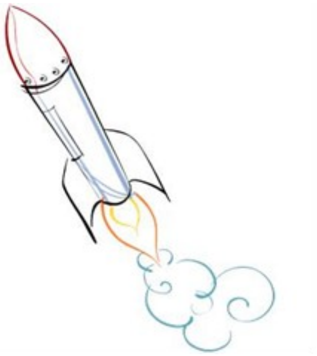
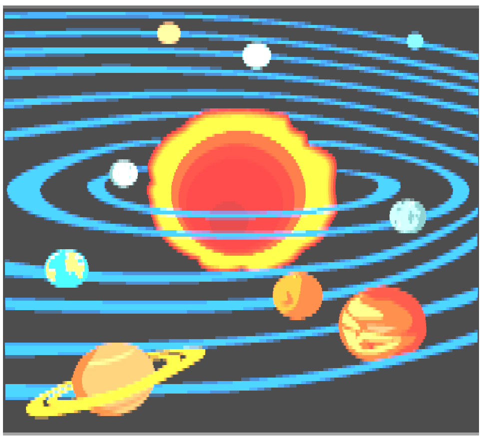
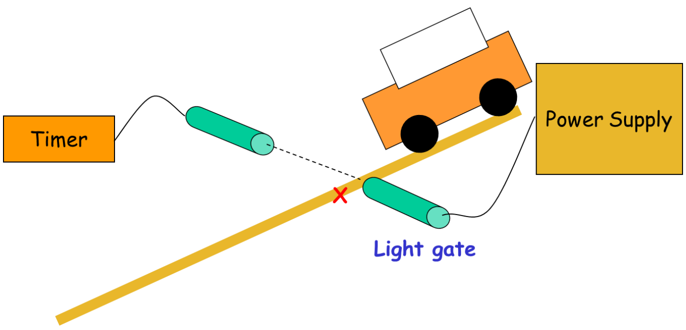


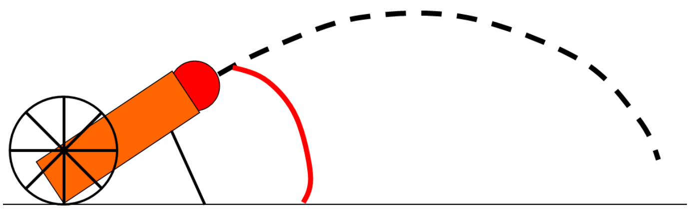
National 5

Dynamics and Space

Self Checks







DATA SHEET

Speed of light in materials

Material	*Speed* in m s^{-1}
Air	$3{\cdot}0 \times 10^{8}$
Carbon dioxide	$3{\cdot}0 \times 10^{8}$
Diamond	$1{\cdot}2 \times 10^{8}$
Glass	$2{\cdot}0 \times 10^{8}$
Glycerol	$2{\cdot}1 \times 10^{8}$
Water	$2{\cdot}3 \times 10^{8}$

Speed of sound in materials

Material	*Speed* in m s^{-1}
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Gravitational field strengths

	Gravitational field strength on the surface in N kg^{-1}
Earth	9·8
Jupiter	23
Mars	3·7
Mercury	3·7
Moon	1·6
Neptune	11
Saturn	9·0
Sun	270
Uranus	8·7
Venus	8·9

Specific heat capacity of materials

Material	*Specific heat capacity* in J kg^{-1} °C^{-1}
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Specific latent heat of fusion of materials

Material	*Specific latent heat of fusion* in J kg^{-1}
Alcohol	$0{\cdot}99 \times 10^{5}$
Aluminium	$3{\cdot}95 \times 10^{5}$
Carbon Dioxide	$1{\cdot}80 \times 10^{5}$
Copper	$2{\cdot}05 \times 10^{5}$
Iron	$2{\cdot}67 \times 10^{5}$
Lead	$0{\cdot}25 \times 10^{5}$
Water	$3{\cdot}34 \times 10^{5}$

Melting and boiling points of materials

Material	*Melting point* in °C	*Boiling point* in °C
Alcohol	−98	65
Aluminium	660	2470
Copper	1077	2567
Glycerol	18	290
Lead	328	1737
Iron	1537	2737

Specific latent heat of vaporisation of materials

Material	*Specific latent heat of vaporisation* in J kg^{-1}
Alcohol	$11{\cdot}2 \times 10^{5}$
Carbon Dioxide	$3{\cdot}77 \times 10^{5}$
Glycerol	$8{\cdot}30 \times 10^{5}$
Turpentine	$2{\cdot}90 \times 10^{5}$
Water	$22{\cdot}6 \times 10^{5}$

Radiation weighting factors

Type of radiation	*Radiation weighting factor*
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3

Speed, Distance and Time

1. Find the missing values in the following table.

	average speed (ms^{-1})	distance (m)	time (s)
(a)		100	20
(b)		20	4
(c)	25		0·5
(d)	16		55
(e)	1 200	60	
(f)	75	15 000	

2. A runner completes a 200 m race in 25 s. What is his average speed?

3. An athlete takes 4 minutes 20 s to complete a 1500 m race. What is the average speed?

4. A car travels a distance of 2 km in a time of 3 minutes. Calculate the average speed of the car in metres per second.

5. A fighter jet can travel at 680 m/s. How far will it travel in 25 s at this speed?

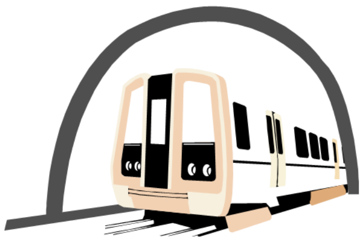
6. A girl can walk at an average speed of 2 m/s. How far will she walk in 20 minutes?

7. How far will a jet aircraft travel in 5 minutes if it flies at 400 metres per second?

8. A train travels 200 km in 1h. How far would it travel in 1 second?

9. How long will it take a cyclist to travel 40 km at an average speed of 5m/s?

10. The Channel Tunnel is approximately 50 km long.



How long will it take a train travelling at 90 m/s to travel from one end of the tunnel to the other?

11. On a fun run, a competitor runs 10 km in 1 hour 3 minutes.

What is her average speed in:

(a) km/h? (b) m/s?

12. A hill walker walks at an average speed of 1·6 ms^{-1}. How long will it take her to cover a distance of 33 km?

13. A lorry takes 4 hours to travel 150 km. Calculate the average speed of the lorry in ms^{-1}.

14. In 1889 the first Daimler car reached a speed of 20 kmh^{-1}. How far would the Daimler car travel in 3 hours 30 minutes if it travelled at a constant speed of 20 kmh^{-1}? (HINT: keep speed in kmh^{-1} and time in h, then distance will be in km.)

15. Richard Noble captured the world land speed record in 1983 in his vehicle Thrust 2. The car travelled one kilometre in 3·5 seconds. Calculate the average speed of the car.

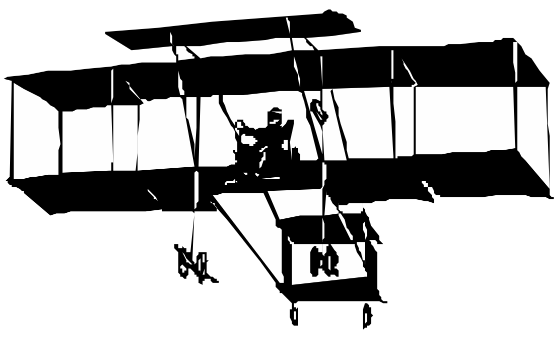
16. The French TGV train is one of the fastest commercial trains ever to operate. Its maximum speed is 270 kmh^{-1}.
   (a) Calculate its maximum speed in ms^{-1}.
   (b) The TGV takes 2 hours to travel the 425 km between Paris and Lyon. Calculate its average speed for this journey in kmh^{-1}.

17. The table below shows part of a timetable for the Glasgow to Aberdeen Inter-City Express.

Station	*Departure time*	*Distance* (km)
Glasgow	1025	0
Perth	1125	100
Dundee	1148	142
Aberdeen	1324	250

   (a) Calculate the average speed of the train in ms^{-1} over the whole journey.
   (b) Between which stations is the train's average speed greatest?

18. The Wright brothers were the first people to fly an aeroplane. Their first flight in 1903 lasted only 12 seconds and covered just 36 metres.



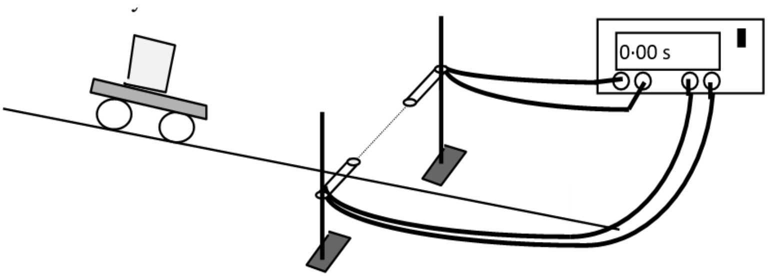
   (a) Calculate the average speed of the plane during that first journey.

   (b) Today Concorde can fly at Mach 2 (twice the speed of sound). How long would it take Concorde to travel 36 metres? (Speed of sound in air = 340 ms^{-1})

Instantaneous Speed

1. The following experiment is used for measuring the instantaneous speed of a trolley as it travels down a runway.

Use the equation



$$\text{instantaneous speed} = \frac{\text{length of card}}{\text{time to cut beam}}$$

to find the missing values in the following table:

	instantaneous speed (ms^{-1})	*card length* (m)	*time* (s)
(a)		0·2	0·10
(b)		0·1	0·10
(c)		0·08	0.04
(d)		0.14	0·2
(e)		0.15	0·3
(f)		0·3	0.4

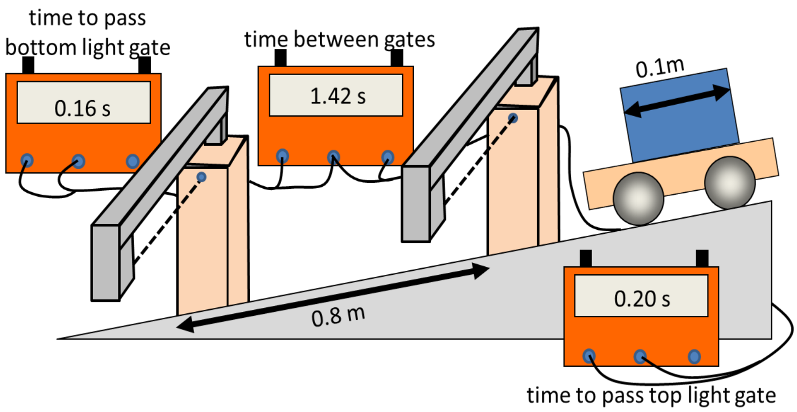
2. A car of length 3·5 m passes a student. The student records a time of 2·4 s between the front and the back of the car passing her.
Calculate the instantaneous speed of the car.

3. A runner decides to analyse his track performance in order to improve his overall running time during the 400 m event. He sets up light gates at six points round the track so that he can work out his instantaneous speed at each point.

Position	*width of runner* (m)	*time* (s)	*instantaneous speed* (ms^{-1})
A	0·2	0·025	
B	0·2	0·026	
C	0·2	0·030	
D	0·2	0·029	
E	0·2	0·025	
F	0·2	0·024	

Use the results to calculate his instantaneous speed at each position and state at which positions the runner is (a) fastest and (b) slowest.

4. The following experiment is set up to investigate the change in speed as a trolley rolls down a ramp.



(a) Calculate the speed of the trolley as it passes through the top light gate.
(b) Calculate the speed of the trolley as it passes through the bottom light gate.
(c) Calculate the average speed of the trolley on the ramp.

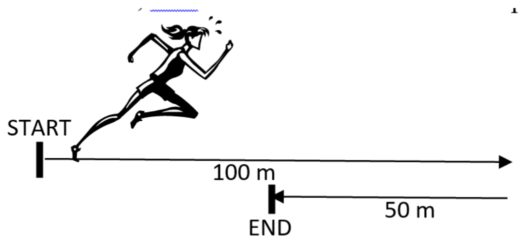
Distance and Displacement

1. A boy walks 50 m, East then runs for 100 m in the same direction.

(a) State the distance travelled by the boy.
(b) State the final displacement of the boy from the start point. (Remember to give a direction!)

