SOLUTIONS

Topic 1. Basic Scientific Skills

Sub-topic 1. Physical quantities, units and measurement

Unit 1. Scientific notation

Activity 1: Practice scientific notation

1.

a. $22 = 2{,}2 \times 10^{1}$

b. $8\ 100 = 8{,}1 \times 10^{3}$

c. $26\ 550\ 000 = 2{,}655 \times 10^{7}$

d. $5{,}5 = 5{,}5 \times 10^{0}$

e. $0{,}1 = 1 \times 10^{-1}$

f. $0{,}00068 = 6{,}8 \times 10^{-4}$

g. $20\ 010\ 000 = 2{,}001 \times 10^{7}$

2.

a. $6{,}5 \times 10^{-2} = 0{,}065$

b. $7 \times 10^{1} = 70$

c. $1{,}693 \times 10^{6} = 1\ 693\ 000$

d. $2{,}78 \times 10^{-5} = 0{,}0000278$

Unit 2. Physical quantities, SI units and conversions

Activity 1: Practice writing the correct units for scientific quantities

1. Thembi's mass is 90 **kg**
2. The temperature of the air outside is 300 **K**
3. The length of a plank is 6 **m**
4. The force that pulls Mandla toward the earth is 980 **N**
5. The time for an egg to boil is 600 **s**
6. The air pressure is 101 000 **Pa**
7. The current is 0,5 **A**

Activity 2: Practice converting units

(a)	80 cm = 0,8 m	(b)	0,25 m = 250 mm
(c)	1 kg = 1000 g	(d)	2 500 mg = 2,5 g
(e)	1500 Pa = 1,5 kPa	(f)	150 000 000 nm = 0,15 m
(g)	8×10^{-7} m = 800 nm	(h)	5×10^{8} µm = 500 m
(i)	15 nm = $1,5 \times 10^{-8}$ m	(j)	3 000 nm = 3 µm

Activity 3: Practice converting between units

1. 12 cm = 120 mm = 0,12 m
2. 220 g = 220 000 mg = 0,22 kg
3. 0,1 nm = 1×10^{-10} m
4. $1,5 \times 10^{11}$ m = $1,5 \times 10^{8}$ km
5. 2×10^{-6} g = 2 µg
6. $5,97 \times 10^{27}$ g = $5,97 \times 10^{24}$ kg
7. 25 ^{o}C = 298 Kelvin.
8. 200 Kelvin = -73 ^{o}C.
9. 7 884 000 minutes ÷ 60 minutes/hour = $1,314 \times 10^{5}$ hours ÷ 24 hours/day = $5,475 \times 10^{3}$ days ÷ 365 days/year = 15 years
10. 22 atm × 101 325 Pa/atm = $2,2292 \times 10^{6}$ Pa = $2,2292 \times 10^{3}$ kPa
11. $1,08 \times 10^{6}\ \cancel{\text{km}}\cdot\text{hr}^{-1} \times 10^{3}\ \text{m}\cdot\cancel{\text{km}}^{-1} = \dfrac{1,08\times10^{9}\ \text{m}\cdot\cancel{\text{hr}}^{-1}}{3600\ \text{sec}\cdot\cancel{\text{hr}}^{-1}} = 3 \times 10^{5}\ \text{m}\cdot\text{s}^{-1}$

Sub-topic 2. Problem solving techniques

Unit 1. Problem-solving strategies

Activity 1 – *Working with scientific formulae*

1. $d = \dfrac{m}{V} = \dfrac{15\ \text{g}}{5\ \text{cm}^3} = 3\ \text{g}\cdot\text{cm}^{-3}$.
2. $m = d\,V = 0,4\ \text{g}\cdot\text{cm}^{-3} \times 250\ \text{cm}^3 = 100\ \text{g}$
3. $V = \dfrac{m}{d} = \dfrac{500\ \text{g}}{0,4\ \text{g}\cdot\text{cm}^{-3}} = 1\ 250\ \text{cm}^3 \div 250\ \text{cm}^3\cdot\text{cup}^{-1} = 5$ cups

Sub-topic 3. Graph drawing, analysis and interpretation

Assessment: Basic Scientific Skills **Total marks = 30**

Assess your understanding of this topic by answering the following questions.

1.

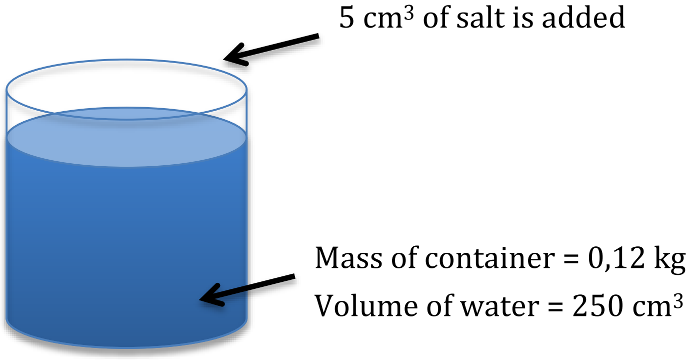
a. 0,1 mm = 1×10^8 nm (2)

b. 0,1 mm = 1×10^5 µm (2)

c. 0,1 mm = 1×10^{-7} km (2)

2.

Step 1 – Draw a diagram



(1)

Step 2 – Given: Mass of container = 0,12 kg × 1000 = 120 g **(1)**

Volume of water = 250 cm^3 ; Density of water = 1 g·cm^{-3}

Volume of salt = 5 cm^3 ; Density of salt = 2 g·cm^{-3}

Step 3 – Work out what is being asked:

We are asked to calculate the total mass, i.e. mass of water + mass of container + mass of salt.

Step 4 – Select equation or concept:

The equation that we need to use in this case is:

$d = \frac{m}{V}$, where we will make m the subject of the formula: m = d V. **(1)**

Step 5 – Do the calculation:

Mass of water: m = d V = 1 g·cm^{-3} × 250 cm^3 = 250 g

Mass of salt: m = d V = 2 g·cm^{-3} × 5 cm^3 = 10 g

Total mass = mass of water + mass of container + mass of salt

= 250 g + 120 g + 10 g = 380 g **(1)**

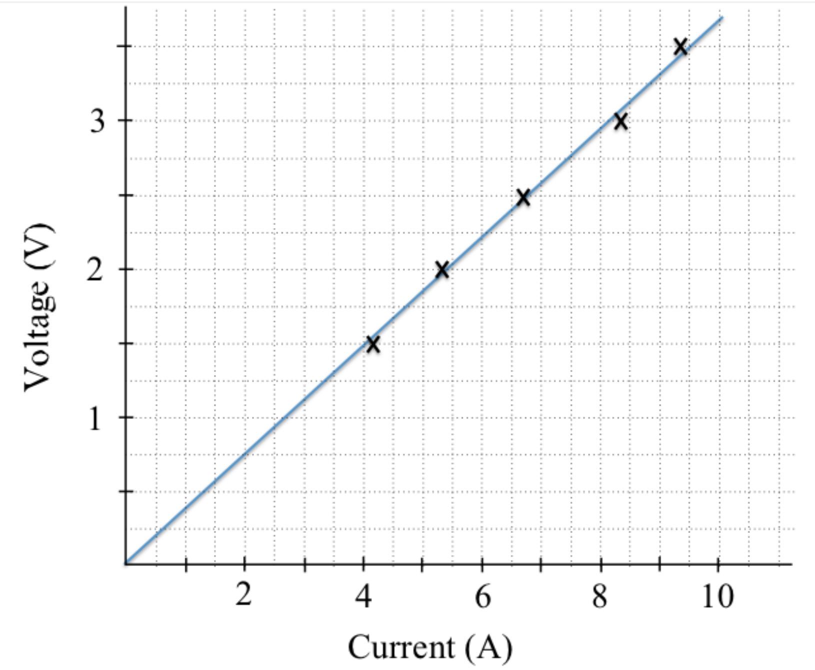
In kg, total mass = 380 g ÷ 1000 = 0,38 kg **(1)**

Step 6 – Reflect on your answer:

The total mass of the container, the water and the salt is 380 g, which is 0,38 kg. **(1)**

3.

a. and b. The plotted points and best fit line are shown on the diagram below:



(1) mark for each correctly plotted point = (5)

(1) mark for the best-fit line = (1)

c. gradient = $\frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{3,5\ V - 0\ V}{9,5\ A - 0\ A}$ = 0,37 Ω.

(1) mark for each correct current and voltage reading + (1) for correct answer (between 0,35 Ω and 0,4 Ω) = (5)

d. This tells us that the resistance of the resistor is 0,37 Ω. (1)

4.

a. As time increases, position rises more slowly at the beginning, and more quickly at the end (**OR** speed of movement is increasing) (2)

b. As volume increases, pressure decreases (**OR** volume is inversely proportional to pressure) (2)

c. As time increases, displacement changes periodically from positive to negative values in a regular repeated pattern. (2)

Topic 2. Mechanics

Sub-topic 1. Vectors

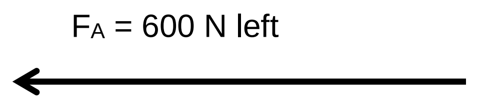
Unit 1. Introduction to vectors and scalars

Activity 1: Identify vectors and scalars

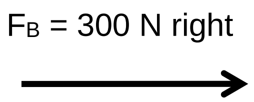
a. Temperature = scalar
b. Force = vector
c. Mass = scalar
d. Density = scalar
e. Volume = scalar
f. Weight = vector
g. Heat = scalar

Activity 2 – *Representing vectors*

a) Scale: 1 cm = 100 N



(b)



(c)

(d)

Activity 3 – *Adding vectors in 1 dimension*

You are given the following force vectors:

F_A = 90 N to the left F_B = 30 N to the right F_C = 60 N to the left

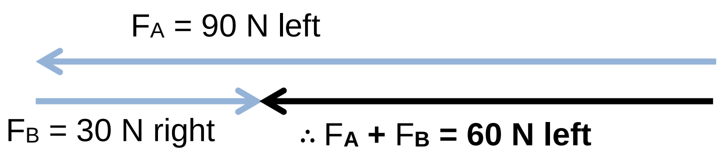
Use vector diagrams to find the resultant vectors:

a. $F_A + F_B$

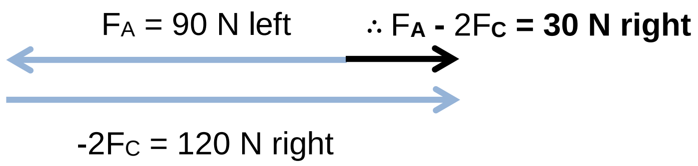
b. $F_A - 2F_C$

1.

a) Scale: 1 cm = 10 N



b) Scale: 0,5 cm = 10 N



Unit 2. Vectors in 2 dimensions

Activity 1 – *Directions of vectors in 2 dimensions*

a. Direction = 20° above the +x axis

b. Direction = 30° below the -x axis

c. Direction = 70° above the -x axis

OR Direction = 20° left of the +y axis

Activity 2: Practice adding vectors in 2 dimensions

<u>Frame of reference</u>: Let the +y direction be North.

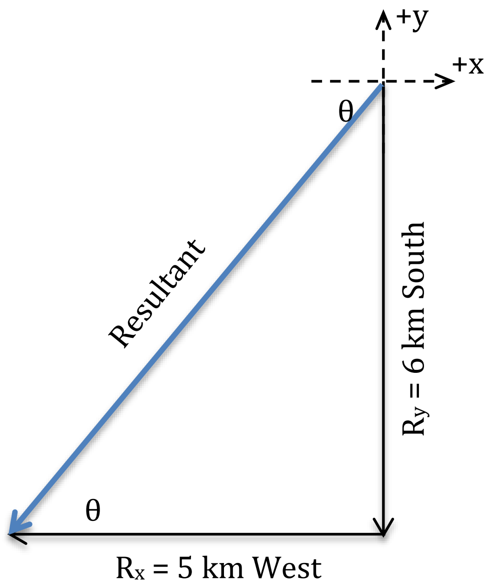
We can then draw a head-to-tail vector diagram of the jogger's movements R_x and R_y. This is shown on the right. Her resultant displacement is therefore:

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(5\text{ km})^2 + (6\text{ km})^2} = 7{,}81\text{ km}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{R_y}{R_x} = \frac{6\text{ km}}{5\text{ km}}$$

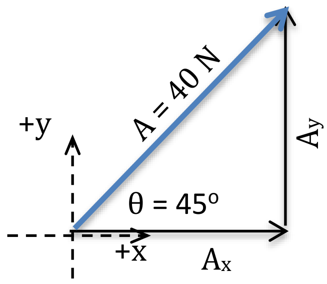
Therefore $\theta = 50{,}2^{\circ}$

The jogger's resultant displacement is therefore 7,81 km in a direction of 50,2° below the –x axis (or South of West)



Activity 3: Finding components of vectors

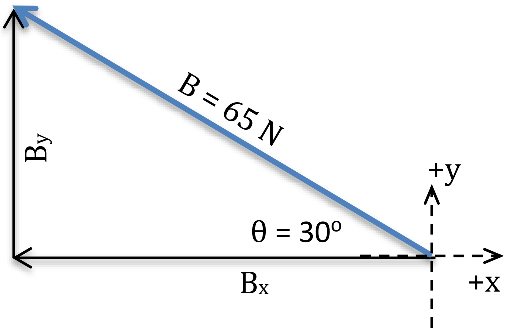
a. The diagram of vector A is shown on the right.



$A_y = + A \sin 45^o = + 40 \text{ N} \sin 45^o = + 28{,}28 \text{ N}$

$A_x = + A \cos 45^o = + 40 \text{ N} \cos 45^o = + 28{,}28 \text{ N}$

b. The diagram of vector B is shown on the right.



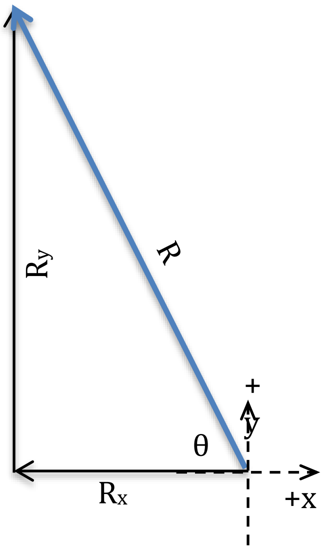
$B_y = + B \sin 30^o = + 65 \text{ N} \sin 30^o = + 32{,}5 \text{ N}$

$B_x = - B \cos 30^o = - 65 \text{ N} \cos 30^o = - 56{,}29 \text{ N}$

Sum of all of the components that are parallel to the x-direction and y-direction:

$R_x = A_x + B_x = 28{,}28 \text{ N} – 56{,}29 \text{ N} = -31{,}01 \text{ N}$

$R_y = A_y + B_y = 28{,}28 \text{ N} + 32{,}5 \text{ N} = + 60{,}78 \text{ N}$



Therefore resultant of vectors A + B:

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(31{,}01 \text{ N})^2 + (60{,}78 \text{ N})^2} = 68{,}23 \text{ N}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{R_y}{R_x} = \frac{60{,}78 \text{ N}}{31{,}01 \text{ N}}$$

Therefore $\theta = 65{,}56^o$

The resultant of vectors A + B is therefore 68,23 N in a direction of 65,56° above the –x axis.

Assessment Activity: Vectors **Total marks = 30**

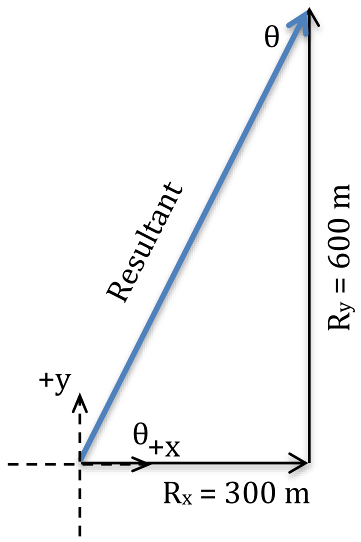
1. A scalar only has a magnitude, while a vector has a magnitude and a direction. (3)

2. Examples of a scalar: mass, temperature, heat, time (any 2)

   Examples of a vector: displacement, velocity, force, weight(any 2) (4)

3. (6)

We can draw a head-to-tail vector diagram of Nonhle's movements R_x and R_y. This is shown on the right. (3 marks for correct diagram)



Her resultant displacement is therefore:

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(300\text{ m})^2 + (600\text{ m})^2} = 670{,}82\text{ m} \quad (1)$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{R_y}{R_x} = \frac{600\text{ m}}{300\text{ m}} \quad (1)$$

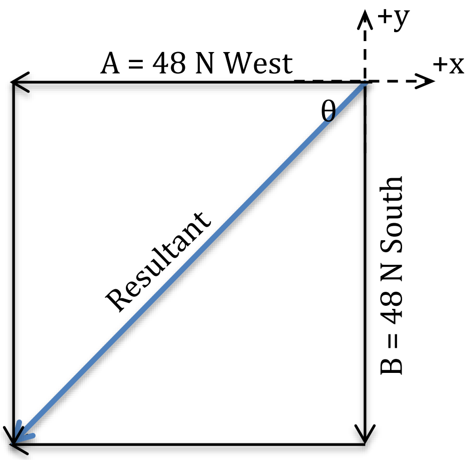
Therefore $\theta = 63{,}44^o$ (1)

Nonhle's resultant displacement is therefore 670,82 m in a direction of 63,44^o above the +x axis

4. (6)

<u>Frame of reference</u>: Let the +y direction be North.

We can then draw a tail-to-tail vector diagram of the forces, and then complete the parallelogram. This is shown on the right. (3 marks for correct diagram)



The resultant force is therefore:

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(48\text{ N})^2 + (48\text{ N})^2} = 67{,}88\text{ N} \ (1)$$

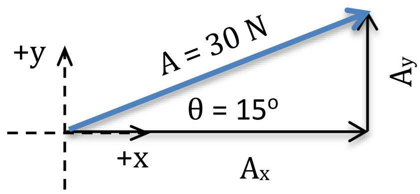
$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{B}{A} = \frac{48\text{ N}}{48\text{ N}} \quad (1)$$

Therefore $\theta = 45^o$ (1)

The resultant force is therefore 67,88 N in a direction of 45^o below the –x axis (or South of West)

5.

A diagram representing vector A is shown on the right.



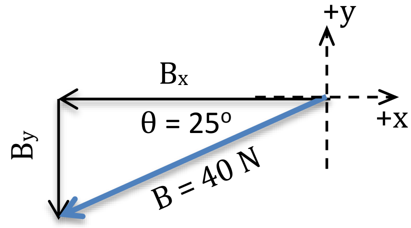
A_y = + A sin 15^o = + 30 N sin 15^o = + 7,76 N (1)

A_x = + A cos 15^o = + 30 N cos 15^o = + 28,98 N (1)

The diagram of vector B is shown on the right.

B_y = - B sin 25° = - 40 N sin 25° = - 16,91 N (1)

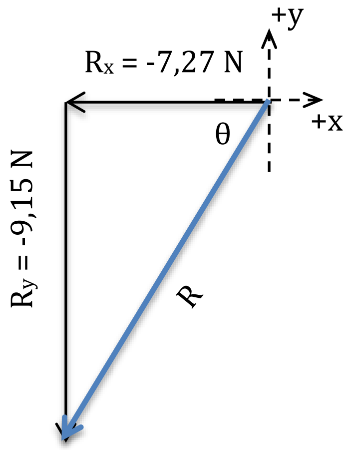
B_x = - B cos 25° = - 40 N cos 25° = - 36,25 N (1)



Sum of all of the components that are parallel to the x-direction and y-direction:

$R_x = A_x + B_x$ = 28,98 N – 36,25 N = -7,27 N (1)

$R_y = A_y + B_y$ = 7,76 N – 16,91 N = -9,15 N (1)



Therefore resultant of vectors A + B:

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(7{,}27\ \text{N})^2 + (9{,}15\ \text{N})^2} = 11{,}69\ \text{N}\ \ (1)$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{R_y}{R_x} = \frac{9{,}15\ \text{N}}{7{,}27\ \text{N}}\ (1)$$

Therefore θ = 51,53° (1)

The resultant of vectors A + B is therefore 11,69 N in a direction of 51,53° below the –x axis. (1) + (1) for the diagram

Sub-topic 2. Motion in 1-dimension

Unit 1. Position, displacement, distance

Activity 1 – Finding positions

1.

a. Sindi: -1 m

Ken: +2 m

Mzi: +5 m

2.

a. Sindi: -6 m

b. Ken: -3 m

3.

a. Sindi: +3 m

b. Mzi: -3 m

Activity 2 – Finding displacements

1. **<u>Given:</u>** x_i = 2,5 m and x_f = -4 m

   Displacement: $\Delta x = x_f - x_i$ = -4 m – 2,5 m = -6,5 m

2. **<u>Given:</u>** x_i = -5 m and x_f = -3,5 m

   Displacement: $\Delta x = x_f - x_i$ = -3,5 m – (-5 m) = +1,5 m

3. **<u>Given:</u>** x_i = -4 m and Δx = +2 m

   From $\Delta x = x_f - x_i$ we get $x_f = x_i + \Delta x$ = -4 m + 2 m = -2 m

4.

   a. Felix's starting position x_i = -4 m

   b. Felix changed his direction of movement at +6 m

   c. Felix's ending position x_f = -1 m

   d. The total distance covered by Felix = 10 m + 7 m = 17 m

   e. Felix's displacement: $\Delta x = x_f - x_i$ = -1 m – (-4 m) = +3 m

Unit 2. Speed, velocity, acceleration

Activity 1 – Test your understanding of speed and velocity

1.

