

SURFING

NSW PHYSICS

FOCUS AREA
1

Fundamentals Of Mechanics



• Brian Shadwick •

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Depth study content integration

Each depth study must include:

- **Working scientifically skills**, specifically from **questioning and predicting**, and **communicating**
- **At least two other working scientifically skills outcomes** (e.g. planning investigations, conducting investigations, processing data, analysing data, and problem solving)
- **Further development of at least one knowledge and understanding outcome** (see outcomes in topic areas in the syllabus document)



Assessment of depth studies must:

- Address questioning and predicting and communicating skills outcomes
- Address a minimum of two additional working scientifically skills outcomes
- Include assessment of at least one knowledge and understanding outcome

Scalar and Vector Quantities

Describe uniform straight line (rectilinear) motion and uniformly accelerated motion through qualitative descriptions.

1 Distance and Displacement

Distance is a measure of how far an object has moved. Distance is measured in units like centimetres (cm), metres (m), and kilometres (km). Distance is a **scalar quantity** which means *no direction* is required.

Displacement is a measure of how far, and in what direction, an object is from its starting point. Displacement is also measured in centimetres, metres and kilometres. Displacement is a **vector quantity** which means *a direction must be given* whenever we state a displacement.

For example, Billy Box rolls from the shade of his favourite tree to a creek bed. The creek is 300 metres from the tree in a westerly direction. When he gets to the creek Billy will have rolled 300 metres west. We say the:

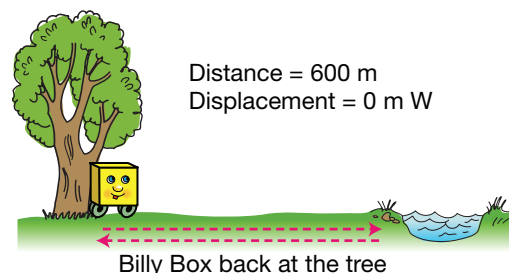
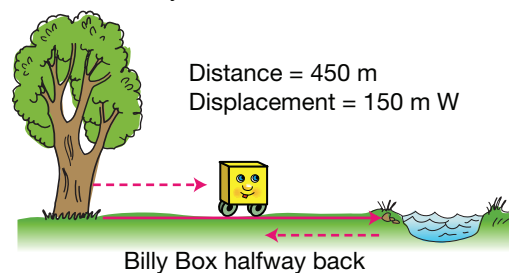
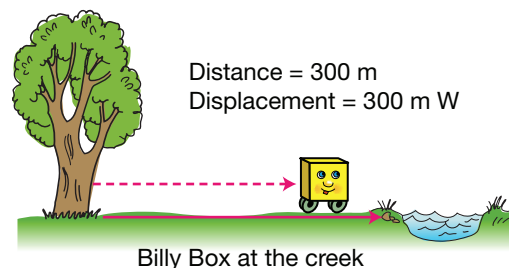
- Distance Billy rolled is 300 m.
- Displacement is 300 m west.

Note that the only difference between the distance travelled and the displacement is that the *direction* of displacement is (and *must be*) stated. However, when Billy Box is halfway back to the tree notice that the:

- Distance Billy rolled is 450 m.
- Displacement is 150 m west.

Notice the distance travelled and the displacement are quite different this time. When Billy Box is back at the tree the:

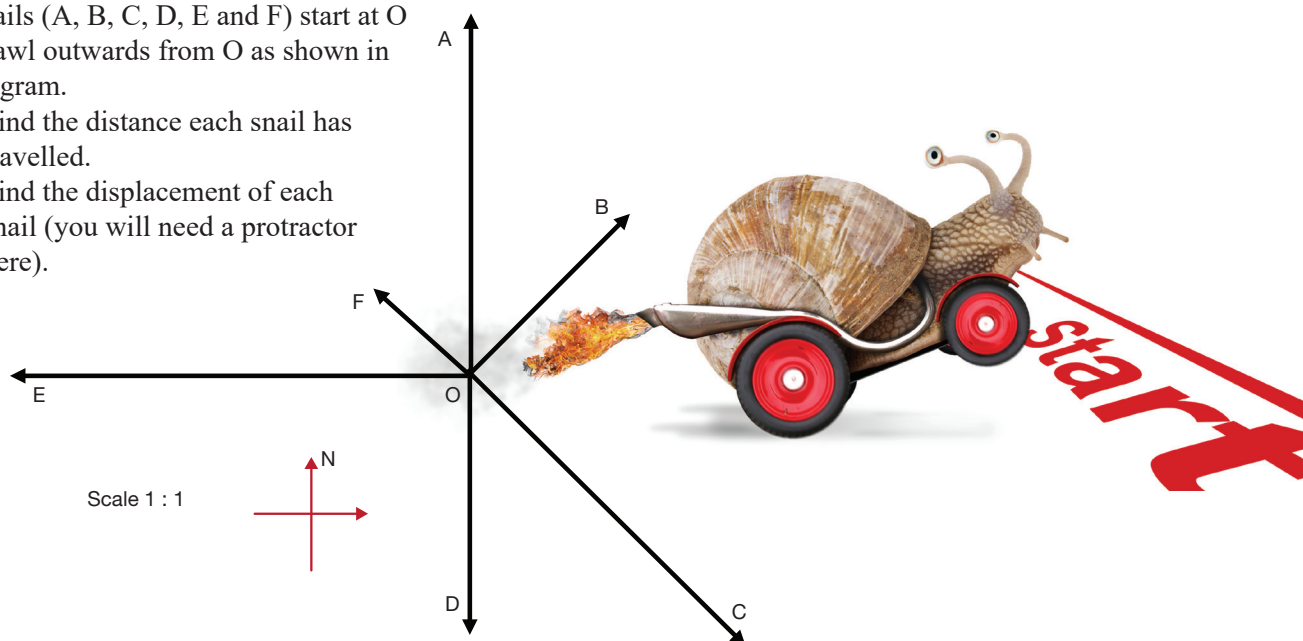
- Distance Billy rolled is 600 m.
- Displacement is zero.



QUESTIONS

1. Six snails (A, B, C, D, E and F) start at O and crawl outwards from O as shown in the diagram.

- Find the distance each snail has travelled.
- Find the displacement of each snail (you will need a protractor here).



QUESTIONS

- Expressing the directions as *bearings*, calculate the displacement of each of the snails in Figure 2.4. Each snail started at the origin. (Don't forget the scale!)

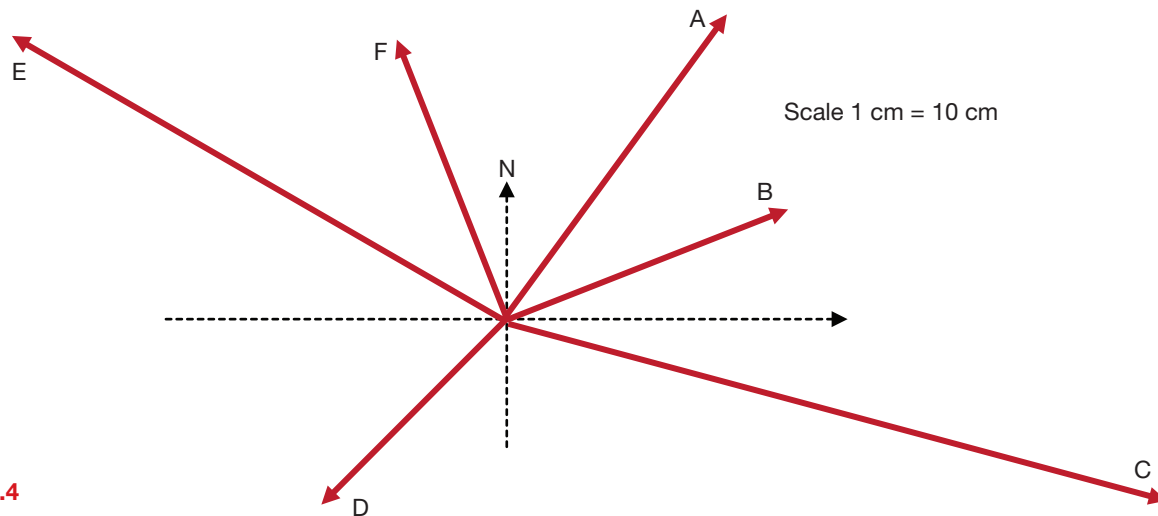


Figure 2.4

- A car travels from S to T, 70 km apart, by the road shown in Figure 2.5. Draw up a table to show how far the car has travelled when it is at A, B, C, D and T, and what its displacement is at each position. Record the displacement direction in the two different ways shown above.
- The map in Figure 2.6 has been drawn to scale where 1 cm = 10 km. Imagine that 10 different people start from J. Nine of them travel to each of the other marked places, and the tenth travels to the top of Little Ugly. What is the displacement of each person when each is at their destination?

