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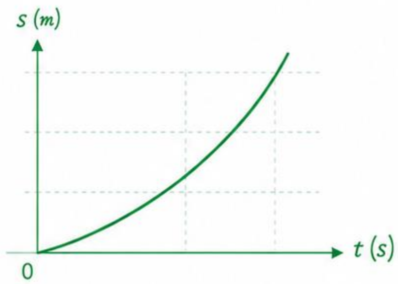
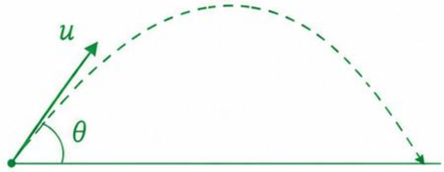
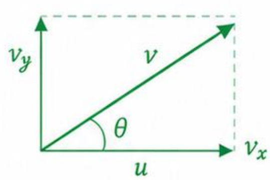


$v = u + at$

Maths and Motion



$s = ut + \frac{1}{2}at^2$



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5-A-Day

Manipulate the following equations for letters in bold.

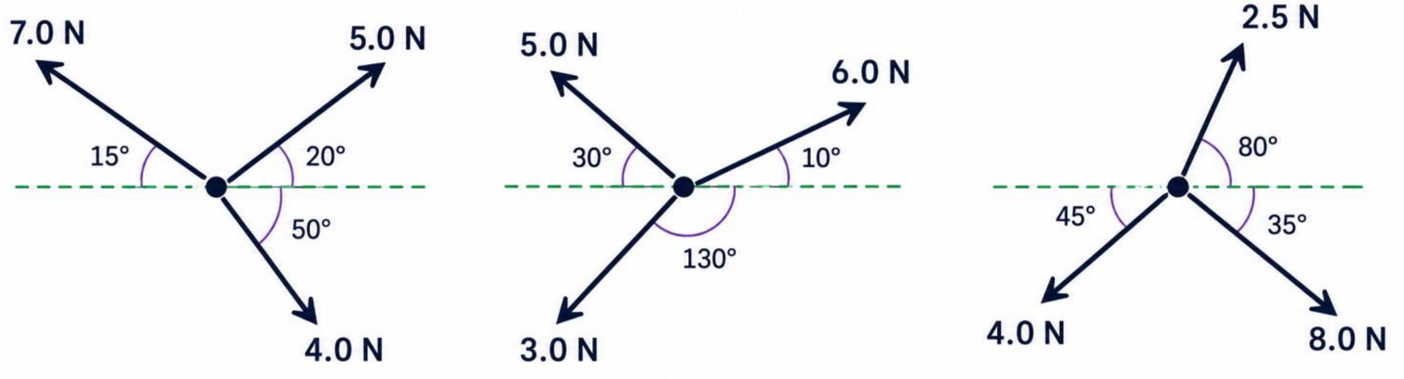
1. $s = \frac{(u+v)\boldsymbol{t}}{2}$
2. $E = \frac{1}{2}\boldsymbol{k}x^2$
3. $P = \frac{\boldsymbol{V}^2}{R}$
4. $h\boldsymbol{f} = \emptyset + KE_{max}$
5. $\varepsilon = I(R + \boldsymbol{r})$

5-A-Day

1. Convert $12mm^2$ into m^2.
2. Write 10mm and 15Mm using index notation.
3. Sides of 2km and 0.07Mm are measured, calculate the area of this shape.
4. A wire with a cross-sectional area of $15mm^2$ is used in an experiment. Using the equation $Pressure = \frac{Force}{Area}$ and knowing that a force of 15kN was applied to the wire, calculate the pressure on the wire..
5. A wave travels 12.6km in 400ms. Calculate the speed of the wave.

3-Today

Find the resultant vector from the diagrams below.



5-A-Day

1. Define the term velocity.
2. Define the term acceleration.
3. Sketch a graph for a vehicle beginning from rest, travelling at a constant acceleration of $2 m/s^2$ for 5s and then at a constant velocity for 12s.
4. Calculate the maximum speed of the vehicle.
5. Calculate the distance travelled by the vehicle in this time.

5-A-Day

1. Calculate velocity if $a=2m/s^2$, $u=5m/s$ and $t=10s$.
2. A ball is rolled along a table with an initial velocity of 5m/s. The ball decelerates at $1.4m/s^2$. Calculate the distance travelled by the ball after 3s.
3. A vehicle has a velocity of 12m/s. Calculate the initial velocity if the vehicle had been decelerating at a rate of $4m/s^2$ over 20m.
4. A ball thrown vertically into the air has a deceleration of $9.81m/s^2$. If the initial velocity of the ball was 15m/s, calculate the height of the ball when the speed is 5m/s.
5. The ball reaches its maximum height when the velocity is zero. Calculate the time taken for the ball to fall from maximum height to the ground.

5-A-Day

1. Define the term acceleration.
2. **Explain** how the acceleration of a projectile varies with time.
3. **Explain** how the vertical component of velocity changes with time.
4. A projectile is fired from the edge of a table 80cm high. The projectile has an initial horizontal velocity of 6m/s. Calculate the time taken for the projectile to reach the ground.
5. Calculate the horizontal distance travelled by the projectile.

5-A-Day

1. Define the terms velocity and acceleration.
2. A projectile is fired at an angle of 30° to the horizontal with a velocity of 12m/s. Calculate the total flight time of the projectile.
3. Calculate the range of the projectile.
4. **Explain** why the kinetic energy of the projectile is not zero at maximum height.
5. What % of the original KE of the projectile remains at maximum height?

2.3 Nature of quantities

This section provides knowledge and understanding of scalars and vectors quantities. Vector quantities add and subtract very differently to scalar quantities; hence

2.3.1 Scalars and vectors

	Learning outcomes
	Learners should be able to demonstrate and apply their knowledge and understanding of:
(a)	scalar and vector quantities
(b)	vector addition and subtraction
(c)	vector triangle to determine the resultant of any two coplanar vectors
(d)	resolving a vector into two perpendicular components; $F_x = F \cos \theta$; $F_y = F \sin \theta$.

