Isaac Essential Physics

Step up to GCSE Physics

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Isaac Physics Project

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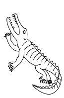
Use this collection of worksheets in parallel with the electronic version at http://isaacphysics.org/books/step_up_phys. Marking of answers and compilation of results is free on Isaac Physics. Register as a student or as a teacher to gain full functionality and support.

 used with kind permission of M. J. Rutter.

Note for the Student

Physics is the part of Science which uses maths the most. Most physics ideas can be written down as equations more easily than they can be written down in words. The courses you study later (like GCSE) will require you to use many equations to solve problems.

In each two-page section, an idea is explained. You then have a worked example and then a set of questions to answer. Practising the questions will build your confidence. You can then make a flying start to GCSE.

Note for the Teacher

The material in this book builds on concepts which have already been introduced to students in a qualitative fashion. This book places these ideas on a more mathematical footing.

Students, teachers and schools are welcome to use this material with students prior to beginning formal GCSE (or equivalent) programmes of study to provide a good foundation. Equally, it may be used alongside other resources as the early parts of GCSE courses are taught. It also has a role as extension and challenge material for younger pupils, and can be used as a bank of practice material for older students needing to gain confidence.

All questions are also available at `http://isaacphysics.org/books/step_up_phys`. Teachers may set questions to their classes and monitor progress. Equally, students completing questions on the website receive immediate feedback on their answers. A pdf version of the notes without the red text is available at `http://isaacphysics.org/books/step_up_phys` for projection in class during class discussion.

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ACM, Cambridge, 2021

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Force and Motion

1 Displacement

Displacement s measures the location of something.
When something moves its displacement changes.
In our questions, the direction of a displacement is given by its sign:

$+$ means 'on the right'
$-$ means 'on the left'

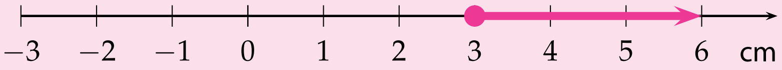
If the change of displacement is positive, the object is moving to the right.
If the change is negative, the object is moving to the left.

Δ (delta) means change in.

$$\text{Change in displacement } (\Delta s) = s_{\text{final}} - s_{\text{starting}}$$

If it ends up back at the starting point, the total displacement is zero. The total distance travelled will not be zero if it moved.

Example 1 – *Calculate the change in displacement for the motion shown below. State the distance travelled.*



Object moved from $s_{\text{starting}} = +3$ cm to $s_{\text{final}} = +6$ cm,
Change in displacement $\Delta s = 6$ cm $- 3$ cm $= +3$ cm
Distance moved $= 3$ cm

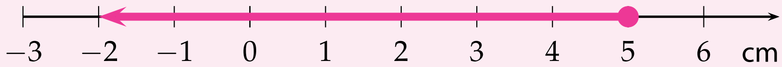
Example 2 – *An object moves directly from $s = +3$ cm to $s = -5$ cm. Calculate the change in displacement. State the distance travelled.*
Change in displacement $\Delta s = -5$ cm $- (3$ cm$) = -8$ cm
Distance moved $= 8$ cm

1.1 Calculate the change in displacement when an object moves from $s = +1$ cm to $s = +7$ cm. State the distance travelled.

1.2 Calculate the change in displacement when an object moves from $s = +4$ cm to $s = -3$ cm. State the distance travelled.

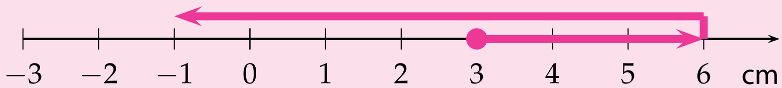
1.3 Where does something end up if $s_{\text{starting}} = -1$ cm and $\Delta s = +6$ cm?

1.4 Calculate the change in displacement for the motion shown below. State the distance travelled.



1.5 An object moved 10 cm to the right, and ended up at $s = 3$ cm. Where did it start?

Example 3 – *Calculate the change in displacement for the two-stage motion shown below. State the distance travelled.*



Starting position $s_{\text{starting}} = 3$ cm, final position $s_{\text{final}} = -1$ cm
Change in displacement $\Delta s = (-1 \text{ cm}) - 3 \text{ cm} = -4$ cm
Distance moved $= 3 \text{ cm} + 7 \text{ cm} = 10$ cm

1.6 Calculate the overall change in displacement if an object moves from $s = -2$ cm to $s = -8$ cm then to $s = +7$ cm.

1.7 Calculate the total distance travelled if an object moves from $s = +23$ cm to $s = +8$ cm then to $s = +18$ cm.

1.8 For motion from -2 cm to $+10$ cm, then to -1 cm, calculate the

(a) displacement change in the first stage of the motion,

(b) displacement change in the second stage of the motion,

(c) the overall displacement change.

(d) How are your last three answers related?

1.9 An ant starts at $s = +4$ cm. It has displacement changes of $\Delta s = +8$ cm, then $\Delta s = -20$ cm then $\Delta s = +12$ cm. Where does it end up?

1.10 A snail starts at $s = 0$ cm. It has displacement changes of $\Delta s = -9$ cm, then $\Delta s = +20$ cm then $\Delta s = -8$ cm. What extra displacement change would be needed to return it to its starting point?

2 Units of Distance

Distances can be measured in different units. To convert from one unit to another, you multiply or divide by a conversion factor.

Example 1 – *There are* 1.61 *km in one mile. What is* 5 *miles in km?*

$$\begin{aligned} 1.61\text{ km} &= 1.00\text{ miles} \\ &\qquad \text{multiply by } 5 \text{ on each side} \\ 5 \times 1.61\text{ km} &= 5.00\text{ miles} \\ 5\text{ miles} &= 5 \times 1.61\text{ km} = 8.05\text{ km} \end{aligned}$$

Example 2 – *There are* 1.61 *km in one mile. What is* 45 *km in miles?*

$$\begin{aligned} 1.61\text{ km} &= 1.00\text{ miles} \\ &\qquad \text{divide by } 1.61 \text{ on each side} \\ 1.00\text{ km} &= \frac{1.00\text{ miles}}{1.61} \\ &\qquad \text{multiply by } 45 \text{ on each side} \\ 45\text{ km} &= \frac{1.00\text{ miles}}{1.61} \times 45 = 28.0\text{ miles} \end{aligned}$$

The final line could be written

$$45.00\text{ km} = \frac{1.00\text{ miles}}{1.61\ \cancel{\text{km}}} \times 45\ \cancel{\text{km}}$$

The km units 'cancel out' on the right. If we wanted to convert miles to kilometres, we would multiply by $\dfrac{1.61\text{ km}}{1.00\text{ miles}}$.

2.1 There are 2.54 cm in one inch (1 in). Convert

(a) 141 cm into inches,

(b) 30.5 cm into inches,

(c) 12 inches into centimetres,

(d) 0.40 in into centimetres.

(e) How many inches are there in 100 cm?

2.2 Sailors and pilots use nautical miles. 1 nautical mile $= 1.85$ km

(a) Convert 62 nautical miles into km?

(b) Convert 94 km into nautical miles?

2.3 You buy a car and find that the speedometer is in km/hr (kilometres travelled each hour). To enable you to stay within the British speed limit of 30 mph (30 miles travelled each hour), work out how many km/hr are equivalent to 30 mph.