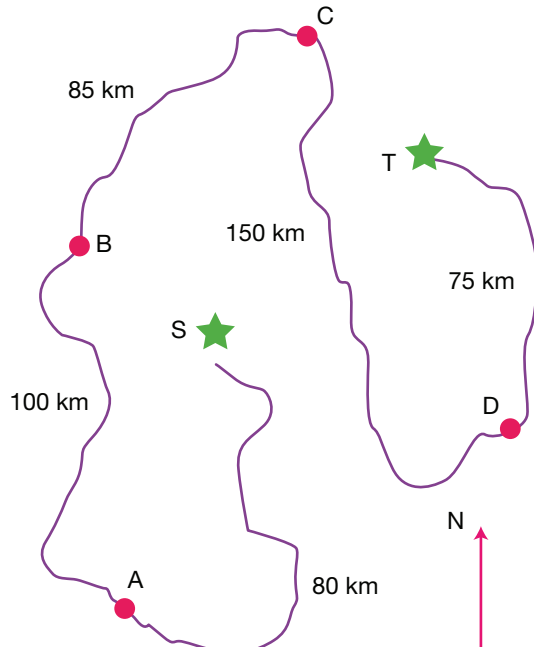


Figure 2.5

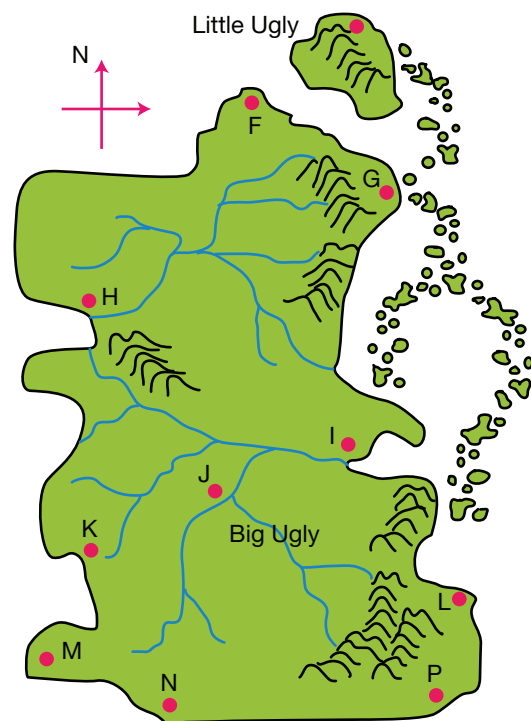


Figure 2.6

5 Acceleration

When an object speeds up we say that it **accelerates** or has an acceleration **in the direction of the motion**, or that it has a **positive acceleration**. When an object slows down, it also accelerates, but more correctly we say that it has a **negative acceleration** or that it has an acceleration **against the motion**, or that it **decelerates**. A moving object also accelerates when it changes direction whether its speed changes or stays the same because a change in direction *is* a change in velocity.

Acceleration is a measure of the rate at which velocity changes.

Acceleration may be positive (speeds up) or negative (slows down).

Acceleration tells us how much the velocity changes each second.

Acceleration is usually measured in metres per second per second (m s^{-2}).

Acceleration also occurs when the direction of travel changes.

Acceleration is a vector quantity and the direction *must* be stated.

Example: Consider a car which is moving at 10 m s^{-1} east and which accelerates to 50 m s^{-1} east over a period of 5 seconds. Find its acceleration.

Solution: Its speed changes from 10 m s^{-1} east to 50 m s^{-1} east, a change of 40 m s^{-1} east. This change takes 5 seconds. So, on average, the change in speed is 8 m s^{-1} each second. We say that the acceleration of the car is 8 m s^{-2} east. Notice that this answer can be found using the equation:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time for change to occur}} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}} = \frac{50 - 10}{5} = 8 \text{ m s}^{-2}$$

To make things a bit simpler we use symbols for each of these quantities and usually express the above equation as follows.

$$a = \frac{v - u}{t}$$

Where a = acceleration in m s^{-2}

u = initial velocity in m s^{-1}

v = final velocity in m s^{-1}

t = time taken for change in seconds

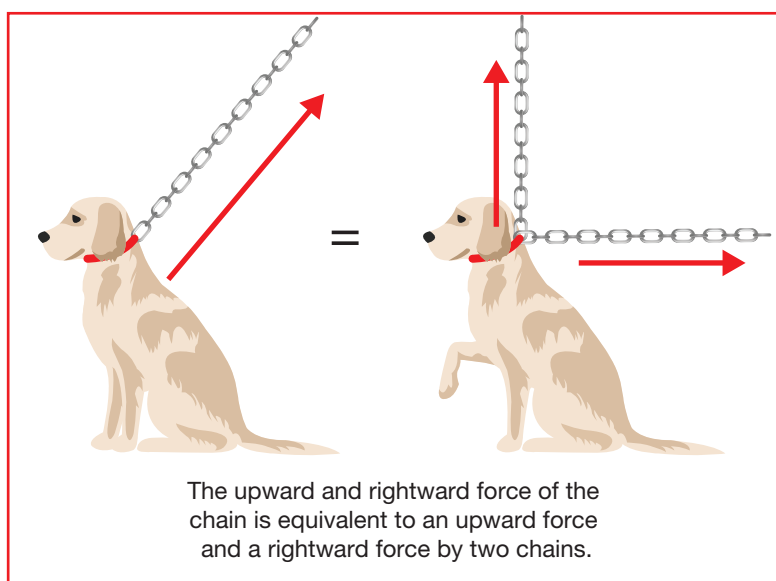
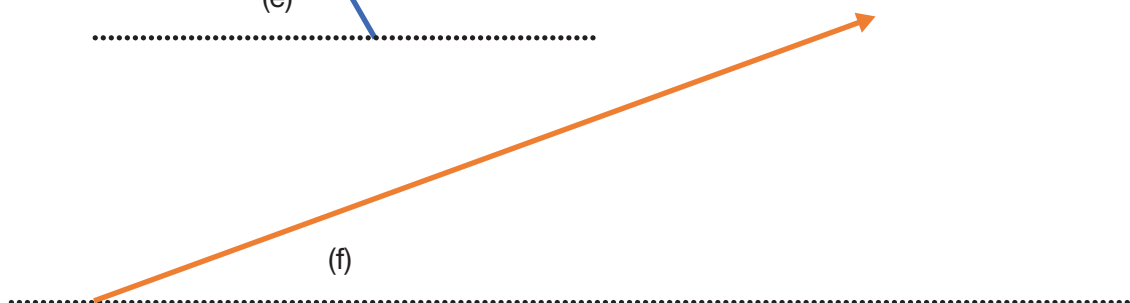
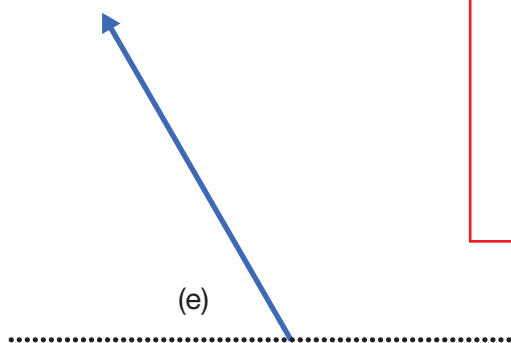
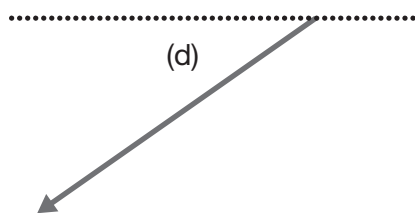
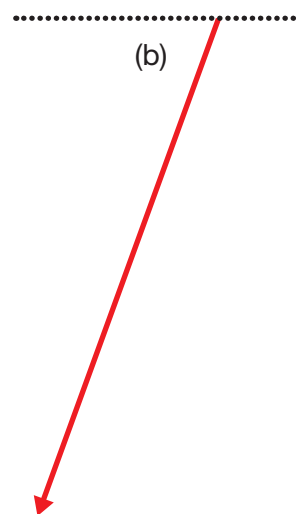
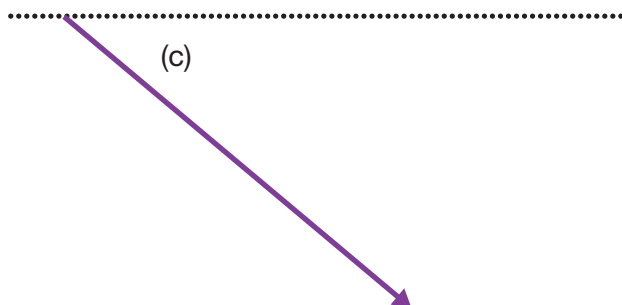
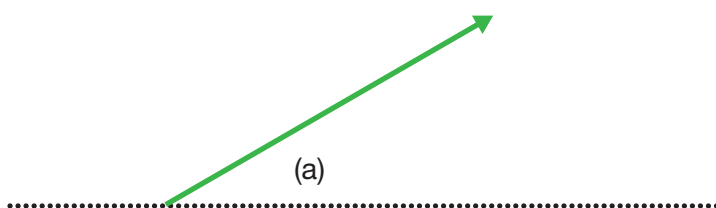
Notice that this equation can be rearranged to give: $v = u + at$

Note also that if acceleration is constant (including zero), the average velocity of an object is given by: $v_{\text{av}} = \frac{u + v}{2}$

QUESTIONS

1. A car, at rest, accelerates at 3 m s^{-2} N for 12 s. Calculate its velocity after 4, 8 and 12 s.
2. A rock falls from rest. Its speed when it hits the ground 3 s later is 29.4 m s^{-1} . Calculate its acceleration.
3. A car moving at 32 m s^{-1} W hits a wall and stops in 0.02 s. Calculate the acceleration stopping the car.
4. After 4 s of accelerating at 2.5 m s^{-2} , a car moves at 50 m s^{-1} . Calculate its initial velocity if the acceleration was:
 - (a) Positive (in direction of motion).
 - (b) Negative (opposing motion).
5. A rocket accelerates at 40 m s^{-2} until its speed is 1800 m s^{-1} . How long does this take?
6. A car accelerates at 4.5 m s^{-2} S for 6 s. After this time it is moving at 36 m s^{-1} S. Calculate its initial velocity.
7. A car accelerates at 2.5 m s^{-2} E for 16 s. After this time the car is moving at 10 m s^{-1} W. Calculate its initial velocity.