Math’s skills

Example 1

Make x the subject of the formula in each of the following cases.

a) $a + x = y + z$

b) $a + 3x = y + z$

c) $ax = y + z$

Solutions:

a) $a + x = y + z$

$a + x - a = y + z - a$ *Subtract a from both sides*

$x = y + z - a$

b) $a + 3x = y + z$

$3x = y + z - a$ *Subtract a from both sides*

$x = \frac{y+z-a}{3}$ *Divide both sides by 3*

c) $ax = y + z$

$x = \frac{y+z}{a}$ *Simply divide both sides by a*

Example 2

Make x the subject of the formula in each of the following cases.

a) $a(x+b)=c$

b) $\frac{x}{a}=1+\frac{y}{b}$

c) $\frac{x+y}{y}=\frac{y}{a}+\frac{a}{y}$

Solutions:

a) $a(x+b)=c$

$ax+ab=c$	*Expand the brackets*
$ax=c-ab$	*Subtract ab from each side*
$x=\frac{c-ab}{a}$	*Divide both sides by a*

b) $\frac{x}{a}=1+\frac{y}{b}$

$bx=ab+a$	*Remove the fractions by multiplying both sides by ab*
$x=\frac{ab+a}{b}$	*Divide both sides by b*

c) $\frac{x+y}{y}=\frac{y}{a}+\frac{a}{y}$	*There is an implied bracket in the first term so put it in*
$\frac{(x+y)}{y}=\frac{y}{a}+\frac{a}{y}$	
$a(x+y)=y^2+a^2$	*Remove the fractions by multiplying both sides by* ay
$ax+ay=y^2+a^2$	*Expand the brackets*
$ax=y^2+a^2-ay$	*Subtract* ay *from both sides*
$x=\frac{y^2+a^2-ay}{a}$	*Divide both sides by* a

1. *Rearrange v=u+at for t.*

A) $t = v - u - a$

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

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

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

2. *Using the formula $v^2 = u^2 + 2as$, rearrange for u.*

A) $u = \sqrt{v^2 - 2as}$

B) $u = \sqrt{v^2} - 2as$

C) $u = \sqrt{v^2 + 2as}$

D) $u = \sqrt{\frac{v^2}{2as}}$

3. *Using the formula $s = ut + \frac{at^2}{2}$*, rearrange for a.

A) $a = s - ut - t^2$

B) $a = \frac{s-ut}{t^2}$

C) $a = \sqrt{\frac{(s-ut)}{2t^2}}$

D) $a = \frac{2(ut-s)}{t^2}$

Rearrange the following equations

a. $C = \pi d$ for d

b. $c_1 v_1 = c_2 v_2$ for v_2

c. $F = BQv$ for Q

d. $Q = U + pV$ for p

e. $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ for N_s

f. $\theta = \frac{\lambda}{d}$ for d

g. $s = \frac{(u+v)t}{2}$ for u

h. $KE = \frac{1}{2}mv^2$ for v

i. $s = ut + \frac{1}{2}at^2$ for a

j. $\frac{pV}{T} = nR$ for T

k. $a^2 = b^2 + c^2$ for b

l. $\sin\theta = \frac{a}{b}$ for θ

1. *Using the formula* $v = u + at$ where $v = 3, u = 2\ and\ a = 0.5, give\ the\ value\ for\ t$.

A) 0.5

B) 1

C) 2

D) 4

2. *Using the formula* $v^2 = u^2 + 2as$ where $v = 5, u = 3\ and\ a = 0.8, give\ the\ value\ for\ s$.

A) 5

B) 8

C) 10

D) 15

3. *Using the formula* $s = ut + at^2$where $\mathrm{s} = 15, u = 5\ and\ t = 8, give\ the\ value\ for\ a$.

A) 0.39

B) -0.39

C) 0.80

D) -0.80

Units, constants and prefixes

Base units

Base Quantity	SI Unit & Abbreviation
Length	metre, m
Time	second, s
Mass	kilogram, kg
Temperature	kelvin, K
Electric current	ampere, A
Amount of substance	mole, mol
Luminous Intensity	candela, cd

Force is measured in Newtons, but a Newton is not a base unit. It is made up of other units but we use the Newton for simplicity.

Force = mass x acceleration

Acceleration is the change in velocity per unit time.

N = kg x m/s /s

Constants

Physical constants

acceleration of free fall	g	$9.81\ \text{m s}^{-2}$
elementary charge	e	$1.60 \times 10^{-19}\ \text{C}$
speed of light in a vacuum	c	$3.00 \times 10^{8}\ \text{m s}^{-1}$
Planck constant	h	$6.63 \times 10^{-34}\ \text{J s}$
Avogadro constant	N_A	$6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	R	$8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
Boltzmann constant	k	$1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	G	$6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
permittivity of free space	ε_0	$8.85 \times 10^{-12}\ \text{C}^{2}\ \text{N}^{-1}\ \text{m}^{-2}\ (\text{F m}^{-1})$
electron rest mass	m_e	$9.11 \times 10^{-31}\ \text{kg}$
proton rest mass	m_p	$1.673 \times 10^{-27}\ \text{kg}$
neutron rest mass	m_n	$1.675 \times 10^{-27}\ \text{kg}$
alpha particle rest mass	m_α	$6.646 \times 10^{-27}\ \text{kg}$
Stefan constant	σ	$5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

Prefixes

Prefix name	Prefix symbol	Factor
tera	T	
	G	10^{9}
mega		10^{6}
kilo	k	
deci		10^{-1}
	c	10^{-2}
milli	m	
micro		10^{-6}
nano	n	
	p	10^{-12}
femto		10^{-15}

Note – You must be careful to distinguish between units and prefixes. For example, mm is a milli (prefix) metre (unit)

A wave travels 300Mm/s, calculate the distance travelled by the wave in 12ns.

A) 36m
B) 0.36m
C) 3600m
D) 3.6m

Pressure is force applied per unit area. A force of 120kN is applied over a square area of side 50mm. Calculate the pressure acting on this area.