(a) **<u>Given:</u>** D = 7,2 km = 7,2 × 10^3 m and Δt = 30 minutes × 60 sec·min^{-1} = 1 800 s

Average speed $= \frac{D}{\Delta t} = = \frac{7{,}2\times10^3\ \text{m}}{1\ 800\ \text{s}} =$ 4 m·s^{-1}

(b) **<u>Given:</u>** Δx = 3,6 km = 3,6 × 10^3 m and Δt = 30 minutes × 60 sec·min^{-1} = 1 800 s

$v = \frac{\Delta x}{\Delta t} = \frac{3{,}6\times10^3\ \text{m}}{1\ 800\ \text{s}}$ = 2 m·s^{-1} to the East

(c) **<u>Given:</u>** Δx = 3,6 km and Δt = 30 minutes = 0,5 hr

$v = \frac{\Delta x}{\Delta t} = \frac{3{,}6\ \text{km}}{0{,}5\ \text{hr}}$ = 7,2 km·hr^{-1} to the East

OR v = 2 m·s^{-1} × 10^{-3} × 3600 sec·hr^{-1} = 7,2 km·hr^{-1} to the East

2.

(a) **Given:** $x_i = +3$ m and $x_f = -3$ m, $\Delta t = 6$ s

Since velocity is constant from 0 s to 6 s, we can use this time interval to find the instantaneous velocity after 3 s.

Instantaneous velocity: $v = \frac{dx}{dt} = \frac{-3\text{ m} - 3\text{ m}}{6\text{ s} - 0\text{ s}} = \frac{-6\text{ m}}{6\text{ s}} = -1\text{ m·s}^{-1}$

(b) **Given:** $x_i = -3$ m and $x_f = +6$ m, $\Delta t = 2$ s

Since velocity is constant for these 2 seconds, we can use this time interval to find the instantaneous velocity after 1 s of this motion.

Instantaneous velocity: $v = \frac{dx}{dt} = \frac{+6\text{ m} - (-3\text{ m})}{2\text{ s} - 0\text{ s}} = \frac{+9\text{ m}}{2\text{ s}} = +4{,}5\text{ m·s}^{-1}$

(c) **Given:** $x_i = +3$ m and $x_f = +6$ m and total time = 8 s

Average velocity: $v = \frac{\Delta x}{\Delta t} = \frac{+6\text{ m} - 3\text{ m}}{8\text{ s}} = \frac{+3\text{ m}}{8\text{ s}} = +0{,}375\text{ m·s}^{-1}$

(d) **Given:** Total distance D = 6 m + 9 m = 15 m and total time = 8 s

Average speed $= \frac{D}{\Delta t} = = \frac{15\text{ m}}{8\text{ s}} = 1{,}875\text{ m·s}^{-1}$

(e) **Given:** $v = -3\text{ m·s}^{-1}$ and $\Delta t = 6$ s and $x_i = +6$ m

From $v = \frac{\Delta x}{\Delta t}$ we get $\Delta x = v \times \Delta t = -3\text{ m·s}^{-1} \times 6\text{ s} = -18\text{ m}$

From $\Delta x = x_f - x_i$ we can find $x_f = \Delta x + x_i = -18\text{ m} + 6\text{ m} = -12\text{ m}$

Activity 5 – Investigating acceleration

1. **Given:** $v_i = +4\text{ m·s}^{-1}$ and $v_f = +4\text{ m·s}^{-1}$ and $\Delta t = 2$ s

$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{4\text{ m.s}^{-1} - 4\text{ m.s}^{-1}}{2\text{ s}} = 0\text{ m.s}^{-2}$

2. **Given:** $v_i = 0\text{ m·s}^{-1}$ and $v_f = +4\text{ m·s}^{-1}$ and $\Delta t = 2$ s

$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{4\text{ m.s}^{-1} - 0\text{ m.s}^{-1}}{2\text{ s}} = +2\text{ m.s}^{-2}$

3. **Given:** $v_i = +8\text{ m·s}^{-1}$ and $v_f = +4\text{ m·s}^{-1}$ and $\Delta t = 2$ s

$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{4\text{ m.s}^{-1} - 8\text{ m.s}^{-1}}{2\text{ s}} = -2\text{ m.s}^{-2}$

4. **Given:** $v_i = -4\text{ m·s}^{-1}$ and $v_f = 0\text{ m·s}^{-1}$ and $\Delta t = 2$ s

$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{0\text{ m.s}^{-1} - (-4\text{ m.s}^{-1})}{2\text{ s}} = +2\text{ m.s}^{-2}$

5. **Given:** $v_i = -4\text{ m·s}^{-1}$ and $v_f = -8\text{ m·s}^{-1}$ and $\Delta t = 2$ s

$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{-8\text{ m.s}^{-1} - (-4\text{ m.s}^{-1})}{2\text{ s}} = -2\text{ m.s}^{-2}$

- Acceleration is zero when there is no change to the velocity

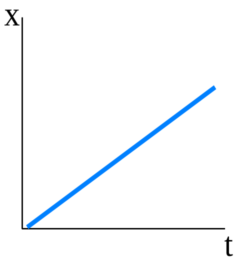
- Acceleration is positive when velocity increases in a positive direction, or decreases (slows down) in a negative direction.
- Acceleration is negative when velocity decreases in a positive direction, or increases (speeds up) in a negative direction.

Unit 3.	Graphs of motion

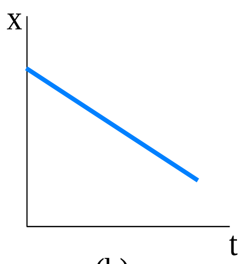
Activity 1 – Position-time graphs for uniform motion

1. Graph 1 = walk in a negative direction with uniform velocity, then in a positive direction with uniform velocity
   Graph 2 = walk in a positive direction with uniform velocity, then stand still
   Graph 3 = walk in a negative direction with fast uniform velocity, then in a negative direction with a slower uniform velocity

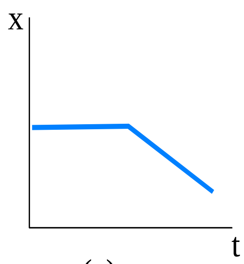
2.



(a)



(b)



(c)

3.
   a. The woman starts at a position of 1m and runs with a constant velocity in a positive direction for 2 seconds. She then stops for 2 seconds at a position of 1,5 m, and then she runs in a negative direction with a constant velocity for 2 seconds until she reaches a position of 0 m.

   b.
      i. Velocity between 0 s and 2 s:

      $$v = \frac{\Delta x}{\Delta t} = \frac{1{,}5\ \text{m} - 1\ \text{m}}{2\ \text{s} - 0\ \text{s}} = 0{,}25\ \text{m·s}^{-1}$$

      ii. Velocity between 2 s and 4 s:

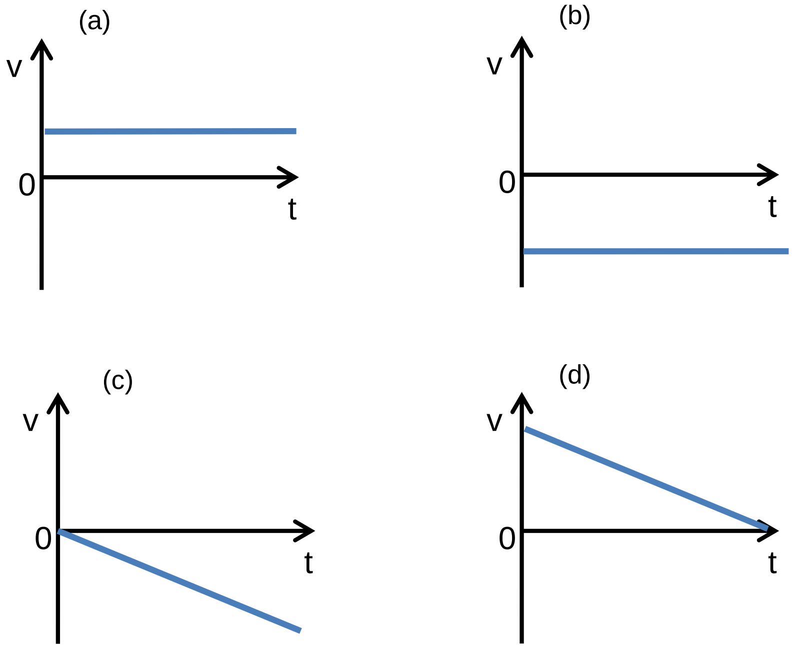
      $$v = \frac{\Delta x}{\Delta t} = \frac{1{,}5\ \text{m} - 1{,}5\ \text{m}}{4\ \text{s} - 2\ \text{s}} = 0\ \text{m·s}^{-1}$$

      iii. Velocity between 4 s and 6 s:

      $$v = \frac{\Delta x}{\Delta t} = \frac{0\ \text{m} - 1{,}5\ \text{m}}{6\ \text{s} - 4\ \text{s}} = -0{,}75\ \text{m·s}^{-1}$$

Activity 3 – Velocity-time graphs

1.



2.

a. Cameron rode with increasing velocity in the positive direction for 2 seconds. He then rode with a uniform velocity for another 2 seconds, and then he slowed down while still riding in the positive direction for another 2 seconds.

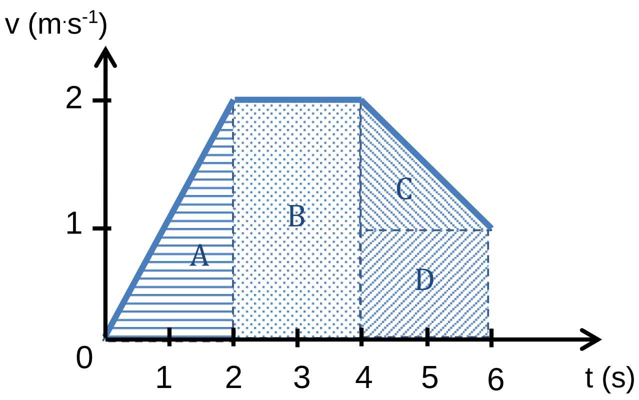
b.

i. a = gradient of v-t graph = $\frac{v_f - v_i}{\Delta t} = \frac{2\ m{\cdot}s^{-1} - 0\ m{\cdot}s^{-1}}{2\ s - 0\ s}$ = 1 m·s^{-2}

ii. a = $\frac{v_f - v_i}{\Delta t} = \frac{2\ m{\cdot}s^{-1} - 2\ m{\cdot}s^{-1}}{4\ s - 2\ s}$ = 0 m·s^{-2}

iii. a = $\frac{v_f - v_i}{\Delta t} = \frac{1\ m{\cdot}s^{-1} - 2\ m{\cdot}s^{-1}}{6\ s - 4\ s}$ = -0,5 m·s^{-2}

c. Total displacement = area under v-t graph
= area of A + area of B + area of C + area of D
= $(\frac{1}{2} \times 2\ s \times 2\ m{\cdot}s^{-1}) + (2\ s \times 2\ m{\cdot}s^{-1}) + (\frac{1}{2} \times 2\ s \times 1\ m{\cdot}s^{-1}) + (2\ s \times 1\ m{\cdot}s^{-1})$
= 2 m + 4 m + 1 m + 2 m
= 9 m



Activity 4 – Acceleration-time graphs

a. Δv = area underneath a-t graph

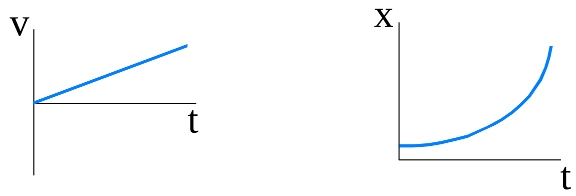
$= (\text{base} \times \text{height})$

$= (5\text{ s} \times 1{,}5\text{ m·s}^{-2})$

$= 7{,}5\text{ m·s}^{-1}$

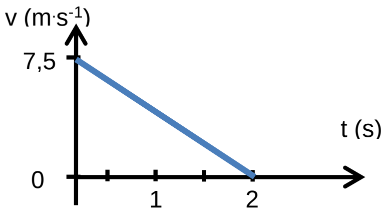
So the final velocity after the 5 seconds was $0\text{ m·s}^{-1} + 7{,}5\text{ m·s}^{-1} = 7{,}5\text{ m·s}^{-1}$

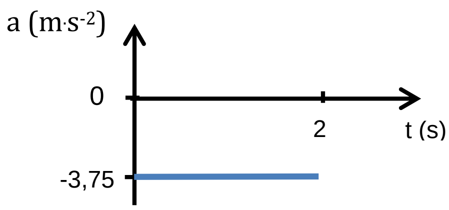
b.



c. $a = \frac{v_f - v_i}{\Delta t} = \frac{0\text{ m·s}^{-1} - 7{,}5\text{ m·s}^{-1}}{2\text{ s} - 0\text{ s}} = -3{,}75\text{ m·s}^{-2}$

d. The velocity-time and acceleration-time graphs are shown below:

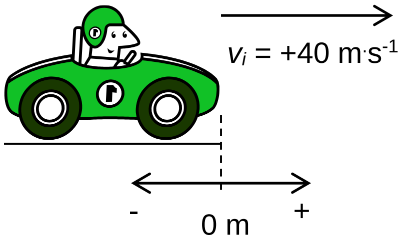




Unit 4. Equations of motion

Activity 1 – Solving Problems with Equations of Motion

1. Step 1: Diagram of the scenario:



Step 2: Given:

$v_i = +40\ m{\cdot}s^{-1}$

For the car to stop, $v_f = 0\ m{\cdot}s^{-1}$

$t = 10\ s$

Step 3:

We are asked to calculate the acceleration of the car, so we must solve for a.

Step 4:

The equation that we will use is $v_f = v_i + a\Delta t$

Step 5: Calculation:

From the equation $v_f = v_i + a\Delta t$

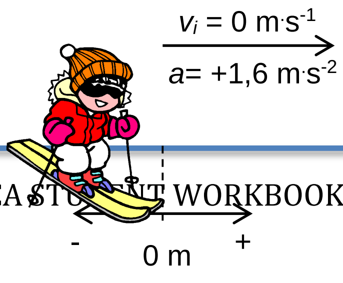
We can solve for a:

$$a = \frac{v_f - v_i}{\Delta t} = \frac{0-(40\ m{\cdot}s^{-1})}{(10\ s)} = -4\ m{\cdot}s^{-2}$$

Step 6:

The acceleration of the car is $-4\ m{\cdot}s^{-2}$.

2. Step 1: Diagram of the scenario:



a. Step 2: Given:

$a = 1.6\ m{\cdot}s^{-2}$ and $t = 5$ s and $v_i = 0\ m{\cdot}s^{-1}$

Step 3:

We are asked how far she travels during the first 5 seconds.

Step 4:

The equation that we will use is $\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$

Step 5: Calculation:

$\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2 = 0 + \frac{1}{2} \times 1.6\ m{\cdot}s^{-2} \times (5\ s)^2 = 20\ m$

Step 6:

She travels 20 m during the first 5 seconds.

b. Step 2: Given:

$a = 0\ m{\cdot}s^{-2}$ and $t = 5$ s.

We need to calculate the final velocity after the first 5 seconds to give us the initial velocity at the start of this 5 seconds.

$v_f = v_i + a\Delta t = 0 + (1.6\ m{\cdot}s^{-2}) \times (5\ s) = 8\ m{\cdot}s^{-1}$

So for the second 5 s, $v_i = 8\ m{\cdot}s^{-1}$

Step 3:

We are asked how far she travels during the second 5 seconds.

Step 4:

The equation that we will use is $\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$

Step 5: Calculation:

$\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2 = (8\ m{\cdot}s^{-1} \times 5\ s) + 0 = 40\ m$

Step 6:

She travels 40 m during the second 5 seconds.

c. Step 2: Given:
v_i = 8 m·s^{-1} and Δx = 8 m and v_f = 0 m·s^{-1}

Step 3:

We are asked to calculate her acceleration, *a.*

Step 4:

The equation that we will use is $v_f^2 = v_i^2 + 2a\Delta x$

Step 5: Calculation:

From the equation $v_f^2 = v_i^2 + 2a\Delta x$

We can solve for a:

$$a = \frac{v_f^2 - v_i^2}{2 \times \Delta x} = \frac{0-(8\ \text{m}\cdot\text{s}^{-1})^2}{2 \times 8\ \text{m}} = -4\ \text{m}\cdot\text{s}^{-2}$$

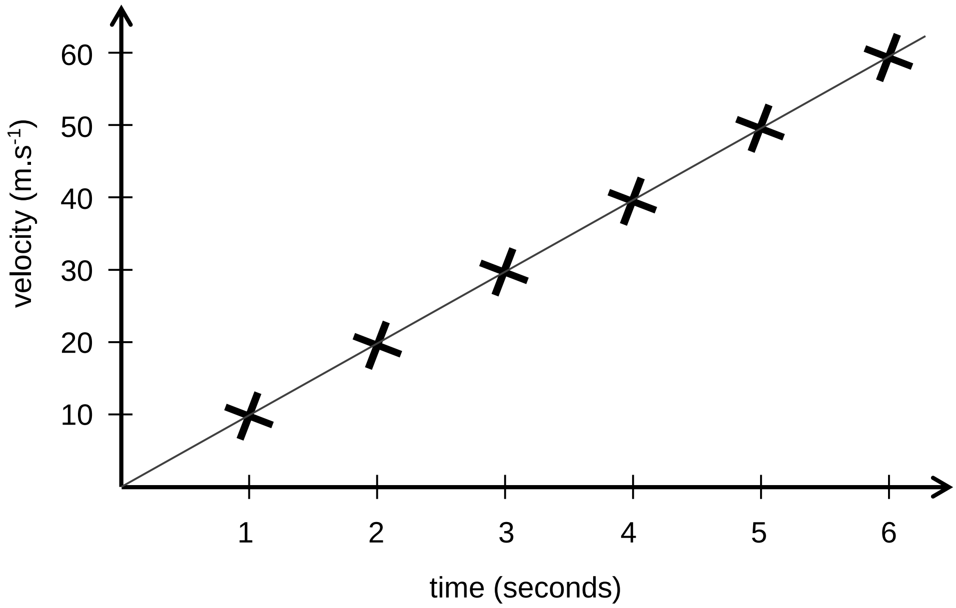
Step 6:

Her acceleration up the slope is -4 m·s^{-2}.