2. Find the horizontal and vertical components of each of the following vectors. All vectors are drawn to a scale where 1 cm = 10 m.

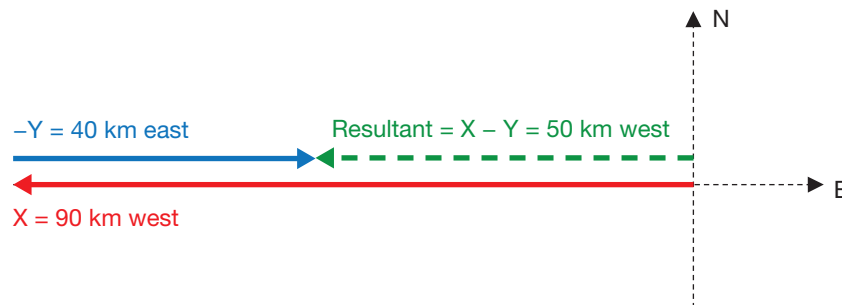


9 Subtracting Vectors In a Straight Line

When we subtract vectors from each other we draw them in the scale diagram one after the other, each one starting where the previous one finished – head to tail addition as we did when we added them, but to subtract we need to **change the direction** of the vectors we are subtracting. Remember in physics, subtraction means ‘opposite direction’.

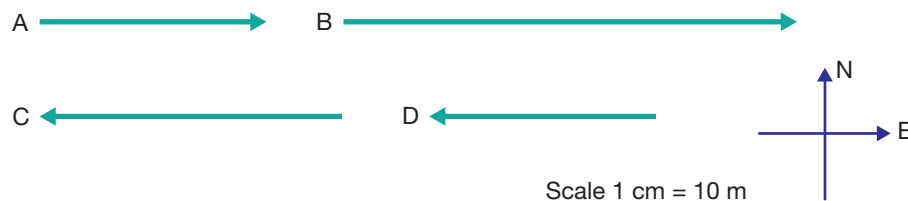
Example: Vector $X = 90 \text{ km west}$. Vector $Y = 40 \text{ km west}$. What we want is the value of $X - Y$. We would draw the vector diagram for this problem as follows.

- Draw in the compass cross set of axes.
- Starting at the origin, draw in a vector to represent the vector 90 km west (red vector).
- Recalling that $-Y = Y$ in the opposite direction, then $-Y = 40 \text{ km east}$.
- Starting from the head of the 90 km west vector, draw in the 40 km east vector (blue).
- The resultant vector is the green vector from the starting point (origin) to the end point (head of the 40 km east vector).



QUESTIONS

The diagram shows several displacement vectors. Use them to answer the questions below.



1. Using vector diagrams, find:

- $C - A$
- $D - B$
- $B - C$
- $D - A$
- $A - B - C$
- $B - C - D$
- $A - C - D$
- $A - B - C - D$
- $B - C - D - A$
- $C - D - A - B$

21 Analysing Experimental Data

QUESTIONS

Experiment 1

The table shows the results of an experiment involving a toy car moving along in a straight line.

- Copy the results table and add a third column for *distance travelled*. Complete this column.
- On the same axes, graph the displacement and distance travelled data.
- Use your graph to find the average speed and velocity of the object.
- How fast would the object go to move the same distance in 20 s?

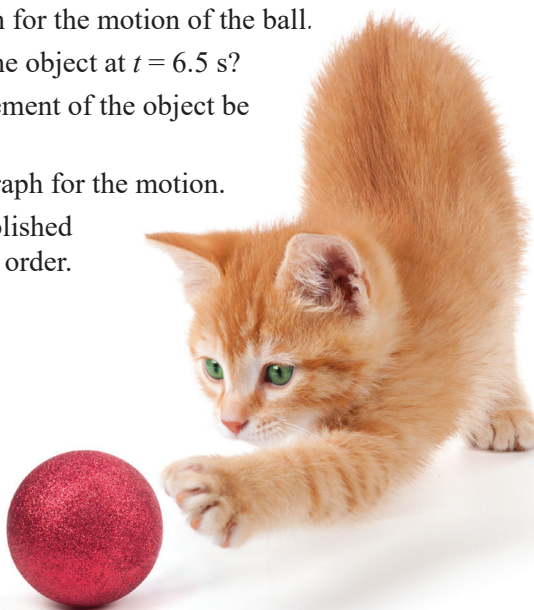


Time (s)	Displacement (m)
0	0
5	0
10	10
15	20
20	30
25	30
30	30
35	20
40	10
45	0
50	-10

Experiment 2

A ball was rolled across three level, connected surfaces A, B and C. As it rolled, the data shown in the table was collected.

- Draw a displacement-time graph for the motion of the ball.
- What was the displacement of the object at $t = 6.5$ s?
- At what time would the displacement of the object be 85 cm?
- Use this to draw a speed-time graph for the motion.
- The three surfaces are carpet, polished wood and rubber, but not in that order.
Use your graphs to identify:
 - The boundaries between the surfaces.
 - The length of each surface.
- Calculate the average velocity of the ball across each surface.



Time (s)	Displacement (cm)
0	0
1	20
2	40
3	60
4	80
5	97
6	111
7	122
8	129
9	131
10	132
11	132
12	132

22 Analysing Two Velocity Experiments

QUESTIONS

Experiment 1

In an experiment, Pat and Chris took measurements to determine how fast a moving footway was moving. They took two sets of readings – firstly with Chris walking on the moving footway in the same direction as the footway movement, and secondly with the Chris walking at the same rate in the opposite direction. In each case, Pat timed how long it took to walk Chris to walk 50 metres. Their results are shown in the table.

Time to walk 50 m in same direction as movement of footway (seconds)	Time to walk 50 m in opposite direction to footway movement (seconds)
7.1	17.2
7.0	16.6
6.8	16.0
6.8	17.5
7.5	16.2
6.7	17.2
7.7	16.0

Use these results to answer the following questions:

- Calculate how fast the footway was moving.
- Calculate how fast Chris was walking.
- Find Chris's speed relative to the footway in each case.
- Calculate Chris's speed relative to Pat in each case.

Experiment 2

Three students were timed swimming 50 metres freestyle at three separate places. Four measurements were made for each student. The measurements made were as follows.

Swim	Katrina	Sophia	Donna
1	36.2 sec	30.6 sec	40.2 sec
2	34.8 sec	29.7 sec	39.5 sec
3	35.7 sec	32.2 sec	41.3 sec
4	36.9 sec	31.5 sec	39.0 sec

Use these results to answer the following questions.

- Calculate the average speed of each swimmer.
- If they all raced in the same pool and swam to their averages, calculate who would win, come second and third.
- Calculate the time between first and second.
- Calculate the time between second and third.
- Calculate the distance between first and second.
- Calculate the distance between second and third.
- Assume the pool ran north-south, and the swimmers swam towards the north. Calculate the speed of each swimmer relative to the other two swimmers.



23 Analysing Two Acceleration Experiments

QUESTIONS

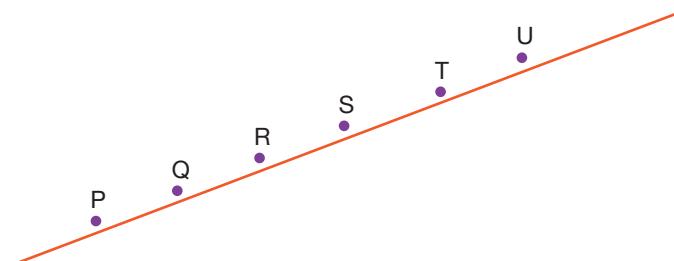
Experiment 1

In an experiment, a ball was rolled down a ramp from rest, from various positions as shown in the diagram.

The results in the table were obtained. For an object starting from rest, the acceleration is given by:

$$a = \frac{2s}{t^2}$$

Analyse this information to find the acceleration of the ball down the ramp. Include at least one graph.



Starting position	Distance up slope (m)	Average time to roll down (s)
P	0.5	0.55
Q	1.0	0.82
R	1.5	1.00
S	2.0	1.21
T	2.5	1.30
U	3.0	1.38

Experiment 2

The results shown in the table were collected in an experiment where a ball was dropped from different heights, and the time taken to fall measured.