Example 3 – *Convert 14 miles into nautical miles?*

$$14 \text{ miles} = 14 \cancel{\text{miles}} \times \frac{1.61 \text{ km}}{1.00 \cancel{\text{miles}}} = 22.5 \text{ km}$$

$$22.5 \text{ km} = 22.5 \cancel{\text{km}} \times \frac{1.00 \text{ nautical miles}}{1.85 \cancel{\text{km}}} = 12.2 \text{ nautical miles}$$

This could be done in one stage (NM means nautical miles):

$$14 \cancel{\text{miles}} \times \frac{1.61 \cancel{\text{km}}}{1.00 \cancel{\text{miles}}} \times \frac{1.00 \text{ NM}}{1.85 \cancel{\text{km}}} = 12.2 \text{ NM}$$

2.4 Convert 43 nautical miles into miles.

2.5 A ship travels at 12 kt (that means 12 nautical miles each hour). How many miles does it travel each hour?

2.6 On a day when £1.00 is equivalent to €1.16, what is the price of a €15.50 calculator in British pounds?

Remember: 1 mm $= 0.001$ m, 1 cm $= 0.01$ m, 1 km $= 1000$ m

2.7 What is 287 cm in m?

2.8 What is 87 mm in m?

2.9 What is 32 nautical miles in m?

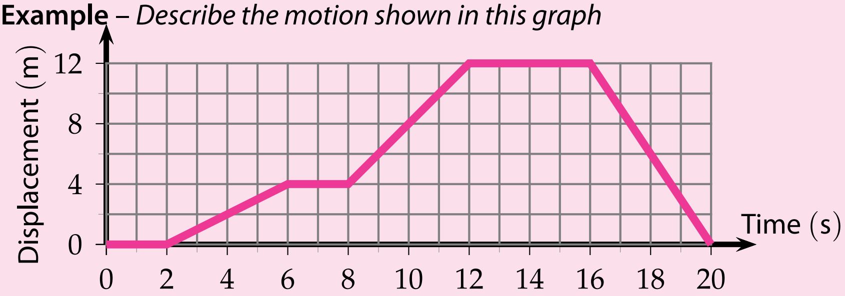
2.10 What is 0.001 miles in cm?

3 Displacement – time graphs

On a displacement – time graph, we show where something is at different times.

The displacement s is plotted on the y or vertical $\uparrow$ axis.
The time t is plotted on the x or horizontal $\rightarrow$ axis.
Straight lines represent motion at a steady (constant) speed.
Straight, horizontal lines represent times when the object is not moving.
The steeper the line, the faster the object.

Example – *Describe the motion shown in this graph*



The object remains stationary at $s = 0$ m for the first two seconds
The object starts moving at $t = 2$ s at a steady speed.
It reaches $s = 4$ m when $t = 6$ s.
It remains stationary for two more seconds (until $t = 8$ s).
It then starts moving at a steady speed.
It reaches $s = 12$ m four seconds later, at $t = 12$ s.
It stays there for 4 s, then reverses to its starting point at $t = 20$ s.

3.1 Answer these questions using the graph in the example.

(a) At what times was the object at $s = 6$ m?

(b) Where was the object at $t = 10$ s?

(c) For how many seconds was the object moving forwards?

(d) Work out the distance travelled.

(e) Calculate the displacement change between $t = 8$ s and 10 s.

(f) Was it moving faster at $t = 4$ s or at $t = 11$ s?

3.2 Make a graph with displacement from 0 to 4 km, and time from 0 to 20 min. Then draw the line for a person who sets out at $t = 0$ min. They walk 0.8 km before they reach a bus stop 8 min later. They wait until $t = 15$ min, then catch the bus. This takes them to town ($s = 4$ km) five minutes later.

In this next graph, the displacement s measures how far a lift (elevator) is above the ground floor of a building. The floors are 4 m apart.

3.3 Describe where the lift is when s is negative?

3.4 When is the lift moving upwards?

3.5 Where is the lift when $t = 6$ s? Give your answer as a value of s and also a floor number.

3.6 During which part of the motion is the lift fastest? How can you tell?

3.7 For how many seconds is the lift stationary?

3.8 When the lift is moving up only one floor (storey), how much time does it take?

3.9 When the lift is moving up only one floor (storey), how many metres does it move each second?

3.10 What is the change in displacement each second when the lift is moving downwards?

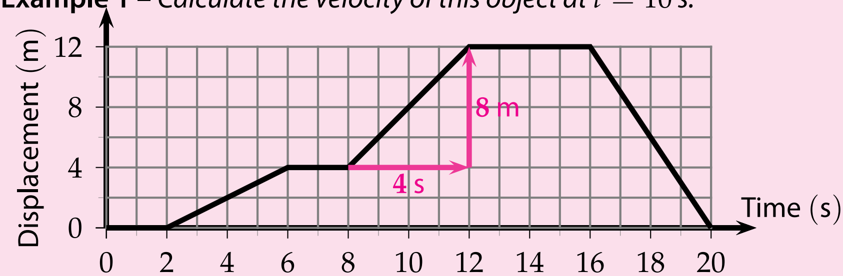
4 Velocity

The change in displacement Δs each second is called the velocity v. You can read off the Δs for one second on a straight part of a displacement – time graph.

You can also calculate the velocity by dividing the displacement change Δs by the time taken Δt. This gives the displacement change each second.

$$\text{Velocity (m/s)} = \frac{\text{Displacement change (m)}}{\text{Time taken (s)}}, \text{ or } v = \frac{\Delta s}{\Delta t}$$

Example 1 – *Calculate the velocity of this object at $t = 10$ s.*



10 s is part of a straight line between $t = 8$ s and $t = 12$ s.
The time taken $\Delta t = 12 - 8 = 4$ s.
The displacement change $\Delta s = 12 - 4 = +8$ m.
Velocity $v = \dfrac{\Delta s}{\Delta t} = \dfrac{+8\text{ m}}{4\text{ s}} = +2$ m/s.

The velocity is given by the gradient of the line on the displacement – time graph. Gradient is the change in the vertical $\uparrow$ co-ordinate divided by the change in the horizontal $\rightarrow$ co-ordinate.

4.1 In the graph above, calculate the velocity at
(a) $t = 4$ s?
(b) $t = 7$ s?
(c) $t = 18$ s?
(d) $t = 9$ s?

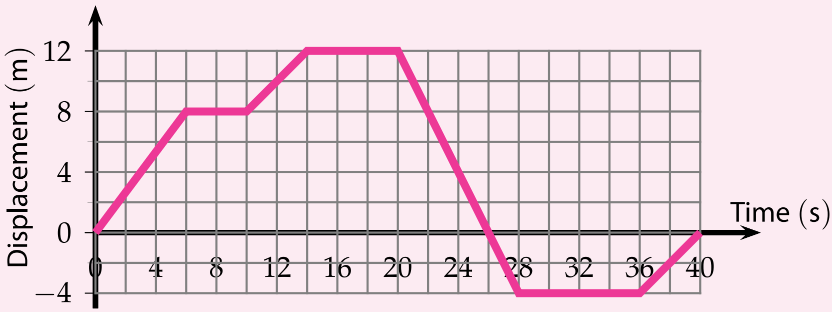
In our questions, the direction of a velocity is given by its sign:

$+$ means 'moving forwards' or 'moving upwards'
$-$ means 'moving backwards' or 'moving downwards'

The speed is the magnitude (size) of the velocity (without its direction). If $v = -3$ m/s, it means moving backwards, travelling 3 metres every second. The speed is just 3 m/s (without the $-$ sign).

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

Example 2 – *Calculate the average speed in the graph above.*
Total distance $=$ 12 m $+$ 12 m (there and back) $=$ 24 m
Total time $=$ 20 s, so Average speed $= \dfrac{24\text{ m}}{20\text{ s}} = 1.2$ m/s.



4.2 Calculate the velocity at
(a) $t = 4$ s,
(b) $t = 8$ s,
(c) $t = 12$ s,
(d) $t = 16$ s,
(e) $t = 22$ s,
(f) $t = 27$ s,
(g) $t = 30$ s,
(h) $t = 37$ s,

4.3 Calculate the speed at $t = 24$ s.

4.4 Calculate the total distance moved in the first 14 s of the motion.

4.5 Calculate the average speed in the first 14 s of the motion.

4.6 Calculate the average speed in the first 26 s of the motion.

4.7 Calculate the total distance moved in the motion shown.

4.8 Calculate the average speed over the whole graph.

5 Re-arranging equations

Many equations in Physics involve three quantities. On these pages, we practise re-arranging equations so that we can calculate what we need.