Unit 5. Projectile motion

Activity 1 – Gravitational acceleration of a falling object

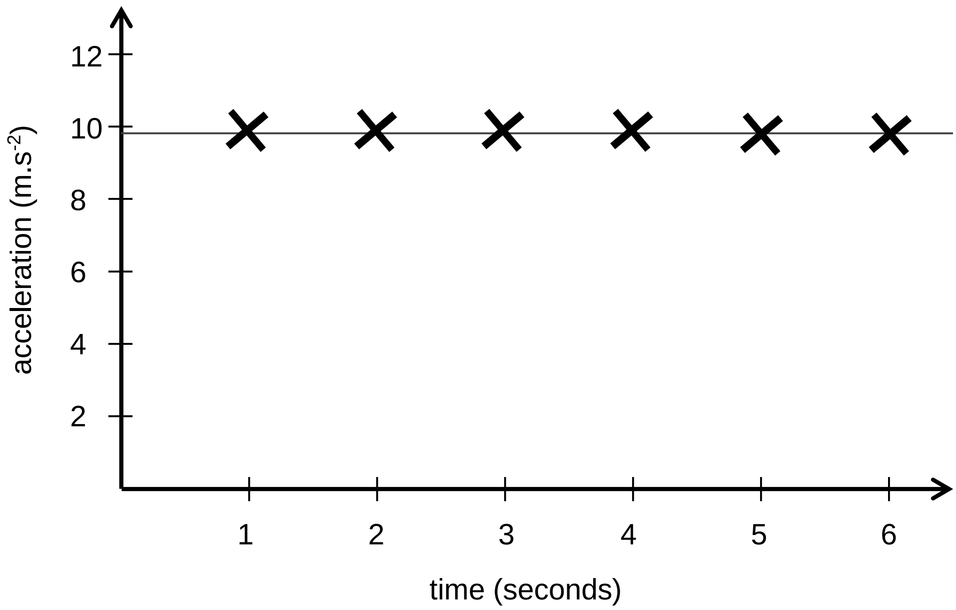
1. Your velocity-time graphs should look similar to the one given below:



2. The best-fit line should go through the points as accurately as possible.
3. The shape of the graph should be a straight line with a positive gradient.
4. The acceleration of the ball between the following times is:
   a. between 0s and 1s: a = 9,8 $m{\cdot}s^{-2}$
   b. between 2s and 3s: a = 9,8 $m{\cdot}s^{-2}$
   c. between 3s and 6s: a = 9,8 $m{\cdot}s^{-2}$
5.

Acceleration ($m{\cdot}s^{-2}$)	Time (s)
9,8	1
9,8	2
9,8	3
9,8	4
9,8	5
9,8	6

6. Your acceleration vs time graph should look like the one below:



7. The shape of the acceleration-time graph for an object falling freely in the air is a straight horizontal line with a value of 9,8 $m{\cdot}s^{-2}$.
8. The acceleration of the balls does not depend on their masses, but is a constant (9,8 $m{\cdot}s^{-2}$), regardless of the mass of the object.

Case 1: An object is dropped from rest

Example:

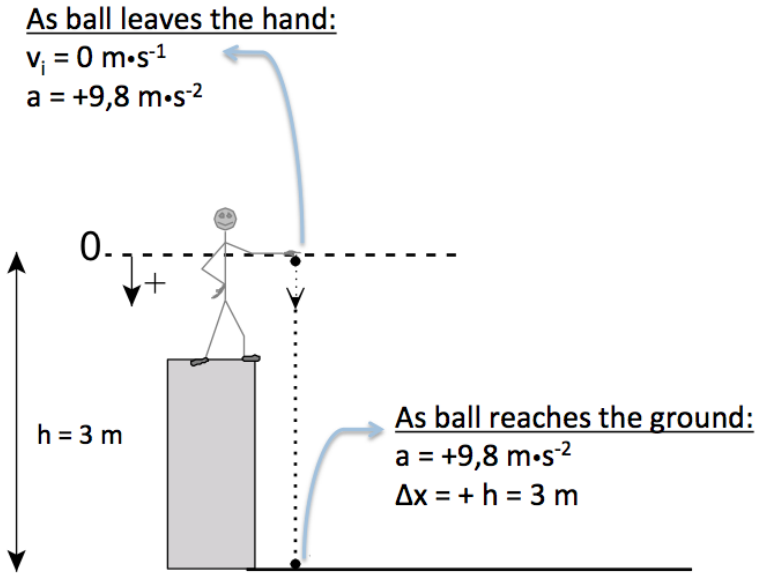
Ayanda was standing on a bridge, and dropped a stick into the river, which was 3 m below the height that he dropped the stick from.

a. Calculate the final velocity of the stick just before it hit the water.
b. Calculate the amount of time that it would take for the stick to hit the water.

Solution:

Step 1 and 2: Diagram of the scenario with given information:

Frame of reference: Choose down as +



Step 3: a. We are asked to find the stick's final velocity, v_f.

b. We are asked to find the time taken for the stick to hit the water, Δt.

Step 4: a. The equation that we will use is $v_f{}^2 = v_i{}^2 + 2a\Delta x$

b. The equation that we will use is $v_f = v_i + a\Delta t$

Step 5: Calculation:

a. From the equation $v_f{}^2 = v_i{}^2 + 2a\Delta x = 0 + 2 \times (9{,}8\ \text{m·s}^{-2}) \times 3\ \text{m} = 58{,}8\ \text{m}^2\text{·s}^{-2}$

Therefore $v_f = \sqrt{58{,}8\ \text{m}^2 \cdot \text{s}^{-2}} = 7{,}67\ \text{m·s}^{-1}$

b. From the equation $v_f = v_i + a\Delta t$

We can solve for Δt:

$\Delta t = (v_f - v_i) / a = (7{,}67\ \text{m·s}^{-1} - 0) / (9.8\ \text{m·s}^{-2}) = 0{,}78\ \text{s}$

Step 6: a. The stick had a final velocity of +7,67 m·s^{-1} downwards.

b. The time for the stick to hit the water is 0,78 seconds.

Case 2: An object is thrown upward, and then falls back to the same height that it was thrown from

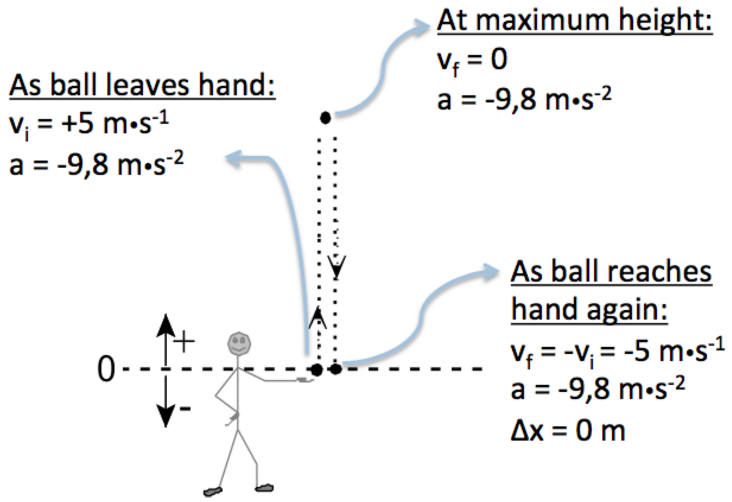
Kagiso threw a ball upward with an initial velocity of 5 $m{\cdot}s^{-1}$.

a. What was the maximum height reached by the ball?
b. After how much time did the ball fall back to the position that Kagiso threw it from?

Solution:

Step 1 and 2: Diagram of the scenario with given information:

Frame of reference: Choose up as +



Step 3: a. We are asked to find the maximum height, Δx, where $v_f = 0$.

b. We are asked to find the time for the full motion, Δt, where $v_f = -v_i$.

Step 4: a. The equation that we will use is $v_f^2 = v_i^2 + 2a\Delta x$

b. The equation that we will use is $v_f = v_i + a\Delta t$

Step 5: Calculation:

a. From the equation $v_f^2 = v_i^2 + 2a\Delta x$ we solve for Δx:

$\Delta x = (v_f^2 - v_i^2) / 2a = (0 - (5\ m{\cdot}s^{-1})^2) / (2 \times (-9,8\ m{\cdot}s^{-2})) = +1,28$ m

b. From the equation $v_f = v_i + a\Delta t$ we can solve for Δt:

$\Delta t = (v_f - v_i) / a = (-5\ m{\cdot}s^{-1} - (+5\ m{\cdot}s^{-1})) / (9,8\ m{\cdot}s^{-2}) = 1,02$ s

OR we can find the time to the maximum height:

$\Delta t = (v_f - v_i) / a = (0\ m{\cdot}s^{-1} - (+5\ m{\cdot}s^{-1})) / (9,8\ m{\cdot}s^{-2}) = 0,51$ s

Therefore total time = 0,51s × 2 = 1,02 s

Step 6: a. The maximum height reached is 1,28 m above the starting position.

b. The total time of the motion is 1,02 seconds.

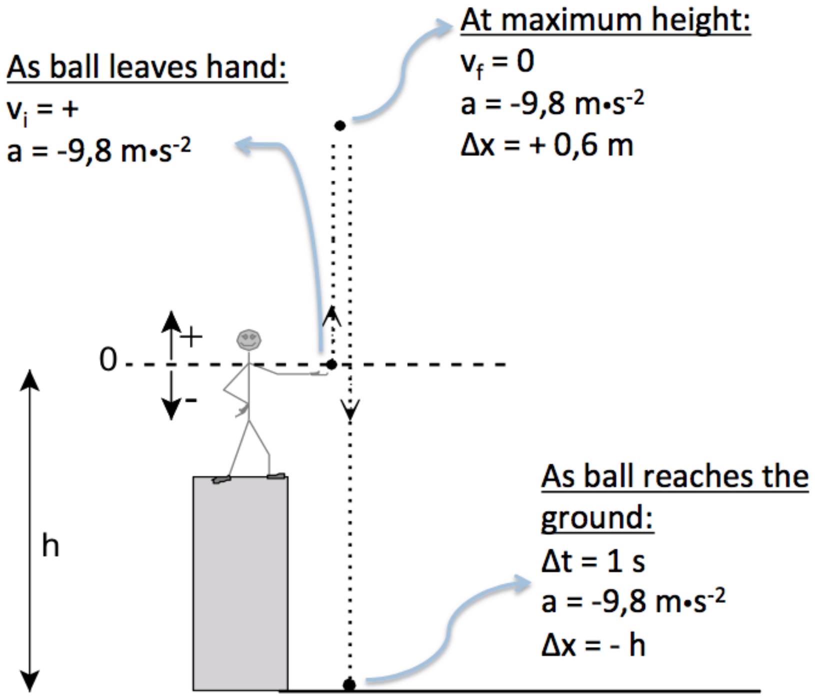
Example 3: An object is thrown up and then falls down to a position below its starting position

A flea jumps from a table to a height of 0,6 m above the table, and falls to the ground below the table 1 second after it jumped. What is the height of the table above the ground?

Solution:

Step 1 and 2: Diagram of the scenario with given information:

Frame of reference: Choose up as +



Step 3: We are asked to find the height of the table, which is the magnitude of the displacement for the flea's full motion, Δx. To be able to do this, we need to find the initial velocity, v_i.

Step 4: We will first use the equation $v_f^2 = v_i^2 + 2a\Delta x$ to find v_i

We will then use the equation $\Delta x = v_i\Delta t + ½a\Delta t^2$ to find Δx.

Step 5: Calculation:

From the equation $v_f^2 = v_i^2 + 2a\Delta x$ we solve for v_i:

$v_i^2 = v_f^2 - 2a\Delta x = 0^2 - (2 \times (-9,8 \text{ m·s}^{-2}) \times 0,6 \text{ m}) = 11,76 \text{ m}^2\text{·s}^{-2}$

Therefore $v_i = \sqrt{11,76 \text{ m}^2 \cdot \text{s}^{-2}} = +3,43 \text{ m·s}^{-1}$

Therefore $\Delta x = v_i\Delta t + ½a\Delta t^2 = 3,43 \text{ m·s}^{-1} \times 1 \text{ s} + (½ \times (-9,8 \text{ m·s}^{-2}) \times (1 \text{ s})^2) = -1,47 \text{ m}$

(This displacement is negative, since we chose up as the positive direction, and the ground is **below** the table.)

Step 6: The height of the table is 1,47 m above the ground.

Assessment: Motion in 1 dimension **Total marks = 100**

1. The completed table is shown below (1 mark for each correct entry). (15)

Description	Name of quantity	Units	Scalar / Vector
The total length of the path of motion	***Distance***	***m***	***Scalar***
The change in position from starting point to ending point	***Displacement***	***m***	***Vector***
The rate at which distance is covered	***Speed***	$m{\cdot}s^{-1}$	***Scalar***
The rate of change of position	***Velocity***	$m{\cdot}s^{-1}$	***Vector***
The rate of change of velocity	***Acceleration***	$m{\cdot}s^{-2}$	***Vector***

2.

a. **<u>Given:</u>** x_i = -4 m and x_f = +5 m and Δt = 3,6 s
Average velocity: $v = \frac{\Delta x}{\Delta t} = \frac{+5\text{ m}-(-4\text{ m})}{3{,}6\text{ s}} = \frac{+9\text{ m}}{3{,}6\text{ s}}$ = +2,5 $m{\cdot}s^{-1}$ (2)

b. **<u>Given:</u>** x_i = +5 m and x_f = -6 m and Δt = 2 s
Velocity: $v = \frac{\Delta x}{\Delta t} = \frac{-6\text{ m}-5\text{ m}}{2\text{ s}} = \frac{-11\text{ m}}{2\text{ s}}$ = -5,5 $m{\cdot}s^{-1}$ (2)

c. **<u>Given:</u>** x_i = -4 m and x_f = -6 m and Δt = 3,6 s + 2 s = 5,6 s
Average velocity: $v = \frac{\Delta x}{\Delta t} = \frac{-6\text{ m}-(-4\text{ m})}{5{,}6\text{ s}} = \frac{-2\text{ m}}{5{,}6\text{ s}}$ = -0,36 $m{\cdot}s^{-1}$ (3)

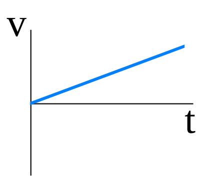
3.

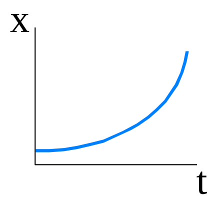
a. 2 $m{\cdot}s^{-2}$ means that the velocity increases by 2 $m{\cdot}s^{-1}$ in each second.
OR 2 $m{\cdot}s^{-2}$ is the acceleration, which is the rate of change of velocity. (3)

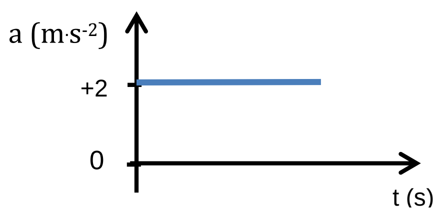
b. (i) from the equation $a = \frac{\Delta v}{\Delta t}$ we get Δv = a Δt = 2 $m{\cdot}s^{-2}$ × 1 s = 2 $m{\cdot}s^{-1}$
(ii) v = a Δt = 2 $m{\cdot}s^{-2}$ × 2 s = 4 $m{\cdot}s^{-1}$
(iii) v = a Δt = 2 $m{\cdot}s^{-2}$ × 5 s = 10 $m{\cdot}s^{-1}$ (6)

c. $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ = 0 $m{\cdot}s^{-1}$ × 5 s + (½ × (-2 $m{\cdot}s^{-2}$) × (5 s)^2) = -25 m (4)

d. (3) marks for each correct shape
(9)







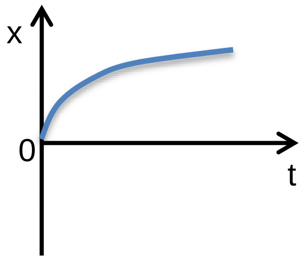
4.

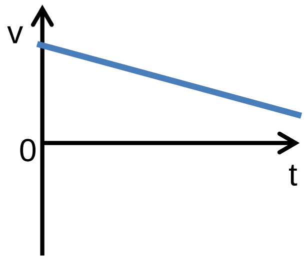
a. Given: $v_i = 28\ m{\cdot}s^{-1}$; $a = -1{,}50\ m{\cdot}s^{-2}$; $v_f = 10\ m{\cdot}s^{-1}$

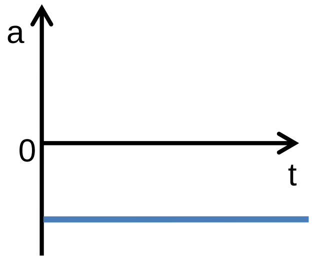
Calculation: From the equation $v_f = v_i + a\Delta t$ we can solve for Δt:

$\Delta t = (v_f - v_i) / a = (10\ m{\cdot}s^{-1} - (+28\ m{\cdot}s^{-1})) / (-1{,}50\ m{\cdot}s^{-2}) = 12\ s$ (4)

b. (3) marks for each correct shape (9)







5. Frame of reference: Take down as +

Given: $v_i = 0\ m{\cdot}s^{-1}$; $a = +9{,}8\ m{\cdot}s^{-2}$; $\Delta x = 8\ m$

Calculation: $v_f^2 = v_i^2 + 2a\Delta x = 0 + 2 \times (9{,}8\ m{\cdot}s^{-2}) \times 8\ m = 156{,}8\ m^2{\cdot}s^{-2}$

Therefore $v_f = \sqrt{156{,}8\ m^2 \cdot s^{-2}} = 12{,}52\ m{\cdot}s^{-1}$ (4)

6. Frame of reference: Take up as +

a. Given: At max height $v_f = 0\ m{\cdot}s^{-1}$; $a = -9{,}8\ m{\cdot}s^{-2}$; $\Delta x = 6\ m$

Calculation: From the equation $v_f^2 = v_i^2 + 2a\Delta x$ we solve for v_i:

$v_i^2 = v_f^2 - 2a\Delta x = 0^2 - (2 \times (-9{,}8\ m{\cdot}s^{-2}) \times 6\ m) = 117{,}6\ m^2{\cdot}s^{-2}$

Therefore $v_i = \sqrt{117.6\ m^2 \cdot s^{-2}} = +10{,}84\ m{\cdot}s^{-1}$

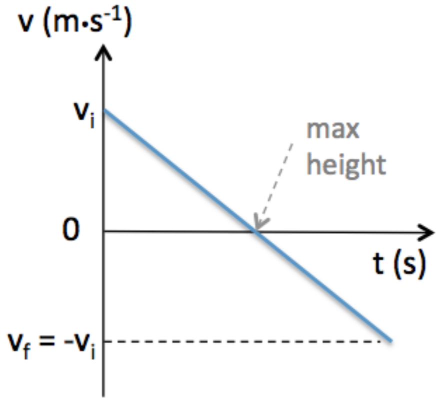
Therefore when the ball return to the height it was thrown from

$v_f = -10{,}84\ m{\cdot}s^{-1}$

From the equation $v_f = v_i + a\Delta t$ we can solve for Δt:

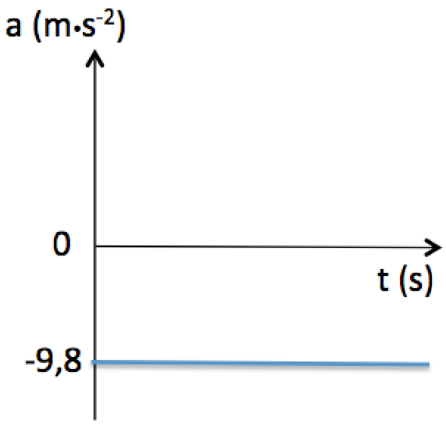
$\Delta t = (v_f - v_i) / a = (-10{,}84\ m{\cdot}s^{-1} - (10{,}84\ m{\cdot}s^{-1})) / (-9{,}8\ m{\cdot}s^{-2}) = 2{,}21\ s$ (5)

b.



(3)

c.