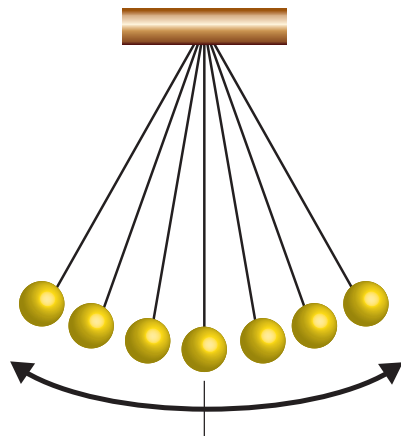
- Graph the information.
- Estimate how long it would take the object to fall 0.5 metres.
- Estimate how long it would take to fall 3.25 metres.
- If it took 2.00 seconds to hit the ground, from what height did it fall?
- Copy the table into your book and add a third column headed t^2 .
- Calculate values for t^2 and complete your table.
- Graph distance fallen against t^2 .
- What shape graph do you get?
- What does this tell you?
- Given that twice the gradient of your graph is equal to the acceleration of the falling object (see equation in Experiment 1 above), calculate this acceleration.
- Predict if this object is falling on Earth or not. Account for your answer.

Distance object falls (m)	Average time to fall (s)
1.0	0.58
2.0	0.82
3.0	1.00
4.0	1.15
5.0	1.29
6.0	1.41

24 Analysing an Experiment – Pendulums

QUESTIONS

In an experiment to determine the acceleration due to gravity on planet X, and the relationship between the period of the swing and the length of the pendulum, a pendulum bob was set swinging back and forth on strings of various lengths. The time for the bob to complete 20 swings was measured and the results are shown in the table below. Use the results to answer the questions.



$$T = 2\pi\sqrt{\frac{L}{g}}$$

From which we may calculate 'g' as :

$$g = \frac{4\pi^2L}{T^2}$$

1. Complete the table by making appropriate calculations for the value of the accelerations.

Length of pendulum string (m)	Time for 20 complete swings (s)	Time for one swing (s)	(Time for one swing) ² (s ²)	Acceleration due to gravity (m s ⁻²)
1.0	51	2.6		
2.0	76	3.8		
3.0	88	4.4		
4.0	100	5.0		
5.0	115	5.8		
6.0	125	6.3		
7.0	140	7.0		
Average value of acceleration on planet X				

- Graph the length of the pendulum (y-axis) against the period of swing (x-axis).
- Can we describe the relationship between length and period from this graph? Explain your answer.
- Draw another graph which will enable you to describe this relationship.
- Use this second graph to determine the value of the acceleration due to gravity on planet X.
- Which of the two values you have for the acceleration due to gravity is the most reliable? Explain your answer.



Botofumeiro pendulum swings on a 20 metre rope hanging from the ceiling of Santiago Cathedral.

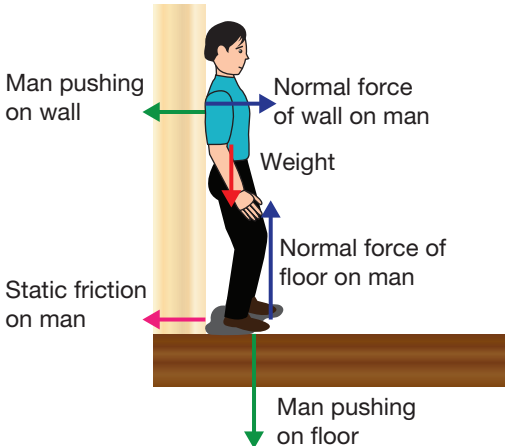
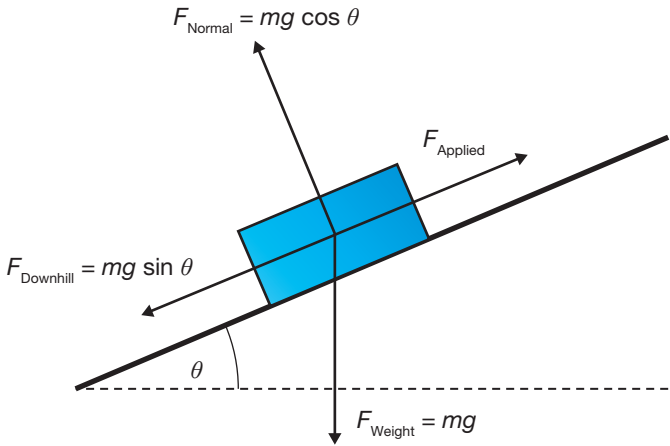
Types Of Forces

Learn about various types of forces and situations in which they act including the concept of balanced forces when objects are in equilibrium which is a focus of Newton's first law of motion.

30 Types Of Forces

From previous work we know that a force is a push or pull acting upon an object as a result of its interaction with another object. There are a variety of types of forces which can be broadly classified into two groups on the basis of whether the force resulted from the contact or non-contact of the two interacting objects.

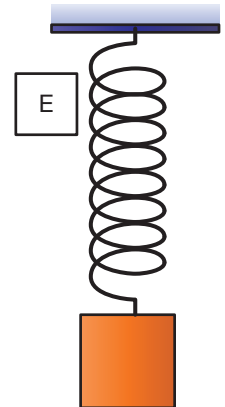
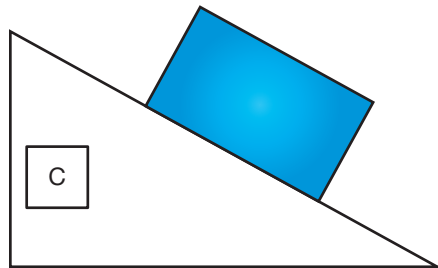
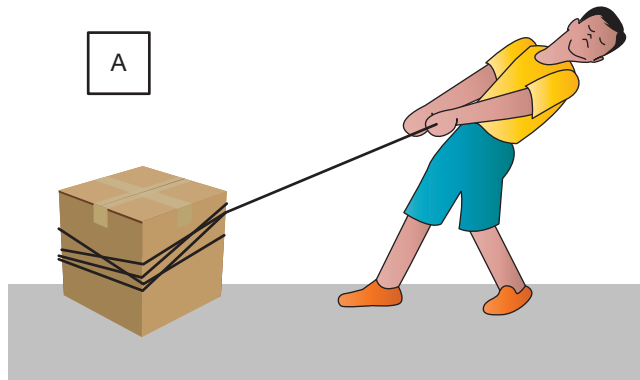
Contact forces	Forces that act at a distance
Applied forces	Gravitational force
Normal forces	Electric forces
Frictional forces	Magnetic forces
Air resistance	
Tension	
Forces in springs	

Contact force	Description of force
Applied force	An applied force is a force that is applied to an object by a person or another object. For example, if a person is pushing a chair across the room, then there is an applied force acting on the chair.   PUSH PULL
Normal force	The normal force is the support force exerted upon an object that is in contact with another stable object. For example, if a man is standing on a floor, then the floor is exerting a vertically upward force on him supporting his weight. A normal force can also be exerted horizontally between two objects that are in contact with each other. For example, if a the man leans against a wall, the wall pushes horizontally back on him. Note that normal forces are always exerted at right angles to the surface applying them. So if a box is resting on a ramp, then only part of its weight force ($mg \cos \theta$). Note also that all normal forces are also reaction forces as described in Newton's third law of motion.  

Frictional force	Friction is the force exerted by a surface as an object moves across it or makes an effort to move across it. There are at least two types of friction force – sliding and static friction. Friction usually opposes the motion of an object. For example, if a box slides across the floor, then the floor exerts a frictional force on the box in the opposite direction of its motion. Friction results from the two surfaces being pressed together closely, causing intermolecular attractive forces between molecules of different surfaces. Friction therefore depends upon the nature of the two surfaces and upon the degree to which they are pressed together. Direction of motion Direction of friction force Friction force acts opposite the direction of motion Force Less friction More force More friction
Air resistance	Air resistance is a type of frictional force that acts upon objects as they travel through the air. Although air resistance opposes the motion of an object., we will frequently ignore it as its magnitude (compared to the other forces involved) will be very small. Air resistance is most noticeable for objects that are travelling at high speeds (sky diver, plane or a parachute) or for objects with large surface areas. Gravity Air resistance
Tension	Tension forces are any forces that are transmitted through strings, ropes, cables or wires. Tensional force is directed in both directions throughout the length of the string, rope, cable or wire. Tension Tension Weight
Spring force	Forces in springs are caused by any applied force that either stretches or compresses them. The force produced within the spring is a restoring force which will return the spring to its original state once the deforming force is removed. The restoring force always acts in the opposite direction to the applied force. For springs which obey Hooke's law, the magnitude of the amount of stretch or compression of the spring is directly proportional to the applied force. Restored spring – restoring force acts to pull the spring back to its original length. No applied force – no restoring force within the spring. Compressional force – restoring force within the spring acts to extend the spring back to its original length.

QUESTIONS

1. What is the essential difference between contact forces and forces that act at a distance?
2. Copy each of the following diagrams into your book and draw in vector arrows to represent any contact forces involved. Label each force.



31 Equilibrium and Newton's First Law

A body is said to be in **equilibrium** if it is at rest or if it is moving with uniform velocity.