Let's use the equation $A = b \times c$, usually written $A = bc$

$$\text{If } b = 2 \text{ and } c = 5\text{, then } A = b \times c = 2 \times 5 = 10.$$

$$\text{We can get } c = 5 \text{ from } 5 = \frac{10}{2} \text{ so } c = \frac{A}{b}.$$

$$\text{We can get } b = 2 \text{ from } 2 = \frac{10}{5} \text{ so } b = \frac{A}{c}.$$

We can also use algebra:

$$\text{If } b = \frac{A}{c} \xrightarrow{\times c \text{ on both sides}} bc = \frac{A\cancel{c}}{\cancel{c}} \quad \text{then} \quad bc = A$$

and

$$\text{If } bc = A \xrightarrow{\div b \text{ on both sides}} \frac{\cancel{b}c}{\cancel{b}} = \frac{A}{b} \quad \text{then} \quad c = \frac{A}{b}.$$

Re-arrangement causes the quantities to cross the $=$ sign on a diagonal:

moving c in $b = \frac{A}{c}$ gives $bc = A$ moving b in $bc = A$ gives $c = \frac{A}{b}$

Example 1 – *If $B = fg$, write an equation for g.*

Dividing both sides by f gives $\frac{B}{f} = \frac{\cancel{f}g}{\cancel{f}} = g$, so $g = \frac{B}{f}$

5.1 In the following equations, write an equation for a.

(a) $b = ac$
(b) $q = ra$
(c) $d = av$
(d) $h = 2a$
(e) $v = au$
(f) $w = ra$
(g) $g = ac$
(h) $1 = na$

5.2 In the following equations, write an equation for v.

(a) $b = \frac{v}{c}$
(b) $w = \frac{v}{p}$

(c) $f = \frac{g}{v}$

(d) $t = \frac{v}{1}$

(e) $x = \frac{q}{v}$

(f) $z = \frac{1}{v}$

Example 2 – *If $y = kx$ and $y = 0.25$ when $x = 0.4$, calculate k.*

Rearrange $y = kx$ by dividing both sides by x: $\frac{y}{x} = k$

So $k = \frac{y}{x} = \frac{0.25}{0.4} = 0.625$

5.3 If $y = kx$ and $y = 6$ when $x = 2$, calculate k.

5.4 If $s = ut$ and $s = 32$ when $t = 8$, calculate u.

5.5 If $q = It$ and $q = 0.25$ when $t = 250$, calculate I.

5.6 If $a = \frac{v}{t}$ and $a = 10$ when $v = 5$, calculate t.

Example 3 – *If $y = kx$, and $y = 90$ when $x = 6$, calculate y when $x = 4$.*

Assume k does not change. Divide both sides by x to get $\frac{y}{x} = k$

so $k = \frac{90}{6} = 15$. Now use the new x. $y = kx = 15 \times 4 = 60$

5.7 If $s = ut$, and $s = 30$ when $t = 0.50$, calculate t when $s = 15$.

5.8 If $T = An$, and $A = 120$ when $n = 3$, calculate A when $n = 24$.

Example 4 – *If $\frac{a}{b} = \frac{c}{d}$ and $a = 2$, $b = 6$ and $c = 12$, calculate d?*

Multiply both sides by bd giving $ad = bc$. Now divide by a, so $d = \frac{bc}{a}$

Now put in the data to give $d = \frac{6 \times 12}{2} = 36$

5.9 If $\frac{r}{s} = \frac{u}{v}$, $r = 2.5$ and $v = 12$,

(a) calculate u if $s = 6$.

(b) calculate s if $u = 10$.

6 Calculating velocities

On page 7, we introduced the formula for velocity. This is the displacement change each second:

$$\text{Velocity (m/s)} = \frac{\text{Displacement change (m)}}{\text{Time taken (s)}}, \text{ or } v = \frac{\Delta s}{\Delta t}$$

Since the velocity is the displacement change each second, you can calculate the displacement change:

$$\text{Displacement change (m)} = \text{Velocity (m/s)} \times \text{Time taken (s)}, \text{ or } \Delta s = v\,\Delta t$$

The time taken can also be worked out. To do this, you divide the total displacement change by the displacement change each second. This is the same as dividing by the velocity. So

$$\text{Time taken (s)} = \frac{\text{Displacement change (m)}}{\text{Velocity (m/s)}}, \text{ or } \Delta t = \frac{\Delta s}{v}$$

Now, we put these three equations next to each other:

$$v = \frac{\Delta s}{\Delta t} \qquad \Delta s = v\,\Delta t \qquad \Delta t = \frac{\Delta s}{v}$$

This is the same equation written three ways, each with a different subject.

Example 1 – *How long does it take an object at $+4$ m/s to move $+20$ m?*
We want to know t, so take $\Delta s = v\,\Delta t$ and divide both sides by v to give

$$\Delta t = \frac{\Delta s}{v} = \frac{+20\text{ m}}{+4\text{ m/s}} = 5\text{ s}$$

6.1 How much time does it take a coach at $+26$ m/s to travel $+1000$ m?

6.2 How far will an object at $+12$ m/s travel in 9.5 s?

6.3 The world record for running 400 m is 40.3 s. Calculate the velocity.

6.4 How far will a car travel during the 0.60 s reaction time of its driver

(a) when the velocity is 13 m/s (this is 30 mph)?

(b) when the velocity is 31 m/s (this is 70 mph)?

6.5 Complete the table below, filling in the missing values

Displacement change (m)	**Velocity (m/s)**	**Time taken (s)**
$+400$	$+8.4$	(a)
-0.15	-0.025	(b)
$+1500$	(c)	25
$+92\,000$	(d)	1460
(e)	-31	250
(f)	$+250$	7200

Units: 1 km = 1000 m; 1 cm = 0.01 m; 1 mm = 0.001 m; 1 mile = 1610 m; 1 nautical mile = 1850 m; 1 inch = 0.025 m

Example 2 – *How far (in km) will a train travel in 45 min at 230 mph?*

$$\Delta s = v\,\Delta t = \frac{230\text{ miles}}{1\text{ hr}} \times 45\text{ min} = \frac{230 \times 1610\text{ m}}{1 \times 60\text{ min}} \times 45\text{ min}$$
$$= \frac{230 \times 1610\text{ m} \times 45\,\cancel{\text{min}}}{60\,\cancel{\text{min}}} = 280\,000\text{ m} = 280\text{ km}$$

6.6 Complete the table:

Displacement change	**Velocity**	**Time taken**
90 miles	18 m/s	(a)
42.2 km	(b)	2.00 hr
(c)	13 mph	25 min

6.7 A ship travels at 21 kt, which means 21 nautical miles each hour.

(a) How far will it travel each hour in metres?

(b) What is its speed in m/s?

(c) How much time will it take to cover a distance of 230 km?

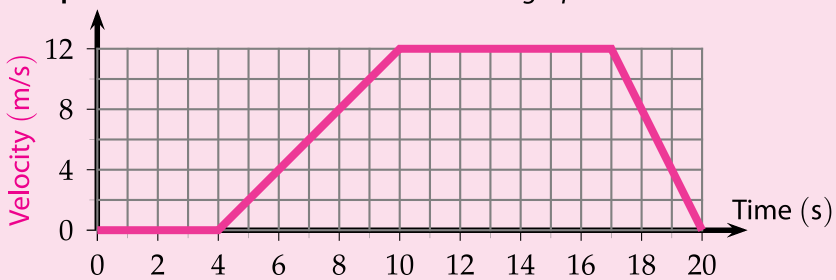
6.8 A garden snail can move half an inch every second. How much time will it take to cross an 80 cm pavement?

7 Velocity – time graphs

It can be helpful to show an object's velocity at different times.

The velocity v is plotted on the y or vertical $\uparrow$ axis.
The time t is plotted on the x or horizontal $\rightarrow$ axis.
Horizontal lines represent motion at a steady (constant) speed.
Horizontal lines along the axis represent an object not moving.

Example – *Describe the motion shown in this graph*



The object is stationary ($v = 0$ m/s) for the first four seconds
At $t = 4$ s the object begins to speed up. It accelerates.
It reaches a velocity of $v = 12$ m/s when $t = 10$ s.
It keeps going at that speed for 7 s
During this time, it travels $\Delta s = v\,\Delta t = 12$ m/s $\times$ 7 s $= 84$ m.
At $t = 17$ s, it slows down. It decelerates.
It comes to rest at $t = 20$ s.

The steeper the line, the greater the acceleration or deceleration.
A straight (not horizontal) line represents a constant acceleration. The change in velocity is the same each second.

7.1 Answer the questions using the graph in the example.

(a) At what times is $v = 4$ m/s?

(b) State the velocity at $t = 9$ s.

(c) For how many seconds was the object moving forwards?