(3)

7. Frame of reference: Take up as +
   Given: $a = -9{,}8\ m{\cdot}s^{-2}$; $\Delta t = 6\ s$; $v_f = -v_i$
   Calculation: From the equation $v_f = v_i + a\Delta t$ we solve for v_i:

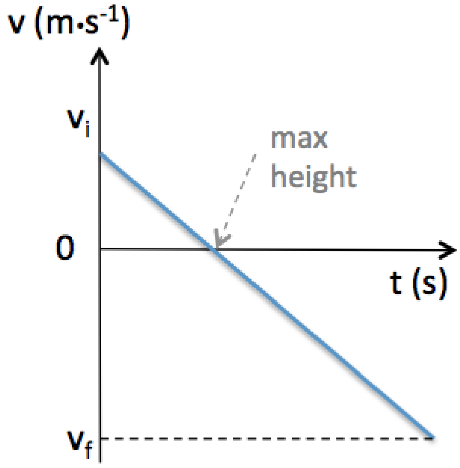
   $-v_i = v_i + a\Delta t$

   Therefore $2v_i = -a\Delta t = -(-9{,}8\ m{\cdot}s^{-2}) \times 6\ s = 58{,}8\ m$

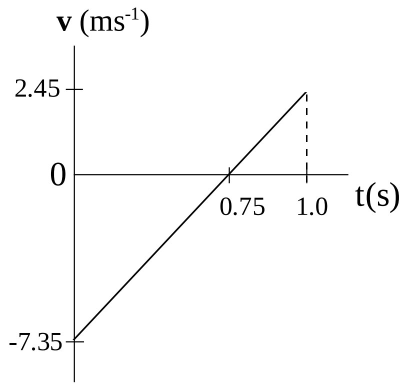
   Therefore $2v_i = ½ \times 58{,}8\ m = 29{,}4\ m$ (5)

8.
   a. Frame of reference: Take up as positive, and the starting point of the ball as the zero position
      Given: $v_i = +8\ m{\cdot}s^{-1}$; $\Delta x = -9\ m$; $a = -9{,}8\ m{\cdot}s^{-2}$
      To find v_f:
      $v_f^{\ 2} = v_i^{\ 2} + 2\ a\ \Delta x = (8ms^{-1})^2 + 2 \times (-9{,}8ms^{-2}) \times -9m = 240\ m^2s^{-2}$
      $\therefore v_f = \pm\sqrt{240m^2s^{-2}} = -15{,}5\ m{\cdot}s^{-1}$ (We choose the negative sign since final velocity is down) (5)

   b. (3)



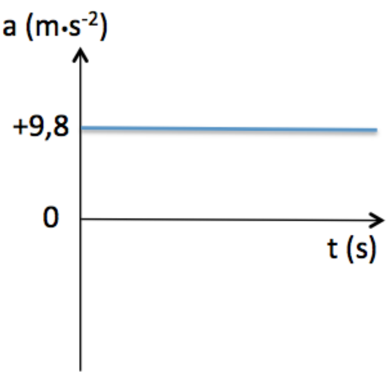
2. The graph below represents the motion of an object in the air.



a. Δx = area under v-t graph = area of triangle 1 + area of triangle 2
   $= (\frac{1}{2}\text{ base} \times \text{height})_1 + (\frac{1}{2}\text{ base} \times \text{height})_2$
   $= (\frac{1}{2} \times 0{,}75\text{ s} \times 7{,}35\text{ m·s}^{-1}) + (\frac{1}{2} \times 0{,}25\text{ s} \times 2{,}45\text{ m·s}^{-1})$
   $= 2{,}76\text{ m} + 0{,}31\text{ m}$
   $= 3{,}07\text{ m}$ (4)

b. <u>Given</u>: $v_i = -7{,}35\text{ m·s}^{-1}$; $a = +9{,}8\text{ m·s}^{-2}$; $\Delta t = 0{,}5\text{ s}$
   To find v_f: $v_f = v_i + a\Delta t = -7{,}35\text{ m·s}^{-1} + (+9{,}8\text{ m·s}^{-2})(0{,}5\text{ s}) = -2{,}45\text{ m·s}^{-1}$ (3)

c. (3)



d. <u>Frame of reference</u>: Down is positive. (1)
   The ball is thrown upward with an initial velocity of 7,35 m·s^{-1} (1) and after it has reached its maximum height (1) it falls back down to a height

that is above its starting position (1). Its final velocity just before it lands is 2,45 $m \cdot s^{-1}$. (1) (5)

Sub-topic 3. Force and Newton's laws

Unit 1. Forces

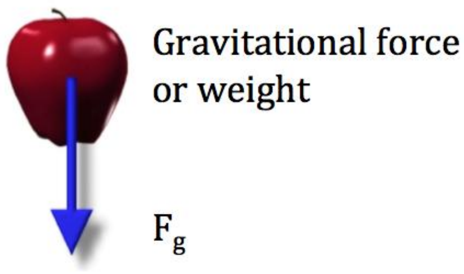
Activity 1 – Observing the gravitational force

NOTE: This is an investigation activity, so it is not important that you get these answers correct. The most important thing is for you to think about the movement of an object in the air.

1. The ball rises in the air, slowing down as it rises, until it stops at the top, and then turns to fall down again, speeding up as it falls.
2. There is a gravitational force acting on the ball pulling it towards the earth. This is why it slows down on its way up, and speeds up on its way down again.
3. The ball does not continue moving upward forever because there is a downward force acting on the ball (gravity).

As the ball is dropped towards the Earth:

1. The ball falls down towards the ground, speeding up as it falls.
2. There is a gravitational force acting on the ball pulling it towards the earth. This is why it speeds up as it falls.



Think about this:

A bathroom scale actually measures **weight**, since this is the force that pulls us toward the earth, and so our weight exerts a force on the scale. The scale is then designed to measure this force, and to convert the size of this force into units of mass.

Activity 2 – Calculate mass and weight

The missing information is shown in the table below:

Mass (g)	Mass (kg)	Weight (N)
500 g	***500 g ÷ 1000 = 0,5 kg***	***0,5 kg × 9,8 m·s^{-2} = 4,9 N***
100 g	***100 g ÷ 1000 = 0,1 kg***	***0,1 kg × 9,8 m·s^{-2} = 0,98 N***
5 kg × 1000 = 5000 g	5 kg	***5 kg × 9,8 m·s^{-2} = 49 N***
10 kg × 1000 = 10 000 g or 1 × 10^{4} g	***98 N ÷ 9,8 m·s^{-2} = 10 kg***	98 N
20 kg × 1000 = 20 000 g or 2 × 10^{4} g	20 kg	***20 kg × 9,8 m·s^{-2} = 196 N***
0,5 g	***0,5 g ÷ 1000 = 5 × 10^{-4} kg***	***5 × 10^{-4} kg × 9,8 m·s^{-2} = 196 N***
0,03 kg × 1000 = 30 g	0,03 kg	***0,03 kg × 9,8 m·s^{-2} = 0,294 N***
3500 kg × 1000 = 3,5 × 10^{6} g	3 500 kg	***3500 kg × 9,8 m·s^{-2} = 3,43 × 10^{4} N***
2 500 g	***2500 g ÷ 1000 = 2,5 kg***	***2,5 kg × 9,8 m·s^{-2} = 24,5 N***
90 kg × 1000 = 9 × 10^{4} g	***882 N ÷ 9,8 m·s^{-2} = 90 kg***	882 N

Activity 3 – The effect of air resistance on a falling object

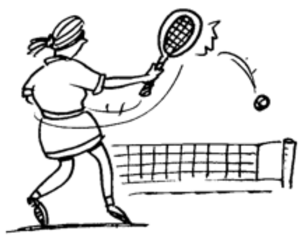
NOTE: This is an investigation activity, so it is not important that you get these answers correct. The most important thing is for you to think about the movement of both of these objects in the air.

1. When the feather and the stone are dropped at the same time, the stone hits the ground first.
2. The reason for this is that the air resistance force has a greater effect on the feather, since it has a larger surface area for the air resistance to have effect. There is a smaller air resistance force acting on the stone, so the effect of the weight is much greater.
3. If the feather and the stone were dropped at the same time on the moon, where there is no air, there would be no air resistance force, so they would both have the same acceleration (9,8 m·s^{-2} downward). Therefore they would

hit the ground at the same time.

Activity 4 – Identifying forces

1)



Applied force of racquet on ball

Weight of ball towards the earth

Air resistance force opposing the ball's motion in the air

Tension force of rope on the tyre

Weight of girl and tyre towards the earth

Normal force of tyre on the girl, upward

Tension force of elastic band on the fingers

Applied force of fingers on the elastic band

Applied force of man pushing on ball

Friction force between the ball and the ground, opposing the ball's motion

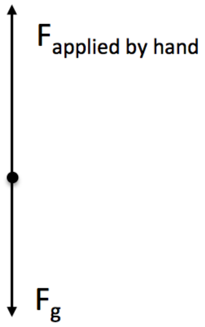
Weight of ball towards the earth

Normal force of the ground on the tyre, upward

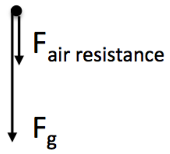
2) No, we can not see the effect of the force that the man is exerting on the wall. This does not mean that there are no forces acting, it just means that all of the force on the wall are balanced, and there is no net force on the wall.

Activity 5 – Free body diagrams

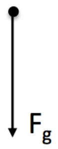
a. While the apple is still in contact with the hand, which is pushing up on the apple:



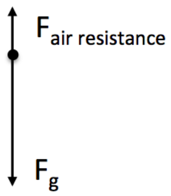
b. When the apple is rising in the air:



c. When the apple is at its maximum height:



d. When the apple is falling back down to the ground:



Activity 6: Find the components of a force

$F_x = F \cos \theta = 100\ N \times \cos 30^o = 86{,}6\ N$

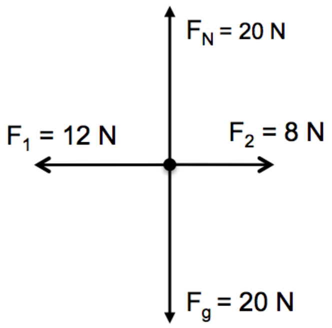
$F_y = F \sin \theta = 100\ N \times \sin 30^o = 50\ N$

Assessment Activity: *Types of force*

1. Your answer should read something like the descriptions below (not exactly, as this should be in your own words):
    a. Gravitational force: *the force of attraction (pull) that objects/bodies have on one another due to their masses **OR** the force that pulls an object towards the earth because of its mass*
    b. Tension force: *the force in a rope, that has the same magnitude in both directions along the rope*
    c. Applied force: *the force that is exerted on an object in some way by an external source, eg a hand*
    d. Frictional force: *the force that opposes an object's motion, as a result of resistance by the air or surface that the object is traveling along*.
    e. Normal force: *the force that a surface exerts on an object to balance the weight of the object.*

2.
    a. $5{,}5 \times 10^4$ g ÷ 1000 = 55 kg.
    b. F_g = 55 kg × 9,8 $m{\cdot}s^{-2}$ = 539 N.
    c. If a 2 kg mass has a weight of 3,26 N on the moon,
    then a 2 kg mass has a weight of 3,26 N ÷ 2 = 1,63 N.
    Therefore Thandi's weight on the moon = 55 kg × 1,63 N/kg = 89,65 N

3.
    a. Free body diagram:

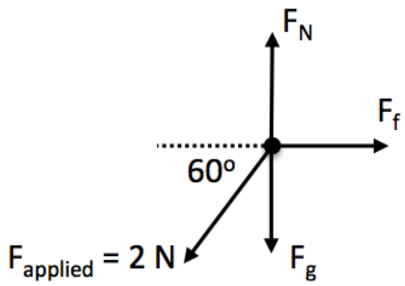


    b. F_N = 20 N
    c. Let the left direction be positive.
    Therefore F_{Net} = 12 N – 8 N = 4 N left

4. A child is hanging from two ropes. Her weight is 250 N, and all of the forces are in equilibrium.
    a. Tension in each rope = 250 N ÷ 2 = 125 N.
    b. If the tension in the rope on the left increases by 50 N, then the tension in the rope on the right decreases by 50 N, so it is 125 N – 50 N = 75 N.

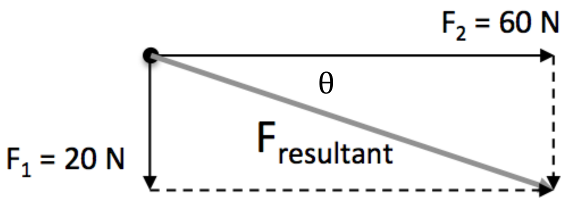
5.

a. Free body diagram:



b. $F_{\text{applied x}} = 2\text{ N} \cos 60^{\circ} = 1\text{ N}$
$F_{\text{applied y}} = 2\text{ N} \sin 60^{\circ} = 1{,}73\text{ N}$

6. The free body diagram is shown below, together with the parallelogram of forces and the resultant force.



$F_{\text{resultant}} = \sqrt{F_1^2 + F_2^2} = \sqrt{(20\text{ N})^2 + (60\text{ N})^2} = 63{,}25\text{ N}$

$\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}} = \dfrac{F_1}{F_2} = \dfrac{20\text{ N}}{60\text{ N}}$

Therefore $\theta = 18{,}43^{\circ}$

The resultant force is therefore 63,25 N in a direction of 18,43° below the +x axis (or South of East).

Unit 2. Newton's Laws of Motion

Discussion point: *It is not important that you get the correct answers for these questions, but that you refect on them for yourself.*

- When you throw a stone in the air, it does not continue moving in a straight line forever because forces such as gravity and air resistance act on it, to pull it to the ground and to slow it down.
- If you roll a ball along a horizontal surface, it does not continue moving in a straight line forever because frictional forces act on it, opposing its motion and eventually causing it to stop.

Activity 1: Newton's first and second law

1. <u>Given</u>: $m = 150$ kg ; $a = 2$ $m{\cdot}s^{-2}$

   $F_{net} = ma = 150 \text{ kg} \times 2 \text{ m}{\cdot}\text{s}^{-2} = 300 \text{ N}$

2. <u>Given</u>: $F_{net} = 500$ N ; $m = 25$ kg.

   From the equation $F_{net} = ma$ we solve for a:

   $a = \frac{F_{net}}{m} = \frac{500 \text{ N}}{25 \text{ kg}} = 20 \text{ m}{\cdot}\text{s}^{-2}$

3.
   a. According to Newton's first law, there should be no net force on the ball for it to move with a constant velocity in a straight line. The ball did not continue to move with a constant velocity after it had been pushed by Thomas' hand because there was a frictional force that opposed the motion of the ball, resulting in a net force on the ball in the opposite direction of its motion.

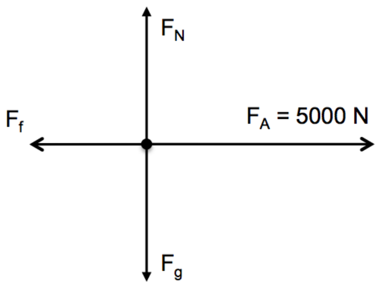
   b. <u>Given</u>: $F_{friction} = 0{,}2$ N ; $m = 50 \text{ g} \div 1000 = 0{,}05$ kg

      Since there are no other unbalanced forces on the ball, $F_{net} = F_{friction} = 0{,}2$ N.

      From the equation $F_{net} = ma$ we solve for a:

      $a = \frac{F_{net}}{m} = \frac{0{,}2 \text{ N}}{0{,}05 \text{ kg}} = 4 \text{ m}{\cdot}\text{s}^{-2}$

4.
   a. Free body diagram:



   b. From the equation $F_{net} = ma$ we solve for a:

      $a = \frac{F_{net}}{m} = \frac{4000 \text{ N}}{1000 \text{ kg}} = 4 \text{ m}{\cdot}\text{s}^{-2}$

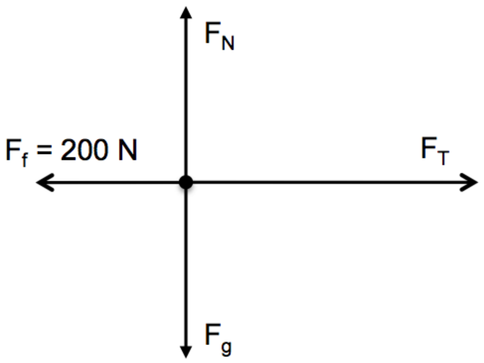
   c. Choose right as +

      $F_{net} = F_A + F_f$

      Therefore $F_f = -F_A + F_{net} = -5000 \text{ N} + 4000 \text{ N} = -1000 \text{ N}$

      The frictional force is 1000 N to the left.

5. The free body diagram is shown below:



Given: m = $1{,}4\times10^3$ kg; a = 0,5 m·s^{-2}

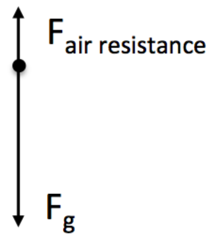
F_{net} = ma = $1{,}4\times10^3$ kg × 0,5 m·s^{-2} = 700 N

Let the direction $F_{net} = F_T + F_f$

Therefore $F_T = -F_f + F_{net}$ = -200 N + 700 N = +500 N

The tension force is 500 N in the direction of the acceleration of the car.

6. The free body diagram is shown below:



Given: F_g = 11,76 N; a = 9 m·s^{-2}

Choose down as +

F_{net} = ma = 1,2 kg × 9 m·s^{-2} = 10,8 N

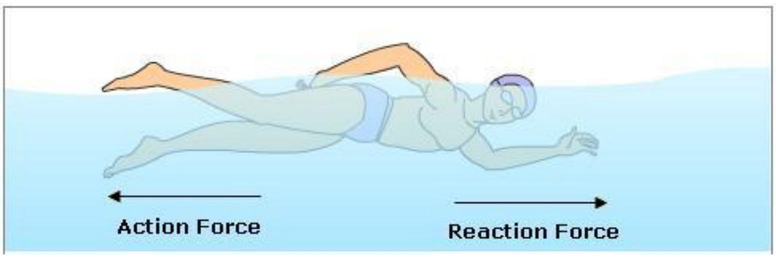
But $F_{net} = F_g + F_a$

Therefore $F_a = -F_g + F_{net}$ = -11,76 N + 10,8 N = -0,96 N

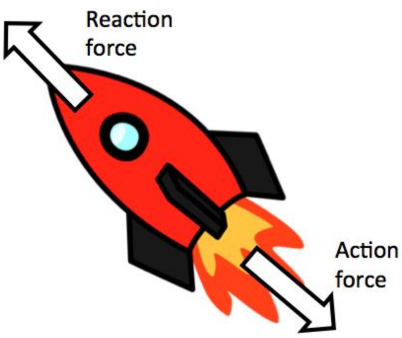
The air resistance force is 0,96 N upward.

Activity 2: Newton's third law

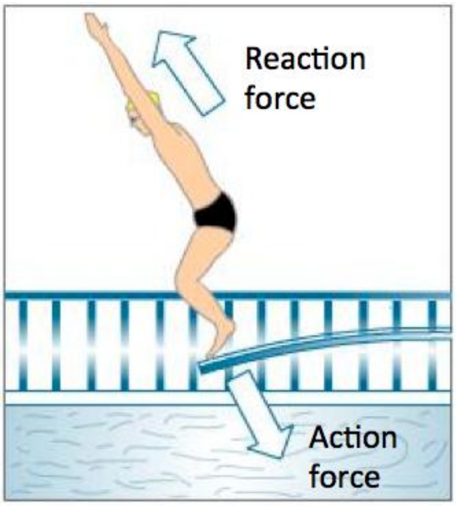
1.



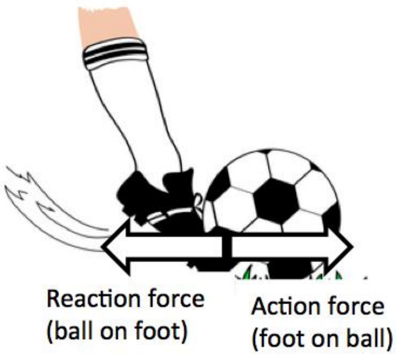
2.


Reaction
force
Action
force

3.


Reaction
force
Action
force

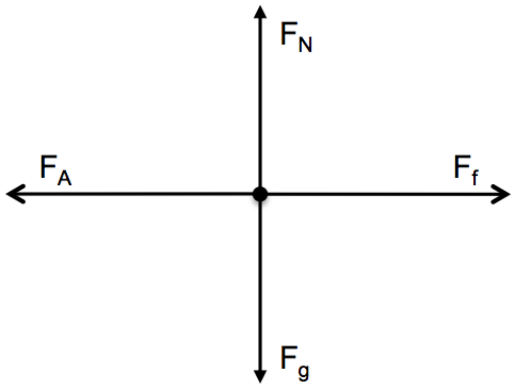
4.