In other words if the acceleration of a body is zero, the body is said to be in equilibrium. It is sometimes referred to as being in translational equilibrium.

Alternately we could express this in the following way:

When two or more forces act on a body such that the resultant effect on the body is zero and the body retains its state of rest or of uniform motion then the body is said to be in equilibrium.

Notice how the concept of equilibrium is the focus of **Newton's first law of motion**:

A body at rest, or moving with constant velocity, will remain at rest or moving with constant velocity unless an unbalanced force acts on it.

We know from previous work that unbalanced forces will produce an acceleration and this changes the state of motion of the object thus removing its equilibrium.

There are two types of equilibrium: **static** equilibrium and **dynamic**.

Static equilibrium exists if all the forces acting on a body add to zero, and the body is at rest. For example, a book resting on a table, a car parked on the side of the road and a can of drink sitting on a shelf in the fridge are all in static equilibrium.

Dynamic equilibrium exists if all the forces acting on a body add to zero, and the body is moving at constant velocity. A plane moving at constant speed, a parachute jumper falling towards the ground at constant velocity and a car moving along a straight road at constant velocity are all in dynamic equilibrium.

QUESTIONS

1. State the conditions needed for translational equilibrium.
2. Explain the idea of static equilibrium.
3. Explain the idea of dynamic equilibrium.
4. Identify each of the following objects as being in static equilibrium, in dynamic equilibrium or as not being in equilibrium.
 - (a) A book sitting on a desk.
 - (b) Pendulum swinging back and forth.
 - (c) Ball rolling down a slope.
 - (d) Ball suspended by a string from the ceiling.
 - (e) Earth in orbit around the Sun.
 - (f) Plane flying horizontally at constant speed.
 - (g) Rocket during take-off.
 - (h) Arrow moving towards target.
 - (i) Car travelling at constant speed up hill.
 - (j) Car travelling at constant speed on flat road.
 - (k) Car travelling at constant speed down hill.
 - (l) Person sitting on a chair.
 - (m) Can of beans on shelf in pantry.
 - (n) Rocket travelling between Earth and the Moon.



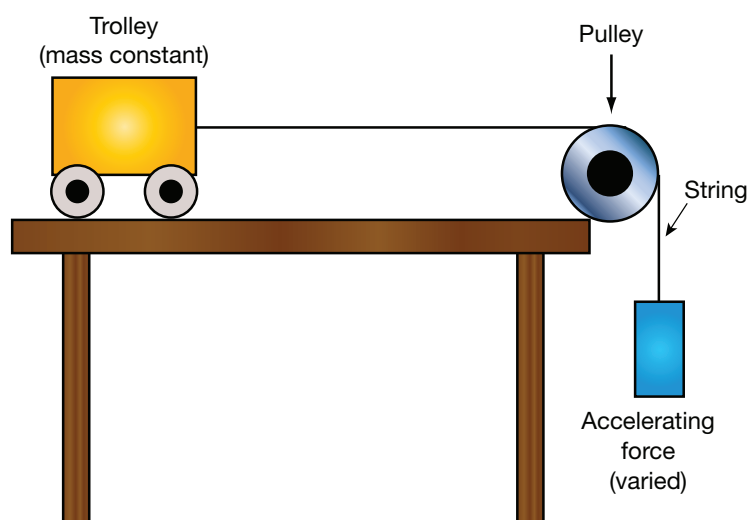
Analysing Motion and Force Experiments

Investigate, describe and analyse the acceleration of a single object subjected to a constant net force and relate the motion of the object to Newton's second law of motion through the use of graphs and vectors. Derive relationships including $F = ma$ and relationships of uniformly accelerated motion.

40 Analysing a Motion Experiment 1

QUESTIONS

In this experiment, a trolley was placed on the bench and accelerated by a force attached to it by a string, which passed over a pulley. The mass of the trolley was kept constant and different forces were used to accelerate it from rest. The time it took the trolley to travel 1.0 m across the benchtop was measured. The results are shown in the table.



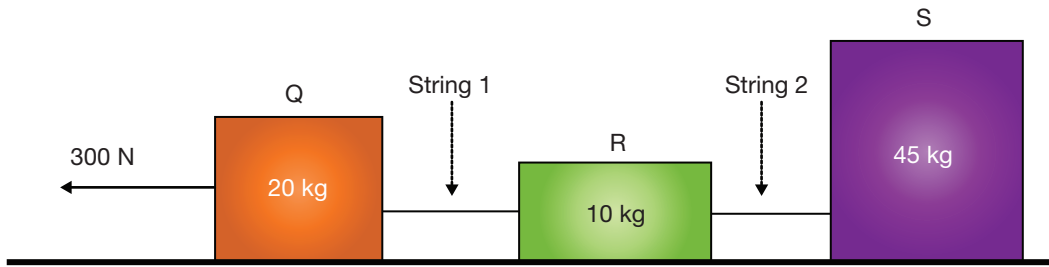
Analysis

- Copy the table into your book and add columns to show the following quantities.
 - Initial speed of trolley.
 - Average speed of trolley.
 - Final speed of trolley.
 - Acceleration of trolley.

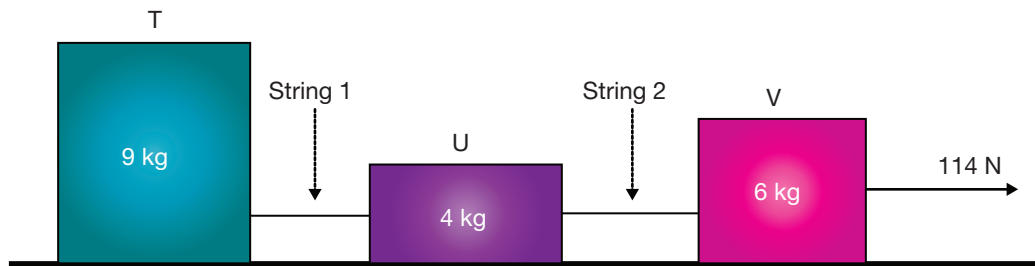
Run	Accelerating force (N)	Time to travel 1.0 m (s)
1	F	1.63
2	$2F$	1.15
3	$3F$	0.94
4	$4F$	0.82
5	$5F$	0.73

- Use the results to calculate values to complete your table.
- Draw a graph to show the relationship between the force and acceleration produced.
- Use your graph to write a conclusion for the experiment.

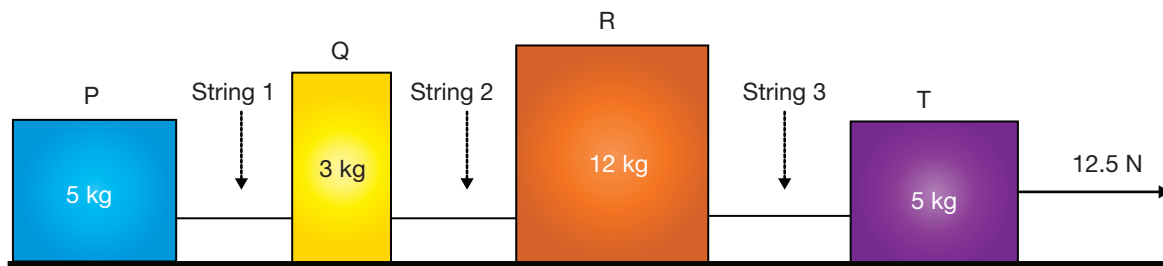
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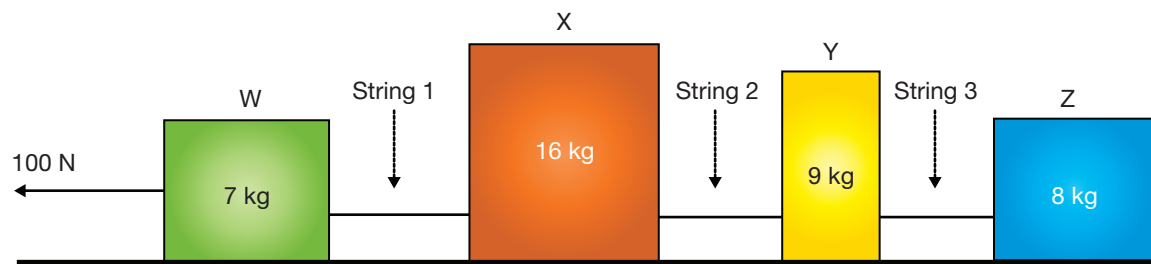
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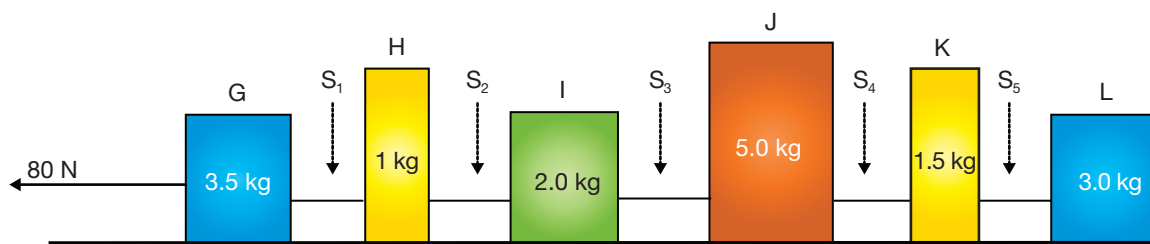
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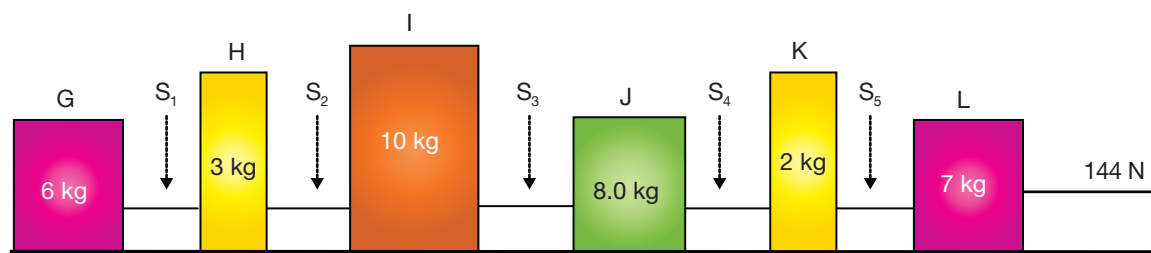
6.