(d) For how many seconds was the object decelerating?

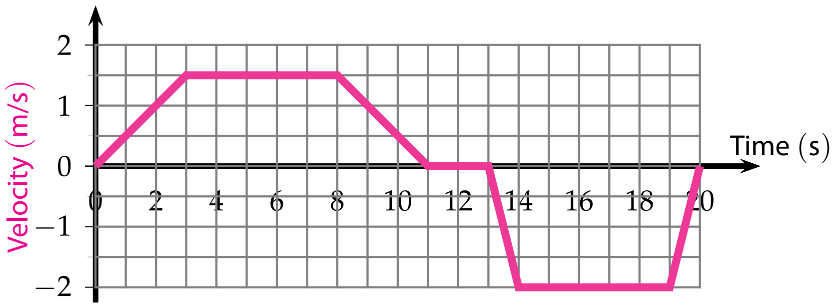
(e) Was it moving faster at $t = 8$ s or at $t = 19$ s?

(f) What was the velocity change between $t = 6$ s and $t = 8$ s?

(g) How far did it move between $t = 10$ s and $t = 12$ s?

7.2 Draw a graph with a maximum velocity of 10 m/s and time which goes up to 20 s. Then draw the line for a person who waits until $t = 4$ s. They then take 2 s to accelerate to $v = 10$ m/s. They continue at this speed until $t = 15$ s. Then they decelerate and come to a stop two seconds later.

This graph shows the velocity of a hoist used to lift building materials on a construction site. Positive values of v are used when the hoist is rising.



7.3 Describe what the hoist is doing when v is negative?

7.4 When is the hoist moving upwards?

7.5 When does the hoist arrive at the upper level?

7.6 How fast is the hoist when $t = 9$ s? Which way is it moving?

7.7 Work out the greatest upwards velocity.

7.8 Study the part of the graph where the hoist starts moving upwards.

(a) How much time does it take to reach top speed?

(b) How much velocity does it gain each second?

7.9 Work out the hoist's maximum speed.

7.10 When is the hoist decelerating (slowing down)?

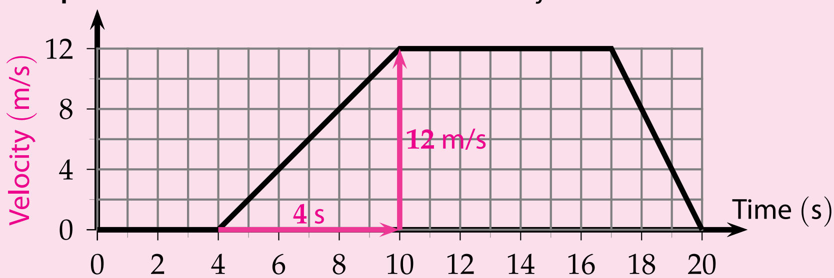
8 Acceleration

The change in velocity Δv each second is called the acceleration a. You can read off the Δv for one second on a straight part of a velocity – time graph.

You can also calculate the acceleration by dividing the velocity change Δv by the time taken Δt. This gives the velocity change each second.

$$\text{Acceleration } (\text{m/s}^2) = \frac{\text{Velocity change } (\text{m/s})}{\text{Time taken } (\text{s})}, \text{ or } a = \frac{\Delta v}{\Delta t}$$

Example – *Calculate the acceleration of this object at $t = 6$ s.*



6 s is part of a steady acceleration between $t = 4$ s and $t = 10$ s.
The time taken for this acceleration $\Delta t = 10 - 4 = 6$ s.
In this time, the velocity change $\Delta v = 12 - 0 = +12$ m/s.

$$\text{Acceleration } a = \frac{\Delta v}{\Delta t} = \frac{+12 \text{ m/s}}{6 \text{ s}} = +2 \text{ m/s}^2.$$

The acceleration is given by the gradient of the line on the velocity time graph. Gradient is the change in the vertical $\uparrow$ co-ordinate divided by the change in the horizontal $\rightarrow$ co-ordinate.

8.1 In the graph above, calculate the acceleration at
(a) $t = 2$ s.
(b) $t = 5$ s.
(c) $t = 14$ s.
(d) $t = 18$ s.

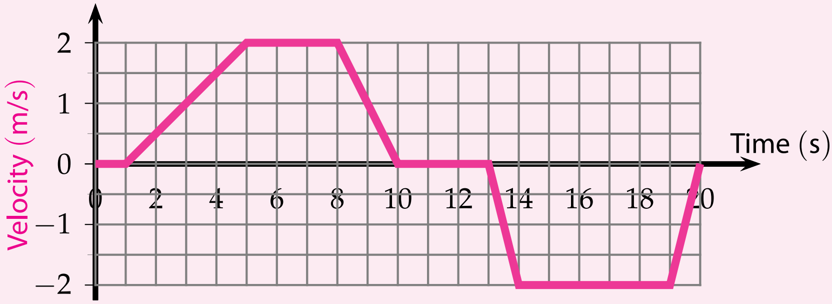
In our questions, the direction of a velocity is given by its sign:

$+$ means v is getting larger
$-$ means v is getting smaller

An acceleration of -3 m/s^2 could refer to an object slowing down while going forwards. It could also describe an object speeding up while reversing.

8.2 An acceleration is positive. This could mean that the object is speeding up while moving forwards. What is the other possibility?

Questions 3 to 7 use this graph. It shows the velocity of a hoist on a building site.



8.3 Calculate the acceleration at

(a) $t = 6$ s.

(b) $t = 9$ s.

(c) $t = 12$ s.

(d) $t = 13.5$ s.

(e) $t = 15$ s.

(f) $t = 19.5$ s.

8.4 When is the hoist getting faster?

8.5 When is the hoist stationary?

8.6 When is the hoist slowing down?

8.7 When is the hoist's velocity increasing at the greatest rate?

8.8 You accelerate at $+25$ m/s^2 for 6.4 s, and you were at rest to begin with. Work out your top speed.

8.9 Redo question 8 if you started with a velocity of 32 m/s.

8.10 You have a starting velocity of $+45$ m/s and an acceleration of -10 m/s^2. How long would it take you to stop?

9 Calculating accelerations

On page 15, we introduced the formula for acceleration. This is the velocity change each second:

$$\text{Acceleration}\left(\text{m/s}^2\right) = \frac{\text{Velocity change}\,(\text{m/s})}{\text{Time taken}\,(\text{s})}, \text{ or } a = \frac{\Delta v}{\Delta t}$$

As the acceleration is the velocity change each second, you can work out the velocity change:

$$\text{Velocity change}\,(\text{m/s}) = \text{Acceleration}\left(\text{m/s}^2\right) \times \text{Time}\,(\text{s})\text{, or } \Delta v = a\,\Delta t$$

The time taken can also be calculated. To do this, you divide the velocity change by the velocity change each second. This is the same as dividing by the acceleration. So

$$\text{Time}\,(\text{s}) = \frac{\text{Velocity change}\,(\text{m/s})}{\text{Acceleration}\left(\text{m/s}^2\right)}, \text{ or } \Delta t = \frac{\Delta v}{a}$$

Now, we put these three equations next to each other:

$$a = \frac{\Delta v}{\Delta t} \qquad \Delta v = a\,\Delta t \qquad \Delta t = \frac{\Delta v}{a}$$

This is the same equation written three ways, each with a different subject.

Example 1 – *An object's velocity is $+10$ m/s. How much time does it take to reach $+30$ m/s with an acceleration of $a = +5$ m/s^2?*
The change in velocity needed is $\Delta v = 30 - 10 = 20$ m/s
We want to know t, so take $\Delta v = a\,\Delta t$ and divide both sides by a to give

$$\Delta t = \frac{\Delta v}{a} = \frac{+20\text{ m/s}}{+5\text{ m/s}^2} = 4\text{ s}$$

9.1 An aeroplane needs to reach a speed of $+48$ m/s from rest in 16 s. What does the acceleration need to be?

9.2 A van with an acceleration of $+1.2$ m/s^2 reaches a speed of 25 m/s from rest. How much time does it take?

9.3 My maximum braking acceleration is -4.5 m/s^2, and I must stop in 3.5 s. Calculate my top speed.

9.4 Complete the table below, filling in the missing values

Velocity change (m/s)	**Acceleration** (m/s^2)	**Time taken** (s)
-13	-2.5	(a)
$+75$	(b)	40
(c)	-6.7	2.5
(d)	-9.8	3.8

9.5 Large accelerations are often measured in g where $1g = 10$ m/s^2.

(a) How much speed can you gain at $3g$ in five minutes?