Reaction force
(ball on foot)
Action force
(foot on ball)

Assessment Activity: *Newton's Laws* **Total marks = 70**

1. Newton's first law of motion: *An object continues in a state of rest or uniform velocity (1) unless it is acted upon by an external unbalanced force.* (1) (2)

2.
   a. Net force on the box = 0 N (1)
   b. There is a frictional force (1) that opposes (1) the applied force (or acts in the opposite direction). (2)
   c. Free body diagram: (1 mark for each correctly labeled force) (4)

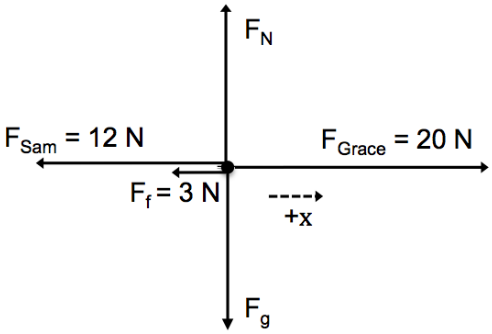


3. The net force on the bicycle is 0 N (1). According to Newton's first law (1), there is no net force on an object for it to move with a constant velocity in a straight line. (1) (3)

4.
   a. F_g = 0,05 kg × 9,8 m·s^{-2} = 0,49 N (3)
   b. Gravitational force, or weight (1)
   c. The ball exerts a force of 0,49 N on the earth (Newton's third law). (2)
   d. $F_{net} = F_A + F_f$ = 10 N – 2 N = 8 N.
      From the equation F_{net} = ma we solve for a:
      $a = \frac{F_{net}}{m} = \frac{8\text{ N}}{0{,}05\text{ kg}}$ = 160 m·s^{-2} in the direction of the applied force (5)

5. <u>Given</u>: m = 10 kg ; a = 2 m·s^{-2}
   a. F_{net} = ma = 10 kg × 2 m·s^{-2} = 20 N (3)
   b. Let the direction of the acceleration be positive.
      $F_{net} = F_A + F_f$
      Therefore $F_A = -F_f + F_{net}$ = -(-5 N) + 20 N = 25 N
      The applied force is 25 N in the direction of the acceleration of the object. (5)

6.
   a. Free body diagram: (1 mark for each correctly labeled force) (5)



b. $F_{net} = F_{Grace} + F_{Sam} + F_f = 20\ N - 12\ N - 3\ N = 5\ N$
From the equation $F_{net} = ma$ we solve for a:
$a = \frac{F_{net}}{m} = \frac{5\ N}{15\ kg} = 0{,}33\ m{\cdot}s^{-2}$ in the direction of the force applied by Grace (6)

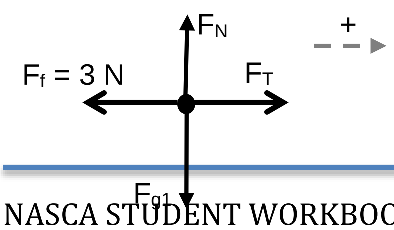
7. Given: m = 50 g ÷ 1000 = 0,05 kg ; a = 0,4 $m{\cdot}s^{-2}$
$F_{Ax} = F_A \cos\theta = 0{,}06 \times \cos 60° = 0{,}03\ N$
$F_{Net} = m \times a = 0{,}05\ kg \times 0{,}4\ m{\cdot}s^{-2} = 0{,}02N$
But $F_{Net} = F_f + F_{Ax}$
Therefore $F_f = F_{Net} - F_{Ax} = 0{,}02N - 0{,}03N = -0{,}01N$
The frictional force is 0,01 N in the opposite direction to the motion of the car. (6)

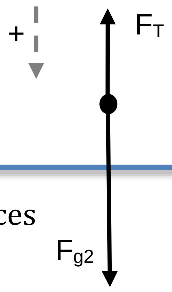
8. Given: m_1 = 1 200 kg; m_2 = 400 kg; F_A = 2 000 N.
a. If we ignore friction, we can treat the car and trailer as one combined mass.
The only force on the system is the applied force.
Therefore $F_{net} = F_A$ = 2 000 N
From the equation $F_{net} = ma$ we solve for a:
$a = \frac{F_{net}}{m_1 + m_2} = \frac{2000\ N}{1200\ kg + 400\ kg} = 1{,}25\ m{\cdot}s^{-2}$ in the direction of the applied force (5)
b. For the trailer: $F_{net} = ma = 400\ kg \times 1{,}25\ m{\cdot}s^{-2} = 500\ N$ (3)
c. Given: m_1 = 1 200 kg; m_2 = 400 kg; F_A = 2 000 N;
Total frictional force on the system F_f = -100 N - 150 N = -250 N (the negative signs show that friction opposes the motion).
Therefore $F_{net} = F_A + F_f$ = 2000 N - 250 N = 1750 N
$a = \frac{F_{net}}{m_1 + m_2} = \frac{1750\ N}{1200\ kg + 400\ kg} = 1{,}09\ m{\cdot}s^{-2}$ in the direction of the applied force.
For the car: $F_{net} = ma = 1200\ kg \times 1{,}09\ m{\cdot}s^{-2} = 1308\ N$ (6)

9. **Frame of reference:** Since the book (m_1) will move to the right, we choose **right** as + for this object, and since the weight (m_2) will move down, we choose **down** as + for this object.

Free body diagram for m_1:

Free body diagram for m_2:





Calculation:

The net force on object m_1 can be expressed as $F_{net\ 1} = m_1a = 2a$

But we can also express the net force as: $F_{net\ 1} = F_T + F_f$

$\therefore 2a = F_T + (-3)$ (Equation 1)

The weight of object m_2 is: $F_{g2} = m_2g = 1 \times 9{,}8 = 9{,}8$ N

The net force on object m_2 can be expressed as $F_{net\ 2} = m_2a = 1a$

But we can also express the net force as: $F_{net\ 2} = F_{g2} + F_T$

$\therefore 1a = 9{,}8 + (-F_T)$ (Equation 2)

From (Equation 2): $F_T = 9{,}8 – a$

Substitute this into (Equation 1): $2a = (9{,}8 – a) – 3$

$\therefore 3a = 6{,}8$

$\therefore a = 2{,}27$ m·s^{-2} to the right (8)

Sub-topic 4. Momentum and impulse

Unit 1. Linear momentum and impulse

Reflection Question:

NOTE: This is an investigation activity, so it is not important that you get these answers correct. The most important thing is for you to think about the movement of the ball.

- The ball's velocity will remain constant if it rolls along a frictionless surface.
- After it has left your hand net force on the ball = 0 N.
- The momentum keeps the ball moving forward after it has left your hand.

Activity 1 –Momentum

1. Given: m = $1,2 \times 10^3$ kg ; v = 72 km·hr^{-1} $\times \frac{1000\ \text{m/km}}{3600\ \text{s/hr}}$ = 20 m·s^{-1}

   p = mv = $1,2 \times 10^3$ kg $\times$ 20 m·s^{-1} = $2,4 \times 10^4$ kg·m·s^{-1}

2. Given: m = 20 kg + 7,5 kg = 27,5 kg ; v = 8 m·s^{-1}.

   p = mv = 27,5 kg $\times$ 8 m·s^{-1} = 220 kg·m·s^{-1}

3. p = mv = 27,5 kg $\times$ 6 m·s^{-1} = 165 kg·m·s^{-1}

   Change in momentum = 220 kg·m·s^{-1} - 165 kg·m·s^{-1} =55 kg·m·s^{-1}

   OR Δp = mΔv = 27,5 kg $\times$ (8 m·s^{-1} - 6 m·s^{-1}) = 55 kg·m·s^{-1}

4. $p_1 = m_1v$ = 900 kg $\times$ 100 km·hr^{-1} $\times \frac{1000\ \text{m/km}}{3600\ \text{s/hr}}$ = 25 000 kg·m·s^{-1}

   $p_2 = m_2v$ = 1800 kg $\times$ 20 m·s^{-1} = 36 000 kg·m·s^{-1}

   The 1800 kg vehicle moving at 20 m·s^{-1} has the higher momentum.

Activity 2 –Momentum and Impulse

1. Given: m = 50 g ÷ 1000 = 0,05 kg ; v_i = 500 m·s^{-1} ; v_f = 0 m·s^{-1} ; Δt = 0,025 s.

   a. $F = \frac{m\ \Delta v}{\Delta t} = \frac{0{,}05\text{kg} \times (0\ \text{m}\cdot s^{-1} - 500\ \text{m}\cdot s^{-1})}{0{,}025\ \text{s}}$ = -1000 N

      The block exerted a force of 1000 N on the bullet in the opposite drection to the bullet's motion.

   b. The bullet exerted a force of 1000 N on the block in the same drection as the bullet's motion.

2. Since the bungee rope is made of elastic, this means that it takes a longer time for the person to come to a stop than if the rope was made of non-elastic material. As a result, the forec on the person is much lower with a bungee rope than with a normal non-elastic rope.

3. Frame of reference: Let down be +

   Given: m = 0,1 kg ; v_i = +10 m·s^{-1} ; v_f = -8 m·s^{-1} ; Δt = 0, 2 s.

   $F = \frac{m\ \Delta v}{\Delta t} = \frac{0{,}1\text{kg} \times (-8\ \text{m}\cdot s^{-1} - 10\ \text{m}\cdot s^{-1})}{0{,}2\ \text{s}}$ = -9 N

   The floor exerted a force of 9 N on the ball in the upward direction.

Unit 2. Momentum in collisions

Activity 1: Exploring the momentum of colliding objects

1. The table below contains possible values for this experiment (your values will be different to these, so these are just a guide).
2. To calculate the velocity, the distance travelled by the marble should be divided by the time taken for that distance. (In this example the distance travelled by both marbles was 50 cm = 0,5 m.)

m_1 (kg)	Δt_1 (s)	v_1 ($m \cdot s^{-1}$)	m_1v_1 ($kg \cdot m \cdot s^{-1}$)	m_2 (kg)	Δt_2 (s)	v_2 ($m \cdot s^{-1}$)	m_2v_2 ($kg \cdot m \cdot s^{-1}$)
0,01	1,18	0,424	0,00424	0,01	1,20	0,417	0,00417
0,01	1,41	0,355	0,00355	0,01	1,42	0,352	0,00352
0,01	1,03	0,485	0,00485	0,01	1,05	0,476	0,00476

3. Answers to the questions:
   a) The combined momentum of the marbles before the collision were very similar to the combined momentum of the marbles after the collision in each case.
   b) These values to verify the law of conservation of momentum, although a small amount of momentum was lost in the collision.

Activity 2 – Conservation of momentum

1. **Frame of Reference:** Let the direction of the ball be positive.

   Given: Let the mass of Thandi be m_1 and of the ball be m_2.

   Then $m_1 = 50$ kg ; $m_2 = 1,5$ kg;

   Before the throw $v_{i1} = 0\ m \cdot s^{-1}$; $v_{i2} = 0\ m \cdot s^{-1}$;

   After the throw $v_{f2} = 8\ m \cdot s^{-1}$; $v_{f1} = ?$

   Calculation:

   $m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$

   Therefore $v_{f1} = ((m_1v_{i1} + m_2v_{i2}) - m_2v_{f2}) / m_1$

   $$v_{f1} = \frac{(50 \times 0) + (1,5 \times 0) - (1,5 \times 8)}{50} = -0,24\ m \cdot s^{-1}$$

Thandi's final velocity is 0,24 $m \cdot s^{-1}$ in the opposite direction to the ball's movement.

2. **Frame of Reference:** Let Karl's initial direction be positive.

Given: Let Karl's mass be m_1 and his father's mass be m_2.

Then $m_1 = 65$ kg ; $m_2 = 130$ kg;

Before the collision $v_{i1} = 3\ m{\cdot}s^{-1}$; $v_{i2} = -2\ m{\cdot}s^{-1}$;

After the collision $v_{f2}=0\ m{\cdot}s^{-1}$; $v_{f1}=?$

Calculation:

$m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$

Therefore $v_{f1} = ((m_1v_{i1} + m_2v_{i2}) - m_2v_{f2}) / m_1$

$$v_{f1} = \frac{(65 \times 3) + (130 \times -2) - (130 \times 0)}{65} = -1\ m{\cdot}s^{-1}$$

Karl's final velocity is 1 $m \cdot s^{-1}$ in the opposite direction to his initial movement.

Assessment Activity: Momentum and impulse **Total marks = 35**

1. The completed table is shown below (1 for each correct block): (9)

Movement of the ball	Net force on the ball (UP / ZERO / DOWN)	Momentum of the ball (UP / ZERO / DOWN)	Acceleration of the ball (UP / ZERO / DOWN)
Ball is moving upward	***DOWN***	***UP***	***DOWN***
Ball is at its maximum height	***DOWN***	***ZERO***	***DOWN***
Ball is moving downward	***DOWN***	***DOWN***	***DOWN***

2. $p_1 = m_1v = 0{,}15\ kg \times 100\ km{\cdot}hr^{-1} \times \frac{1000\ m/km}{3600\ s/hr} = 4{,}17\ kg{\cdot}m{\cdot}s^{-1}$

$p_2 = m_2v = 10\ kg \times 0{,}5\ m{\cdot}s^{-1} = 5\ kg{\cdot}m{\cdot}s^{-1}$

The child has the higher momentum. (5)

3. I*mpulse* means the change in an object's momentum, or the force multiplied by the time for which the force acts. (2)

4. <u>Frame of reference:</u> Let the dart's initial direction be +

Given: m = 0,04 kg ; v_i = +50 m·s^{-1} ; v_f = 0 m·s^{-1} ; Δt = 0,05 s.

$$F = \frac{m\,\Delta v}{\Delta t} = \frac{0{,}04\text{kg} \times (0\ \text{m}\cdot s^{-1} - 50\ \text{m}\cdot s^{-1})}{0{,}05\ \text{s}} = -40\ \text{N}$$

The dartboard exerted a force of 40 N on the dart in the opposite direction to the dart's initial velocity. (4)

5. In an isolated system the total linear momentum remains constant, in magnitude and direction. (2)

6. **Frame of reference:** Let the direction of the initial velocity of the ball be positive
Given: m = 0,02 kg; v_i = 15 m·s^{-1}; v_f = -14 m·s^{-1}; Δt = 0,1 s

$p_i = 0{,}02 \times 15 = 0{,}3$ kg·m·s^{-1}; $p_f = 0{,}02 \times (-14) = -0{,}28$ kg·m·s^{-1}

Calculation:

a. $F_{net} = \frac{\Delta p}{\Delta t} = \frac{-0{,}28-0{,}3}{0{,}1} = -5{,}8$ N

The net force exerted on the ball by the wall is 5,8 N in the opposite direction to its initial velocity. (4)

b. The net force exerted on the wall by the ball is 5,8 N in the same direction as the ball's initial velocity. (1)

c. $a = \frac{\Delta v}{\Delta t} = \frac{-14\ \text{m}\cdot s^{-1} - 15\ \text{m}\cdot s^{-1}}{0{,}1\ \text{s}} = -290$ m·s^{-2}

OR from Newton's second law $a = \frac{F}{m} = \frac{-5{,}8\ \text{N}}{0{,}02\ \text{kg}} = -290$ m·s^{-2}

The acceleration of the ball is 290 m·s^{-2} in the opposite direction to its initial velocity. (3)

7. Let the bullet be m_1, and let the gun be m_2. Choose the bullet's direction as positive.

Given: m_1 = 0,005 kg; v_{i1} = 0m·s^{-1}; m_2 = 0,400 kg; v_{i2} = 0 m·s^{-1}; v_{f1} =360 m·s^{-1}
Calculation:
$m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}$
But since both v_{i1} and v_{i2} are 0, then the initial momentum is zero.
The equation becomes: $0 = m_1 v_{f1} + m_2 v_{f2}$
So $v_{f2} = m_1 v_{f1} / m_2$ = -0,005 kg × 360 m·s^{-1} / 0,400 kg = = - 4,5 m·s^{-1}
Therefore the gun's recoil velocity is 4,5 m·s^{-1} in the opposite direction to that of the bullet. (5)

Sub-topic 5. Work, power and energy

Unit 1. Energy conversion and conservation

Activity 1: Exploring gravitational potential energy

In this activity you should find the following:

- More effort is needed to lift the heavier object to the height of the chair than the lighter object.
- Therefore the heavier object (m_2) has the greater gravitational potential energy.
- More effort is needed to lift an object to a greater height than to a lower height.
- Therefore the object lifted to the greater height (h_2) has the greater gravitational potential energy.
    - The greater the mass of an object that is lifted, the ***greater*** the gravitational potential energy of the object.
    - The greater the height that an object is lifted to, the ***greater*** the gravitational potential energy of the object.

Activity 2 – *Gravitational potential energy*

1. The potential energy of these two children is equal, since they have the same mass, and have been lifted to the same height.
2. $E_p = mgh$

   $= 1200 \text{ kg} \times 9{,}8 \text{ m.s}^{-2} \times 20 \text{ m}$

   $= 235\,200 \text{ J} = 235{,}2 \text{ kJ}$

3. The equation $E_p = m\,g\,h$ shows that E_p is proportional to m and h.

   So if we halve the mass, and the height is increased by a factor of 4, the potential energy will increase by a factor of ½ × 4 = 2.

   Therefore $E_p = 2 \times 1\,500 \text{ J} = 3 \text{ kJ}$.

Activity 3 – *Kinetic energy*

1. No, there is no movement, so no kinetic energy is involved.
2. Given: $m = 900 \text{ kg}$; $v = 100 \text{ km·hr}^{-1} \times \frac{1000 \text{ m/km}}{3600 \text{ s/hr}} = 27{,}78 \text{ m·s}^{-1}$

   $E_k = \frac{1}{2} m\,v^2$

   $= \frac{1}{2} \times 900 \text{ kg} \times (27{,}78 \text{ m·s}^{-1})^2$

= 347 278 J = 347,278 kJ

3. If this taxi reduces its speed to 50 $km \cdot hr^{-1}$, its speed has halved, so since kinetic energy is proportional to the square of the speed, the kinetic energy us reduced by a factor of 4.

Activity 4 – *Mechanical energy*

Given: m = 0,5 kg ; h = 1,5 m

a. $E_p = mgh = 0{,}5\ kg \times 9{,}8\ m.s^{-2} \times 1{,}5\ m = 7{,}35\ J$

b. Kinetic energy just before it hits the ground = 7,35 J

c. $E_k = \frac{1}{2} m\, v^2 = 7{,}35\ J$

Therefore $v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 7{,}35\ J}{0{,}5\ kg}} = 5{,}42\ m.s^{-1}$

OR $v_f{}^2 = v_i{}^2 + 2a\Delta x = 0 + 2 \times (9{,}8\ m \cdot s^{-2}) \times 1{,}5\ m = 29{,}4\ m^2 \cdot s^{-2}$

Therefore $v_f = \sqrt{29{,}4\ m^2 \cdot s^{-2}} = 5{,}52\ m \cdot s^{-1}$

Unit 2. Work and power

Activity 1 – Work and Power

1.

a) No work was done, since there was no motion.
b) Tebogo did work in pushing her brither, but her brother did not do any work.
c) No work was done, since there was no motion.
d)
   i) Yes, the weight lifter did do work by lifting the weight upward.
   ii) No work was done, since there was no motion.