2. A girl runs 100 m, East then walks for 50 m in the opposite direction.

(a) State the distance travelled by the girl.
(b) State the final displacement of the girl from the start point. (Remember to give a direction!)



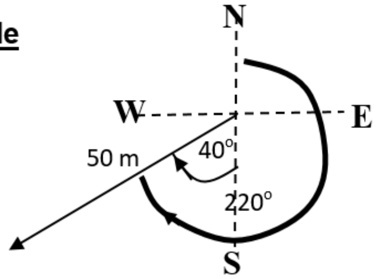
3. A delivery lorry travels 80 km, North then travels South for 100 km.
(a) State the distance travelled by the lorry.
(b) State the final displacement of the lorry for this journey.

4. During a hike, a hillwalker walks 60 m, South then backtracks 20 m, North.
(a) State the distance covered by the hillwalker.
(b) State the displacement of the hillwalker for this stage of the hike.

Vectors and Scalars

Displacement directions can be described using an angle with compass points OR using a three figure bearing; where the angle is clockwise from the North line.

For example



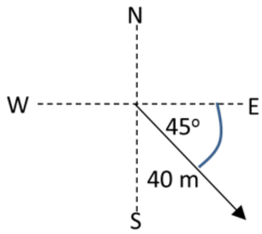
this displacement is "50m @ 40° W of S "

OR

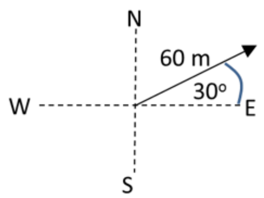
"50m @ 220°"

Describe each of the following displacements using appropriate compass points and with a three figure bearing.

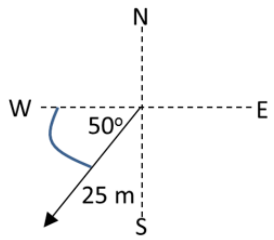
1. (a)



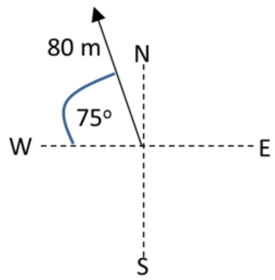
(b)



(c)

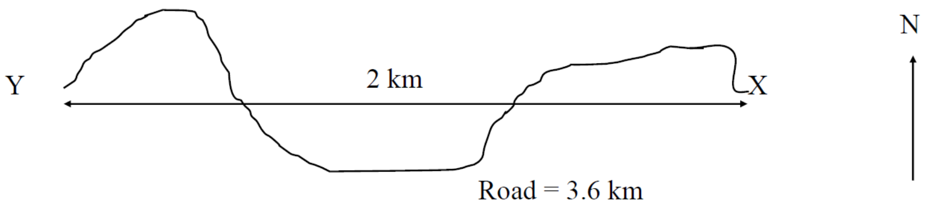


(d)



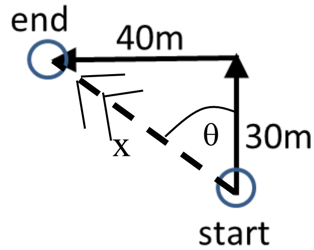
2. What is the difference between a vector quantity and a scalar quantity?

3. A man walks from X to Y along a winding road.



(a) What is his displacement at the end of his walk?
(b) What distance has he walked?
(c) If the man took 40 minutes to complete his walk. Calculate:
  i) his average speed
  ii) his average velocity

4. During an orienteering exercise, a boy walks 30 m, North then 40 m, West.



(a) State the distance travelled during this exercise.
(b) By scale diagram or otherwise, calculate the magnitude of the boy's displacement, x.
(c) From your scale diagram or otherwise, calculate the direction, θ , of this displacement.
(d) Give this angle as a three figure bearing.

5. A man walks 500 m, due North then 1200 m due West.

(a) State the distance travelled by the man.
(b) Use scale drawing, or otherwise, to determine the final displacement of the man from his starting point.

6. A surveyor walks once around the perimeter of a rectangular field, measuring 80 m by150 m, returning to his starting point.
(a) State the distance covered by the surveyor.
(b) What is the displacement of the surveyor when he returns to his starting point.

7. A yacht sails 5 km due West followed by 3 km, North.
(a) State the distance travelled by the yacht.
(b) Calculate the final displacement of the yacht from its starting point.

8. A car travels 8 km, East followed by 8 km, South.
(a) State the distance travelled by the car.
(b) Calculate the final displacement of the car from its starting point.

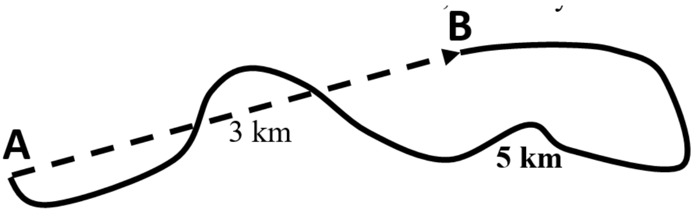
9. A cyclist cycles 5 km, North, then 4 km, West followed by 8 km, South.
(a) State the distance travelled by the cyclist.
(b) Calculate the displacement of the cyclist for this journey.

Speed and Velocity

1. One lap of a running track is 400 m. An athlete completes this lap in 48 s.

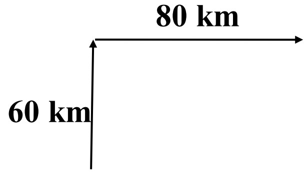
(a) State the distance travelled by the athlete.
(b) State the displacement of the athlete.
(c) Calculate the average speed of the athlete.
(d) Calculate the average velocity of the athlete.

2. A walker travels from A to B along a winding path as shown below. The 5 km walk takes the walker 70 minutes. As the crow flies, B is only 3 km from A, at 085°.

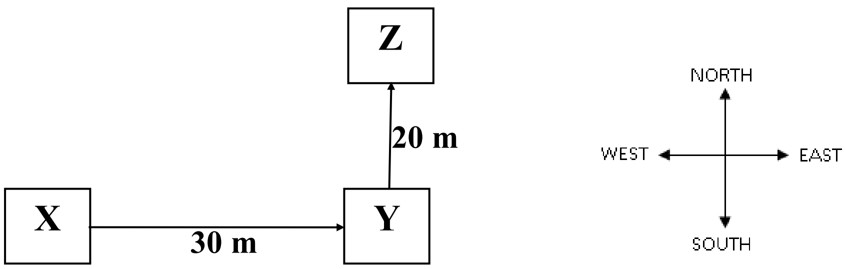


(a) Calculate the average speed of the walker in ms^{-1}.
(b) Calculate the average velocity of the walker in ms^{-1}.

3. A lorry travels 60 km, North, then 80 km, East, as shown here. The journey takes 2 hours.
(a) State the distance travelled by the lorry.
(b) Calculate the overall displacement of the lorry.
(c) Calculate the lorry's average speed in km h^{-1}.
(d) Calculate the lorry's average velocity in km h^{-1}.



4. A boy delivers newspapers to three houses; X, Y and Z, as shown in the diagram below. It takes him 1 minute to reach house Z from house X.



(a) State the distance covered by the boy.
(b) When he reaches house Z, what is the boy's displacement from house X?
(c) Calculate the average speed of the boy between houses X and Y.
(d) Calculate the average velocity of the boy between houses X and Y.

5. A cyclist cycles 500 m, West, followed by 600 m, South, in 110 seconds.
(a) State the distance travelled by the cyclist.
(b) Calculate the overall displacement of the cyclist for the 110 s period.
(c) Calculate the average speed of the cyclist.
(d) Calculate the cyclist's average velocity.

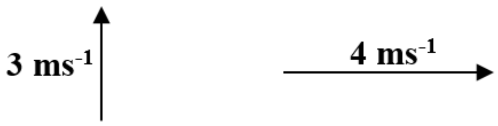
6. During a section of a yacht race, a yacht sails 800 m, East, followed by 400 m, North, with a steady speed of 12 ms^{-1}.
(a) State the distance travelled by the yacht.
(b) Calculate the displacement of the yacht for this section of the race.
(c) Calculate the time taken for the yacht to complete this section of the race.
(d) Calculate the average velocity of the yacht.

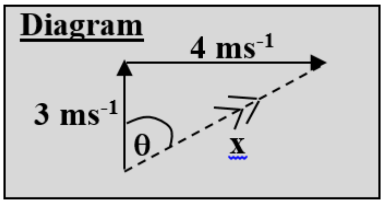
Combining Velocities

1. For each of the following combinations of velocities, draw a diagram to represent the velocities involved and the resultant velocity. **Remember to draw the given velocities NOSE TO TAIL.** The first diagram is drawn for you.

   "**x**" is the magnitude of the resultant velocity.
   "**θ**" is the direction of the resultant velocity, usually given as a three figure bearing.

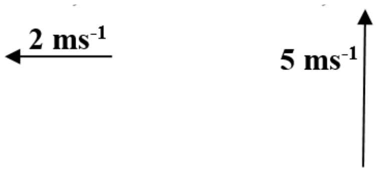
(a) 3 ms^{-1}, North and 4 ms^{-1}, East.



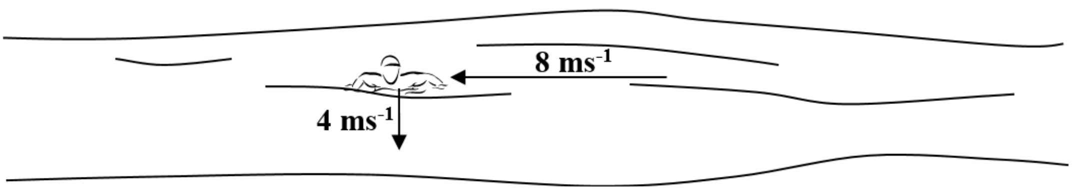


(b) 6 ms^{-1}, South and 4 ms^{-1}, West.

(c) 2 ms^{-1}, West and 5 ms^{-1}, North.



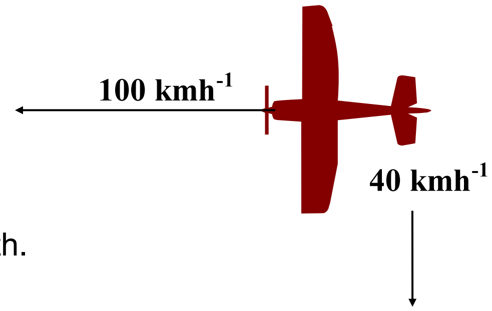
2. A boy aims to swim South across a river with a velocity of 4 ms^{-1}. The river's velocity is 8 ms^{-1}, West.



Calculate the resultant velocity of the boy.

3. A girl aims to swim North across a river with a velocity of 3 ms^{-1}. This river's velocity is 6 ms^{-1}, East.
   Calculate the resultant velocity of the girl.

4. A pilot selects a course of 100 kmh^{-1} due West.
A wind is blowing with a velocity of 40 kmh^{-1}, due South.
Calculate the resultant velocity of the plane.



5. An aircraft pilot sets a course for 800 kmh^{-1}, North.
A wind is blowing at 80 kmh^{-1} from West to East.

(a) Calculate the resultant velocity of the plane. (You should sketch a suitable diagram first.)
(b) Use your answer to part (a) to suggest what course the pilot *should* select so that the plane does fly at 800 kmh^{-1} due North.

6. A model aircraft is flying North at 24 ms^{-1}.
A wind is blowing from West to East at 10 ms^{-1}.
Draw a suitable diagram and use it to calculate the resultant velocity of the model aircraft.

Acceleration

1. A car, starting from rest, reaches a speed of 15 metres per second in a time of 30 seconds. Calculate the acceleration of the car.

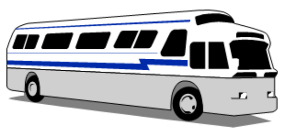
2. A sprinter in a race crossed the finishing line with a speed of 14 ms^{-1}. If her sprint time was 16 seconds, what was her average acceleration?