A) 4.8×10^{10} Pa
B) 48MPa
C) 480MPa
D) 48 Pa

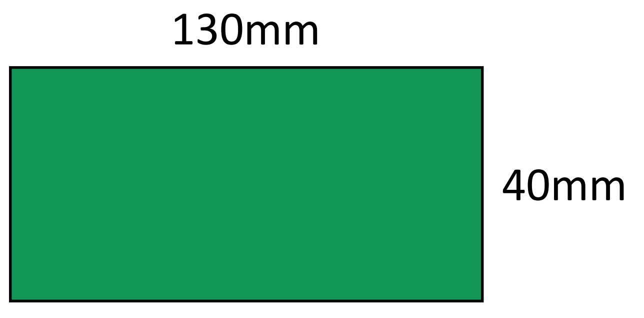
Density if mass per unit volume. A cube of mass 65g has 1 side measured to b 20mm. Calculate the density of the cube.

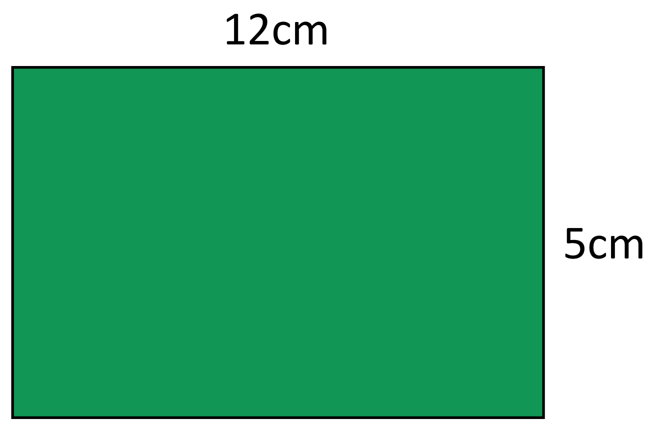
A)8.1 g/m^3
B)8.1×10^{-6} kg/m^3
C)8100 kg/m^3
D)831×10^{6} kg/m^3

Working with area and volume

When making a calculation involving areas and volumes you should first ensure that the values you are given are in m^2 or m^3.

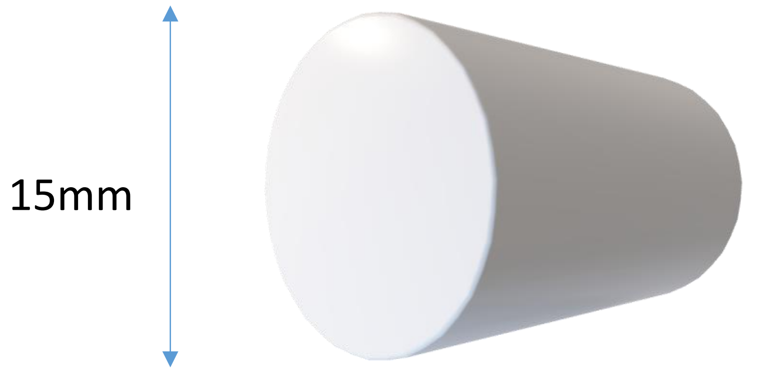
Calculate the areas of the following shapes in m^2.





Convert $140mm^2$ to m^2

Convert $12cm^2$ to m^2.



The cable above has a diameter of 15mm.
Calculate the area of the cable in mm^2, cm^2 and m^2.

The cable is stretched so that the area is decreased by half. Calculate the new diameter in mm.

Dimension conversions

A wire has a cross-sectional area of 12mm^2. Calculate the cross-sectional area in m^2.

A) 12×10^{-3} m^2
B) 12×10^{-6} m^2
C) 12×10^{-9} m^2
D) 12×10^{-12} m^2

A sphere has a volume of 6cm^3. calculate the volume in m^3.

A) 6×10^{-4} m^3
B) 6×10^{-6} m^3
C) 6×10^{-8} m^3
D) 6×10^{-2} m^3

A metal sphere has a mass of 20g and volume of 2.5cm^3. Calculate the density of the sphere.

