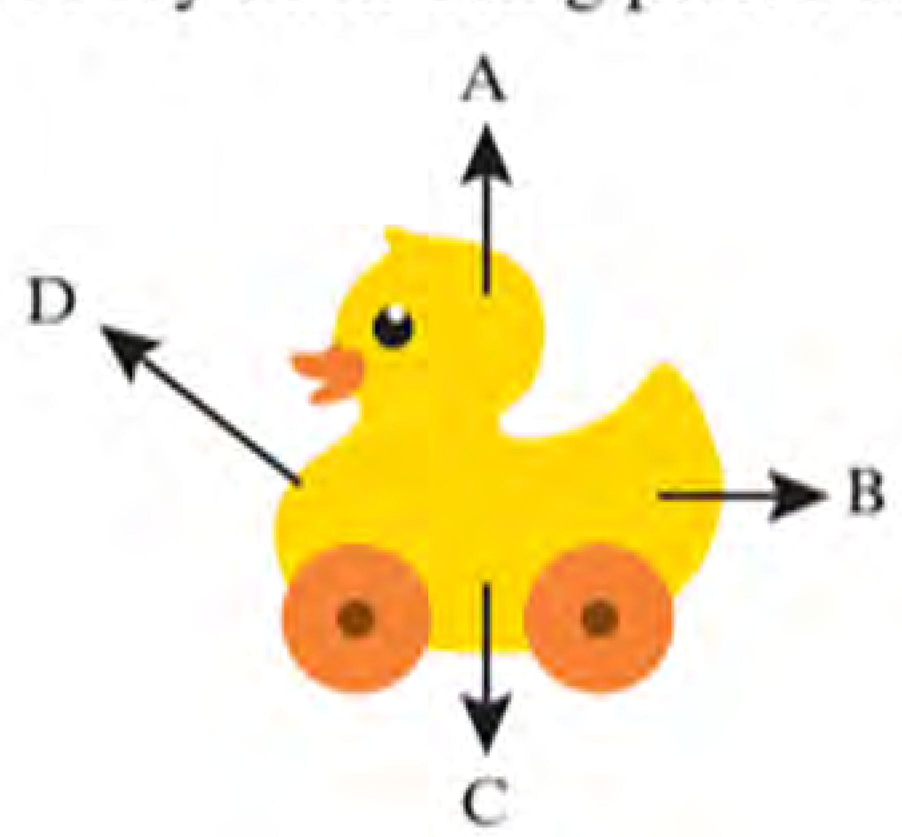
a A box being pushed along rough ground



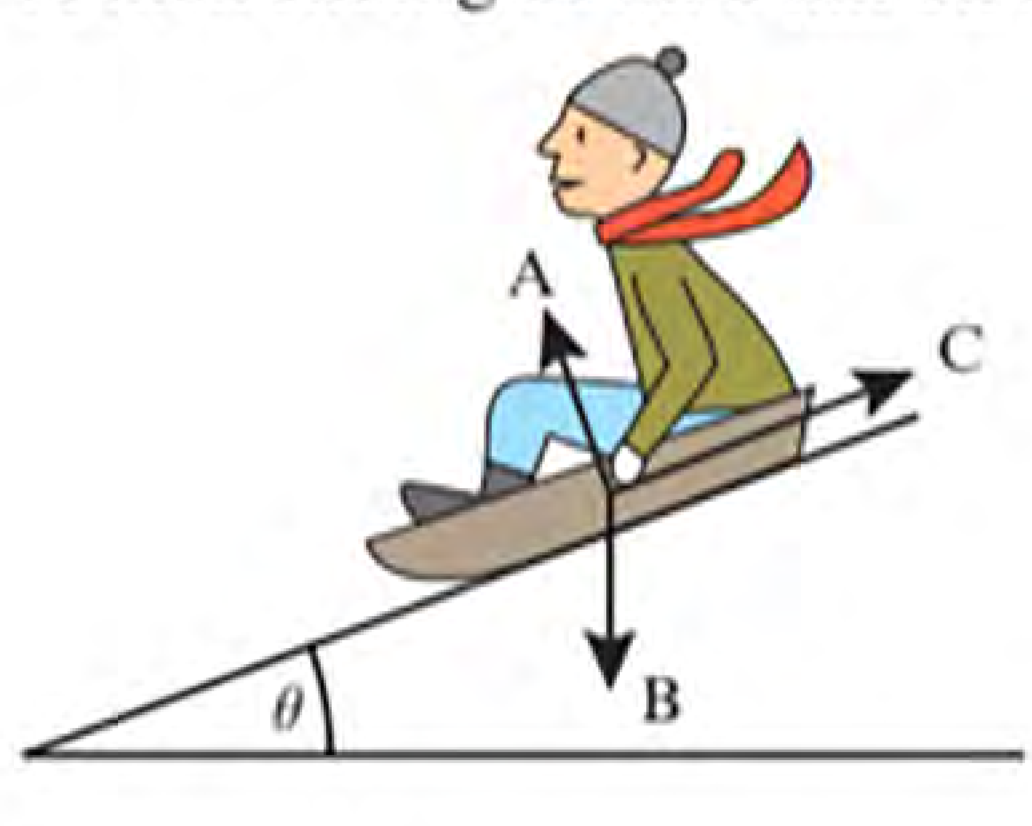
b A man swimming through the water



c A toy duck being pulled along by a string



d A man sliding down a hill on a sledge



8.4 Working with vectors

- **A vector is a quantity which has both magnitude and direction.**

These are examples of **vector** quantities.

Quantity	Description	Unit
Displacement	distance in a particular direction	metre (m)
Velocity	rate of change of displacement	metres per second ($m\ s^{-1}$)
Acceleration	rate of change of velocity	metres per second per second ($m\ s^{-2}$)
Force/weight	described by magnitude, direction and point of application	newton (N)

- **A scalar quantity has magnitude only.**

These are examples of **scalar** quantities.

Quantity	Description	Unit
Distance	measure of length	metre (m)
Speed	measure of how quickly a body moves	metres per second ($m\ s^{-1}$)
Time	measure of ongoing events taking place	second (s)
Mass	measure of the quantity of matter contained in an object	kilogram (kg)

Scalar quantities are always **positive**. When considering motion in a straight line (1-dimensional motion), **vector** quantities can be **positive** or **negative**.