3. A ball is dropped from the roof of a building. What is the acceleration of the ball if its speed is 30 ms^{-1} after 3 seconds?

4. What is the acceleration of a lorry which increases its speed from 5 $ms^{-1}$to 15 ms^{-1} in 40 seconds?

5. A train increases its speed from 15 ms^{-1} to 25 ms^{-1}in a time of 8 seconds. Calculate the acceleration of the train.

6. A bus, travelling at 16 ms^{-1}, takes 32 seconds to come to rest. Calculate the deceleration of the bus.



7. 

It takes 20 seconds for an ice skater to come to rest after skating with a velocity of 8 ms^{-1}. What is her deceleration?

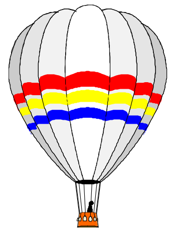
8. A bowling ball is accelerated from rest at 3ms^{-2} for 1.2s. What final speed will it reach?

9. A racing car travelling at 20 ms^{-1} accelerates at a rate of 2 ms^{-2} for 4 seconds.

(a) Calculate its change in velocity.
(b) What is its final velocity, after 4 seconds of acceleration?

10. A remote controlled car accelerated at 0·1 ms^{-2} for half a minute. If it had an initial velocity of 0·2 ms^{-1}, what was its final velocity?

11. A hot air balloon travels upwards with a constant velocity. It then accelerates at 0·08 ms^{-2} for 1 minute. If it reaches a velocity of 5 ms^{-1}, what was its initial velocity just before the acceleration?

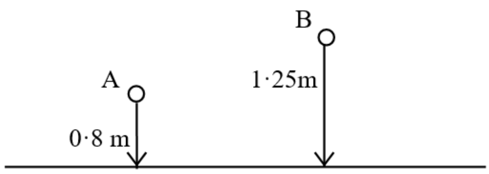


12. How long will it take a car to increase its speed from 8ms^{-1} to 20 ms^{-1} if it accelerates at 3ms^{-2}?

13. A train is accelerating at a rate of 1·2 ms^{-2}. How long will it take for the velocity of the train to increase from 5 ms^{-1} to 16·4 ms^{-1} ?

14. A boy is cycling on a flat road with a velocity of 12 ms^{-1} when he stops pedalling. He decelerates at a rate of 0·4 ms^{-2}. How long does he take to stop?

15. Two identical balls are dropped from rest.
Ball A takes 0·4 s to land. Ball B lands on the floor 0·1 s after ball A.
Both balls accelerate towards the ground at 9.8 ms^{-2}.



What is the maximum velocity reached by each ball?

16. Two identical balls are fired upwards, with a velocity of 6·4 ms^{-1}, from two identical springs.

One ball is on Earth and decelerates at a rate of approximately 10 ms^{-2}, after leaving the spring.
The other ball is on the Moon and decelerates at a rate of 1×6 ms^{-2}.

(a) What is the velocity of each ball at its maximum height?
(b) How long does it take for each ball to reach its maximum height?

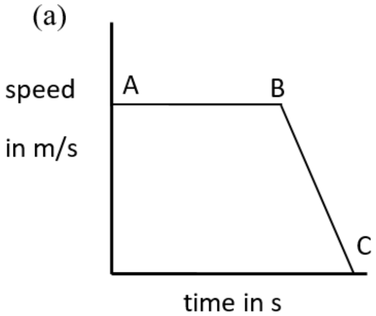
17. A car accelerates at a rate of 0·3 ms^{-2} for 15 seconds and reaches a velocity of 18 ms^{-1}. What was its original velocity?

18. A bus travelling with a constant velocity decelerates at a rate of 0·8 ms^{-2} for 4 s. If its velocity drops to 12 ms^{-1}, what was the initial velocity of the bus?

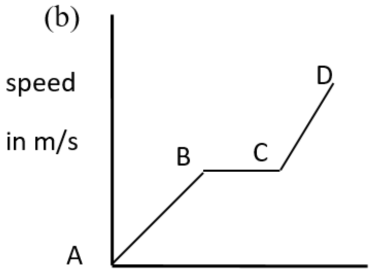
Velocity-time Graphs

1. Describe the motion shown in each of the following speed – time graphs.

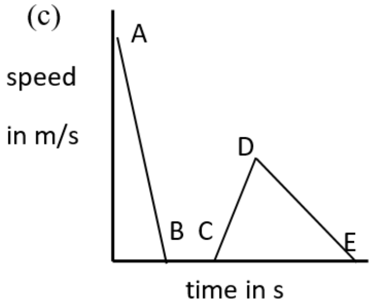
(a)



(b)

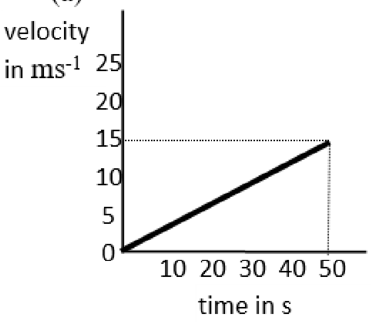


(c)

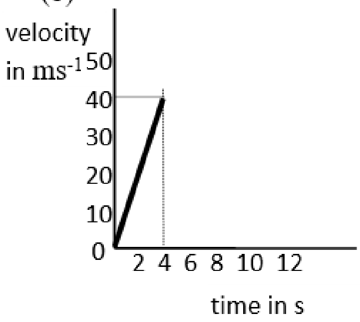


2. Use the graphs below to calculate the **acceleration** over the interval shown.

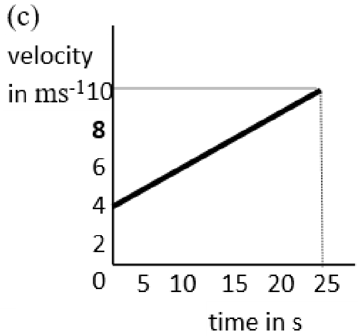
(a)



(b)



(c)



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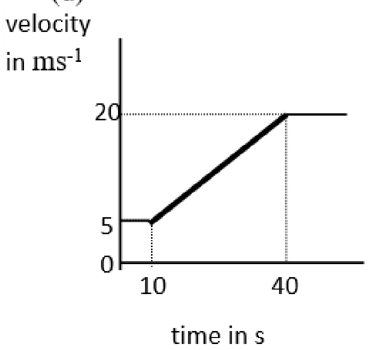

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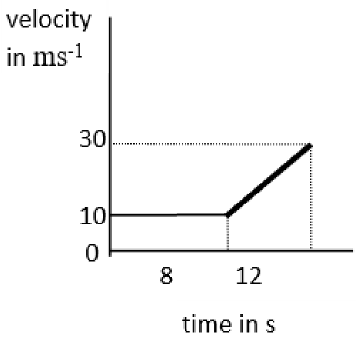

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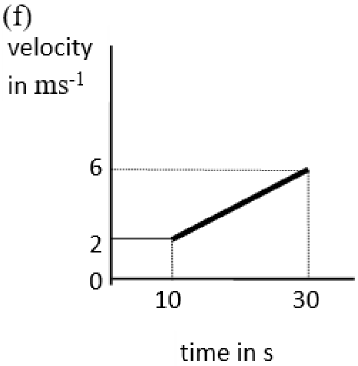
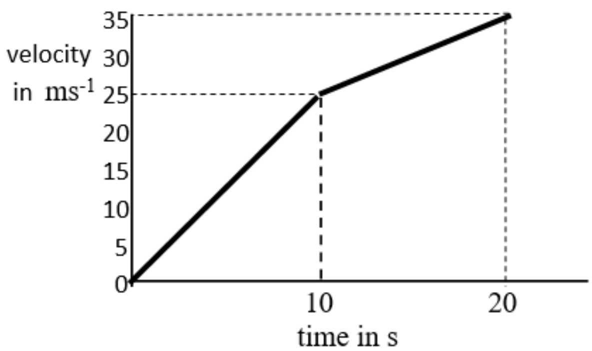


3. This graph shows the journey of a car over a 20s interval.

Calculate the acceleration of the car between:

(a) 0 and 10 seconds

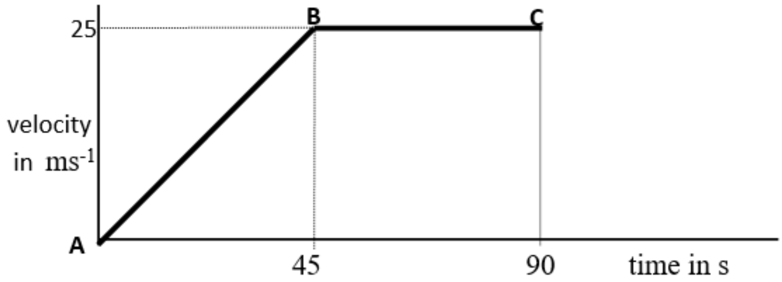
(b) 10 and 20 seconds.



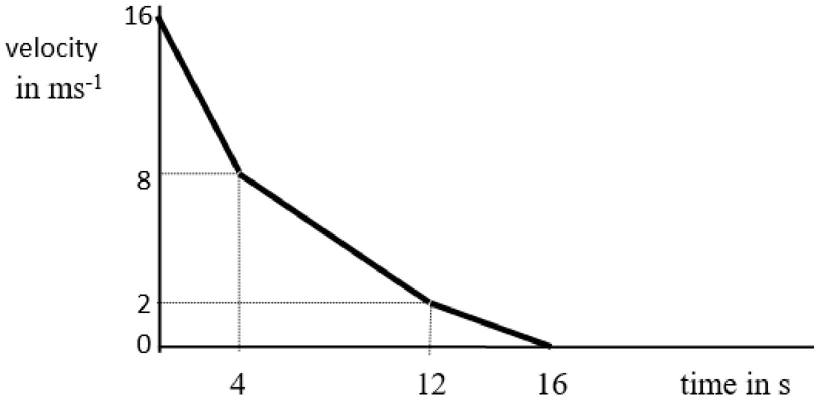
4. Use the velocity - time graph below to calculate the acceleration between:

(*a*) A and B

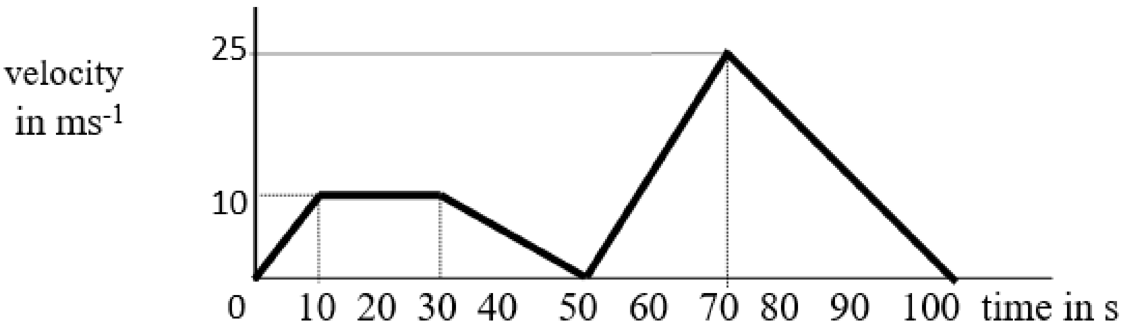
(*b*) B and C.



5. A car changes from 4th to 3rd to 2nd gear as it approaches traffic lights. The velocity - time graph representing the car's motion is shown below. Use the graph to calculate the deceleration of the car in each gear.



6. Lorry drivers use tachographs to record information about their journeys. A section of one journey is represented by the graph below.



(a) During what time interval was the lorry's acceleration greatest?
(b) When was the lorry stationary?
(c) Calculate the deceleration of the lorry before if finally stopped.

7. Draw speed time graphs to represent the following motions:

(a) a motor cycle **accelerating** at 2 ms^{-2} for 8 seconds from rest.

(b) a car **accelerating** at 5 ms^{-2} for 10 seconds from rest.

(c) a train **accelerating** at 2·5 ms^{-2} for 7 seconds from rest.