7.



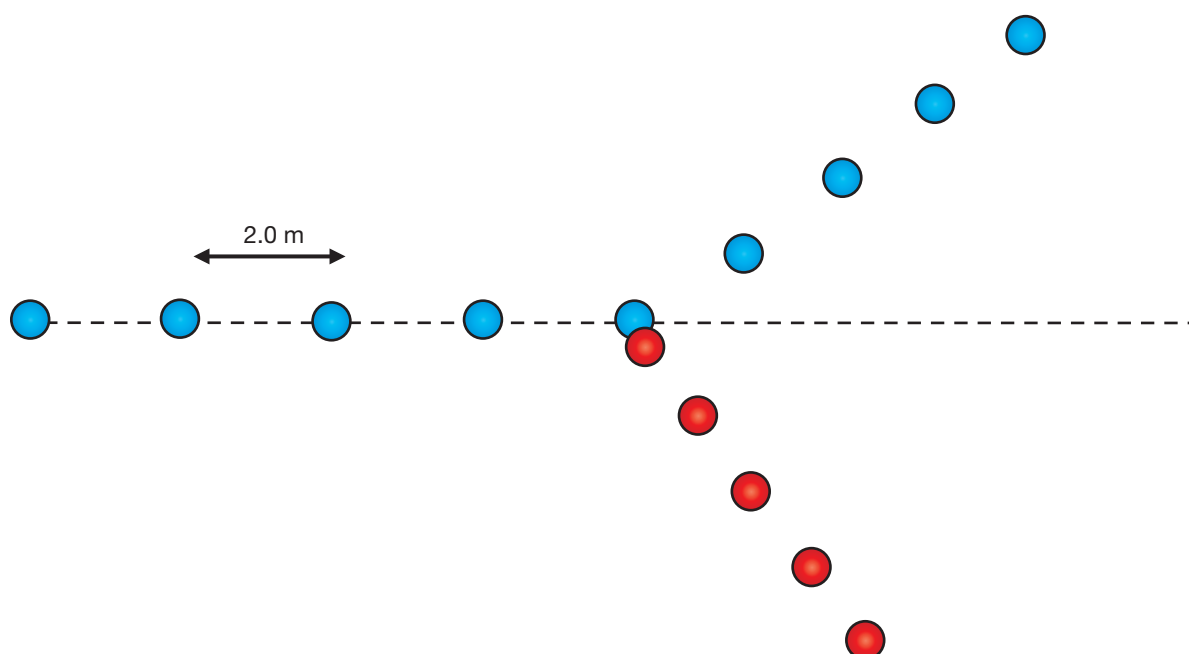
8.



66 Analysing Experimental Data – Two Dimensions

QUESTIONS

1. A group of students did an experiment where a moving ball, X, of mass 0.5 kg, travelled from left to right to collide with an identical ball Y, which was initially stationary. Because the collision was not a direct hit, the balls veered off at angles after the collision as shown in the scale diagram which reproduces their results. They studied the motion using a stroboscopic photograph.
 - The frequency of the stroboscope was 10 Hz.
 - The scale used to draw the diagram is marked on the diagram.



Make appropriate measurements and calculations to determine if momentum has been conserved in this collision.



Elastic and Inelastic Collisions

Analyse and compare the kinetic energy of elastic and inelastic collisions. Quantitatively analyse and predict, using the laws of conservation of momentum:

$\sum mv_{\text{before}} = \sum mv_{\text{after}}$ and kinetic energy: $\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$ the results of interactions in elastic collisions.

67 Elastic and Inelastic Collisions

In the absence of any external forces acting on a system (a closed system):

In **elastic collisions** the kinetic energy of the system is conserved.

In **inelastic collisions** the kinetic energy of the system is *not* conserved.

In **all collisions** the **total momentum** of the system is conserved.

In any collision where any other form of energy is released (heat, light, sound) or when objects in the system are deformed (bent, crushed, broken) or when objects collide and stick together (train engine coupling with carriage, car crashing under truck), the collisions will all be inelastic.

Example:

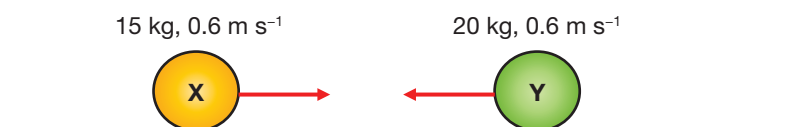
Two balls, X and Y with masses 15 and 20 kg respectively, and both moving at 0.6 m s^{-1} collide head on. After the collision, X rebounds at 0.3 m s^{-1} .

- What is the velocity of Y after the collision?
- Determine whether or not the collision is elastic or inelastic.

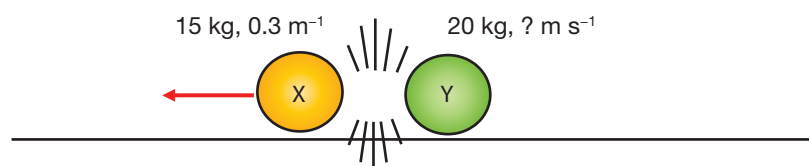
Solution:

Firstly, draw a diagram of the situation to clarify it.

Before collision:



After collision:



From the law of conservation of momentum: $(15 \times 0.6) - (20 \times 0.6) = (15 \times -0.3) + (20 \times v)$
From which $v = +0.075 \text{ m s}^{-1}$

That is, the 20 kg mass rebounds at 0.075 m s^{-1} .

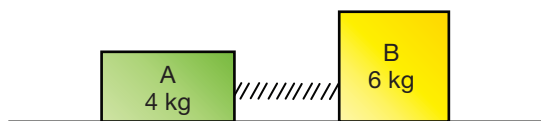
Checking conservation of energy: $\left(\frac{1}{2} \times 15 \times 0.6^2\right) + \left(\frac{1}{2} \times 20 \times 0.6^2\right)$

Compared to $\left(\frac{1}{2} \times 15 \times 0.3^2\right) + \left(\frac{1}{2} \times 20 \times 0.075^2\right)$

Which works out to $2.7 + 3.6 = 6.3$ compared to $0.675 + 0.05625 = 0.73125$

Obviously, kinetic energy is not conserved, so the collision is inelastic.

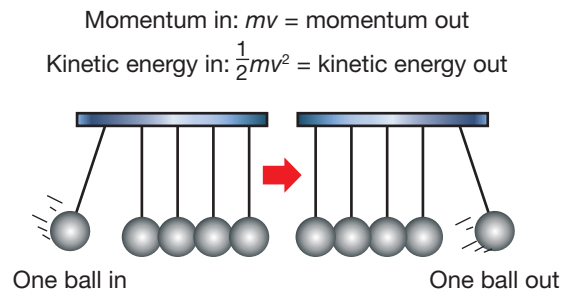
5. On a linear air track (zero friction) glider X, mass 4 kg and moving at 5 m s^{-1} N approaches glider Y, mass 2 kg at rest. Strong magnets on the gliders repel them and prevent them from coming into contact with each other as they interact. Find the velocity of each glider after they interact.
6. Glider P, mass 1 kg, moving at 4 m s^{-1} collides head on with glider Q, mass 4 kg and moving at 3 m s^{-1} . The collision is elastic. Determine the velocity of each glider after the collision.
7. A 0.6 kg puck, P, moving west on a frictionless surface interacts elastically with puck Q moving at 0.5 m s^{-1} in a direction $\text{S } 30^\circ \text{ W}$. After the interaction, P moves off in the direction $\text{S } 39^\circ \text{ W}$ and puck Q moves in a westerly direction. Find:
 - (a) The initial speed of P.
 - (b) The final speed of P.
 - (c) The final speed of Q.
8. Object X, mass 2 kg and moving at 6.0 m s^{-1} east collides elastically with object Y, mass 4 kg and moving at 3.0 m s^{-1} west. Determine the velocities of X and Y after the collision.
9. Object A, mass 5 kg and moving at 2.0 m s^{-1} north collides elastically with object B, mass 3 kg and moving at 2.0 m s^{-1} south. Determine the velocities of X and Y after the collision.
10. Consider two masses A, 4 kg and B, 6 kg at rest on a smooth surface, but connected together by a light, compressed spring as shown in the diagram.