(b) A rollercoaster can accelerate from rest to 49 m/s (109 mph) in 1.05 s. Calculate its acceleration (in g).

(c) Your rocket can accelerate at $7g$. How much time would it take you to reach 3 000 000 m/s (1% of the speed of light)?

Example 2 – *A motorcycle can accelerate from rest to 60 mph in 3.4 s. Calculate its acceleration in m/s^2. 1 mile = 1610 m.*

$$\Delta v = 60 \text{ mph} = \frac{60 \text{ miles}}{1 \text{ h}} = \frac{60 \times 1610 \text{ m}}{60 \times 60 \text{ s}} = 26.8 \text{ m/s}$$

$$a = \frac{\Delta v}{t} = \frac{26.8 \text{ m/s}}{3.4 \text{ s}} = 7.9 \text{ m/s}^2$$

9.6 Calculate the acceleration of a school minibus which can accelerate from rest to 40 mph in 18 s.

9.7 Calculate the acceleration of a train which can accelerate from 40 mph to 160 mph in 180 s.

9.8 The braking distances in the Highway Code assume a car has an acceleration of 6.7 m/s^2 when braking hard.

(a) How much time is taken to stop from 15 m/s?

(b) How much time is taken to stop from 70 mph?

(c) Calculate the speed (in mph) can you stop from in 1.5 s?

Electricity

16 Energy, charge and voltage

Charge Q travels around an electric circuit. It is measured in coulombs (C). Charge is given the symbol Q to represent the quantity of electrical 'material'.

The energy of each coulomb of charge is called the voltage or potential. The voltage change across a component is also called a potential difference.

Energy E is measured in joules (J), Voltage V is measured in volts (V):

$$\text{Energy change(J)} = \text{Charge (C)} \times \text{Voltage (V), or } E = QV$$

The voltage, which measures electrically-stored energy,
- increases when charge passes a battery, cell or generator
- drops when charge passes a bulb, motor or resistor

Example – *A 230 V lamp takes 13.8 J of electrical energy. How much charge has passed?*
The voltage change is 230 V. We have lost 13.8 J of energy.
Energy change = Charge × Voltage, so 13.8 J = Charge ×230 V

$$\text{Charge} = \frac{13.8\text{ J}}{230\text{ V}} = 0.060\text{ C}.$$

16.1 Complete the table below, filling in the missing values

Energy change (J)	**Voltage (V)**	**Charge (C)**
(a)	6.0	0.50
(b)	12.0	2.5
250	(c)	5.0
250	(d)	20.0
18	0.6	(e)

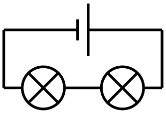
16.2 A 5.0 V USB supply gives 0.45 J of energy to a mobile phone on charge. How much charge is needed?

16.3 A car headlamp which takes 1200 J of electrical energy from 100 C of charge. What is the voltage across it?

16.4 The mains in a home has a voltage of 230 V. How much energy is delivered to an oven when 9720 C of charge passes through it?

16.5 The National Grid enables 0.025 C of charge to carry $10\,000$ J of electrical energy. Calculate the voltage needed.

In a series circuit, there are no junctions. Each charge passes through all of the components (one after another). It loses some of its energy to each component.



16.6 A 9.0 V battery is connected to a series circuit containing two identical light bulbs. 1.5 C of charge flows around the circuit.

(a) Calculate the energy change of the charge in the battery.

(b) How much energy will this charge give to each light bulb?

(c) Work out the voltage across each light bulb

16.7 Two different lamps are connected in series to a 12 V battery. The voltage drops by 7.5 V as 10 C of charge goes through the first lamp.

(a) How much energy was given to this charge by the battery?

(b) How much energy was released in the first bulb?

(c) How much energy will be released in the second bulb?

(d) Calculate the voltage across the second bulb.

In a parallel circuit, the energy carried by each charge does not change as it passes a junction. Not all charge takes the same route.

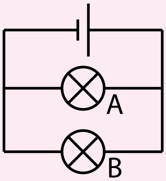
16.8 Two different bulbs are connected in parallel to a 9.0 V battery. Of 12 C leaving the battery, 5.0 C passes through lamp A before returning to the battery. Calculate the

(a) energy given to this 5.0 C by the battery.

(b) energy taken from the 5.0 C by lamp A.

(c) the voltage across lamp A.

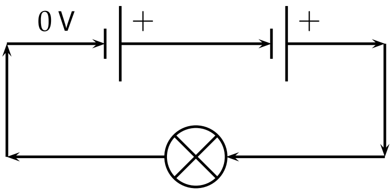
(d) How much charge passes lamp B?



17 Voltage in circuits

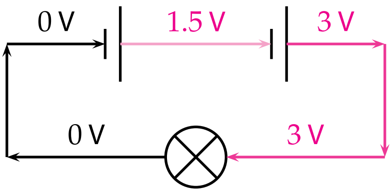
We use the idea of voltage (the energy content of charge) to analyse circuits.

We label the negative terminal of the battery 0 V. Next, we draw arrows to show the direction of charge flow. This is round the circuit from the $+$ of the battery.



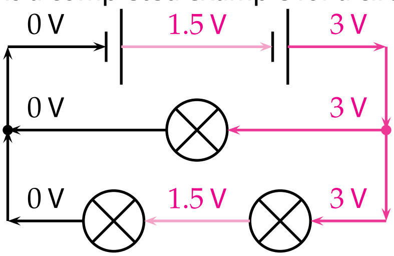
We follow the arrows, starting at the 0 V mark. Each cell adds $+1.5$ V. We label each wire with its voltage. We use a colour code, here black means 0 V.

All points on a wire have the same voltage. This is because charge loses very little energy while flowing down a wire.



The bulb connects a 3 V wire to a 0 V wire. The drop in voltage as the charge goes through it is 3 V. For this lamp, 1.5 V means 'normal' brightness, so the lamp will be brighter than normal.

Here is a completed example for a circuit with junctions:

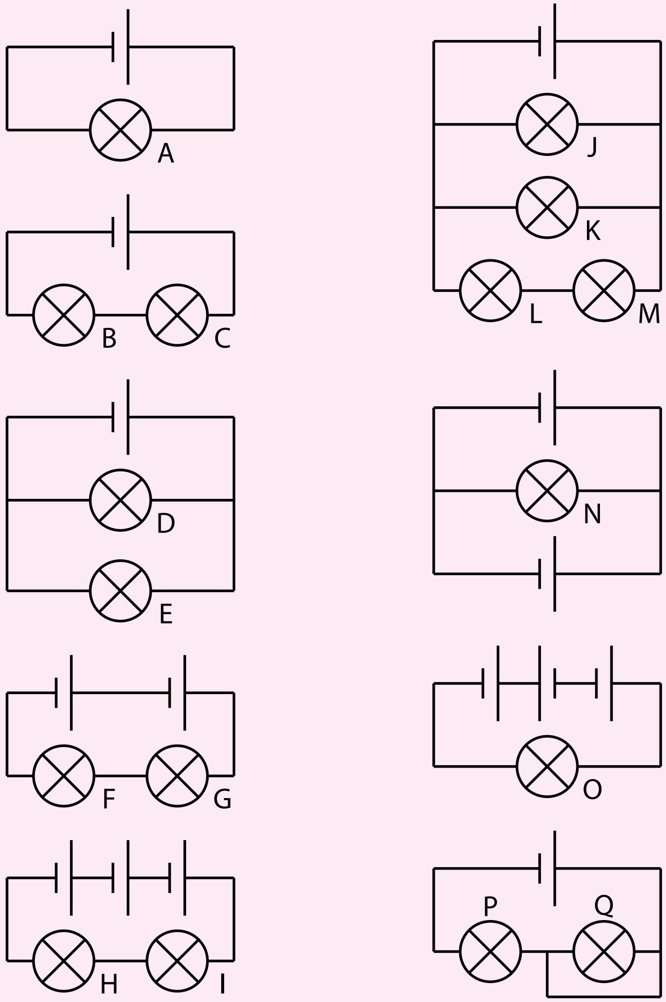


Top bulb:
voltage drop 3 V, bright.