Using velocity-time graphs to calculate displacement

Helpful Hint

To work out the displacement of an object during an acceleration or deceleration you must use:

displacement = area under velocity - time graph

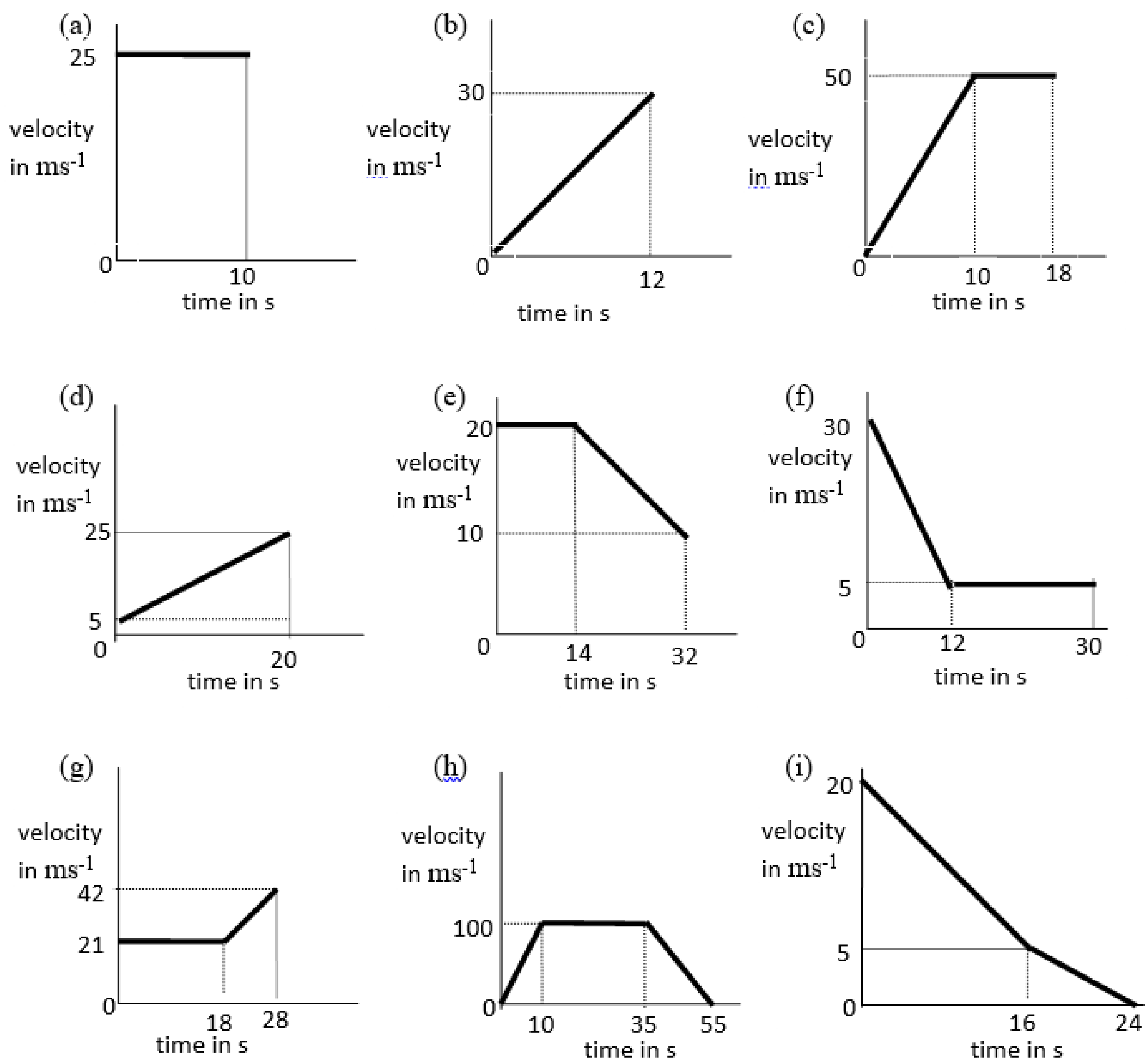
or **distance = area under speed – time graph**

You **cannot** use:

distance = speed x time.

as this is **only** for objects travelling at a constant speed.

8. Use the velocity - time graphs below to calculate the total displacement for each journey.



9. While driving along a motorway a driver spots an accident and brakes. The graph below represents the motion of the car from the instant the driver sees the accident.

(a) When did the driver brake?
(b) Calculate how far the car travelled before braking.
(c) Calculate how far the car travelled after the driver braked.

10. Draw a velocity - time graph to represent the following motion recorded for a train leaving a station.

time (*s*)	0	10	20	30	40	50	60	70	80	90
velocity (ms^{-1})	0	5	10	15	20	25	25	25	30	30

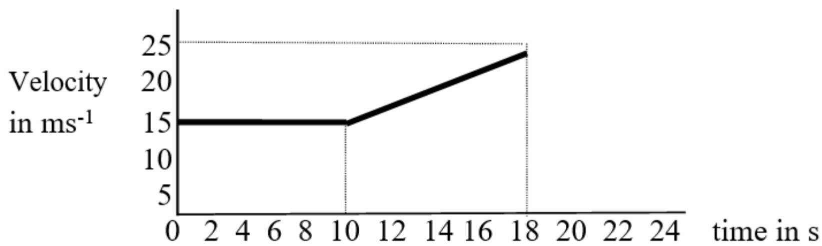
Use the graph to calculate:
(a) the acceleration of the train during the first 50 seconds
(b) the displacement of the train at 90 seconds.

11. Draw a velocity - time graph to represent the following motion recorded as a car approaches traffic lights.

time (*s*)	0	10	20	30	40	50	60	70	80	90
velocity(ms^{-1})	20	20	20	15	15	10	10	5	5	0

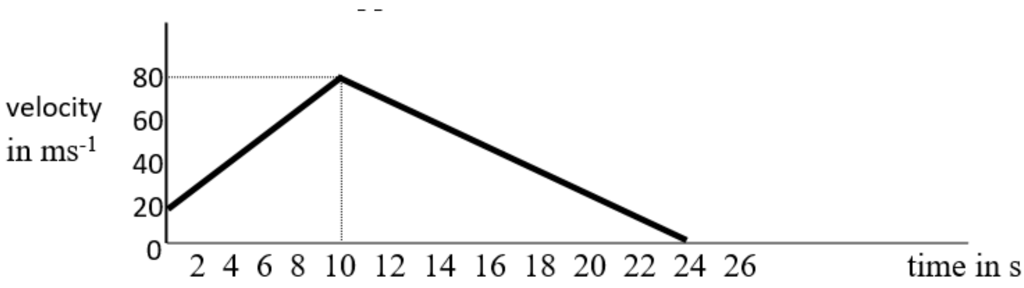
Use the graph to calculate:
(a) the deceleration of the car between 60 seconds and 70 seconds
(b) the displacement of the car from its start point at 90 seconds.

12. A hang glider is cruising over choppy waters at a velocity of 15 m/s when the wind direction suddenly changes and sends him into a deep dive.



(a) State when the dive started
(b) Calculate how far he travelled during the dive.

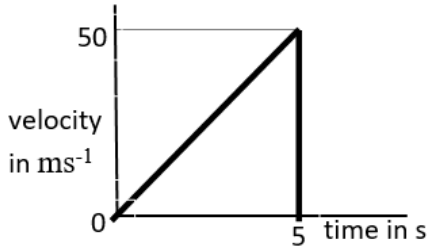
13. The motion of a rocket as it approaches the Moon is shown below.



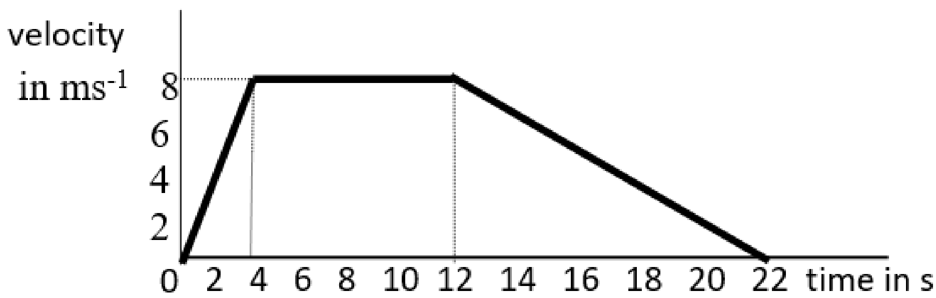
(a) Calculate the distance the rocket travelled during the time it was accelerating.
(b) Does the rocket actually reach the Moon's surface if it is 580 metres above it when its deceleration begins?
You must justify your answer.

14. Use the velocity - time graph of a falling ball shown below to find :

(a) when the ball strikes the ground
(b) the height from which the ball was dropped.



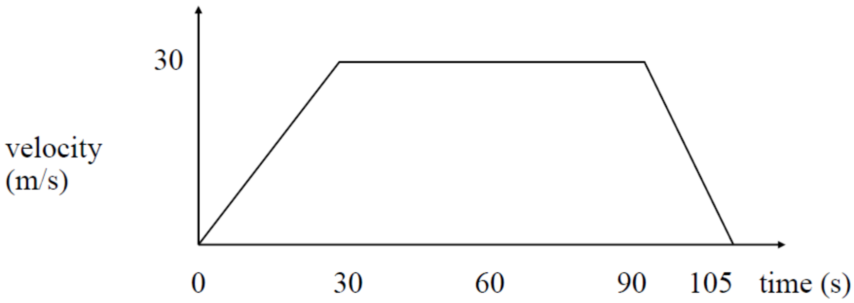
15. Part of a bus journey is represented by the speed time graph below.



Use the graph to calculate :

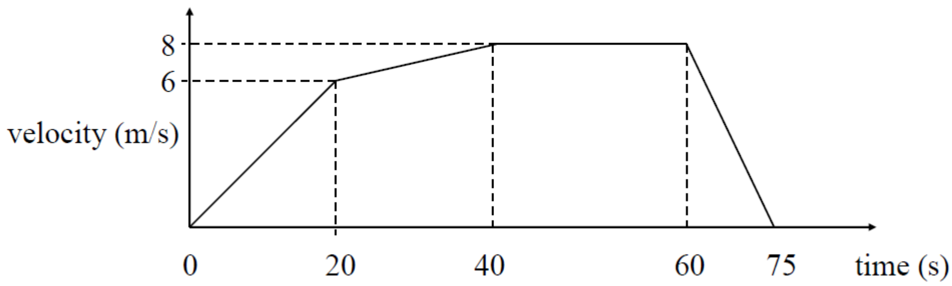
(a) the initial acceleration of the bus
(b) the total distance travelled by the bus
(c) the average speed of the bus.

16. Use the graph below to answer the following questions.



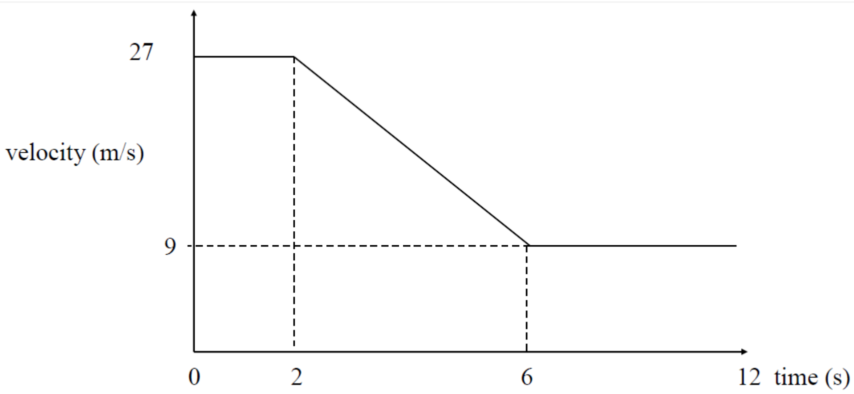
(a) During which time is the vehicle at a constant acceleration?
(b) Calculate the values of:
    (i) The initial acceleration.
    (ii) The final acceleration.
(c) What is the breaking distance of the car?
(d) What is the total distance travelled?
(e) What is the average velocity of the car?

17. The graph below describes the motion of a cyclist.



(a) What is the value of the maximum positive acceleration?
(b) Show by calculation whether the cyclist travels further whilst accelerating, or whilst cycling at the maximum velocity.