A) 8×10^{3} kg/m^3
B) 8 kg/m^3
C) 8×10^{6} kg/m^3
D) 8×10^{-3} kg/m^3

Using graphs

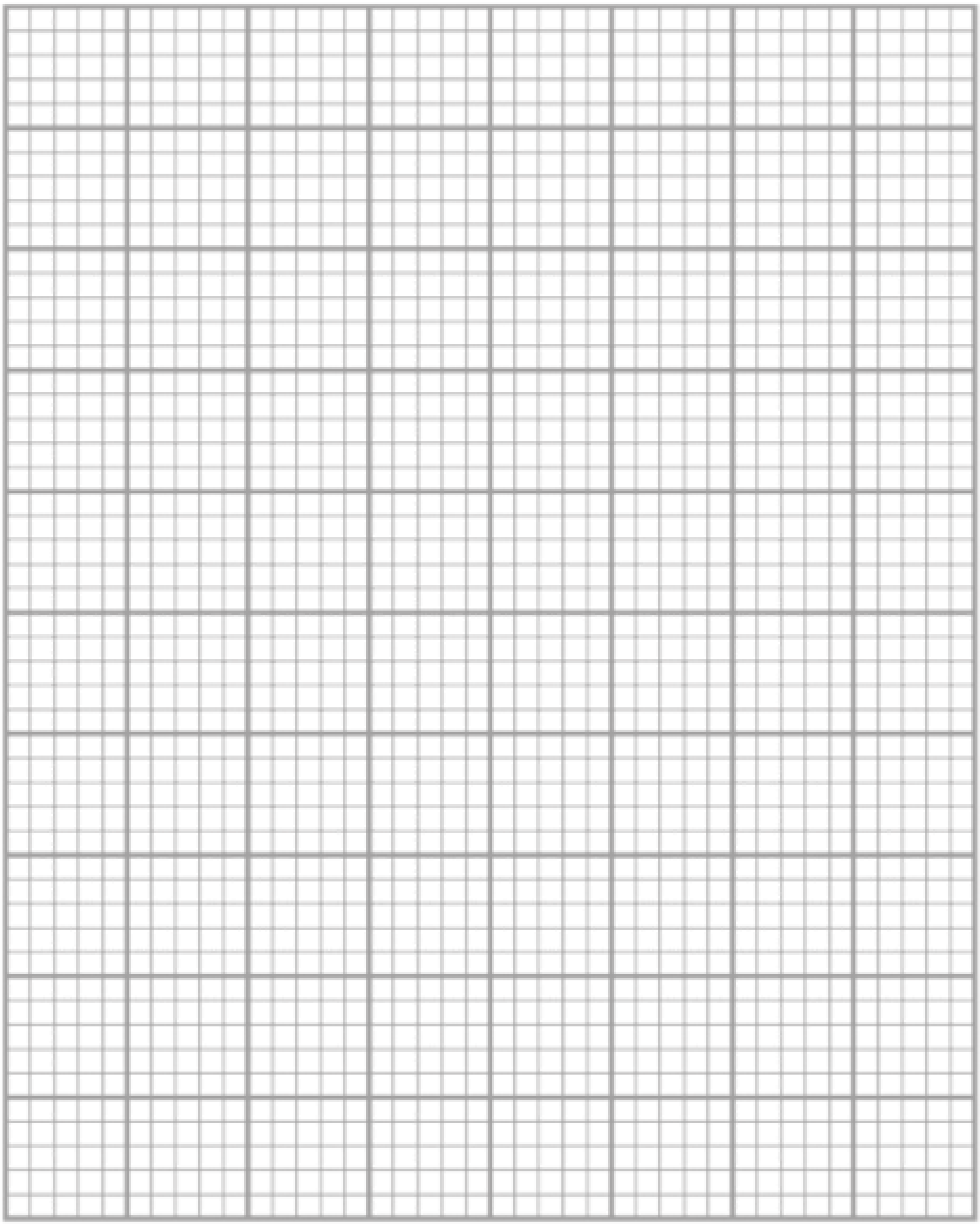
Distance(km)	Time(s)
0	0
12	1
15	2
33	3
43	4
50	5

1. Plot the data for the graph
2. Draw a line of best fit
3. Calculate the gradient of the graph
4. Find the units of the gradient
5. What quantity do these units represent?
6. Calculate the distance the object would have travelled at 12s.
7. At what time would the object be found at a distance of 340m.
8. What is the acceleration of the object?

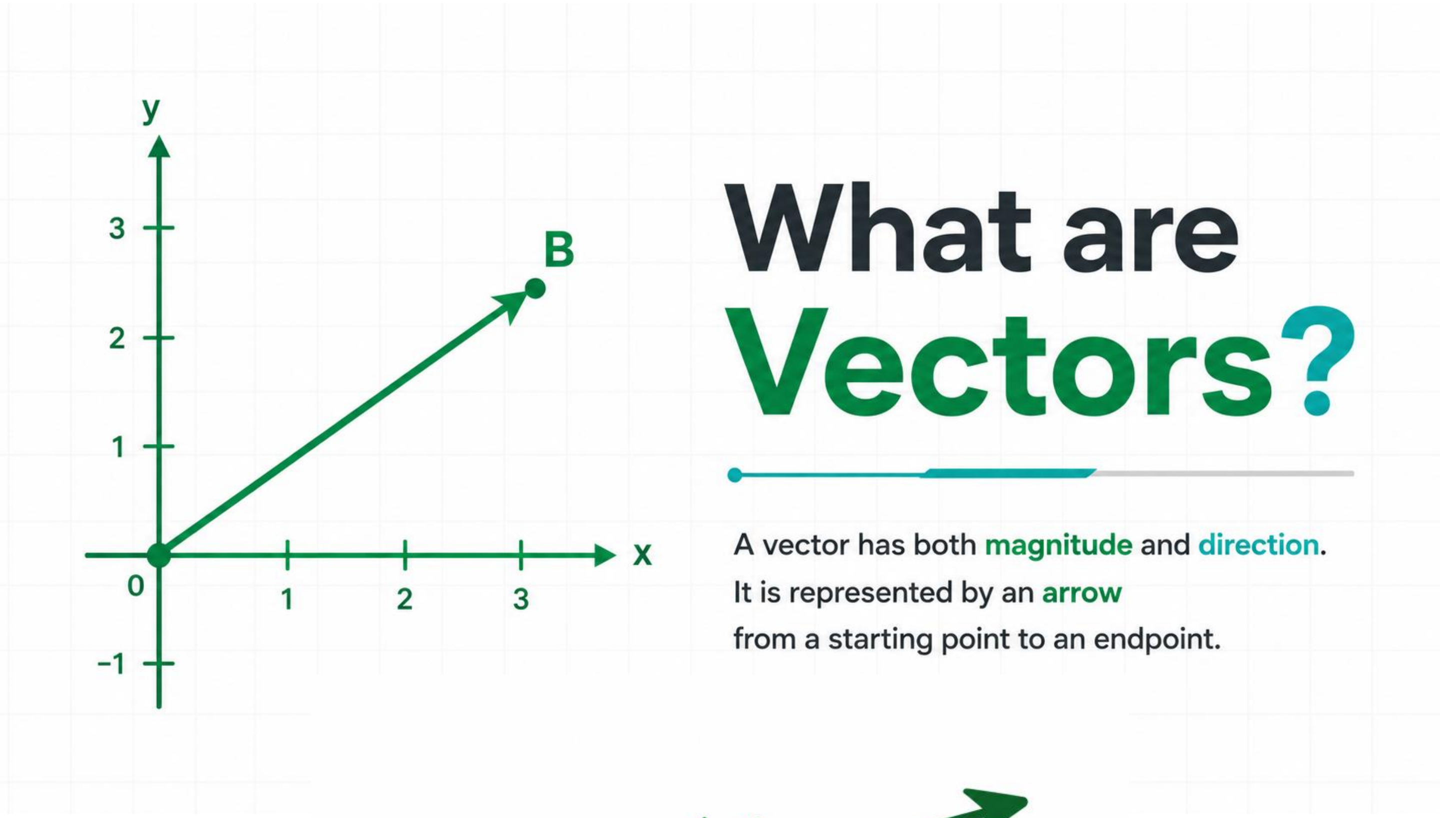
Distance(Mm)	Time(ms)
0	0
0.4	5
1.1	12
1.5	15
1.8	20
2.2	30