When the spring is cut, A moves to the left at 3 m s^{-1} .

- (a) What does B do?
 - (b) Is this interaction elastic or inelastic? Explain your answer.
11. An empty, 10 tonne railway truck rolls at 3 m s^{-1} on a smooth horizontal track and couples with a 20 tonne truck at rest.
 - (a) What is the velocity of the trucks after this interaction?
 - (b) Is the interaction elastic or inelastic, and if inelastic, how much kinetic energy is lost by the system?
12. A 200 g toy car is moving at 0.12 m s^{-1} on a smooth horizontal surface. It collides elastically with a second car at rest. After this collision, the 200 g car continues in its original direction at 0.04 m s^{-1} . Find:
 - (a) The mass of the second car.
 - (b) The velocity of the second car after the collision.

13. Object A, mass 6 kg and moving at 3 m s^{-1} collides elastically with object B, mass 4 kg and moving at 7 m s^{-1} . After the collision, A has twice the speed of B. How fast is each object going after the collision?
14. (a) X, moving at 5 m s^{-1} collides elastically with Y moving at 3 m s^{-1} . After the collision, X moves at 4 m s^{-1} . How fast is Y going?
(b) Justify your answer.
15. Consider the following diagram showing a popular desk 'toy'.



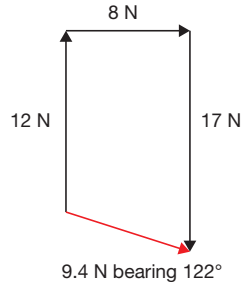
- (a) The diagram indicates that this is an example of an elastic collision. It is actually very close to being an elastic collision, but in fact, is not quite elastic. Justify its not being elastic.
 - (b) There is another observation we make of this 'toy' that shows that its collisions are not elastic. Suggest what this observation is.
16. Find the velocity of the blue car after the collision and determine if the collision is elastic or inelastic.



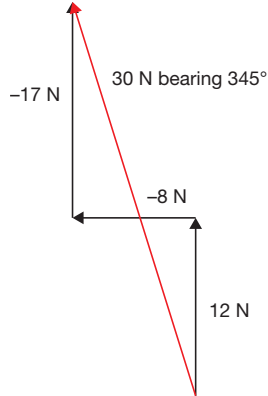
17. Suppose rain falls vertically into an open cart rolling along a straight horizontal track with negligible friction. Would this be considered an elastic or inelastic collision? Justify your answer.

12 Vectors In Two Dimensions 2

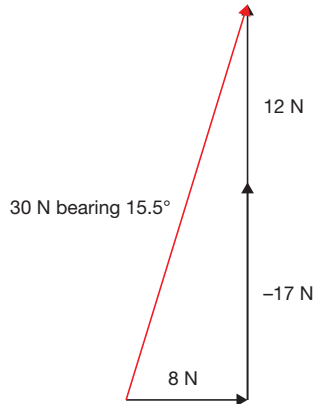
1. (a) 9.43 N bearing 122°



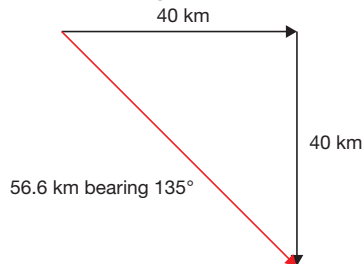
- (b) 30.1 N bearing 344.5°



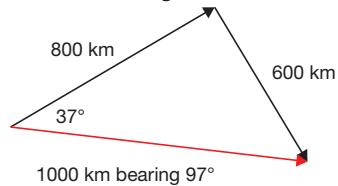
- (c) 30.1 N bearing 15.4°



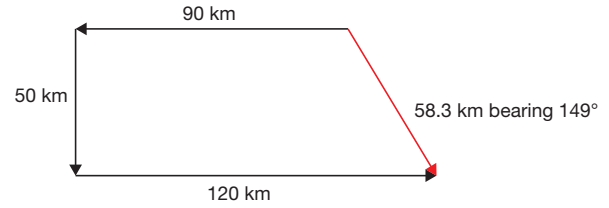
2. 56.6 km bearing 135°



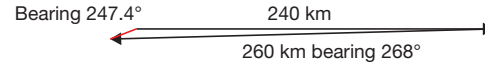
3. 1000 km bearing 097°



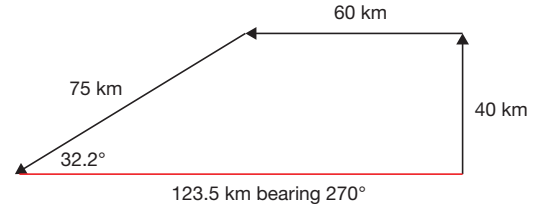
4. 58.3 km bearing 148°



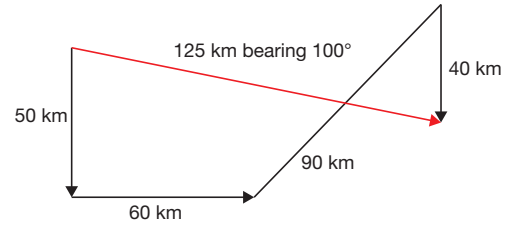
5. 260 km bearing 268°



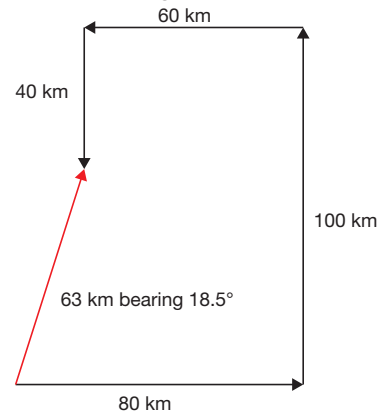
6. 123.5 km bearing 270° (west)



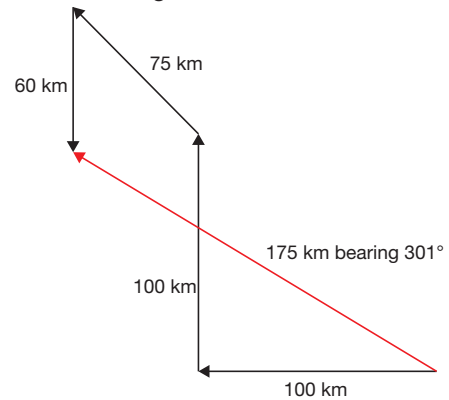
7. 126.4 km bearing 100°

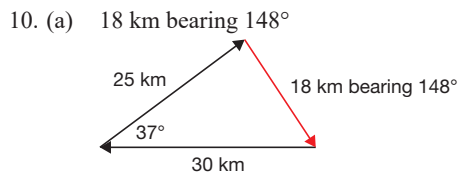


8. 63.2 km bearing 18.5°

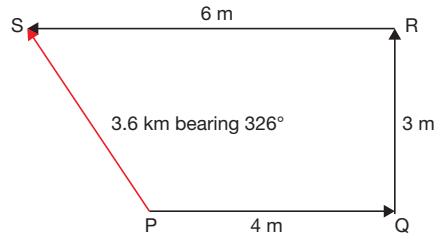


9. 179 km bearing 330°

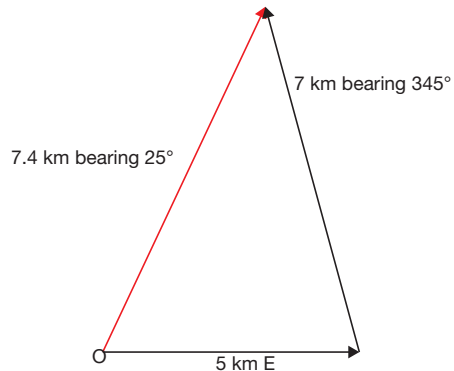




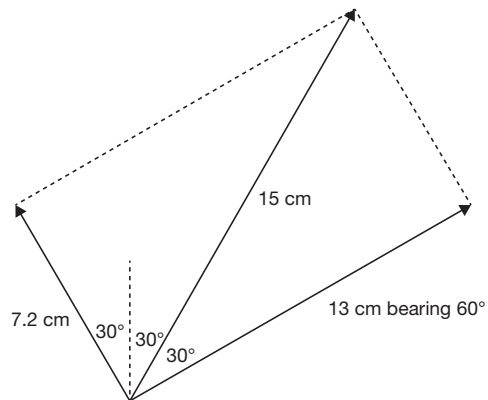
- (b) 40 km bearing 270° (west)
 11. 3.6 m bearing 032°



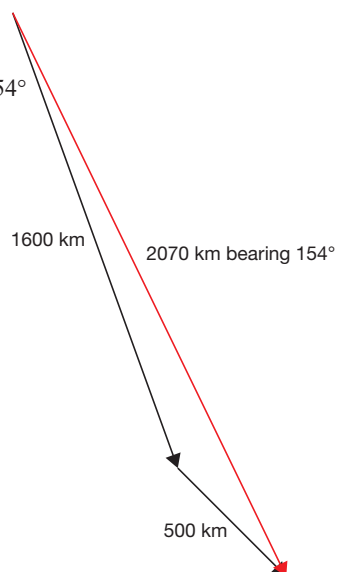
12. 7.47 km bearing 025°



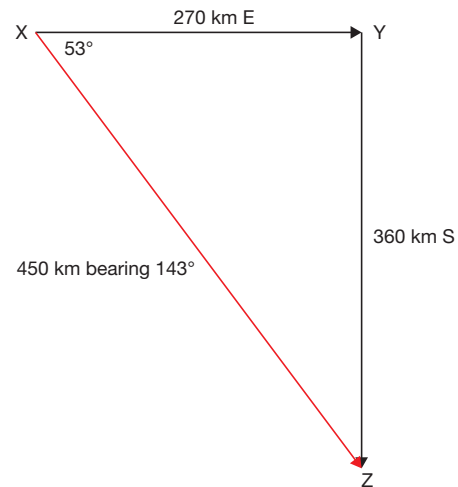
- 13.