18. The velocity-time for a high speed train is shown below.



Due to engineering works on an upcoming bridge 200 m away, the train has to slow down to 9 m/s. The driver applies the brakes 2 s after seeing the warning sign. the driver applies the brakes.
Is the train travelling at the correct speed when it reaches the bridge.
Justify your answer with a calculation.

Weight, Mass and Gravity

1. Find the missing values in the following table.

	Weight (N)	*Mass* (kg)	*Gravitational field strength* (N/kg)
(a)		300	10·0
(b)		0·6	3·7
(c)		0·2	11·7
(d)	230		10·0
(e)	1 680		11·7
(f)	69	6·0	

2. Calculate the weight of each of the following on Earth where the gravitational field strength is approximately 9.8 N/kg :

   (a) a girl whose mass is 50 kg
   (b) a dog of mass 20 kg
   (c) a 9 kg box
   (d) a ball of mass 0·5 kg

3. Each of the following weights was measured on Earth where the gravitational field strength is approximately 10 N/kg. Calculate the mass of each object.

   (a) a man who weighs 750 N
   (b) a tin of peas which weighs 4·5 N
   (c) a chair which weighs 350 N
   (d) a rabbit which weighs 40 N

Helpful Hint

Gravitational field strengths for various planets and the Sun and Moon can be found on the data sheet on page 1.

4. What does a 0.5 kg packet of cornflakes weigh:

   (a) on Earth
   (b) on the Moon
   (c) in Space?

5. An astronaut has a weight of 800 N on Earth.
   What is his mass:
   (a) on Earth
   (b) on the Moon
   (c) in Space?

6. A question in a Physics examination asked, 'What is meant by the weight of an object?'
   Two pupils, Steven and Nicola, answered as follows :

   Steven - 'The weight of an object is the gravitational field strength.'
   Nicola - ' The weight of an object is the force acting on the object due to gravity.'

   (a) Who was correct?
   (b) What does the term 'gravitational field strength' mean?

7. A lift has a weight of 9 000 N on Earth.
   (a) What force, caused by gravity, acts on the lift?
   (b) What is the mass of the lift?

8. A rocket of mass 2 x 10^6 kg travels from Saturn to Earth.
   (a) What is the weight of the rocket on Saturn?
   (b) What is the weight of the rocket on Earth?

9. An astronaut who weighs 784 N on Earth goes to a planet where he weighs 304 N.

   (a) Calculate the mass of the astronaut.
   (b) Show by calculation which planet the astronaut is on.

7. What would an astronaut weigh on Earth, if his weight on Venus was 528 N?

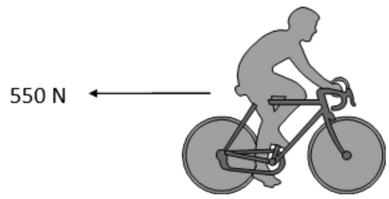
Newton's First Law

1. A fully loaded oil super-tanker moves at a constant speed of 12 ms^{-1}. It's engines produce a constant forward force of 16 000 N. What is the size of the friction force acting on the tanker?

2. A clock hangs from a peg on a wall. If the weight of the clock is 2 N what is the size of the upward force provided by the peg?

3. David cycles along the road at a constant speed of 8 ms^{-1}. The total friction force acting on David and the bike is 550 N.

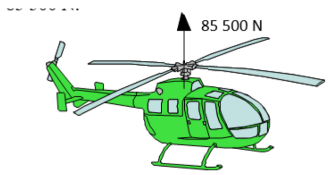
   What size is the forward force provided by David pedalling?



4. A crane holds a concrete slab of mass 750 kg at a steady height while workmen prepare to position it on the building they are constructing.

(a) What is the weight of the concrete slab?
(b) What is the tension in the crane cable?

5. A helicopter is hovering at a constant height of 35 m. The upward lift force on the helicopter is 85 500 N.

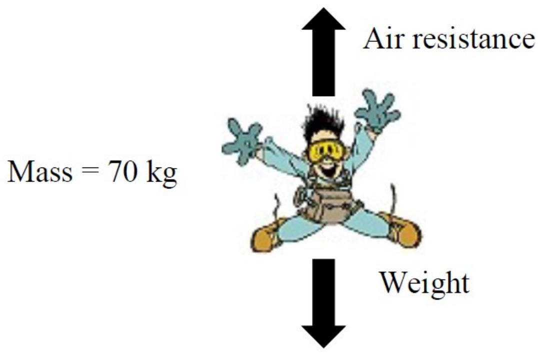


(a) What is the weight of the helicopter?
(b) What is the mass of the helicopter?

6. A lift travels upwards at a constant speed of 4 ms^{-1}. The mass of the lift is 800 kg and it is carrying a load which has a mass of 153 kg.

(a) What is the total mass of the lift and its load?
(b) What is the total weight of the lift and its load?
(c) What is the tension in the lift cable as the lift travels upwards?
(d) What is the tension in the lift cable when it stops at the second floor?
(e) The maximum tension the lift cable can provide is 16 400 N.
What is the greatest mass that the cable can hold?

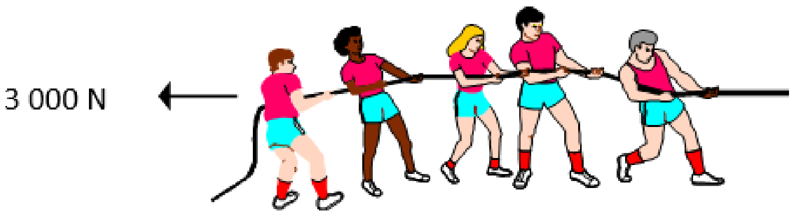
7. The diagram below shows the forces acting on a sky diver.
The sky diver is falling at a constant velocity.



(a) State the name given to this velocity.
(b) Calculate the weight of the sky diver.
(c) State the size of the air resistance force?

8. Explain, using Newton's First Law, why passengers without seat belts in a moving car are thrown forwards in the car, when the car stops suddenly.

9. In a tug of war the blue team pull the red team with a force of 3 000 N to the left. The two teams remain stationary.



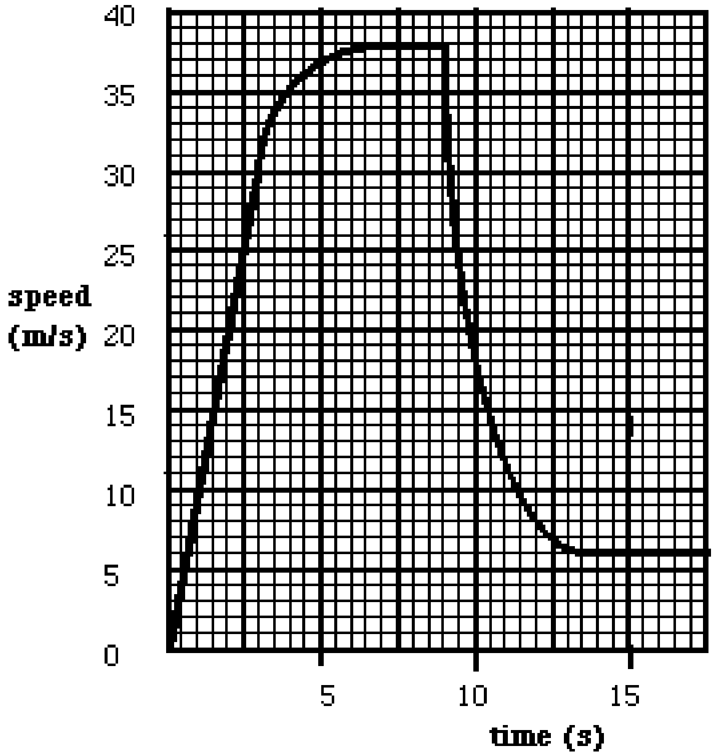
(a) What is the size and direction of the force exerted by the red team on the blue team?

(b) Each member of the red team can pull with an average force of 250 N. Calculate how many people there are in the red team.

(c) One of the members of the red team sprains her ankle and has to leave the competition. What would be the force exerted by the red team now?

(d) What would happen now?

10. David is doing a parachute jump to raise money for charity. The graph below shows his speed at different points in his journey. Use this graph to answer the questions below.



(a) During what time was David travelling at a constant speed?

(b) At what time did David open his parachute?

(c) Describe the forces acting on David 15 seconds after he jumped out of the plane.

(d) 16 seconds after jumping out of the plane the friction force acting on David was 745 N. Calculate David's mass.

(e) What would be the size of the friction force acting on David 8 seconds after leaving the plane?

Newton's Second Law

1. What force is needed to accelerate a 5 kg mass at $3 ms^{-2}$?

2. What force will accelerate a 250 g mass at $2 ms^{-2}$?

3. What force would be needed to accelerate a 10 000 kg lorry at $1.5 ms^{-2}$?

4. What mass would accelerate at $2 ms^{-2}$ when acted upon by a 12 N force?

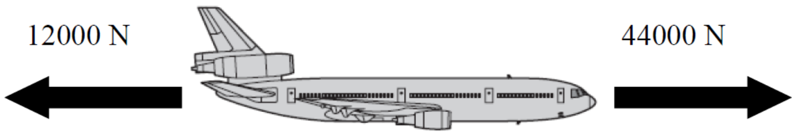
5. Find the mass of a boy and his bike if they accelerate at $1·5 m/s^2$ when pushed with a force of 65 N.

6. A car on an automatic wash and valet machine is pulled by a force of 500 N and accelerates at $0·25 m/s^2$. What is the mass of the car?

7. Calculate the acceleration of a steel ball bearing of mass 100 g when fired with a force of 1·5 N in a pin ball machine.

8. A ship of mass 1×10^7 kg is accelerated by a force of $3·2 \times 10^6$ N. Calculate the size of the acceleration.

9. An aircraft is flying at a constant height. The mass of the aircraft and its passengers is 50 000 kg.



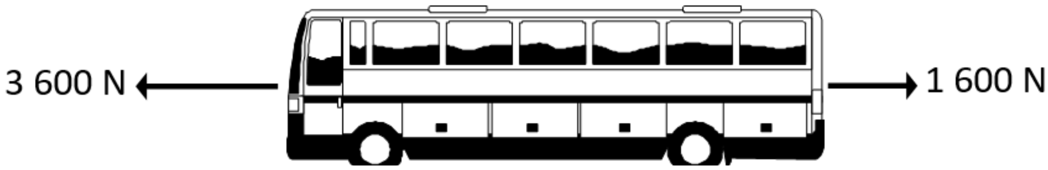
(a) Find the unbalanced force acting on the aircraft.
(b) Find the acceleration of the aircraft.

10. A car, which has an engine that provides a forward force of 6000 N, has a total force of 1200 N resisting its motion
What is the acceleration of the car if the mass is 1600 kg?

11. The forces acting on a sprinter are shown below:

(a) Find the resultant force acting on the athlete.
(b) Find the mass of the athlete if she is accelerating at $1.5 ms^{-2}$.

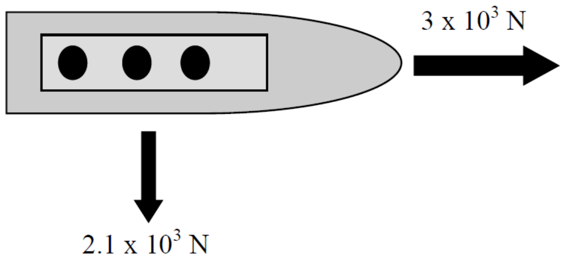
12. The forces acting on a bus are shown below



If the total mass of the bus and passengers is 4 500 kg, calculate:

(a) the unbalanced force acting on the bus
(b) the acceleration of the bus.

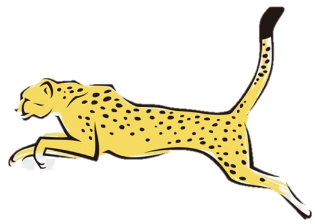
13. A tug boat is sailing along a river with an engine force of 3x103 N. It experiences a tidal force of 2.1x103 N as shown in the diagram below.



(a) Find the resultant force acting on the boat.
(b) Find the acceleration of the boat if it has a mass of 15 000 kg.