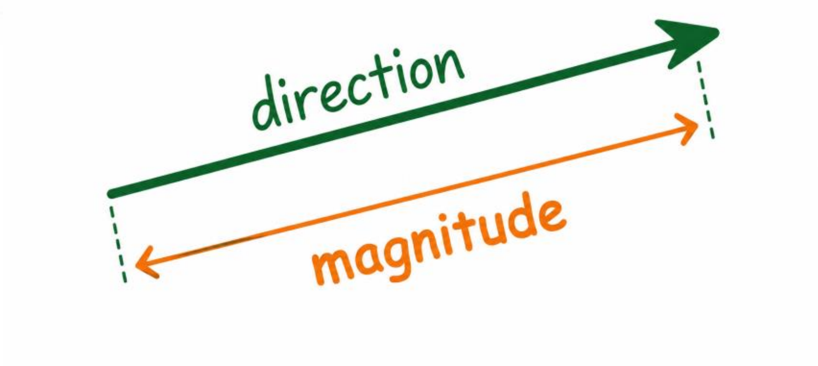
2

1



1. Plot the data for the graph
2. Draw a line of best fit
3. Calculate the gradient of the graph
4. Find the units of the gradient
5. What quantity do these units represent?
6. Calculate the distance the object would have travelled at 1.2ms.
7. At what time would the object be found at a distance of 3400km.



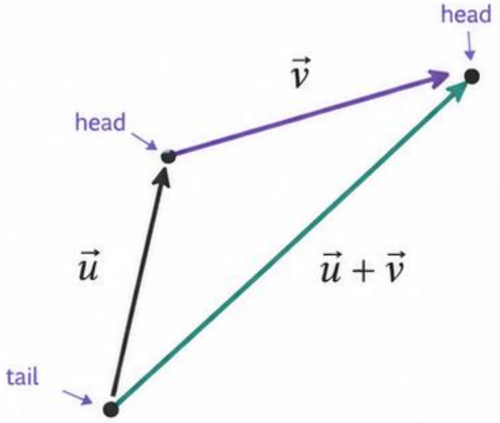


Define the term vector

Define the term scalar

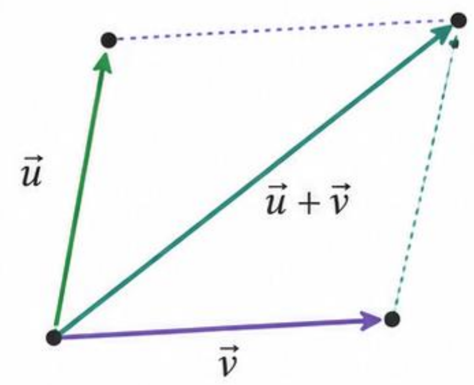
GRAPHICAL METHODS FOR VECTOR ADDITION

1. TRIANGLE (HEAD-TO-TAIL) METHOD



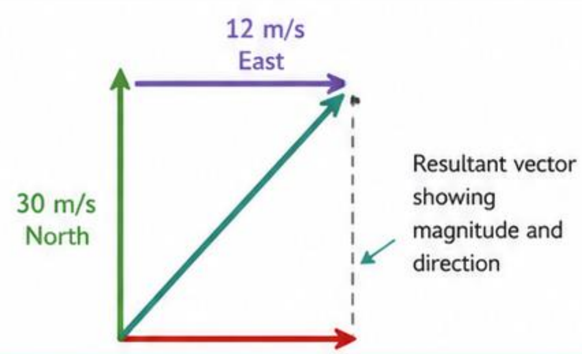
1. Place the vectors with the head of the previous vector connected to the tail of the successive vector.
2. The resultant vector $\vec{u} + \vec{v}$ is formed by connecting the tail of the first vector to the head of the last vector.

2. PARALLELOGRAM METHOD



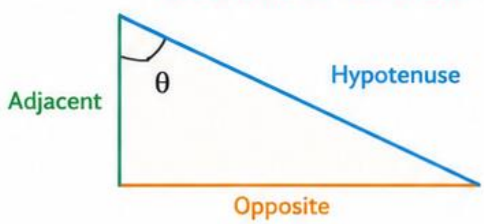
1. Place both vectors, $\vec{u}$ and $\vec{v}$, at the same initial point.
2. Complete the parallelogram.
3. The diagonal of the parallelogram is the resultant vector $\vec{u} + \vec{v}$.

A glider flies at 30 m/s north with a cross wind of 12 m/s east.



RESOLVING VECTORS

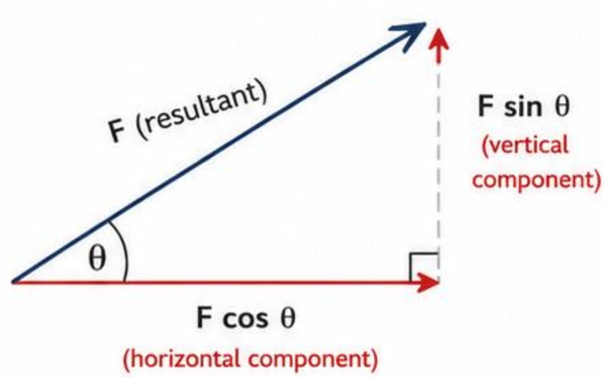
TRIGONOMETRY REMINDER



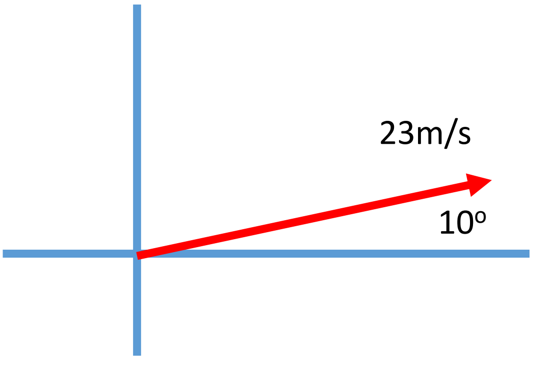
$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}} \qquad \cos\theta = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\tan\theta = \frac{\text{Opposite}}{\text{Adjacent}}$$