Assessment Activity: Work, energy and power **Total marks = 70**

Multiple choice questions:

1. C. (3)
2. A. (3)

Written response questions:

1. (1) mark for each correct answer. (12)

Description	Name of quantity	Units	Equation
Energy of movement	*Kinetic energy*	*J*	$E_k = \frac{1}{2} m\, v^2$
Energy that an object has because of its height above the earth	*Gravitational potential energy* ***OR*** *Potential energy*	*J*	$E_p = m\, g\, h$
The sum of the gravitational potential energy and the kinetic energy of the object	*Mechanical energy*	*J*	$E_M = E_p + E_k$
The rate at which work is done	*Power*	*W*	$P = \frac{W}{\Delta t}$

2.

a. $E_p = mgh$

$= 1{,}5\ \text{kg} \times 9{,}8\ \text{m.s}^{-2} \times 3\ \text{m}$

$= 44{,}1\ \text{J}$ (3)

b. 44,1 J (1)

c. $E_k = \frac{1}{2} m\, v^2 = 44{,}1\ \text{J}$

Therefore $v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 44{,}1\ \text{J}}{1{,}5\ \text{kg}}} = 7{,}67\ \text{m.s}^{-1}$ (3)

d. From the equation $v_f = v_i + a\Delta t$

We can solve for Δt:

$\Delta t = (v_f - v_i) / a = (7{,}67\ \text{m·s}^{-1} - 0) / (9.8\ \text{m·s}^{-2}) = 0{,}78\ \text{s}$ (3)

3. **<u>Given</u>**: $m = 2 \times 10^3$ kg; $h_1 = 10$ m; $h_2 = 0$ m

$v_1 = 0\ \text{m·s}^{-1}$; $v_2 = ?$

From the equation: $E_{p_1} + E_{k_1} = E_{p_2} + E_{k_2}$

We first find:

$E_{p_1} + E_{k_1} = mgh_1 + \frac{1}{2} m{v_1}^2$

$= 2 \times 10^3\ \text{kg} \times 9{,}8\ \text{m·s}^{-2} \times 10\ \text{m} + 0$

$= 196\ 000\ \text{J}$

So 0196 000 J = $E_{p_2} + E_{k_2}$

$= mgh_2 + \frac{1}{2} m{v_2}^2$

$= 0 + (0{,}5 \times 2 \times 10^3\ \text{kg} \times {v_2}^2)$

So $v_2{}^2 = \frac{196\ 000\ J - 0}{0{,}5 \times 2000\ kg} = 196\ m^2{\cdot}s^{-2}$

So $v_2 = 14\ m{\cdot}s^{-1}$ (6)

4.

a. **Given**: $m = 0{,}03$ kg, $E_p = 1{,}176 \times 10^{-2}$ J, $g = 9{,}8\ m.s^{-2}$
From the equation $PE = mgh$ we can find the height:

$$h = \frac{E_p}{g{\cdot}m} = \frac{1{,}176 \times 10^{-2}\ J}{9{,}8\ m{\cdot}s^{-2} \times 0{,}03\ kg} = 0{,}04\ m \quad (3)$$

b. The kinetic energy of the ball at its lowest position is equal to the potential energy at the highest position = $1{,}176 \times 10^{-2}$ J (1)

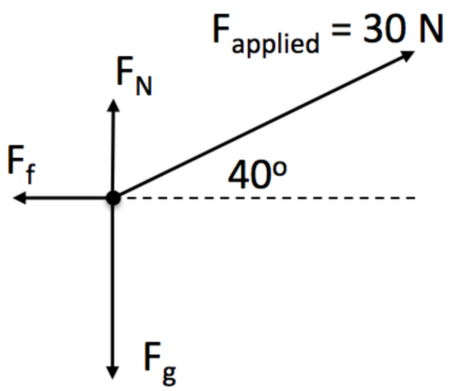
c. From $E_k = \frac{1}{2}mv^2$ we get $v = \sqrt{\frac{2\ E_k}{m}} = \sqrt{\frac{2 \times 1{,}176 \times 10^{-2}\ J}{0{,}03\ kg}} = 0{,}885\ m{\cdot}s^{-1}$ (3)

d. Total mechanical energy of the system = PE at max height = $1{,}176 \times 10^{-2}$ J (1)

e. The ball does not keep swinging to the same height forever because in a real life situation there are frictional forces, causing energy to be dissipated, until eventually all of the energy is used up and the ball stops moving. (3)

5.

a) Free body diagram: (1 mark for each force correctly labeled) (4)



b) $F_{applied\ x} = F_{applied} \cos\theta = 30\ N \times \cos 40^{\circ} = 23\ N$
Therefore work done on the box by Rashid is:
$W = F_x\,\Delta x = 23\ N \times 5\ m = 11{,}5\ J$ (4)

c) $P = \frac{W}{\Delta t} = \frac{11{,}5\ J}{120\ s} = 0{,}096\ W$ (3)

d) Constant velocity means $F_{net} = 0$ N
But $F_{net\ x} = F_{applied\ x} + F_f$
Therefore $F_f = F_{net\ x} - F_{applied\ x} = 0 - 23$ N = -23 N
The frictional force between the box and the floor was 23 N in the opposite direction to the box's motion. (5)

e) Work done on the box by the frictional force is:
$W = F_x \Delta x = -23 \text{ N} \times 5 \text{ m} = -115 \text{ J}$ (3)

f) Let up be +
Zero velocity in y-direction means $F_{net\ y} = 0$ N
But $F_{net\ y} = F_{applied\ y} + F_N + F_g$
Therefore $F_N = F_{net\ y} - F_{applied\ y} - F_g = 0 - (30 \text{ N} \times \sin 40^o) - (20 \text{ kg} \times -9{,}8 \text{ m·s}^{-2})$
$= 0 - (19{,}3) - (-196) = 176{,}7$ N (6)

Topic 3. Waves

Sub-topic 1. Transverse and longitudinal waves

Unit 1. Transverse waves

Activity 1: Observing the movement of a wave

In this activity you should notice the following:

- You should observe that the slinky moves back and forth in a regular motion, transverse to the direction of movement of the wave along the slinky
- The piece of coloured wool moves to and fro, but does not move forward with the wave along the slinky.

Go to https://www.youtube.com/watch?v=y66PSaiGH7Y to see a transverse wave on a slinky.

Activity 2: *Test your understanding of the characteristics of a wave*

a. If 3 consecutive peaks (ie 2 full wavelengths) have a distance of 60 cm, then

$\lambda = 60 \text{ cm} \div 2 = 30 \text{ cm}$

b. 4 full wavelengths pass the boat in 6 seconds, so the number of wavelengths in 1 second are:

$$\text{frequency} = \frac{\text{number of wavelengths}}{\Delta t} = \frac{4}{6\text{s}} = 0{,}67 \text{ s}^{-1}$$

Therefore the frequency f = 0,67 Hz.

c. $T = \frac{1}{f} = \frac{1}{0{,}67\ s^{-1}}$ = 1,55 seconds

d. v = f × λ = 0,67 Hz × 0,3 m = 0,2 $m{\cdot}s^{-1}$

Unit 2. Longitudinal waves

Activity 1: Making a longitudinal wave

In this activity you should notice the following:

- You should observe that the slinky moves back and forth in a regular motion, parallel with the direction of movement of the wave along the slinky
- The piece of coloured wool moves back and forth, but does not move forward with the wave along the slinky.

Go to https://www.youtube.com/watch?v=GIkeGBXqWW0 to see a longitudinal wave on a slinky.

Activity 2 – *Properties of a Longitudinal Wave*

a. If 3 consecutive compressions (ie 2 full wavelengths) have a distance of $2{,}5 \times 10^{-2}$ m, then $\lambda = 2{,}5 \times 10^{-2}\ m \div 2 = 1{,}25 \times 10^{-2}\ m = 0{,}0125\ m$

b. v = 5 $cm{\cdot}s^{-1}$ = 0,05 $m{\cdot}s^{-1}$ therefore $f = \frac{v}{\lambda} = \frac{0{,}05\ m{\cdot}s^{-1}}{0{,}0125\ m} = 4\ s^{-1} = 4\ Hz$

c. $T = \frac{1}{f} = \frac{1}{4\ s^{-1}}$ = 0,25 seconds

d. The amplitude is the maximum displacement from rest position

$= \frac{1}{2} \times 1 \times 10^{-3}\ m = 5 \times 10^{-4}\ m$

Activity 3: Observing the effect of a sound wave

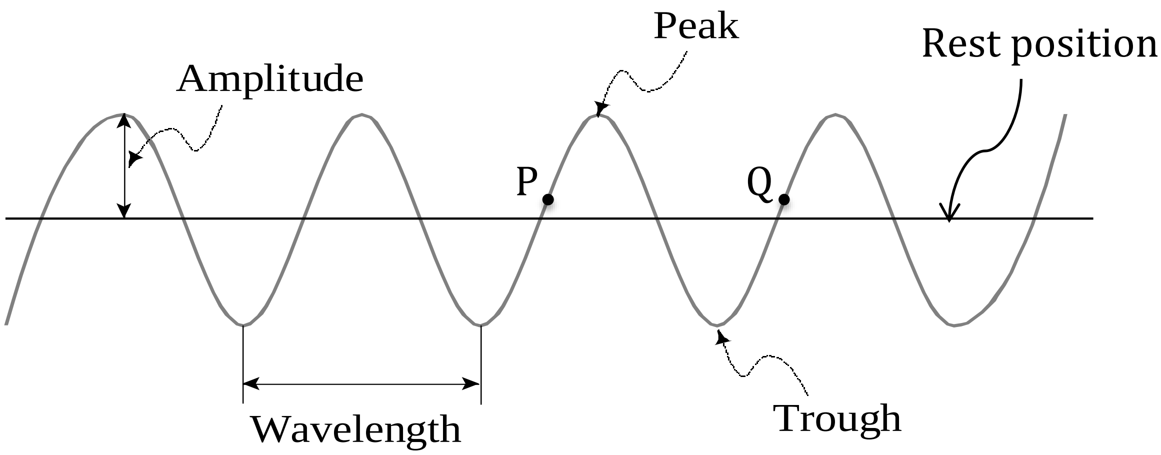
In this activity you should notice the following:

- You should observe that the salt granules jump up and down slightly with the loud sound, showing that the sound is causing the cling film to vibrate.

Assessment Activity: Transverse and longitudinal waves **Total marks = 50**

1. Example of a transverse wave: light or water wave
   Example of a longitudinal wave: sound wave (2)

2. (1) mark for each correct label on the diagram as shown below (6)



3. <u>Given</u>: λ = 25 mm = 0,025 m
   a. 5 full wavelengths pass a point in 2 seconds, so the number of wavelengths in 1 second are:
      $$\text{frequency} = \frac{\text{number of wavelengths}}{\Delta t} = \frac{5}{2\text{s}} = 2{,}5\ \text{s}^{-1}$$
      Therefore the frequency f = 2,5 Hz.
      (4)
   b. $T = \frac{1}{f} = \frac{1}{2{,}5\ \text{s}^{-1}} = 0{,}4$ seconds (3)
   c. $v = f \times \lambda = 2{,}5\ \text{Hz} \times 0{,}025\ \text{m} = 0{,}0625\ \text{m·s}^{-1}$ (3)

4.
   a. A = rarefaction
      B = compression
      C = wavelength (3)
   b. The particles of the medium vibrate backwards and forwards (1) around a fixed position, parallel to the direction of movement of the wave (1) (2)
   c. The direction of the movement of energy is away from the source as the wave travels through the medium. (2)

5.

a. Khaya should hold his end of the spring steady while Thembi moves hers to create the wave. Thembi should move her end of the spring forward and then backward in a continual movement. (2)

b. <u>Given</u>: length D = 2 m; Δt = 1,6 s

$v = \frac{D}{\Delta t} = \frac{2}{1,6} = 1,25\ m{\cdot}s^{-1}$ (3)

c. Distance between four successive compressions (3 full wavelengths) = 60 cm

Therefore λ = 60cm / 3 = 20 cm = 0,2 m (2)

d. $f = \frac{v}{\lambda} = \frac{1,25\ m{\cdot}s^{-1}}{0,2\ m} = 6,25\ s^{-1} = 6,25\ Hz$ (3)

e. $T = \frac{1}{f} = \frac{1}{6,25\ s^{-1}} = 0,16$ seconds (3)

f. amplitude = ½ × 5mm = 2,5 mm = 0,0025 m (2)

6. Given: f = 500 Hz ; D = 2,04 km = 2040 m ; Δt = 6 seconds.

a. $v = \frac{D}{\Delta t} = \frac{2040}{6} = 340\ m{\cdot}s^{-1}$ (3)

b. $T = \frac{1}{f} = \frac{1}{500\ s^{-1}} = 0,002$ seconds (3)

c. To find the distance between two successive rarefactions of the sound wave we need to calculate the wavelength:

$\lambda = \frac{v}{f} = \frac{340\ m{\cdot}s^{-1}}{500\ s^{-1}} = 0,68\ s^{-1} = 0,68\ Hz$ (4)

Sub-topic 2. Geometrical optics

Unit 1. Reflection

Activity 1: Exploring the reflection of a ray of light

In this activity you should observe that the angle of incidence is equal to the angle of reflection, no matter what angle you use for the angle of incidence.

Activity 2: Reflection from a mirror

1.

a. Nosipho will see Gareth's image formed 5 m behind the mirror, which is 7 m away from Nosipho.

b. Gareth will see Nosipho's image formed 2 m behind the mirror, which is 7 m away from Gareth.

2. When writing is reflected in a mirror, it is inverted, and so it looks like it is written backwards. So when a car sees the ambulance label (which is written backwards) in its mirror, the writing will be inverted, and will look like it is written forwards to the driver of the car.

Unit 2.	Refraction

Activity 1: *Refractive index*

a. $n_{water} = \frac{c}{v} = \frac{3\times10^8 m\cdot s^{-1}}{2{,}25\times10^8 m\cdot s^{-1}} = 1{,}33$

b. Given: $f = 7{,}5 \times 10^{14}$ Hz ; $n_{glass} = 1{,}5$. Find the following:

  a. From the equation $n_{glass} = \frac{c}{v}$ we can make v the subject of the formula:

  $$v = \frac{c}{n_{glass}} = \frac{3\times10^8 m\cdot s^{-1}}{1{,}5} = 2 \times 10^8\ m\cdot s^{-1}$$

  b. The frequency of the light does not change, so $f = 7{,}5 \times 10^{14}$ Hz in glass.

  c. From the equation $v = f\lambda$ we can make λ the subject of the formula:

  $$\lambda = \frac{v}{f} = \frac{2\times10^8 m\cdot s^{-1}}{7{,}5\times10^{14} s^{-1}} = 2{,}67 \times 10^{-7}\ m.$$

c. Given: $v_X > v_Y$.

  a. Substance Y has the greater optical density, since it slows light down more.

  b. $\lambda \propto v$, so the red light has the longest wavelength in Substance X.

  c. The frequency of the red light stays the same in both substances.

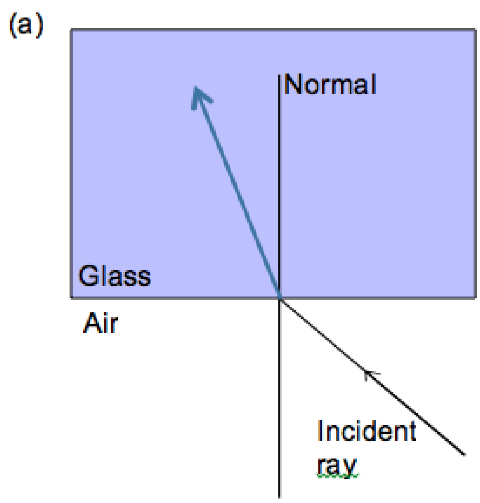
Activity 2: Constructing ray diagrams for refraction

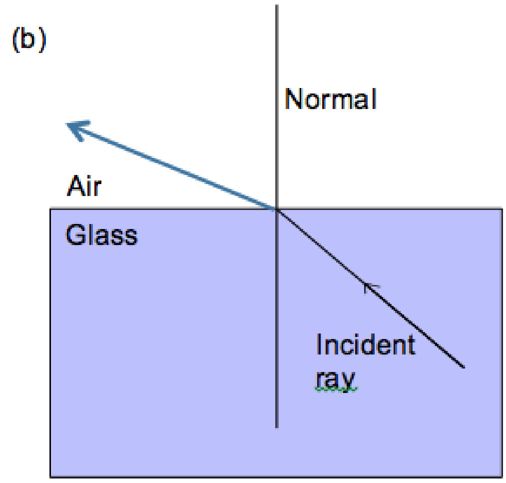
In this activity you should observe the following:

- As the light ray enters the Perspex from the air at some angle to the normal, the ray is bent towards the normal.
- As the ray emerges again from the Perspex into the air, the ray is bent away from the normal.

Activity 3: Test your understanding of refraction

The completed ray diagrams are shown below:





Unit 3.	Total internal reflection

Activity 1: Observing total internal reflection

In this activity you should observe that the stream of water that comes out of the bottle is lit up, showing that the torch light is totally internally reflected, even when the water path is curved.

Assessment Activity: Geometrical optics **Total marks = 60**

Multiple choice questions:

Choose the correct answer for the questions below:

1. B (3)
2. C (3)
3. C (3)

Written response questions:

1. (6)

A = Angle of incidence	B = Angle of reflection
C = Angle of refraction	D = Incident ray
E = Reflected ray	F = Refracted ray

2. For a light ray that is reflected off a surface: angle of incidence = angle of reflection (2)

3.

   a. A line that is at 90^{o} to a surface (2)
   b. The angle between the incident ray and the normal. (2)
   c. The angle between the reflected ray and the normal. (2)
   d. The angle between the refracted ray and the normal. (2)
   e. The angle of incidence for which the angle of refraction is 90^{o}

      OR the minimum angle of incidence for which the refracted ray disappears. (2)
   f. When the angle of incidence is greater than the critical angle, the ray is not refracted, but is totally internally reflected. (2)

4.

   a. 60^{o} (2)
   b. 60^{o} (2)
   c. 30^{o} (2)
   d. The image will be formed 2 cm behind the mirror, in a straight line with the object. (3)

5. Distance between poster and Tumelo = 60 cm = 0,6 m
   Distance between poster and mirror = 0,6 m + 1,5 m = 2,1 m
   The image of the poster is therefore formed 2,1m behind the mirror.
   Distance from Tumelo = 1,5 m + 2,1 m = 3,6 m. (4)

6. <u>Given</u>: $f = 5 \times 10^{14}$ Hz ; $v_{air} = 3\times10^{8}\ m{\cdot}s^{-1}$; $v_{diamond} = 1{,}25 \times 10^{8}\ m{\cdot}s^{-1}$

   a. $n_{diamond} = \frac{c}{v} = \frac{3\times10^{8} m{\cdot}s^{-1}}{1{,}25\times10^{8} m{\cdot}s^{-1}} = 2{,}4$ (3)
   b. The frequency of the light wave in diamond doesn't change, so

      $f = 5 \times 10^{14}$ Hz. (2)
   c. $\lambda = \frac{v}{f} = \frac{1{,}25\times10^{8} m{\cdot}s^{-1}}{5\times10^{14} s^{-1}} = 2{,}5 \times 10^{-7}$ m. (3)

7.

   a. Ruby (2)
   b. Ruby (2)

c. It bends towards the normal, since it is moving from a less to a more optically dense medium. (3)

d. From $n_{ruby} = \frac{c}{v}$ we can solve for v:

$v_{ruby} = \frac{c}{n} = = \frac{3 \times 10^8 m \cdot s^{-1}}{1,54} = 1,95 \times 10^8$ m·s^{-1} (3)

Topic 4. Electricity and Magnetism

Sub-topic 1. Electrostatics

Unit 1. Coulomb's Law

Activity 1: Investigating charge

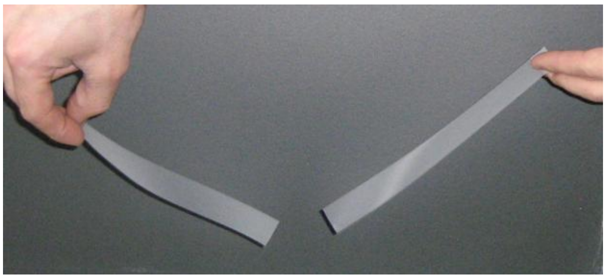
In this activity you should observe that the ruler attracts the pieces of paper once it is rubbed.

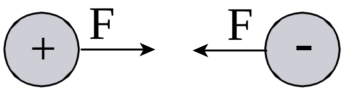
Activity 2: Investigating the interaction between two objects with the same charge

In this activity you should observe that when two pieces of tape are charged in the same way, there is a force of repulsion between them, since they have like charges.

Activity 3: Investigating the interaction between two objects with opposite charge

In this activity you should observe that when two pieces of tape are charged so that they have opposite charges, there is a force of attraction between them.





Activity 4: Test your knowledge of forces between charges

1. A ruler is negatively charged by rubbing it.
   a. Electrons were added to the ruler
   b. The charge on the tape is positive.
   c. The charge on the tape is negative.
   d. The two pieces of tape from (b) and (c) will attract each other, since they have unlike charges.
2. If Object C is negatively charged, so Object B must also be negatively charged (repulsion means like charges). This means that Object A is positively charged (attraction means unlike charges).

Activity 5: Investigating polarisation

In this activity you should notice that the stream of water is bent towards the charged balloon. This is because water is a polar substances. When a positively charged object is brought near to a polar substance, it causes the particles to turn around so that their negative end is nearer to the charged object, and their positive end is further away.