14. A cheetah can accelerate at 2.96 ms^{-2}. They have an average mass of 70 kg.

(a) Find the unbalanced force acting on the cheetah.
(b) If the cheetah is providing a forward force of 1000N, find the force of friction acting on the cheetah.



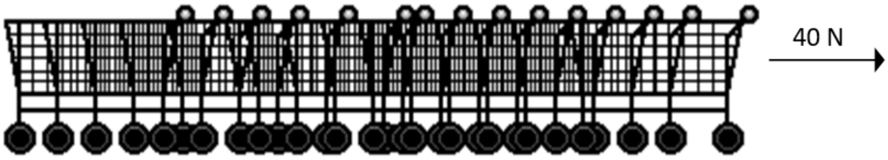
15. An 800 kg car is accelerated from 0 to 18 ms^{-1} in 12 seconds.

(a) What is the resultant force acting on the car?
(b) At the end of the 12 s period the brakes are operated and the car comes to rest in a time of 5 s. What is the average braking force acting on the car?

16. A car of mass 1 200 kg is accelerating along a dual carriageway at a constant rate of 3 ms^{-2}.

(a) Calculate the unbalanced force acting on the car.
(b) The engine force is 3 800 N. Calculate the force of friction between the tyres and the road surface.

17. A supermarket assistant is collecting trolleys from the car park to return to the store. He applies a force of 40 N to a set of 15 trolleys as shown below:

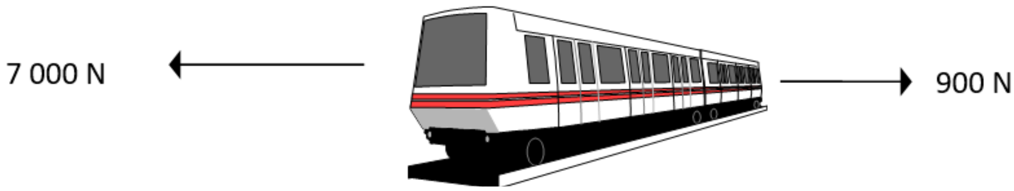


mass of each trolley = 25 kg

(a) Calculate the acceleration of the trolleys.

(b) If the belt breaks and 5 trolleys become separated calculate the new acceleration of the remaining trolleys. Assume that the assistant continues to apply a force of 40 N.

18. Forces acting on a train of mass 50 000 kg are as shown below.



Calculate:

(a) the unbalanced force acting on the train

(b) the acceleration of the train.

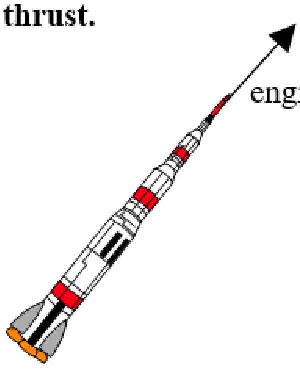
19. A car accelerates at 0·6 ms^{-2} when it's engine force is 1000 N and frictional forces against it are 450 N. Find the mass of the car.

20. A motor cycle is accelerated from rest to 60 ms^{-1} in 16 seconds. If the engine force required to achieve this is 1 200 N, and effects due to friction are ignored, calculate the mass of the motor cycle.

Newton's Second Law – The Space Rocket

Helpful Hint

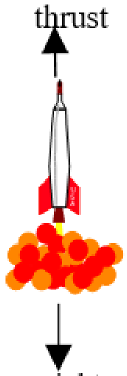
When a spacecraft is **in space** we can ignore gravitational effects so the only force acting on it is its **engine thrust.**



Helpful Hint

To find the **acceleration, a,** of an object during a vertical take-off you will need to calculate the unbalanced force acting on the object first.

Example



1st. Unbalanced force = thrust - weight

2nd. $$\mathbf{a} = \frac{\mathbf{F_u}}{\mathbf{m}}$$

(where F_u = unbalanced force)

1. The engine of a space shuttle can produce a thrust of 600 000 N. The mass of the shuttle is 8×10^5 kg. Calculate the acceleration of the shuttle in space.

2. What engine thrust must be produced by a rocket of mass 3×10^6 kg in order to produce an acceleration of 1·4 ms^{-2} in space?

3. At launch, a space shuttle rocket of mass 75 000 kg produces an engine thrust of 800 000 N.

(a) Use Newton's 3rd Law of motion to explain how the rocket gets off the ground.

(b) Draw a free body diagram to show all the vertical forces acting on the rocket as it accelerates upwards.

(c) Calculate the rate of acceleration of the rocket.

4. At launch, a rocket of mass 18 000 kg accelerates away from the surface of the Earth at 9 ms^{-2}. Calculate the engine thrust of the rocket which causes this acceleration.

5. At launch, a space shuttle rocket of mass 50 000 kg produces an engine thrust of 620 000 N.

(a) Draw a free body diagram to show all the vertical forces acting on the rocket as it accelerates upwards.

(b) Calculate the rate of acceleration of the rocket.

6. Copy and complete the following paragraph, using the word list below.

Word list: **speed** **mass** **acceleration** **weight**

Due to the large amount of fuel in the rocket's tanks at lift-off its ________ is large. The rocket engine provides the thrust to overcome the _________ . As the rocket rises, its mass decreases and the ___________ increases. Far out in space the engine is switched off and the rocket continues on its way at constant __________.

7. Use the stages outlined in the example above to find the missing values in the following table. Assume that each mass is in the Earth's gravitational field.

	Mass **(kg)**	***Weight*** **(N)**	***Thrust*** **(N)**	***Unbalanced force*** **(N)**	***Acceleration*** **(ms^{-2})**
(a)	3	29.4	60		
(b)	200	1 960	21 000		
(c)	1 500		20 000		
(d)	50 000		550 000		
(e)	70 000		840 000		
(f)	76 000		896 800		

8. During space flight, a rocket of mass 25 000 kg, reaches a speed of 12 000 m/s.

(a) Suggest 3 reasons why the acceleration of the rocket will increase.

(b) When the rocket is in space the force of gravity is negligible. Use all of Newton's Laws of Motion to explain how the rocket moves in space.

9. A space shuttle rocket engine produces a thrust of 100 000 N when fired to reposition the shuttle during space flight. If the total mass of the shuttle is 7500 kg, what will be its acceleration?

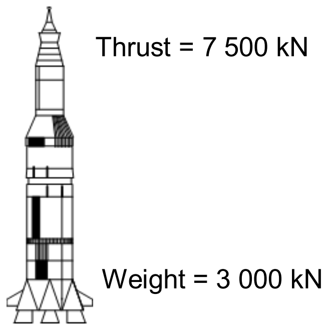
10. The forces acting on a rocket at launch are as shown below.

Use the information to calculate:

(a) the mass of the rocket

(b) the unbalanced force acting on the rocket

(c) the acceleration of the rocket at lift off.



11. A space shuttle has a weight of $1{\cdot}8 \times 10^{7}$ N on Earth. Its engines produce a thrust of $2{\cdot}7 \times 10^{6}$ N during part of its journey through space.
(You will need to refer to the data sheet for parts of this question.)

(a) Calculate the mass of the shuttle.

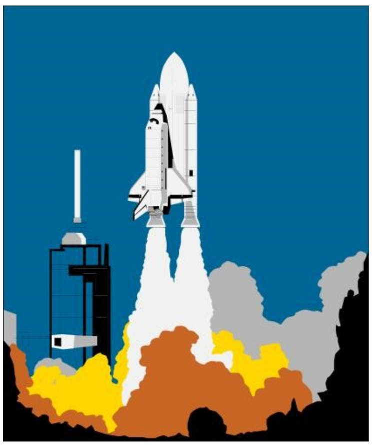
(b) What is the acceleration of the shuttle in space while its engine thrust is $2{\cdot}7 \times 10^{6}$ N?

(c) Could the shuttle have been launched from Earth with this engine thrust of $2{\cdot}7 \times 10^{6}$ N? Explain your answer.

(d) The engine thrust was $2{\cdot}7 \times 10^{7}$ N during the launch from Earth. What was the acceleration of the shuttle during its launch?

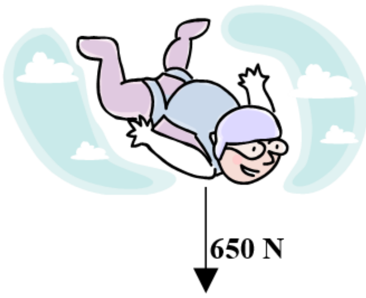
(e) If a similar shuttle was launched from Venus with an engine thrust of $2{\cdot}7 \times 10^{7}$ N, what would be the acceleration of this shuttle during lift off?

(f) What engine thrust would be required in order to launch this shuttle from Jupiter with an acceleration of 5 ms^{-2}?



Freefall and Terminal Velocity

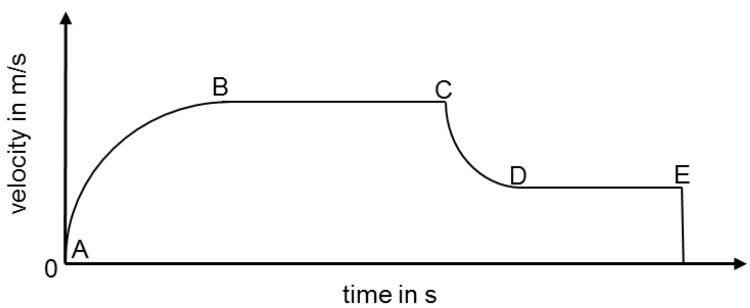
1. A skydiver, who has a weight of 650 Newtons, jumps from a plane.



(a) At the moment she jumps, state the size and direction of the unbalanced force acting on her?
(b) At the moment she jumps, how much air resistance acts on her?
(c) What happens to her speed, initially, as she falls?
(d) How does this affect the air resistance acting on her?
(e) Eventually she reaches "terminal" velocity. What can you say about the forces acting on her at this point?
(f) When she opens her parachute, which force is affected?
(g) Why does she slow down when she opens her parachute?
(h) Explain why she eventually reaches a new, lower, terminal velocity.

2. A parachutist jumps out of an aircraft. Sometime later, the parachute is opened.

The graph shows the motion of the parachutist from leaving the aircraft until landing.



(a) Which parts of the graph show when the forces acting on the parachutist are balanced?

(b) Which point on the graph shows the parachute being opened?

3. A car is travelling along a straight road with a constant velocity of 10 ms^{-1}.

(a) Identify the two main horizontal forces acting on the car.

(b) Describe how these forces compare with each other.

(c) The driver presses the accelerator pedal and the car speeds up. Describe the effect this has on each horizontal force.

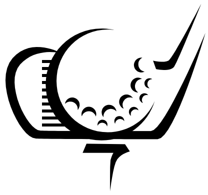
(d) Explain why the car will reach a new “terminal velocity”, with the accelerator in its new position.

Newton’s Third Law

1. State Newton’s third law.

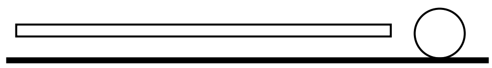
2. For each of the following “action” forces, state the “reaction” force.

(a)



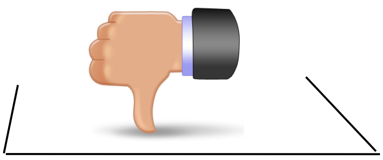
Action: Golf club exerts forward force on ball.

(b)



Action: Cue exerts force on ball.

(c)

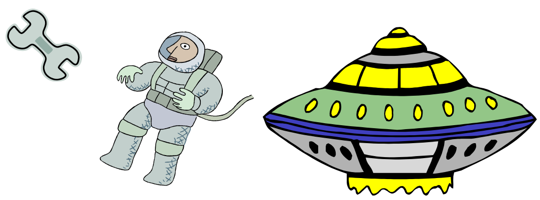


Action: Thumb exerts downwards force on table.

3. Explain why a sniper experiences a force on his shoulder, from his rifle, whenever he fires a shot.

4. An astronaut is carrying out some work on a craft, in space, when the rope attaching him to the spacecraft breaks. The astronaut throws his spanner in a direction away from the space craft.

Use Newton’s third law to explain why this strange move by the astronaut helps him to return to his space craft.