VECTOR COMPONENTS



Example



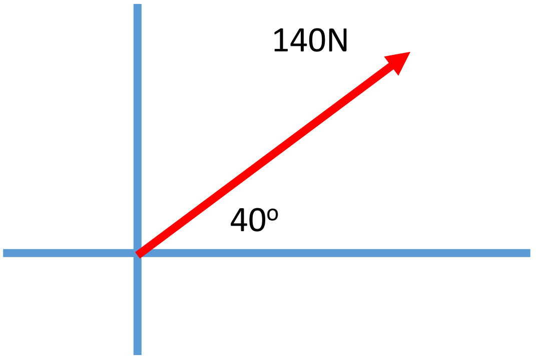
Find the x,y components of the vector.
Calculate the distance travelled in the East direction after 20s.

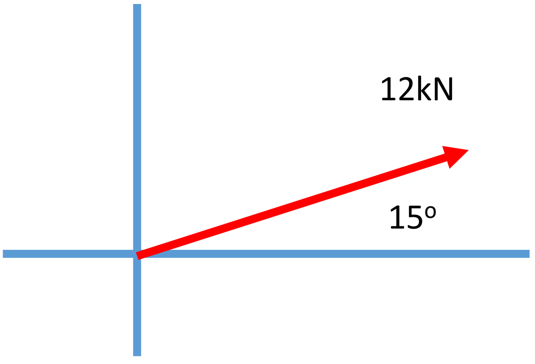
An aircraft is flying North at 150m/s. A crosswind blows to the East at 50m/s.
Sketch a diagram showing the vectors present.
Calculate the velocity of the aircraft.

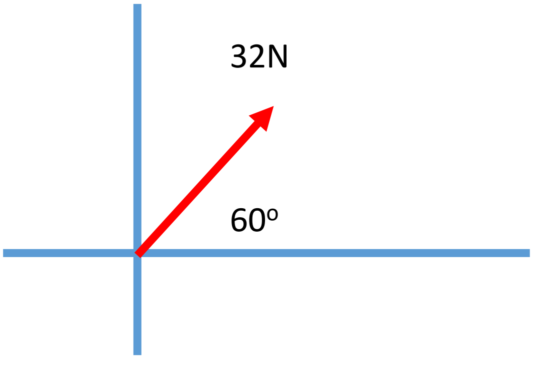
A second aircraft has a bearing of 25° and if flying at 140m/s. Calculate the distance in the North and East directions travelled by the aircraft after 1 hour.

Find the X and Y component of the following.

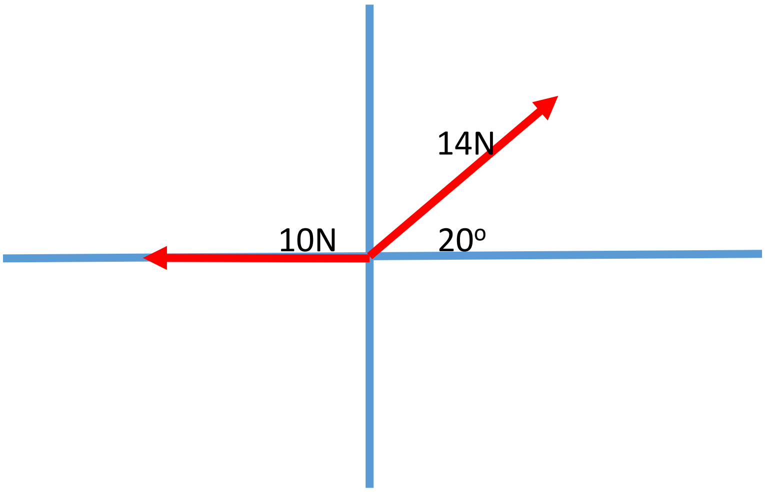
Sin: Away from the angle ***Cos: Through the angle***

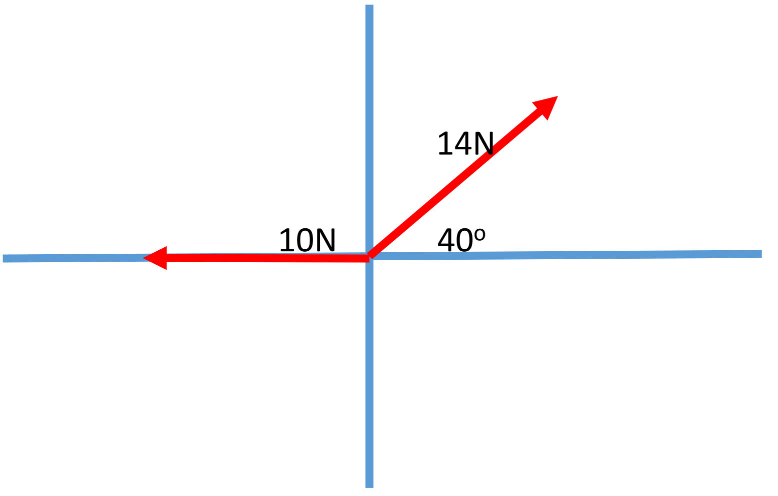


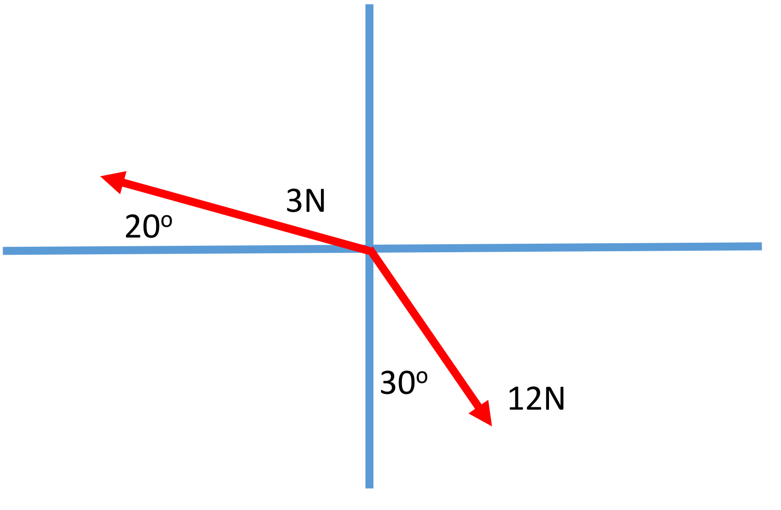




Find the resultant of the following.