Lower bulbs:
voltage drop 1.5 V, normal.

We assume that the bulbs are identical. Therefore the wire in the middle at the bottom was half way between 0 V and 3 V.

Label the circuits below with the voltage of each wire. Then write down the voltage drop for each lamp.
Hint: if the charge goes through a cell the wrong way, then the voltage will drop by 1.5 V.



18 Charge and current

Charge Q travels around an electric circuit. It is measured in coulombs (C). Charge is given the symbol Q to represent the quantity of electrical 'material'.

On page 1 s represented the displacement or position of an object. We used Δs for the change of the object's position during a time period Δt. Here, in a similar way
Q is the total charge which has flown by time t,
ΔQ (delta Q) is the charge which flows during a time interval Δt.

Current I is the charge which flows each second. It is measured in amps (A). Current is given the symbol I to represent the intensity of the charge flow.

$$\text{Current } (\mathrm{A}) = \frac{\text{Charge flow } (\mathrm{C})}{\text{Time taken } (\mathrm{s})}, \text{ or } I = \frac{\Delta Q}{\Delta t}$$

This equation can be re-arranged using the methods on page 9 to give

$$I = \frac{\Delta Q}{\Delta t} \qquad \Delta Q = I\,\Delta t \qquad \Delta t = \frac{\Delta Q}{I}$$

Example – *If* 0.25 *A flows for three minutes, calculate the charge.*
The time must be put in seconds: $\Delta t = 3$ min $= 3 \times 60$ s $= 180$ s
We use equation $\Delta Q = I\,\Delta t = 0.25$ A $\times$ 180 s $= 45$ C.

18.1 How much charge flows if the current is 13 A for 1800 s?

18.2 Calculate the current the if the charge flow during 15 s is 0.60 C.

18.3 Complete the table below, filling in the missing values

Charge flow (C)	**Current (A)**	**Time taken (s)**
320	6.4	(a)
6000	1.2	(b)
450	(c)	3000
(d)	13	330

18.4 A car battery takes seven hours to charge using an 8.0 A current.

(a) How much charge flowed?

(b) The same charge flows when the battery discharges. For how much time can it keep a 4.2 A headlamp lit?

(c) How much time would it take to charge the battery using a 6.0 A current?

18.5 An 'AA' cell can cause 9000 C to flow around a circuit before it needs recharging or replacing.

(a) For how long can the cell light a 0.25 A bulb in a torch?

(b) For how long can the cell light a 50 mA LED in a modern torch? $(1 \text{ mA} = 0.001 \text{ A})$

(c) How long will the cell last in a remote control drawing 0.5 mA?

Battery or cell 'capacity' is usually measured in amp-hours (A h) or milliamp-hours (mA h). A 1000 mA h cell can supply 1000 mA for one hour, 500 mA for two hours, and so on. Capacity $(\text{A h}) =$ Current $(\text{A}) \times$ Time (hours).

18.6 For how much time could a 1000 mA h 'AAA' cell supply the devices listed in question 5?

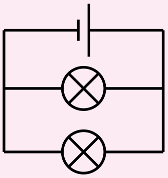
18.7 Calculate the capacity of the battery in question 4.

18.8 Calculate the capacity of the 'AA' cell in question 5.

18.9 How long will it take a solar cell to recharge a battery of the type in question 8 with 100 mA?

18.10 How much charge (in coulombs) can a 1.00 A h cell supply?

18.11 A parallel circuit has two identical light bulbs. 3.0 C flows out of the battery in 12 s.



(a) How much charge passes one bulb?

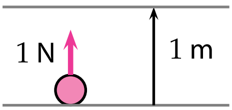
(b) Calculate the current through the battery.

(c) State the current through one lamp.

Energy and Balance

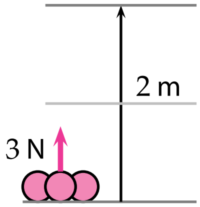
24 Work

In this section, we explore the link between energy and force. A force can cause stored energy to be moved to another store. Energy E is measured in joules (J).



A small apple weighs 1 N. We lift it 1 m.
This needs 1 J of energy.

Three small apples weigh 3 N.
Lifting them 1 m would need 3 J of energy.
Lifting them 2 m, requires 6 J of energy.



The energy given to an object in this way is called the work done on it :

$$\text{Work }(\mathrm{J}) = \text{Force applied }(\mathrm{N}) \times \text{Displacement change }(\mathrm{m}), \; \Delta E = F\,\Delta s$$

The equation can be re-arranged (see page 9) to give

$$F = \frac{\Delta E}{\Delta s} \qquad \Delta E = F\,\Delta s \qquad \Delta s = \frac{\Delta E}{F}$$

Example 1 – *Calculate the energy given to a cart by its engine, which pulls it 25 m East with a force of 35 N in that direction.*
If we use $+$ to mean 'East' then $F = +35$ N, and $\Delta s = +25$ m, so
$\Delta E = F\,\Delta s = 35\text{ N} \times 25\text{ m} = +875$ J so 875 J is given to the cart.

24.1 Calculate the work done on a sack which is dragged 13 m across the floor with a 45 N force.

24.2 Calculate the distance it will take for a 20 N force to do 600 J of work

The displacement change Δs and force F have directions shown by $+$ or $-$.
If the force applied and the displacement are in opposite directions,
Δs and F will have opposite signs, so ΔE will be negative.
Energy will be taken from the object's stores. We say, work is done by it.

Example 2 – *Calculate the work done by a cycle which stops in 8.0 m thanks to 180 N from its brakes.*
Use $+$ to mean 'forwards'. Then $\Delta s = +8.0$ m.
The force is in the other direction, so $F = -180$ N
$\Delta E = F\,\Delta s = -180$ N $\times$ 8.0 m $= -1440$ J. 1440 J of work is done by it.

24.3 Complete the table below, filling in the missing values

Force (**N**)	**Displacement change** (**m**)	**Energy change** (**J**)
$+25$	$+4.0$	(a)
-30	$+23$	(b)
90 down	3.5 down	(c)
90 down	0.62 up	(d)
120 down	(e)	$+7200$
300 East	(f)	-1500
(g)	15 up	$+450$

24.4 A crane lifts 150 bricks (each weighing 28 N) to a height of 3.5 m. How much work does it do?

24.5 A 28 N brick falls 5.2 m into a trench. How much work is done on it?

24.6 A weightlifter lifts a 200 N weight to a height of 55 cm fifteen times. How much work does she do?

24.7 Calculate the distance taken for a 7 kN $=$ 7000 N braking force to stop a van, if 280 kJ of motion energy needs to be taken from it.

24.8 A car moves 2 km at a steady speed. The engine's force is 4 kN.

(a) Calculate the work done on the car by the engine.

(b) How strong are the forces resisting motion? Hint: page **??**

(c) Calculate the work done by the car against the resistance.

Forces at right angles to motion do no work. Example: you don't need engines and fuel to steer a car or truck. This fact becomes important when you solve problems in two dimensions.

25 Gravitational potential energy

When you lift an object, the force you apply $(\uparrow)$ is in the direction of motion $(\uparrow)$. You do work on it, giving it energy. This increases its store of gravitational potential energy (GPE).

Example – *Calculate the increased store of GPE when you lift an* 8.6 *kg bucket of water* 3.5 *m up a ladder.*
Minimum force needed to lift the bucket $=$ Weight
Weight $=$ Mass $\times g = 8.6$ kg $\times$ 10 N/kg $= 86$ N (see page 21)
Work $=$ Force applied $\times$ Displacement change $= 86$ N $\times$ 3.5 m $= 301$ J
Gain in GPE $= 301$ J.