Projectile Motion

Helpful Hint
In this section you should remember that the motion of a projectile should be dealt with in separate calculations for its horizontal and vertical paths.

Horizontally Velocity is constant. ($a = 0\ ms^{-2}$)

$$\bar{v} = \frac{d}{t}$$

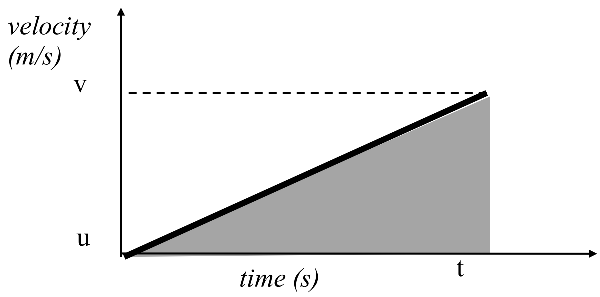
where **v** = average horizontal velocity in metres per second (ms^{-1})
d = horizontal distance travelled in metres (m)
t = time taken in seconds (s).

Vertically Acceleration is downwards due to gravity. ($a = 9.8\ ms^{-2}$ on Earth)

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

where **u** = initial vertical velocity in metres per second (ms^{-1})
v = final vertical velocity in metres per second (ms^{-1})
a = acceleration due to gravity in metres per second per second (ms^{-2})
t = time taken in seconds (s).

To calculate the vertical displacement (height) during any projectile journey you must draw a velocity - time graph for the journey and use:



Height = area under velocity - time graph
= ½ x base x height

= ½ x t x (v-u)

1. A stone is kicked horizontally at 20 ms^{-1} from a cliff top and lands in the water below 2
seconds later.

Calculate :

(a) the **horizontal** distance travelled by the stone
(b) the final **vertical** velocity
(c) the vertical height through which the stone drops.

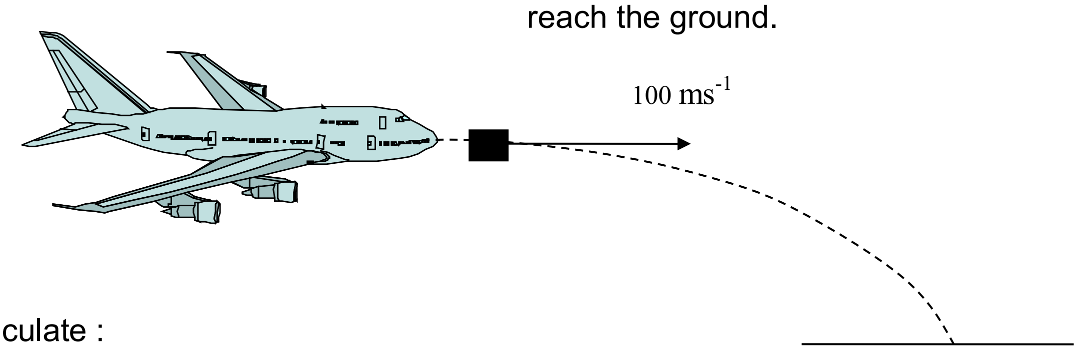
2. A stone thrown horizontally from a cliff lands 24 m out from the cliff after 3 s.

(a) Explain the shape of the path followed by the stone.
(b) Calculate the horizontal speed of the stone.
(c) Calculate the vertical speed at impact.

3. A ball is thrown horizontally from a high window at 6 m/s and reaches the ground after 2 s. Calculate:

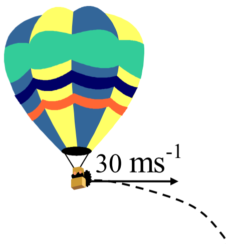
(a) The horizontal distance travelled.
(b) The vertical speed at impact

4. A parcel is dropped from a plane and follows a projectile path as shown below. The horizontal velocity of the plane is 100 ms^{-1} and the parcel takes 12 seconds to reach the ground.



Calculate :
(a) the **horizontal** distance travelled by the parcel
(b) the final **vertical** velocity of the parcel as it hits the ground
(c) the height from which the parcel was dropped.

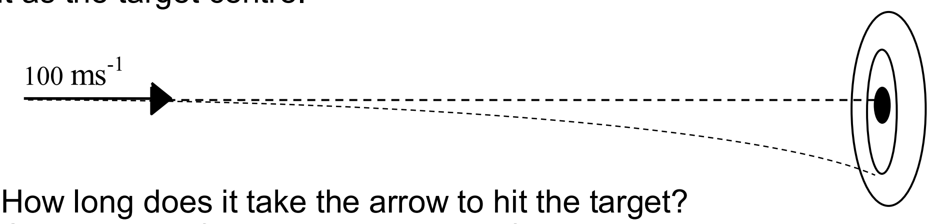
5. Sand bags are released from a hot air balloon while it is moving horizontally at 30 ms^{-1}. The sand bags land on the ground 10 seconds after they are released.



Calculate:

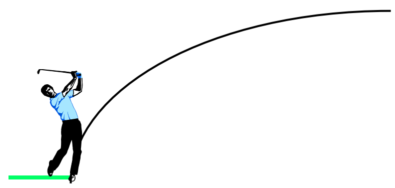
(a) the **horizontal** distance travelled by the sand bags
(b) their final **vertical** velocity.

6. An archer fires an arrow and aims to hit the centre of a target board 50 metres away. The arrow is launched with a horizontal velocity of 100 ms^{-1}, at the same height as the target centre.



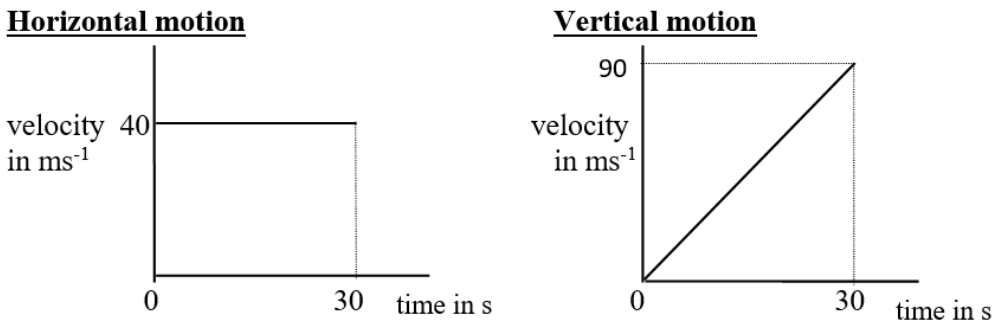
(a) How long does it take the arrow to hit the target?
(b) Calculate the final vertical velocity of the arrow.
(c) By how much does the arrow miss the centre of the target board?

7. A golfer strikes a golf ball and it follows a projectile path as shown below.



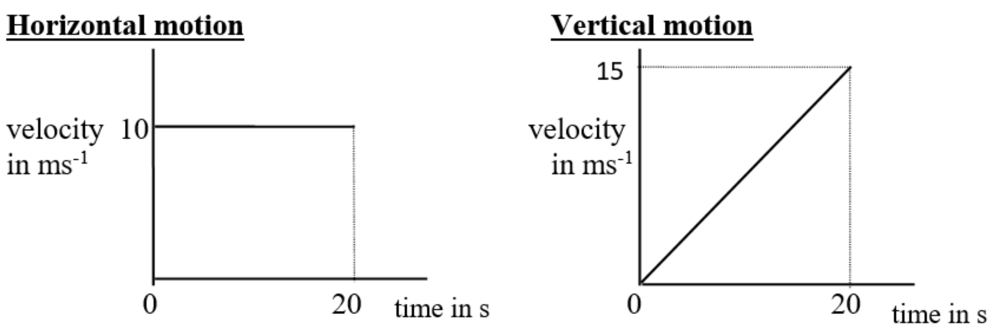
(a) What is the **vertical** velocity of the ball at its maximum height?
(b) What is the horizontal velocity of the ball if it takes 4 seconds to travel 400 metres?

8. Part of the space flight of a shuttle is represented in the velocity time graphs below.



Use the graphs to find out how far the shuttle travels both horizontally and vertically in the 30 second journey.

9. During take off from Mars one of the boosters on a rocket fails causing the rocket to follow a projectile path rather than a vertical one.
The speed time graphs for a 20 second interval immediately after the booster failed are shown below.



Use the graphs to calculate:

(a) the horizontal distance travelled during take off
(b) the acceleration in the vertical direction during the first 20 seconds
(c) the vertical distance travelled.

10. A ball is projected horizontally at 15 m/s from the top of a vertical cliff. It reaches the ground 5 s later. For the period between projection until it hits the ground, draw graphs with numerical values on the scales of the ball's,

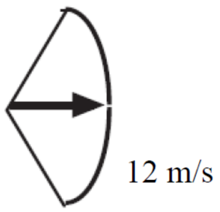
(a) horizontal velocity against time.
(b) vertical velocity against time.
(c) from the graphs calculate the horizontal and vertical distances travelled.

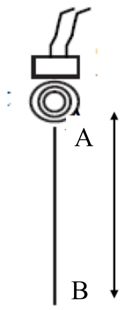
11. A stunt motor cyclist tries to beat the record for riding over double decker buses. He leaves the start position with a horizontal velocity of 35 ms^{-1} and lands 2·4 seconds later.

Calculate :

(a) the horizontal distance travelled by the cyclist
(b) the final vertical velocity of the motor cycle as it touches the ground
(c) the height of the platform.

12. In the experimental set-up shown below, the arrow is lined up towards the target.





As it is fired, the arrow breaks the circuit supplying the electromagnet, and the target falls downwards from A to B. The arrow takes 3 s to hit the target.

(a) Calculate the distance between the target and archer.
(b) Find the height of the target if the arrow has a final vertical velocity of 2 m/s.

Satellites

In this section you can use the two equations which you have met previously in the "Waves and Radiation" unit:

$$v = \frac{d}{t}$$

$$v = f\lambda$$

Where **v** = average wave speed in metres per second (m/s or ms^{-1})
f = frequency in hertz (Hz)
λ = wavelength in metres (m)
d = distance in metres (m)
t = time in seconds (s)

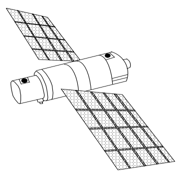
Helpful Hint

Radio waves, television waves and microwaves are all electromagnetic waves which travel at a speed of 3×10^{8} ms^{-1} through space.

1. A telecommunication satellite is in an orbit 20 000 **km** above the surface of the earth. A microwave of frequency 6 **G**Hz is used to send a signal from a ground station to the satellite. Calculate:

   (a) the wavelength of the microwave
   (b) how long it would take the signal to travel 20 000 km.

2. In 1964, SYNCOM, the world's first experimental geostationary satellite was launched into a 36 000 km orbit. A microwave of wavelength 2 cm could be used to communicate with the satellite in its geostationary orbit.



   (a) State what is meant by the term "geostationary satellite".
   (b) Calculate the frequency of microwaves which have a wavelength of 2 cm.
   (c) How long would it take a microwave to travel 36 000 km?

3. (a) What is meant by the term "period" when referring to satellite orbits?
   (b) How does a satellite's height above Earth affect its period?

4. One of the first explorer satellites had an orbit height of 4 000 km above the sur face of the Earth. Another satellite, Early bird, had an orbit height of 36 000 km. Which satellite took longer to make one complete orbit of the Earth?

5. Explain why a satellite can be said to be accelerating if it is travelling at a constant speed.

Distances in Space

1. What is meant by the term ‘light year’?

2. Convert the following distances from light years into metres:

   (a) Earth to nearest star: 4.2 light years.
   (b) Earth to centre of galaxy: 26 000 light years.

3. Convert the following distances from metres into light years.

   (a) Earth to the Sun: $1.5\text{x}10^{17}$m.
   (b) Earth to Andromeda Galaxy: $1.9\text{x}10^{19}$ m.

4. It takes 9 years for the light from Sirius to reach us on the Earth.

   (a) How far is Sirius in metres?
   (b) How long would it take to reach Sirius travelling at 1200 ms^{-1}?