14N
10N
40°


3N
20°
30°
12N

3.1 Motion

This section provides knowledge and understanding of key ideas used to describe and analyse the motion of objects in both one-dimension and in two-dimensions. It also provides learners with opportunities to develop their analytical and experimental skills.

The motion of a variety of objects can be analysed using ICT or data-logging techniques (HSW3). Learners

3.1.1 Kinematics

	Learning outcomes
	Learners should be able to demonstrate and apply their knowledge and understanding of:
(a)	displacement, instantaneous speed, average speed, velocity and acceleration
(b)	graphical representations of displacement, speed, velocity and acceleration
(c)	Displacement–time graphs; velocity is gradient
(d)	Velocity–time graphs; acceleration is gradient; displacement is area under graph.

Motion

Definitions

Speed

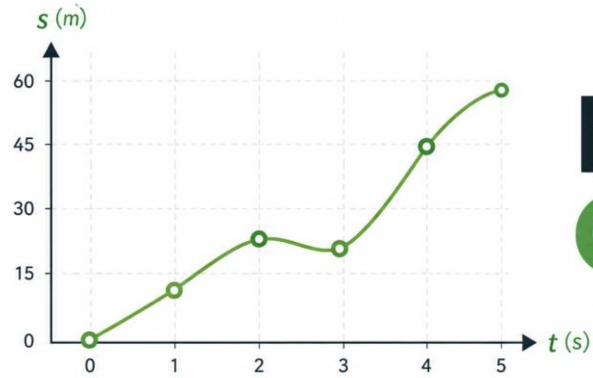
Velocity

Acceleration

Braking distance

Thinking distance

Additional:



Motion Graphs

Example

A runner begins her journey from rest with an acceleration of $0.4 m/s^2$ for 10 seconds. She then continues with this speed for 18 minutes before decelerating at a rate of $0.1 m/s^2$ for 12 seconds.

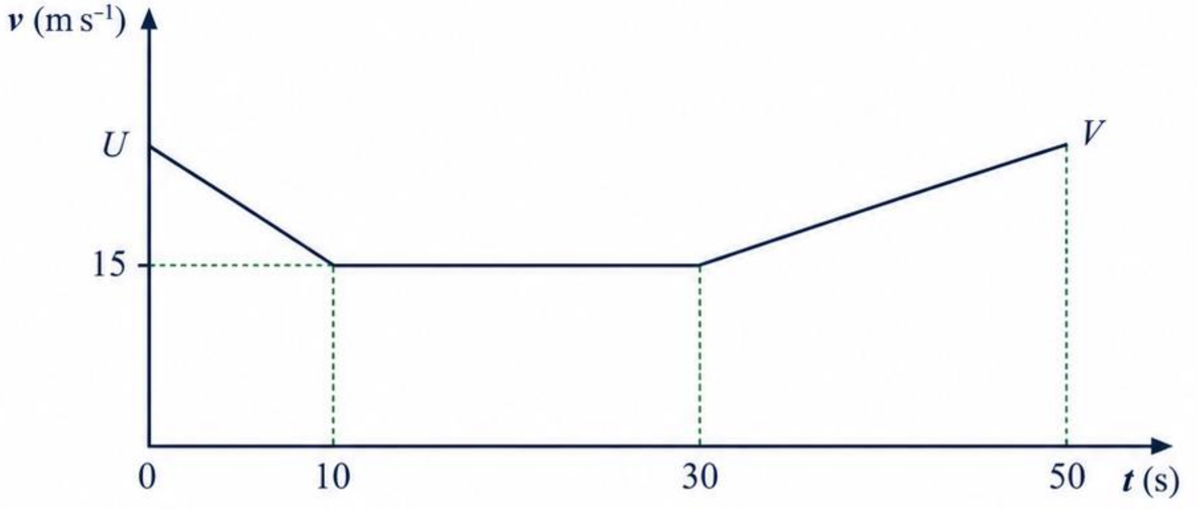
1. Sketch a velocity-time graph for the runner.
2. How much time was spent running?
3. Calculate the highest speed of the runner.
4. Calculate the final speed of the runner.
5. Calculate the runners total distance travelled.

A runner is begins her journey from rest with an acceleration of $0.31 m/s^2$ for 12 seconds. She then continues with this speed for 15 minutes before decelerating at a rate of $0.2 m/s^2$ for 8 seconds.

1. Sketch a velocity-time graph for the runner.
2. How much time was spent running?
3. Calculate the highest speed of the runner.
4. Calculate the final speed of the runner.
5. Calculate the runners total distance travelled.

A journey is made by a small rodent. The rodent begins from rest and accelerates at $1m/s^2$ for 0.8s and then continues at this speed for 5s. The rodent decelerates to a halt in 1.2s and then accelerates in the opposite direction for 0.4s at $1.2m/s^2$. The rodent continues at this speed for 3s.

- Sketch a velocity-time graph of the rodents motion.
- Sketch a displacement-time graph for the rodents motion.
- Calculate the maximum speed travelled by the rodent.
- Calculate the final velocity of the rodent.
- Calculate the total distance travelled by the rodent in this time.
- Calculate the final displacement of the rodent.



The velocity-time graph above represents the motion of a delivery van travelling along a straight horizontal road. At time $t = 0$ the van has velocity U m s^{-1}. During the first 10 seconds the van decelerates at a constant rate of $2a$ m s^{-2} until its velocity becomes 15 m s^{-1}. For the next 20 seconds the van continues at a constant velocity of 15 m s^{-1}. During the final 20 seconds the van accelerates at a constant rate of a m s^{-2}, reaching a velocity of V m s^{-1} at $t = 50$ s.