This is positive, as the displacement change is in the direction of the applied force (upwards). Usually, we write height change to make it clear that we measure displacements upwards when calculating GPE.
We can also write

$$\text{Change in GPE} = \text{Weight} \times \text{Height change} \qquad \Delta E = W\,\Delta h$$
$$= \text{Mass} \times g \times \text{Height change} \qquad = mg\,\Delta h$$

25.1 A 875 kg car is lifted 1.2 m by the jacks at a service station. Calculate the GPE given to it.

25.2 Complete the table below, filling in the missing values

Mass (**kg**)	**Height gain** (**m**)	**GPE gain** (**J**)
12	1.5	(a)
8.2	4.5	(b)
72	0.75	(c)
0.35	(d)	1.0
120	(e)	25
(f)	2.5	1200

25.3 A chocolate bar gives a 72 kg mountaineer 2.2 MJ of energy. If he were able to put this entirely into a store of his GPE, how tall a mountain could he climb? (1 MJ $= 1\,000\,000$ J)

When you lower an object, you still have to support it. The force you apply ($\uparrow$) is opposite to the direction of motion ($\downarrow$). The object is now doing work on you, giving you its energy. This reduces its store of gravitational energy.

25.4 Complete the table below, filling in the missing values. Use negative numbers to represent a loss of height or GPE.

Mass (**kg**)	**Height change** (**m**)	**GPE change** (**J**)
3.1	0.24	(a)
0.62	−0.62	(b)
42	(c)	15
120	(d)	−825

25.5 A lift (elevator) is winched up a shaft. There is a 300 kg counterweight which moves the same distance the other way. One day there are three people (each 76 kg) in the 230 kg lift car.

(a) Calculate the gain in GPE of the of the empty 'car' when the lift goes up 9.0 m (three floors).

(b) Calculate the change in GPE of the lift and the people as they go up three floors (9.0 m).

(c) Calculate the change in GPE of the counterweight when the lift goes up three floors (9.0 m).

If an object drops, you are not applying any force to it. It's own weight acts in the direction of motion, increasing its store of motion (kinetic) energy; at a cost of reducing its gravitational potential energy.

25.6 A 350 kg pumpkin is grown, and then dropped at a festival.

(a) Calculate the GPE gain when the pumpkin is lifted 11 m.

(b) Write down the kinetic energy gained by the pumpkin as it falls to the ground. Assume that nothing resists its motion.

(c) How much kinetic energy would be gained if the air were warmed by 3500 J as the pumpkin fell?

Materials and Forces

30 Density

Density ρ (rho) is the mass of each unit of volume (m^3 or cm^3) of a material. Density is measured in kg/m^3 or g/cm^3.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}, \text{ or } \rho = \frac{m}{V}$$

This equation can be re-arranged using the methods on page 9 to give

$$\rho = \frac{m}{V} \qquad m = \rho V \qquad V = \frac{m}{\rho}$$

Example 1 – *A* 3 *cm* $\times$ 5 *cm* $\times$ 10 *cm block has a mass of* 300 *g. What is the density?*

Volume $V = 3\text{ cm} \times 5\text{ cm} \times 10\text{ cm} = 150\text{ cm}^3$

We re-arrange $m = \rho V$ by dividing both sides by V to give

$$\rho = \frac{m}{V} = \frac{300\text{ g}}{150\text{ cm}^3} = 2.0\text{ g/cm}^3.$$

30.1 Complete the table below, filling in the missing values.

Mass (g)	**Volume** (cm^3)	**Density** (g/cm^3)
60	50	(a)
713	1000	(b)
16.2	(c)	0.84
3.0	(d)	0.60
(e)	400	5.2
(f)	13.5	12

30.2 500 cm^3 of olive oil has a mass of 450 g. Calculate its density.

30.3 Steel has a density of 7.8 g/cm^3. Calculate the mass of a cubic block with a side length 5.0 cm.

We need to be able to use cubic metres as well as cubic centimetres.
1 m $= 100$ cm and so 1 m^3 $= (100 \text{ cm})^3 = 100^3$ cm^3 $= 1\,000\,000$ cm^3

Example 2 – *Pure water has a density of 1.00 g/cm^3. Calculate the mass of a cubic metre of water in kilograms.*
1 cm^3 of water has a mass of 1 g.
1 m^3 $= 1\,000\,000$ cm^3, so 1 m^3 of water will have a mass of $1\,000\,000$ g.
1000 g $= 1$ kg, so this water will have a mass of 1000 kg.

We see from the example above that

$$1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$$

30.4 The density of sea water is 1.03 g/cm^3. Write this in kg/m^3.

30.5 A swimming pool measures 10 m by 25 m and has an average depth of 1.2 m. Calculate the mass of the pure water in it.

30.6 A 750 cm^3 bottle contains a mixture of pure water and ethanol. 10% of the volume is ethanol. Ethanol has a density of 0.79 g/cm^3.

(a) Calculate the volume of the ethanol.

(b) Calculate the mass of the ethanol.

(c) State the volume of the water.

(d) Calculate the mass of the water.

(e) Calculate the density of the mixture.

30.7 Bricks have a density of 1500 kg/m^3. If you can put 1600 kg of bricks on a pallet for loading onto a truck, calculate the volume of bricks.

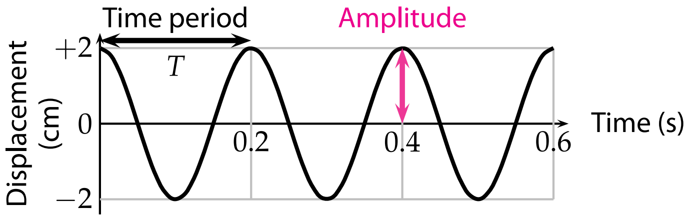
30.8 An airliner has a mass (when empty) of $43\,000$ kg. It is about to carry 150 people with an average mass of 80 kg each. It is not safe to take off if the total mass is more than $75\,000$ kg. Jet fuel has a density of 850 kg/m^3.

(a) Calculate the maximum mass of fuel allowed.

(b) How many m^3 of fuel can be carried?

Waves

35 Frequency



An oscillation is a repeating motion. From the displacement – time graph, we see that the repeating part lasts 0.2 s. This is called the time period T and is measured in seconds (s).

The largest displacement from the centre is called the amplitude. This oscillation has an amplitude of 2 cm.

The number of times the motion repeats each second is called the frequency f and is measured in hertz (Hz).

> **Example** – *Calculate the frequency of the oscillation in the graph above.*
> The time period is $T = 0.2$ s.
> The number of times the motion repeats each second is $\dfrac{1.0\text{ s}}{0.2\text{ s}} = 5$.
> The frequency is 5 Hz.

$$\text{Frequency (Hz)} = \frac{1}{\text{Time period (s)}}, \text{ or } f = \frac{1}{T}. \text{ Re-arranging gives } T = \frac{1}{f}.$$

35.1 Calculate the frequency of an oscillation if $T = 0.020$ s.

35.2 Calculate the frequency of an oscillation which repeats every 0.10 s.

35.3 Calculate the time period of a 25 Hz oscillation.

35.4 Calculate the time period of a 250 Hz oscillation.

35.5 Use your answers to questions 3 and 4 to complete the sentence: When the frequency gets 10 times larger, the time period gets...

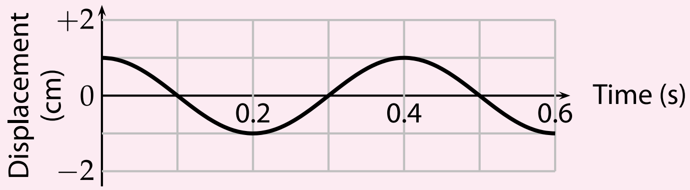
35.6 For each displacement–graph below,

(a) state the amplitude of the motion,

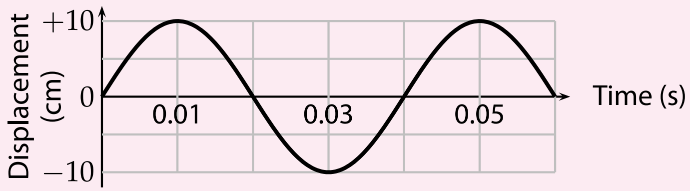
(b) state the time period of the motion,

(c) calculate the frequency of the oscillation.