Activity 6: Test your knowledge of forces between charged and neutral objects

1.

a. A negatively charged object attracts the positive charges in a neutral object, causing the part of the neutral object that is nearby to be positively charged, and the part that is further away to be negatively charged. This results in a force of attraction between the negatively charged object and the positively charge side of the object.

b. Polarization

2.

a. The stream of water is bent towards the charged balloon.

b. This is because water is a polar substance. When a negatively charged object is brought near to a polar substance, it causes the particles to turn around so that their positive end is nearer to the charged object, and their negative end is further away. This results in a force of attraction between the negatively charged object and the positive ends of the particles in the polar substance.

Activity 7: Test your knowledge of Coulomb's Law

1. <u>Given</u>: $Q_1 = 2\times10^{-5}$ C $Q_2 = -6\times10^{-5}$ C r = 0,3 mm = 3×10^{-4} m

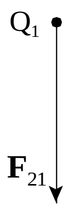
a. Magnitude of the force on charge Q_1 due to charge Q_2 is:

$$F_{21} = k\frac{Q_1Q_2}{r^2} = 9\times10^9\,\mathrm{Nm^2C^{-2}} \times \frac{2\times10^{-5}\,\mathrm{C}\times6\times10^{-5}\,\mathrm{C}}{(3\times10^{-4}\,\mathrm{m})^2} = 1{,}2\times10^8\,\mathrm{N}$$

Since the charges have opposite signs, this is a force of attraction.

Therefore $\mathbf{F}_{21} = 1{,}2\times10^8\,\mathrm{N}$ downward

b. Free body diagram of the force acting on charge Q_1:



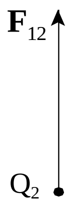
c. Magnitude of the force on charge Q_2 due to charge Q_1 is equal to the magnitude of the force on charge Q_1 due to charge Q_2 (from Newton's third law).

So $F_{12} = 1{,}2\times10^8\,\mathrm{N}$

Since the charges have opposite signs, this is a force of attraction.

Therefore $\mathbf{F}_{12} = 1{,}2\times10^8\,\mathrm{N}$ upward

d. Free body diagram of the force acting on charge Q_2:



2. Since $F \propto \frac{1}{r^2}$, if the distance between the charges is halved, then the force will be increased by a factor of 2^2. Therefore the magnitude of the force will be $F = 8N \times 4 = 32N$

3. **Given**: Q_1 = 1,6 μC F_{21} = 7200 N r = 2 mm = 2 ×10^{-3} m
To find the magnitude of charge Q_2 we can rewrite Coulomb's law with Q_2 as the subject of the formula:

$$Q_2 = \frac{F_{21} r^2}{k Q_1} = \frac{7200 \times (2 \times 10^{-3})^2}{9 \times 10^9 \times 1{,}6 \times 10^{-6}} = 2 \times 10^{-6} \text{ C} = 2\,\mu\text{C}$$

If charge Q_1 experiences a force to the right when it is placed to the left of the unknown charge, then this is a force if attraction. So the unknown charge must be negative.

$$\therefore Q_2 = -2\,\mu\text{C}$$

Unit 2. The electric field

Activity 1: Test your knowledge of the electric field

1. **Given**: q = 2 C **F** = 0,8 N down
The electric field strength is:
$E = \frac{F}{q} = \frac{0{,}8\text{ N}}{2\text{ C}} = 0{,}4\text{ N·C}^{-1}$
The electric field direction is the same as the direction of the force on the positive test charge, so **E** = 0,4 N·C^{-1} downward.

2. **Given**: q = -3 μC = -3 × 10^{-6} C **F** = 90 N left
The electric field strength is:
$E = \frac{F}{q} = \frac{90\text{ N}}{3 \times 10^{-6}\text{ C}} = 3 \times 10^7\text{ N·C}^{-1}$
The electric field direction is opposite to the direction of the force on the negative test charge, so **E** = 3 × 10^7 N·C^{-1} to the right.

3. **Given**: **E** = 5×10^4 N·C^{-1} to the left.

    a. The magnitude of the force is

    $F = E{\cdot}q = 5 \times 10^4 \text{ N·C}^{-1} \times 2 \times 10^{-9} \text{ C} = 1 \times 10^{-4} \text{ N}$

    The direction of the force on a positive test charge is the same as the direction of the electric field.

    Therefore **F** = 1×10^{-4} N to the left

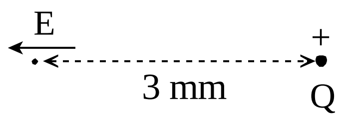
    b. **Given: F** = 500 kN = 5×10^5 N to the right

    Magnitude of the charge is

    $q_2 = \frac{F}{E} = \frac{5\times10^5 \text{ N}}{5\times10^4 \text{ C}} = 10 \text{ C}$

    Since the force and electric field are in opposite directions, the charge must be negative. So q_2 = -10 C.

4. **Given:** r = 3 mm = 3×10^{-3} m   Q = 1,8 μC = $1{,}8\times10^{-6}$ C

    The electric field direction at this point is left, since the electric field points outwards from a positive charge.

    The electric field strength is:

    $$E = \frac{kQ}{r^2} = \frac{9\times10^9 \text{ Nm}^2\text{C}^{-2} \times 1{,}8\times10^{-6} \text{ C}}{(3\times10^{-3}\text{ m})^2} = 1{,}8\times10^9 \text{ N}\cdot\text{C}^{-1}$$

    So the electric field at this point is **E** = $1{,}8\times10^9$ N·C^{-1} to the left.

Reflection Activity

When vehicles drive, the friction between the tyres and the road causes charges to build up on the vehicle. This can be dangerous, especially for petrol tankers, since a spark could jump as a result of this charge, and cause a fire. By hanging a chain from the vehicles, the charge is allowed to drain, or leak, back to the ground.

For more information on health and electrostatics, visit the website: http://www.oocities.org/emrsafety/electrostatic_discharge.htm

Assessment Activity: *Electrostatics* **Total marks = 40**

1. When a positively charged object is brought close to a negatively charged object you will observe a force of repulsion between them. (1)

2.
   a. Electrons were removed from Object A when it was charged. (1)
   b. If object B is **repelled** by Object A, Object B must have a positive charge. (1)
   c. If Object C is **attracted** to Object A, Object C must have a negative charge. (1)
   d. Object B and Object C will attract each other (unlike charges). (1)

3.
   a. Neutral (1)
   b. A negatively charged object attracts the positive charges in a neutral object, causing the part of the neutral object that is nearby to be positively charged, and the part that is further away to be negatively charged. This results in a force of attraction between the negatively charged object and the positively charge side of the object. (3)
   c. Polarization. (1)

4.
   a. Double the charge on one of the objects. **NO** (1)
   b. Increase the charge on one of the objects by a factor of 4. **YES** (1)
   c. Double the charge on both of the objects. **YES** (1)
   d. Increase the charge on both of the objects by a factor of 4. **NO** (1)
   e. Halve the distance between the charges. **YES** (1)
   f. Double the distance between the charges. **NO** (1)
   g. Reduce the distance between the charges by a factor of 4. **NO** (1)
   h. Increase the distance between the charges by a factor of 4. **NO** (1)

5. **Given**: r = 0,3 m E = 600 $N \cdot C^{-1}$ to the left
   a. If the electric field direction at point P is left, this means that Q is a negative charge, since the electric field points inwards towards a negative charge.

      The magnitude of the charge can be found by making Q the subject of the formula:

$$Q = \frac{Er^2}{k} = \frac{600\,NC^{-1} \times (0,3\,m)^2}{9 \times 10^9\,Nm^2C^{-2}} = 6 \times 10^{-9}\,C = 6\,\mu C$$

So Q = - 6 μC (4)

b. **Given**: E = 600 $N{\cdot}C^{-1}$ to the left q = 4 nC = 4×10^{-9} C

The magnitude of the force is

F = E·q = 600 $N{\cdot}C^{-1} \times 4 \times 10^{-9}$ C = $2,4 \times 10^{-6}$ N

The direction of the force on a positive test charge is the same as the direction of the electric field.

Therefore F = $2,4 \times 10^{-6}$ N to the left (4)

6.

a. We can calculate the force on charge Q_1 due to charge Q_2:

$$\mathbf{F}_{21} = k\frac{Q_2Q_1}{r^2} = 9 \times 10^9\,Nm^2C^{-2} \times \frac{1\times10^{-5}\,C \times 6\times10^{-5}\,C}{(3\times10^{-2}\,m)^2} = 6000\,N \text{ right} \quad (4)$$

b. Method 1: If we want to find the magnitude of the electric field at the position where charge Q_1 is located, we can use charge Q_2 in the equation:

$$E = \frac{kQ_2}{r^2} = \frac{9\times10^9\,Nm^2C^{-2} \times 1\times10^{-5}\,C}{(3\times10^{-2}\,m)^2} = 1\times10^8\,N\cdot C^{-1}$$

The direction of the electric field is to the right, since the electric field points inwards towards the negative charge Q_2.

Therefore E = 1×10^8 $N{\cdot}C^{-1}$ to the right

Method 2: We can treat charge Q_1 as the test charge. So the electric field strength at Q_1 is:

$$E = \frac{F}{Q_1} = \frac{6000\ N}{6\times10^{-5}\ C} = 1 \times 10^8\ N{\cdot}C^{-1}$$

The electric field direction is the same as the direction of the force on the positive test charge Q_1, so E = 1×10^8 $N{\cdot}C^{-1}$ to the right. (7)

7. Describe any one of these applications, or any others you have investigated: (3)

- **Photocopying machines** and printers use the principle of electrostatics to make photocopies. Light is reflected off the original page onto a rotating drum. The drum becomes positively charged in the places where light does **not** shine onto it (in other words, the black parts of the page), and a negatively charged black powder is attracted to these positively charged parts of the drum. This is then transferred to the blank paper. This makes it look similar to the original page.
- Electrostatics is also applied in **spray painting**, where particles of paint are given a positive charge as they leave the spray gun. The object to be painted is earthed so that there is an electric field between the spray gun and the object.

The charged paint droplets follow the electric field lines, and are deposited evenly over the object's surface.

- Lightning takes place when a thunder cloud becomes charged by the rubbing together of air and water particles moving past each other. This creates an electric field between the cloud and the ground. A lightning strike occurs when there is a massive release of charge between the cloud and the ground. **Lightning conductors** are tall metal poles that are attached to the earth by a conducting wire. This creates a safe path for lightning to pass through.

Sub-topic 2. Electric circuits

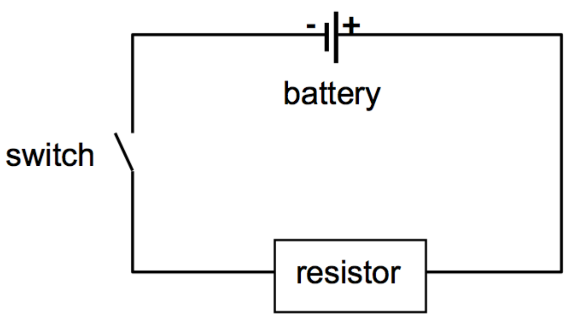
Unit 1. Current, resistance and potential difference in electric circuits

Activity 1: Investigating closed circuits

In this activity you should observe that there are four ways of connecting the battery with the lead and the bulb so that it lights up. In all of these arrangements, there must be a closed loop where the first terminal of the battery (e.g. the positive tip) must be connected to one terminal of the bulb (e.g. the tip), and the other terminal of the bulb (e.g. the casing) must be connected to the second terminal of the battery (e.g. the negative flat end)

Activity 2: Test your understanding of current

1.



2. Current is the rate of the flow of charges, or a measure of how quickly charges flow in a circuit.
3. **<u>Given</u>**: Q = 6 C; Δt = 3 s

   $$I = \frac{Q}{\Delta t} = \frac{6\ C}{3\ s} = 2\ A$$
4. **<u>Given</u>**: I = 0,2 A; Δt = 5 min × 60 s/min = 300 s

   From the equation $I = \frac{Q}{\Delta t}$ we can solve for Q:

$Q = I \times \Delta t = 0{,}2\ A \times 300\ s = 60\ C$

5. Circuit A: $I = \frac{Q}{\Delta t} = \frac{0{,}5\ C}{1\ s} = 0{,}5\ A$

Circuit B: $I = \frac{Q}{\Delta t} = \frac{10\ C}{30\ s} = 0{,}33\ A$

Therefore the bulb in Circuit A will be the brightest, since it has the greatest current.

Activity 3: Measuring current in a 1-bulb circuit

In this activity. you should observe that the current reading is the same at point 1 and point 2 in the circuit. This shows us that the current is the same at all points in a series circuit.

Activity 4: Measuring potential difference

In this activity. you should observe that the voltage reading across the battery is equal to the voltage reading across the resistor when the switch is closed.

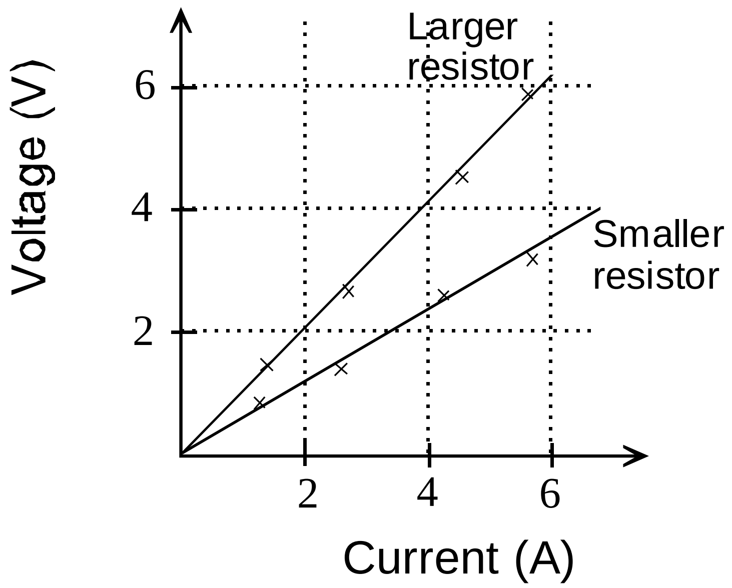
The voltage reading across the switch is 0 V when it is closed, since it has no resistance.

Activity 5: ***Investigating the relationship between current, voltage and resistance***

A possible table of readings is shown below (the values will be different to these, as this will depend on the resistors that you have used.

		Reading 1 (One battery)	**Reading 2** (Two batteries)	**Reading 3** (Three batteries)	**Reading 4** (Four batteries)
Small resistor	Voltage (V)	0,9 V	1,4 V	2,6 V	3,2 V
	Current (A)	1,2 A	2,5 A	4,1 A	5,8 A
Large resistor	Voltage (V)	1,5 V	2,5 V	4,5 V	5,9 V
	Current (A)	1,3 A	2,6 A	4,5 A	5,7 A

From these points, the graphs should look similar to the one below.



The graphs should each be a straight line that goes through the origin, which tells us that the voltage is directly proportional to the current.

The answers to the questions in point 9 of the activity are:

a. The graph with the greater resistance has the steeper slope than the graph for the smaller resistance.

b. The graph for the higher resistance should have the higher value for its gradient.

c. For a resistor that has half the resistance of the smaller resistor, the graph should have half the gradient, in other words, it should be less steep.

d. The physical quantity that the gradient of this graph tells us about is the resistance of the resistor.

Possible conclusions:

- The graph of voltage plotted against current for a resistor is a straight line whose gradient tells us the resistance of a resistor.
- Voltage is directly proportional to current. The gradient of a graph of voltage plotted against current for a resistor tells us the resistance of the resistor.

Activity 6: Calculations with Ohm's Law

1. <u>Given</u>: V = 2 V   I = 0,5 A.

$$R = \frac{V}{I} = \frac{2\ V}{0{,}5\ A} = 4\ \Omega$$

2. Given: R = 3,5 Ω ; I = 2 A.

   From the equation $R = \frac{V}{I}$ we solve for V:

   V = RI = 3,5 Ω × 2 A = 7 V

3.
   a. 6 A
   b. 1,5 A
   c. 0,6 A

Activity 7: Resistors in series

In this activity you should observe that the brightness of the two bulbs connected in series is less than the brightness of one bulb on its own.

This means that the current through the battery in Circuit 2 is less than in Circuit 1.

You should also observe that the battery terminal potential difference is equal to the total potential difference across the resistors in a series circuit.

Activity 8: Test your understanding of resistors in series

1. F > A = B > C = D = E. The circuit with bulb F has the lowest resistance, so it will have the greatest current, hence the greatest brightness. The circuit with bulbs C, D and E has the greatest resistance, so it will have the lowest current, hence the least brightness.

2.
   a. $R_s = R_1 + R_2 + R_3$ = 3 Ω + 2 Ω + 1 Ω = 6 Ω
   b. For resistor R_2: $I = \frac{V}{R} = \frac{4\ V}{2\ \Omega}$ = 2 A

      Therefore $I_{R1} = I_{R3}$ = 2 A (since current is the same everywhere in a series circuit).
   c. If V_{R2} = 4 V, then since R_1 has 1,5 times the resistance of R_2, its voltage must be 1,5 times V_{R2}.

      So V_{R3} = 1,5 × 4 V = 6 V.

      Since R_3 has half the resistance of R_2, its voltage must be half V_{R2}.

So $V_{R3} = ½ \times 4\ V = 2\ V$.

d. $V_{tpd} = V_{R1} + V_{R2} + V_{R3} = 6\ V + 4\ V + 2\ V = 12\ V$

3.

a. $R_s = R_2 + R_3 = 2\ \Omega + 1\ \Omega = 3\ \Omega$

b. The total resistance is half what it was, so the current must be double what it was. Therefore current = 2 × 2 A = 4 A

c. The terminal potential difference of the battery will not change since we are ignoring internal resistance, so $V_{tpd} = 12\ V$.

Activity 9: Resistors in parallel

In this activity, you should observe that the brightness of the bulbs connected in parallel in Circuit 2 is similar to the brightness of the bulb on its own in Circuit 1.

Answers to the following questions:

a. The current in the bulb in Circuit 1 is equal to the current in the bulbs in Circuit 2.

b. The current through the battery in Circuit 1 is less than the current in the battery in Circuit 2.

The voltage reading across the resistor in Circuit 1 is equal to the voltage reading across the battery. Similarly, in Circuit 2, the voltage reading across each resistor is equal to the voltage reading across the battery.

We can conclude that the battery potential difference is equal to the potential difference across each of the resistors in a parallel circuit.

Activity 10: Test your understanding of resistors in parallel

1.

a. $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

$$= \frac{1}{4\ \Omega} + \frac{1}{6\ \Omega}$$

$$= \frac{3}{12\ \Omega} + \frac{2}{12\ \Omega}$$

$$= \frac{5}{12\ \Omega}$$

Therefore $R_p = \frac{12\ \Omega}{5} = 2{,}4\ \Omega$

b. The current is flowing to the left in resistor R_1.

2.

a. $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2+R_3} + \frac{1}{R_4}$

$= \frac{1}{4\ \Omega} + \frac{1}{4\ \Omega+4\ \Omega} + \frac{1}{8\ \Omega}$

$= \frac{2}{8\ \Omega} + \frac{1}{8\ \Omega} + \frac{1}{8\ \Omega}$

$= \frac{4}{8\ \Omega}$

Therefore $R_p = \frac{8\ \Omega}{4} = 2\ \Omega$.

b. The branch with R_2 and R_3 has the same resistance as R_4, so this branch will receive the same current as the R_4 branch. So $I_1 = 1$ A.

R_1 has half the resistance of R_4, so the current divides so that the R_1 branch will receive double the current of the R_4 branch. So $I_2 = 2 \times 1$ A = 2 A.

$I_3 = I_1 + I_2 + 1$ A = 2 A + 1 A + 1 A = 4 A

c. V_{R1} = 8 V since it is connected directly across the battery.

V_{R2} = 4 V since this branch has two 4 Ωresistors that are together connected across the battery, so they share 8 V equally between them.

V_{R4} = 8 V since it is connected directly across the battery.

d.

i. If one of the parallel branches is removed, then there are fewer pathways for the current, so the total resistance will be increased.

ii. Since the resistance is increased, the current through the battery will decrease because current is inversely proportional to resistance.

iii. The potential difference across resistor R_1 will not change, because it is connected directly across the battery, so will receive the full battery terminal potential difference.