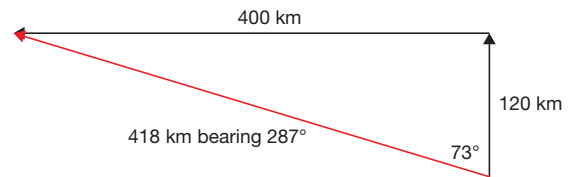
- (a) Bearing 060°
 (b) 13 cm
 14. 2064 km bearing 154°



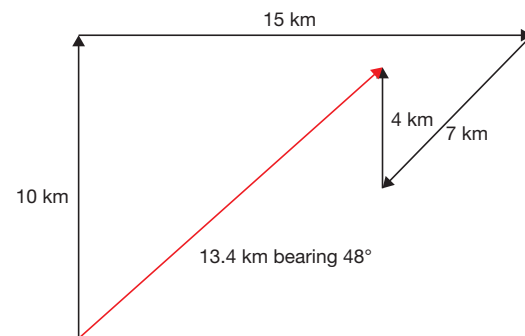
15. (a) 90 km h^{-1}
 (b) 64.3 km h^{-1} bearing 143°
 (c) 5 hours



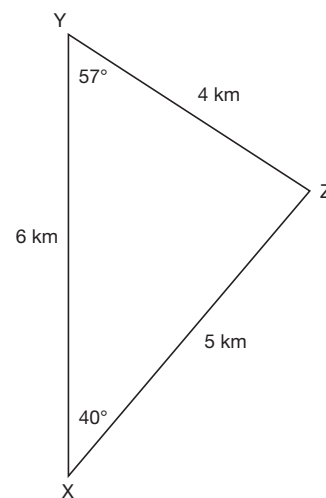
16. (a) 74.3 km h^{-1}
 (b) 59.7 km h^{-1} bearing 287°

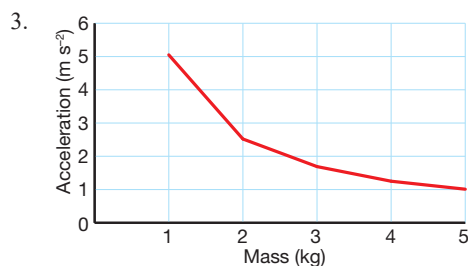


17. 13.5 km bearing 048°

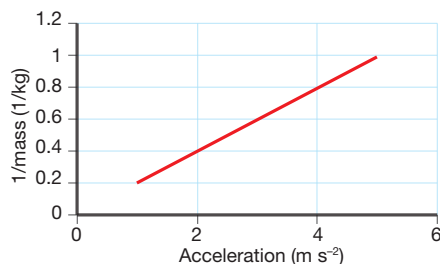


18. (a) Bearing 041° or bearing 319°
 (b) Bearing 229° or bearing 139°





(Note that since this graph is not a straight line, we cannot draw a relationship from it. We need to graph a versus m^{-1} .)



4. If this graph is extrapolated back to the origin, we can say that acceleration is inversely proportional to the mass of the trolley. Combining your conclusions:
 From 1, $a \propto F$
 From 2, $a \propto \frac{1}{m}$
 So, combining these, $a \propto \frac{F}{m}$
 Or, $F \propto ma$
 (We don't know from these experiments that the constant of proportionality is 1, so we should leave the 'proportional to' sign in at this stage.)

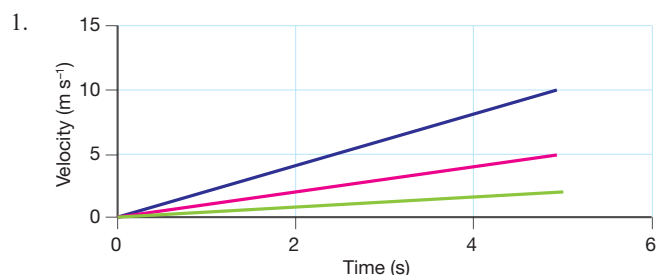
42 Analysing More Motion Experiments

Experiment 1

- $F = m \times 0.16 = 0.16m$ Equation 1
 $F = 0.11(m + 1)$ Equation 2
 $F = 0.09(m + 2)$ Equation 3
 $F = 0.06(m + 4)$ Equation 4
 Solve equations 1 and 2: $0.16m = 0.11(m + 1)$; $0.05m = 0.11$; $m = 2.2$ kg
 Equations 2 and 3: $0.11(m + 1) = 0.09(m + 2)$; $0.02m = 0.07$; $m = 3.5$ kg
 Equations 3 and 4: $0.09(m + 2) = 0.06(m + 4)$; $0.03m = 0.06$; $m = 2.0$ kg
 Average = $\frac{2.2 + 3.5 + 2.0}{3} = 2.56$ kg

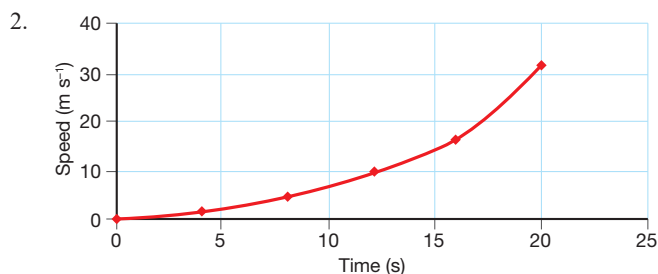
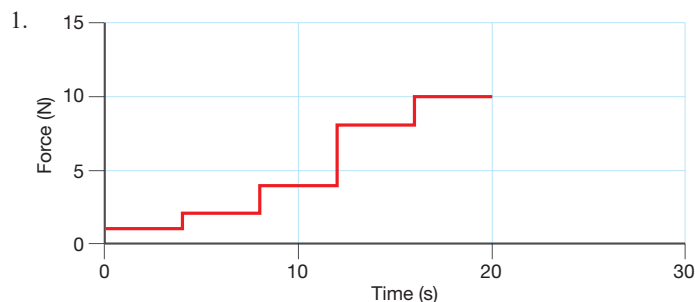
- $F = 0.16m = 0.41$ N

Experiment 2



- 1 kg mass = top line
 2 kg mass = middle line
 5 kg mass = bottom line
- Acceleration.
 - 2 m s^{-2} , 1 m s^{-2} , 0.4 m s^{-2}
 - To determine the relationship between the acceleration produced by a constant force acting on different masses and the masses of the objects.
 - When a constant force acts on objects, the acceleration produced is inversely proportional to the mass of the objects.

Experiment 3



(Note: Straight line 'join the dots' used to compare changes in speed across different surfaces.)

- Analysis involves calculating the average velocity for each section and then multiplying this by the time intervals. Working shown in table.

Time (s)	Δv (m s ⁻¹)	$v_{av} = \frac{u+v}{2}$	$d = v_{av}t$
0 to 4	1	0.5	2
4 to 8	3	2.5	10
8 to 12	6	7	28
12 to 16	6	13	52
16 to 20	16	24	96

- Analysis here requires us to find the velocity change in each time interval, which enables us to calculate the acceleration for each time interval. Net force can be found from $F = ma = 2a$.

Time (s)	F (N)	Δv (m s ⁻¹)	$a = \frac{\Delta v}{\Delta t}$ (m s ⁻²)	Net force
0 to 4	1	1	0.25	0.5
4 to 8	2	3	0.75	1.5
8 to 12	3	6	1.5	3.0
12 to 16	8	6	1.5	3.0
16 to 20	10	16	4.0	8.0

- Friction acting can now be found by subtracting net force on the mass from the force applied. The difference must be the frictional force.

Applied force	1	2	4	8	10
Net force	0.5	1.5	3.0	3.0	8.0
Frictional force	0.5	0.5	1.0	5.0	2.0

Therefore, increasing order of friction of surfaces is:
 $A = B < C < E < D$

43 Newton's Third Law Of Motion

- Action-reaction pairs are:
 - Weight force of weights pushing downwards on hands and force in weight lifter's hands pushing upwards.
 - Force of ball hitting racquet and force of racquet hitting ball.
 - Force of foot on ground pushing backwards and reaction force of ground pushing person forwards.
 - Force of oar pushing water and reaction of water pushing back on the oar.
 - Force of fist hitting bag and reaction of bag putting force on fist.