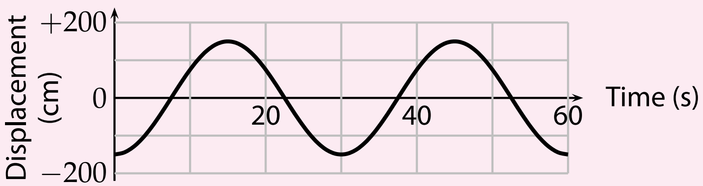
A



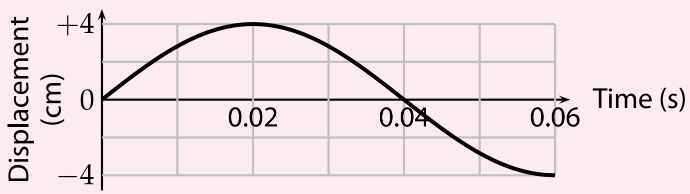
B



C



D



For large frequencies, 1 kHz $= 1000$ Hz, 1 MHz $= 1000\,000$ Hz.
For small times, 1 ms $= 0.001$ s, 1 μs $= 0.000\,001$ s (see page 37).

35.7 Calculate the frequency of an oscillation if $T = 1.0$ ms.

35.8 Calculate the time period of an oscillation if $f = 2.0$ kHz.

35.9 Calculate the frequency of an oscillation if $T = 2.5$ μs.

35.10 Calculate the time period of an oscillation if $f = 5.0$ MHz.

Calculation Practice

38 Force and Motion Calculation Practice

38.1 Use $\Delta s = v\,\Delta t$ to work out how far a 3.5 m/s runner will run in 15 s.

38.2 Use $\Delta s = v\,\Delta t$ to work out how much time a 3.5 m/s runner will take to run 105 m.

38.3 Use $\Delta v = a\,\Delta t$ to work out the acceleration of a car which can reach 25 m/s from rest in 10 s.

38.4 Use $W = mg$ to calculate the weight of a 3.1 kg rabbit.

38.5 Use $F = ma$ to calculate the resultant force needed to give a 12 kg shopping trolley an acceleration of 0.25 m/s^2.

38.6 Use $F = ma$ to calculate the acceleration of a 0.40 kg model rocket if the resultant force is 2.4 N.

38.7 Use $p = mv$ to calculate the momentum of a 0.40 kg model rocket travelling at 25 m/s.

38.8 Calculate the speed of a car which can travel 1600 m in 50 s.

38.9 How far can an 80 m/s train travel in 700 s?

38.10 How fast is a rocket travelling after 40 s of 35 m/s^2 acceleration from rest?

38.11 How much time does it take a motorcycle with an 8.5 m/s^2 acceleration take to reach 31 m/s from rest?

38.12 Calculate the resultant force needed to give a 20 kg backpack an acceleration of 2.5 m/s^2?

38.13 Calculate the acceleration of a 20 kg backpack if the resultant force is 15 N.

38.14 Calculate the momentum of a 5500 kg elephant running at 4.8 m/s.

39 Electricity Calculation Practice

39.1 Use $E = QV$ to calculate the voltage needed to give 9.5 J to 4.0 C of charge.

39.2 Use $E = QV$ to calculate the energy given to 150 C by a 1.5 V battery.

39.3 Use $\Delta Q = I\,\Delta t$ to calculate the charge which flows when a 13 A current is connected for 360 s.

39.4 Use $\Delta Q = I\,\Delta t$ to calculate the current if 4500 C flows in 3600 s.

39.5 Use $V = IR$ to calculate the voltage needed to drive a 3.5 A current through a 20 Ω resistor.

39.6 Use $V = IR$ to calculate the current when a 300 Ω resistor is connected to a 12 V battery.

39.7 Use $P = IV$ to calculate the power of a water heater plugged in to a 230 V supply if the current is 15 A.

39.8 Use $P = IV$ to calculate the voltage needed if you wish to operate a 22 kW machine with a 60 A current.

39.9 Calculate the current flowing when a 28 Ω resistor is connected to a 12 V battery.

39.10 Calculate the charge passing through a 0.30 A light bulb in 400 s.

39.11 Calculate the power of a 0.30 A light bulb connected to a 3.0 V battery.

39.12 Calculate the energy carried by 4.5 C of charge at a voltage of $11\,000$ V.

39.13 Calculate the voltage across a 2.2 Ω resistor when a 32 A current flows through it.

39.14 Calculate the current if 54 C flows in 0.050 s.

39.15 Calculate the resistance of a circuit if 12 mA flows when the supply voltage is 9.0 V.

Extra Questions

42 Force and Motion summary questions

42.1 For motion from $s = -2$ cm to -10 cm, then to $+8$ cm, calculate

(a) the total displacement change, (b) the distance travelled.

42.2 If something starts at $s = +4$ cm and then has displacement changes of $\Delta s = -10$ cm, then $\Delta s = +32$ cm then $\Delta s = -14$ cm, where does it end up?

42.3 A high speed train is attempting a record speed of 150 m/s. There are 1.61 km in one mile.

(a) How many seconds are there in one hour?

(b) How far (in km) would the train go in one hour at 150 m/s?

(c) How far is this distance in miles?

42.4 One day, £1.00 buys 31.2 Czech crowns (CZK). A ticket costs 73 CZK. How much is this in British pounds?

42.5 Use the graph below to answer the questions.

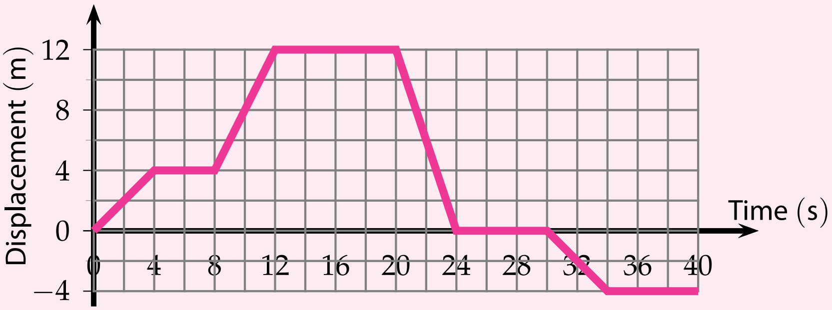
(a) Describe the motion at $t = 14$ s.

(b) Describe the motion between $t = 20$ s and $t = 24$ s.

(c) State the total distance travelled.

(d) Calculate the velocity at $t = 10$ s.

(e) Calculate the average speed for the motion.



42.6 Re-arrange the following equations to make a the subject ($a =$).

(a) $v = ap$

(b) $q = \frac{a}{r}$

(c) $f = ga$

(d) $\frac{y}{t} = \frac{z}{a}$

42.7 How far will a bus travel in 180 s? Its speed is 12 m/s.

42.8 A train travels 240 km in one hour. Calculate the speed in m/s.

42.9 Use the graph below to answer the questions

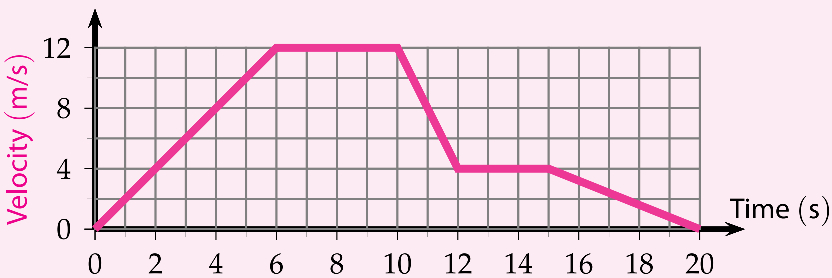
(a) Describe the motion at $t = 9$ s.

(b) State the velocity when $t = 4$ s.

(c) Calculate the acceleration at $t = 3$ s.

(d) Calculate the displacement change in the first 4 s.

(e) Calculate the displacement change between $t = 10$ s and 12 s?



42.10 Calculate the mass of a 15 N weight on Earth.

42.11 A 50 kg cycle has a 300 N force pulling it forward, and two 100 N forces pulling backwards.

(a) Calculate the resultant force.

(b) Calculate the acceleration.

42.12 A 8.1 kg cannon ball is falling, and has a 4.5 m/s^2 acceleration. Calculate the air resistance.

42.13 A 72 kg driver in a 840 kg car is travelling at 12 m/s.

(a) Calculate the momentum of the car and driver.

(b) The car has brakes on each of the 4 wheels. How much force do we expect from each brake if the car is to stop in 3.5 s?