5. The nearest Galaxy is $1.9\text{x}10^{19}$ m away.

   (a) How long would it take to travel to the galaxy at the speed of light?
   (b) How long would it take to travel to the galaxy at 1200 ms^{-1}?

6. The star Beta Centauri is 300 light years from earth. How long does it take light to travel from this star to the earth? (Give your answer in years.)

7. An astronomer on Earth views the planet Pluto through a telescope. Pluto is 5.763×10^{12} m from earth. How long did it take for the light from Pluto to reach the telescope?

Space Exploration

1. Space exploration has required the development of various new technologies. Some of these technologies have resulted in “spin off” developments for domestic use.
   Give 3 examples of items we commonly use that were originally developed for use in space exploration.

2. The ‘Space Laboratory’ Curiosity was designed to carry out experiments on Mars. Why is it not suitable to send humans to Mars to carry out these experiments.

3. The International Space Station orbits the Earth and carries out research in low gravity. Why might this be useful?

4. As well as the benefits mentioned in earlier questions, space travel and exploration also have disadvantages. From the list below select two categories and describe how these could be classed as a disadvantage.

Political Issues	**Accidents**
Health	**Finance**

Understanding the Universe

1. Traditional telescopes based on Earth (terrestrial telescopes) detect light. What other type of signal can telescopes on Earth detect?

2. Terrestrial telescopes are limited because they cannot detect many radiations from space. Telescopes in orbit above our atmosphere can gather much more information about other parts of our galaxy and beyond.

   (a) Why are terrestrial telescopes unable to detect some types of radiation from space?
   (b) Name one space telescope currently in orbit around Earth.

3. Different telescopes are used for different purposes. Give the names of two different types of telescopes.

4. Draw and label a diagram for a refracting telescope.

5. Which lens is used to alter the brightness of the image seen in a refracting telescope.

6. Refracting telescopes were initially used to view stars and nearby planets. Explain one limitation of using a refracting telescope to view objects further away.

7. The Hubble Space Telescope orbits the Earth and takes picture of far away Galaxies. Explain why the images from the Hubble telescope are very clear.

8. Using large telescopes, scientists have discovered evidence of “The Big Bang”. Explain what this evidence is?

9. Explain why Earth is suitable for sustaining life.

10. Describe what is meant by an ‘Exoplanet’.

11. Why can we not detect an Exoplanet using a telescope?

12. Describe how exoplanets are detected.

13. Scientists searching for Exoplanets use the Astronomical Unit. 1 A.U. is the distance from the Sun to Earth (the ‘Habitable Zone’)

    The “Habitable Zone” is the name given to the region in which a planet is thought to be able to sustain life. A particular star is twice as bright as our Sun:

    (a) Estimate the ‘Habitable Zone’ for this particular star.
    (b) Give a reason for your answer.

14. Explain why it is important for humans to have a better understanding of the Universe.

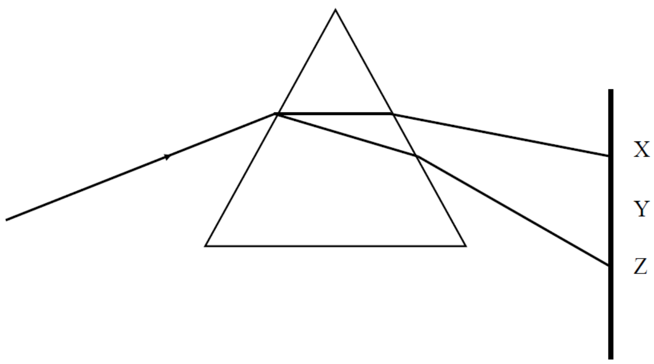
Using the Spectrum

1. List in order of increasing wavelength, the members of the electromagnetic spectrum.

2. What property do all of the members of the electromagnetic spectrum have in common?

3. Describe one use for radio waves in the space industry.

4. White light can be split up into different colours.



(a) Name the colours present at points X,Y and Z.
(b) Explain why the colours of white light can be split this way.

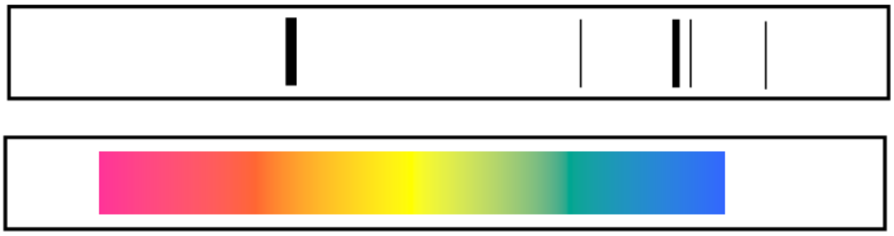
5. Yellow light is part of the visible spectrum. The wavelength of yellow light is 5.9x10-7 m. The visible spectrum also contains red, blue and green light. Use your knowledge of the light spectrum to copy and complete the table below.

Colour	**Wavelength (m)**
	7×10^{-7}
Yellow	
	5.5×10^{-7}
	4.5×10^{-7}

6. Identify the types of spectra shown in the following diagrams.

A

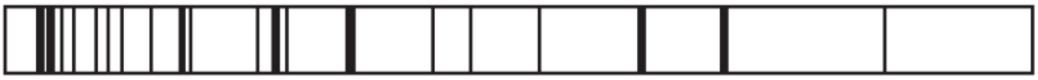
B



7. The line spectrum of distant stars can be used to identify elements which are present in that star. Explain how this is the case.

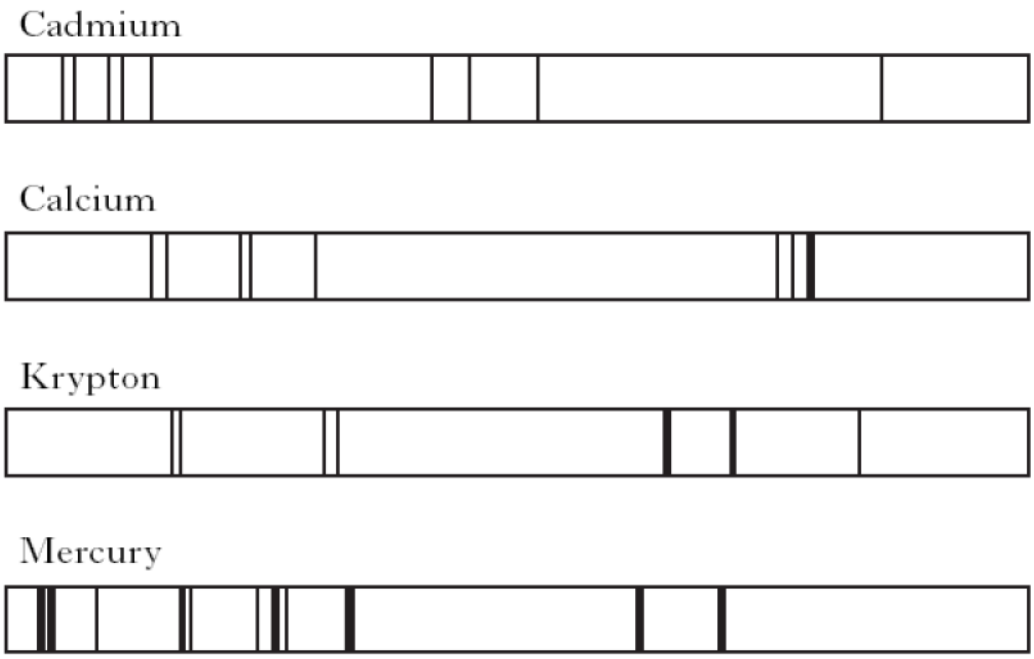
8. Explain how the line spectrum of the Sun was used to discover the element Helium.

9. Some spectral lines of radiation from a distant star are shown below:



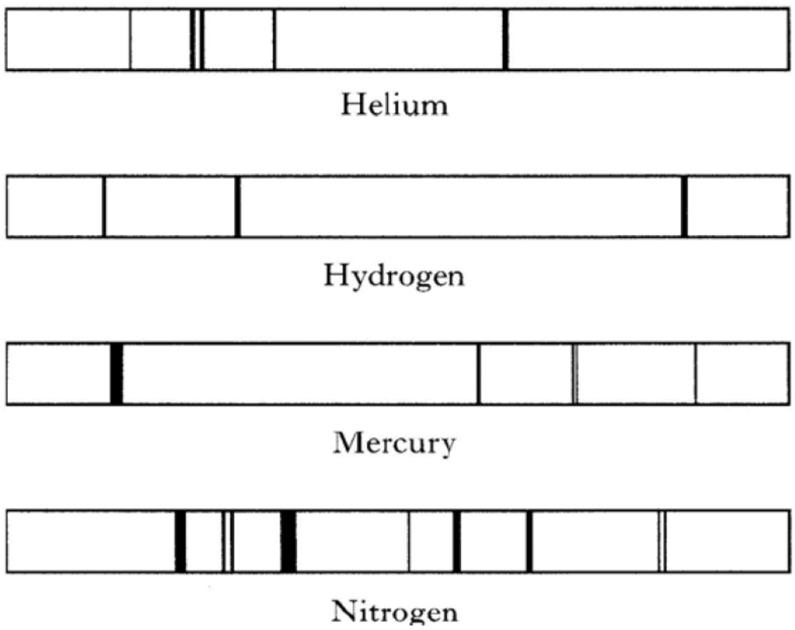
Spectral lines of radiation from distant star

The spectral lines of a number of elements are also shown.



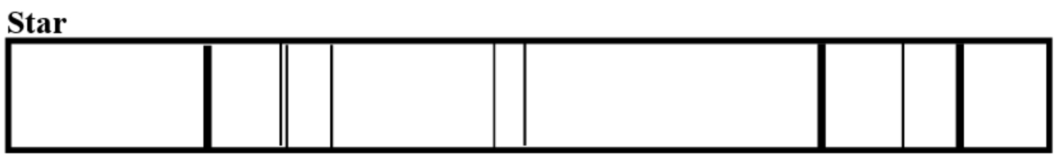
Use the spectral lines of the elements shown above to identify which of these elements are present in the distant star.

10. The following elements were discovered to be on Titan:

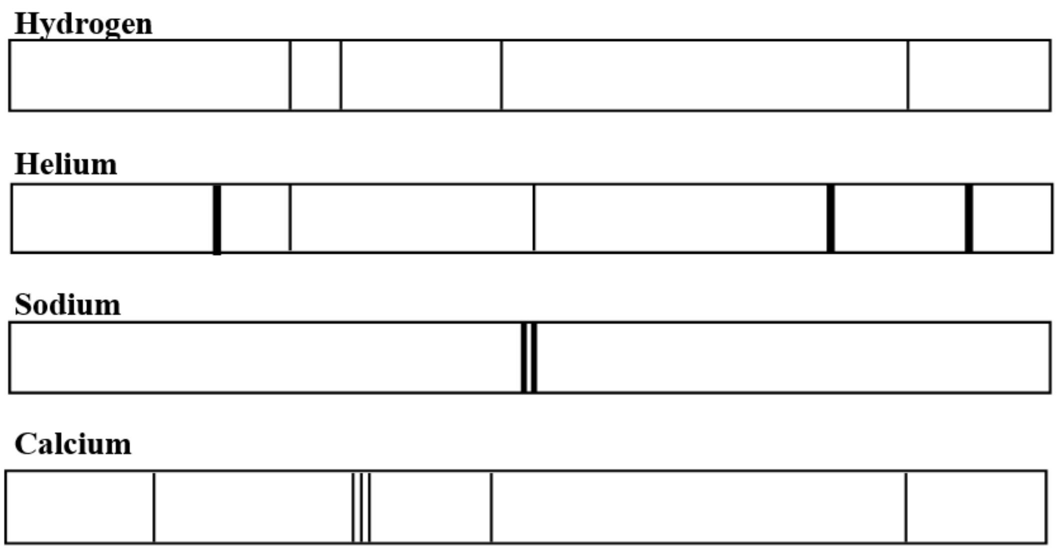


Using the line spectra of each individual element, sketch what the line spectra from Titan may have looked like.

11. Spectral data from a distant star is shown below.



Known spectral data from various elements is as follows:



Identify the elements present in the star.