Unit 2. Energy transfer in electrical circuits

Activity 1: Test your understanding of electrical energy and power

1. Given: V = 2,5 V I = 0,6 A

a. $R = \frac{V}{I} = \frac{2{,}5\ \text{V}}{0{,}6\ \text{A}} = 4{,}17\ \Omega$

b. P = V · I = 2,5 V × 0,6 A = 1,5 W.

c. t = ½ h × 60 min/h = 30 mins × 60 s/min = 1 800 s

$E = P \cdot t = 1{,}5 \text{ W} \times 1\,800 \text{ s} = 2\,700 \text{ J}$

OR $E = V \cdot I \cdot t = 2{,}5 \text{ V} \times 0{,}6 \text{ A} \times 1\,800 \text{ s} = 2\,700 \text{ J}$

2. Given: P = 200 W V = 220 V

From $P = \frac{V^2}{R}$ we can make R the subject of the formula:

$$R = \frac{V^2}{P} = \frac{(220 \text{ V})^2}{200 \text{ W}} = 242\ \Omega$$

3. Given: P = 1760 W V = 220 V

a. From $P = V \cdot I$ we can make I the subject of the formula:

$$I = \frac{P}{V} = \frac{1\,760 \text{ W}}{220 \text{ V}} = 8 \text{ A}$$

b. Given: time = 2 hours per day × 7 days

= 14 hours in one week × 3600 s/hour = 50 400 seconds

$E = V \cdot I \cdot t = 220 \text{ V} \times 8 \text{ A} \times 50\,400 \text{ s} = 88\,704\,000 \text{ J} = 88\,704 \text{ kJ}$

Assessment Activity: Electric circuits **Total marks = 90**

1. The correct answers are shown below (10)

A. Instrument that is used to measure potential difference **voltmeter**

B. Instrument that is used to measure current **ammeter**

C. Unit that is equivalent to C/s **ampere**

D. Unit that is equivalent to V/A **ohm**

E. Unit that is equivalent to J/s **watt**

F. The work done to move a unit charge through a circuit element **electrical potential difference**

G. Circuit element that opposes the path of the current **resistor**

H. The rate of flow of charges in a circuit **current**

I. The work done in moving a unit charge around a complete circuit **emf**

J. The rate at which electrical energy is transferred or converted in an electric circuit **power**

2. Given: $I = 6\ mA = 0{,}006\ A$; $\Delta t = 15\ s$

From the equation $I = \frac{Q}{\Delta t}$ we can solve for Q:

$Q = I \times \Delta t = 0{,}006\ A \times 15\ s = 0{,}09\ C$ (3)

3. Given: $Q = 2\ C$; $\Delta t = 5\ min \times 60\ sec/min = 300\ s$

$I = \frac{Q}{\Delta t} = \frac{2\ C}{300\ s} = 0{,}0067\ A = 6{,}7\ mA$ (3)

4. Series resistors are connected in a single closed loop with the battery. Parallel resistors are connected in separate branches, so that the current splits as it goes to each parallel resistor. (4)

5.

a. $R_s = R_1 + R_2 + R_3 = 6\ \Omega + 6\ \Omega + 3\ \Omega = 15\ \Omega$ (2)

b. Since $R_1 = R_2 = 6\ \Omega$, V across R_1 = 3V

Since $R_3 = ½\ R_2 = 3\ \Omega$, V across R_3 = ½ 3V = 1,5 V (2)

c. $V_{battery} = 3\ V + 3\ V + 1{,}5\ V = 7{,}5\ V$ (3)

d. $I = \frac{V}{R} = \frac{3\ V}{6\ \Omega} = 0{,}5\ A$ (3)

6.

a. $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$= \frac{1}{2\ \Omega} + \frac{1}{4\ \Omega} + \frac{1}{2\ \Omega}$

$= \frac{2}{4\ \Omega} + \frac{1}{4\ \Omega} + \frac{2}{4\ \Omega}$

$= \frac{5}{4\ \Omega}$

Therefore $R_p = \frac{4\ \Omega}{5} = 0{,}8\ \Omega$. (4)

b. $I_1 = ½\ 2A = 1\ A$

$I_2 = 2A$

$I_3 = I_1 + I_2 + 2A = 5\ A$ (6)

c. $V_2 = I\ R_2 = 1A \times 4\Omega = 4\ V$ (2)

d. Therefore battery potential difference = 4 V (2)

e. The total resistance in the circuit will decrease, since there is an additional pathway for the current, which reduced the resistance in the circuit. (2)

f. The current through the battery will increase, since current is inversely proportional to the resistance. (2)

g. The potential difference across resistor R_1 will not change, since these are independent branches. (2)

7.

a. The current strength from a 2,5V battery is 0,5 A (2)

b. To give a current of 0,9A we would need a voltage of 4,5 V. So the number of 1,5V batteries that would be needed is 4,5 V / 1,5 V = 3 batteries. (3)

c. The size of the resistance is the gradient of this graph:

$$R = \text{grad} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{4\,V - 1\,V}{0{,}8\,A - 0{,}2\,A} = 5\ \Omega \qquad (4)$$

8.

a. To find the total resistance, we must first find the equivalent of the parallel resistors:

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{8\ \Omega} + \frac{1}{8\ \Omega} + \frac{1}{4\ \Omega}$$

$$= \frac{4}{8\ \Omega}$$

Therefore $R_p = \frac{8\ \Omega}{4} = 2\ \Omega$. (3)

$R_T = R_1 + R_P = 2\ \Omega + 1\Omega = 3\ \Omega$ (1) (4)

b. To find the current through R_2 we use Ohm's Law:

Therefore $I_{R2} = \frac{V}{R} = \frac{1{,}2\ V}{8\ \Omega} = 0{,}15\ A$ (3)

c. Since R_4 has half the resistance of R_2, the current through R_4 is double the current through R_2. Therefore $I_{R4} = 0{,}3\ A$ (2)

d. The current through R_3 = 0,15 A since it has the same resistance as R_2. So the current through R_1 is the sum of the parallel currents.

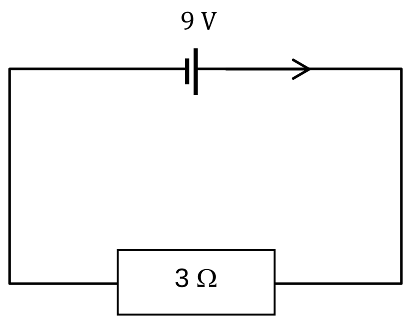
Therefore $I_{R1} = I_{R2} + I_{R3} + I_{R4} = 0{,}15\ A + 0{,}15\ A + 0{,}3\ A = 0{,}6\ A$ (3)

e. To find the battery potential difference we use Ohm's Law:

$V_{battery} = R_T \cdot I = 3\ \Omega \times 0{,}6\ A = 1{,}8\ V$ (4)

9.

a. The circuit diagram for this circuit is shown below: (3)



b. <u>Given</u>: V = 9 V ; R = 3 Ω; t = 5 min × 60 s/min = 300 s

I = V/R = 9 V / 3 Ω = 3 A

W = VIt = 9 V × 3 A × 300 s = 8100 J = 8,1 kJ (3)

c. P = VI = 9 V × 3 A = 18 W = (3)

d. If another 3 Ω resistor is connected in series with the first, the total power dissipated in the circuit will **decrease**. This is because the power is proportional to the voltage and the current. The voltage remains constant but the current decreases with an increase in resistance. (3)

e. If another 3 Ω resistor is connected in parallel with the first, the total power dissipated in the circuit will **increase**. This is because the power is proportional to the voltage and the current. The voltage remains constant but the current increases with a decrease in resistance, since parallel resistors have less resistance than a single resistor on its own. (3)

Sub-topic 3. Magnetism

Unit 1. Magnetism

Activity 1: Exploring magnets

In this activity, you should find that non-metals are not attracted to the magnet, while some metal objects are attracted to the magnet. Some metals are not attracted to the magnet, for example aluminium.

Activity 2: Exploring the interactions between magnets

In this activity, you should find that like poles repel each other (e.g. South and South poles), but unlike poles attract each other (e.g. North and South poles).

The North pole of a compass will be attracted to the South pole of the magnet.

Activity 3: Test your knowledge of interactions between magnets

1.

   a. The magnets will be attracted to each other (since opposite poles are brought close to each other)

   b. The magnets will be repelled by each other (since like poles are brought close to each other)

2.

   a. This side of the magnet is a North pole, since it attracted the South pole of the compass.

   b. If you bring a compass close to the opposite side of the magnet, you will be bringing it close to a like pole (another South pole), so the compass needle will be repelled and deflected away from the magnet.

3.

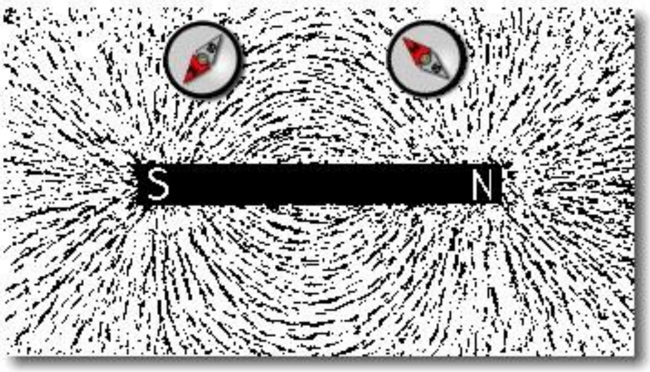
   a. The broken part of the blue half will be a North pole, so if you bring it close to a South pole they will **attract** each other.

   b. The broken part of the red half will be a South pole, so if you bring it close to a South pole they will **repel** each other.

Unit 2. The magnetic field

Activity 1: Exploring the magnetic field around a magnet

In this activity you should find that t he shape of the magnetic field around a bar magnet is similar to that shown in the photograph on the right.

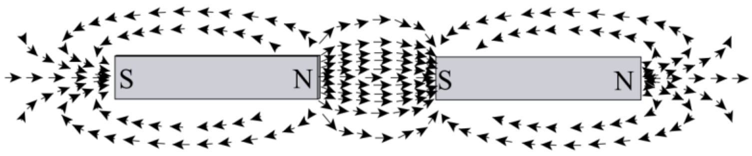


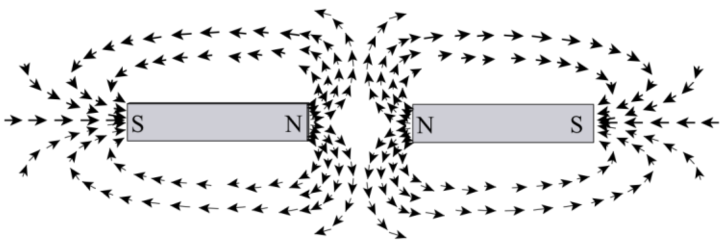
The magnetic field (from http://resources.yesican-science.ca/magnets/lines2.jpg)

3.

Activity 2: Exploring the magnetic field around a group of magnets

In this activity you should fine the magnetic fields around the arrangements of magnets to be something like those shown in the diagrams below:





Assessment Activity: Magnetism **Total marks = 20**

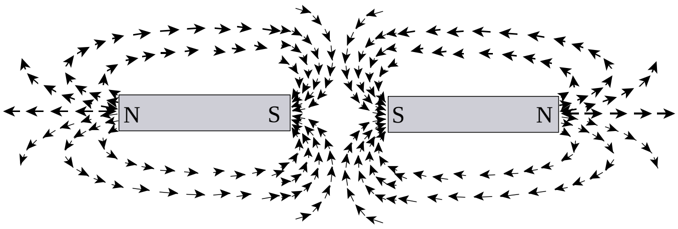
1. The correct words are shown below: (3)
   a. An object that attracts magnetic materials: **a magnet**
   b. An instrument consisting of a small, rotating magnet that shows the direction of a magnetic field: **a compass**
   c. The area around a magnet where a magnetic force would be experienced by another magnet or an object made of ferromagnetic material: **a magnetic field**

2.
   a. You would observe attraction, since these are unlike poles. (2)
   b. You would observe repulsion, since these are like poles. (2)
   c. You would observe attraction, since a magnet attracts objects made from magnetic material (2)
   d. You would not observe any force, since aluminium is a non-magnetic metal. (2)

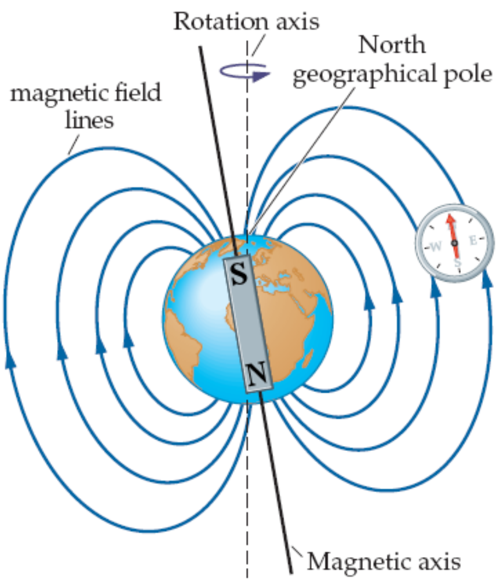
3.

a. If side X is attracted to the North pole, this means side X is a South pole. So side Y must be a North pole. (1)
b. If you bring side X of the bar magnet close to the South Pole of the other magnet, you will observe repulsion, since these are both South poles. (2)

4. (3)



5. The diagram of the Earth's magnetic field lines is shown below. (3)



The Earth's magnetic field (from http://www4.uwsp.edu/physastr/kmenning/images/Earth_field_in-class_answer.png)

Sub-topic 4. Electromagnetism

Unit 1. The magnetic effect of a current

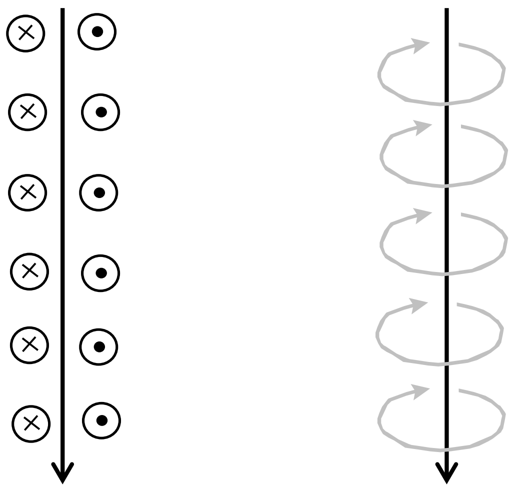
Activity 1: Investigating the magnetic field around a current carrying conductor

In this activity, you should observe that the compass needle is deflected when a current flows in the wire, showing that there is a magnetic field around the wire. The shape of the magnetic field is circular around the wire.

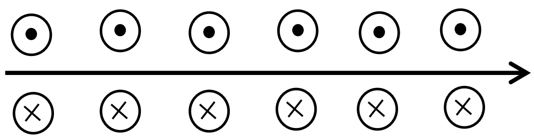
Activity 2: Test your understanding of the magnetic field around a current-carrying wire

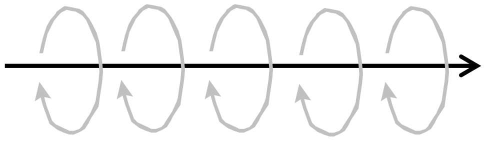
1.

a.

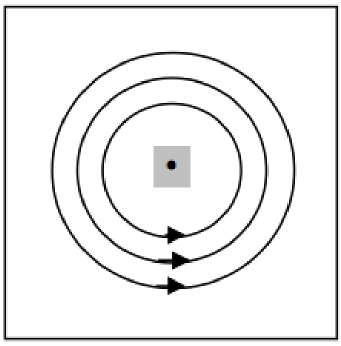


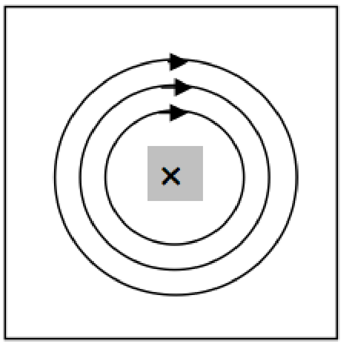
b.





2.

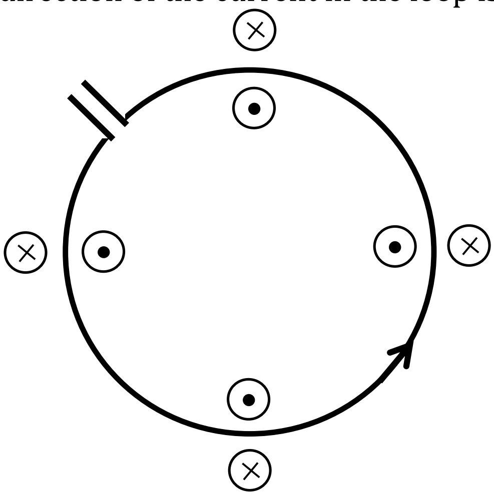




Activity 3: The magnetic field near looped wires

1.
   a. The direction of the magnetic field at the centre of the loop is **into the page**, since the current is flowing in a clockwise direction.
   b. To change the direction of the magnetic field, you need to change the direction of the current to be anti-clockwise.

2. The direction of the current in the loop is shown in the diagram below.



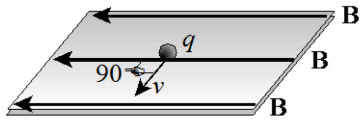
Activity 4: *Build an electromagnet*

In this activity, you should have observed that the nail acted like a magnet when there was current flowing through the coil, since the nail exerted a force of attraction on the paper clips. As soon as the current was stopped, the nail no longer attracted the paper clips. The nail with the wire wrapped around it is called an **electromagnet**. The direction of the magnetic field set up in the nail is shown in the diagram on the right.

Unit 2. Force on a current-carrying conductor

Activity 1: Reflection questions

1. The force on the positive charge shown in the diagram on the right is **down**.
2. The force would be on a *negative* charge moving in this same direction would be opposite, ie **up**.



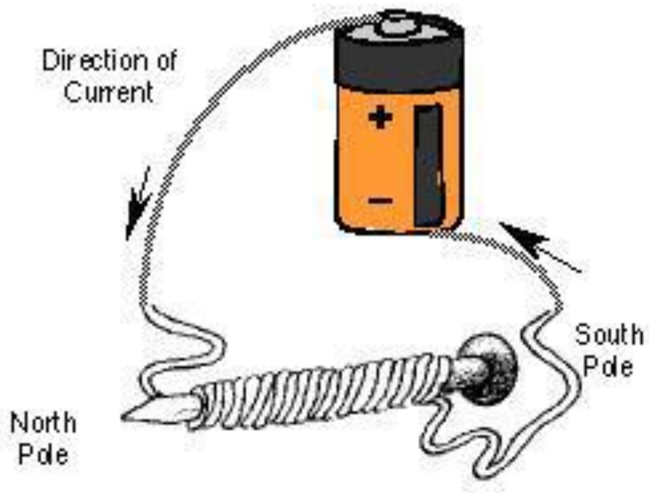
Assessment Activity: Electromagnetism **Total marks = 30**

1. Use a compass. When a current is flowing in the wire, the compass needle will point in the direction of the magnetic field. (3)
2. At point A: direction of magnetic field is **right** (1)

   At point B: direction of magnetic field is **left** (1)

   At point C: direction of magnetic field is **left** (1)

3. The diagram is shown below: (3)



{image taken from
http://content.teachengineering.org/content/cub_/lessons/cub_images/cub_mag_lesson2_activity1_figure1.jpg}

4.

a. Current direction would be into the page. (1)
b. By reversing the current direction (ie out of the page). (1)
c. Force direction is into the page (2)
d. No force, since it is moving parallel to the magnetci field. (2)
e. The compass needle would point to the left (in the direction of the magnetic field). (1)
f. It would point in the direction of the Earth's magnetic North. (2)

5.

a. There WILL be a force of magnetic attraction, since the paper clip is a magnetic material, and will be attracted to the magnet. (3)
b. There will NOT be a force of magnetic attraction, since none of the objects are magnetised. (3)
c. There WILL be a force of magnetic attraction, since the iron rod will become an electromagnet when a current flows through the wire. (3)
d. There WILL NOT be a force of magnetic attraction, since aluminium is non-magnetic, so it wont form an electromagnet. (3)