(a) Calculate the distance travelled by the van while it is moving at the constant velocity of 15 m s^{-1}.

(b) Given that the total distance travelled by the van during the 50 seconds is 800 m, find

(i) the value of U,

(ii) the value of a.

A rowing team is taking part in a race. During the first 20 seconds of the race, the boat accelerates from the rest at a constant rate of a $\mathrm{ms^{-2}}$ until it reaches a speed of V $\mathrm{ms^{-1}}$. During the rest of the race, which lasts for a **further 220** seconds, the boat travels at a constant speed of V $\mathrm{ms^{-1}}$.

a Sketch a velocity - time graph to represent the motion of the boat during the race.

b Find the value of V in terms of a.

....

c The length of the race is **1000** metres. Find the value of a.

....

d State **one** criticism of this model of the motion of the boat.

....

....

3.1.2 Linear motion

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) (i) the equations of motion for constant acceleration in a straight line, including motion of bodies falling in a uniform gravitational field without air resistance

$$v = u + at \qquad s = \frac{1}{2}(u + v)t$$

$$s = ut + \frac{1}{2}at^2 \qquad v^2 = u^2 + 2as$$

(ii) techniques and procedures used to investigate the motion and collisions of objects

(b) (i) acceleration g of free fall

(ii) techniques and procedures used to determine the acceleration of free fall using trapdoor and electromagnet arrangement or light gates and timer

(c) reaction time and thinking distance; braking distance and stopping distance for a vehicle.

Equations of motion

Don't forget about your data sheet!

Module 3 – Forces and motion	
uniformly accelerated motion	$v = u + at$
	$s = \frac{1}{2}(u+v)t$
	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$

s=displacement
u=initial velocity
v=final velocity
a=acceleration
t=time

u= 5m/s
a= $2m/s^2$
t= 6s

Find 'v'

Using these values, find the value for the final velocity.

Step 1: You need to refer to your equation list and find an equation that includes the values you have.
Step 2: Substitute the values you have into the selected equation and calculate an answer.

u= 5m/s
t= 4s
a= $3m/s^2$

Find ‘v’

u= 2m/s
t= 4s
a= $5m/s^2$

Find ‘s’

u= 6m/s
s= 3m
a= $3m/s^2$

Find ‘v’

Deriving the equations of motion

1 1. A cyclist is uniformly decelerated from 28 m/s to 16 m/s over a distance of 264 m. Calculate the deceleration and the time taken to come to rest from 28 m/s.

2 2. A drone moves with uniform acceleration 0.4 m/s^2 in a straight line PQR. The speed of the drone at R is 68 m/s and the times taken from P to Q and from Q to R are 35 s and 25 s respectively. Calculate

(a) Speed at P

(b) Distance QR

3 3. A motorbike accelerates from rest with acceleration 1.2 m/s^2 for 4 seconds. Find the final velocity.

4 4. A tram starts from rest and accelerates uniformly at 1.8 m/s^2 until it reaches a speed of 27 m/s. Find the time taken and the distance travelled.

5 5. A bus travels along a straight road between two stops X and Y. The bus starts from rest at X and accelerates at 1.5 m/s^2 until it reaches a speed of 18 m/s. It then travels at this speed for a distance of 1440 m and then decelerates at 3 m/s^2 to come to rest at Y. Find

(a) Distance from X to Y

(b) Total time taken for the journey

(c) Average speed for the journey

6 6. In travelling the 0.80 m along an air-rifle barrel, a pellet uniformly accelerates from rest to a velocity of 240 m/s. Find the acceleration involved and the time taken for which the pellet is in the barrel.

Hint: Sketching a motion graph can sometimes help you decide which equations to use.

Define *velocity*.

-- [1]

Fig. 4.2 shows a tennis ball moving up a smooth ramp at time $t = 0$.

Fig. 4.2

Fig. 4.3 shows a graph of velocity v against time t for this ball.

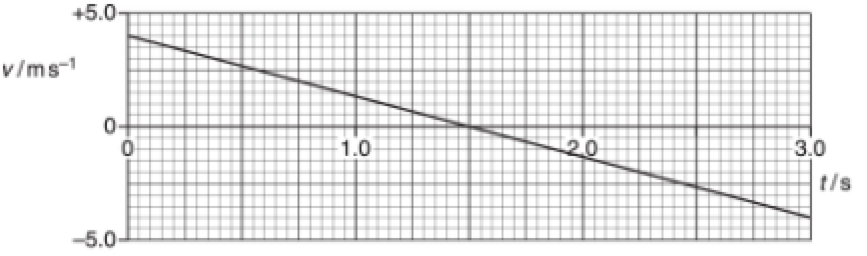


Fig. 4.3

i. Describe, without calculation, the motion of the ball between $t = 0$ and $t = 3.0$ s.

-- [3]

ii. Calculate the maximum distance D travelled by the ball up the ramp.

D = ______________________________ m **[2]**

Two cars, **A** and B, are travelling clockwise at constant speeds around the track shown in **Fig. 16.1**. The track consists of two straight parallel sections each of length 200 m, the ends being joined by semi-circular sections of diameter 80 m.

The speed of **A** is 20 ms^{-1} and that of **B** is 23 ms^{-1}.

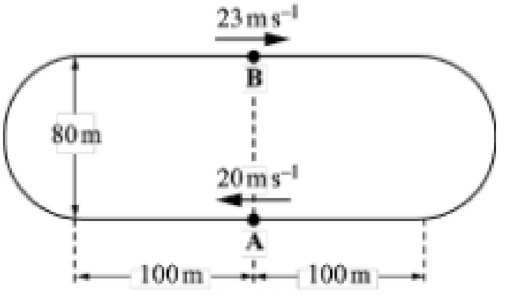


Fig. 16.1

i. Calculate the time for **A** to complete one lap of the track.

time for one lap = _______________ s **[2]**

ii. Starting from the positions shown in **Fig. 16.1** determine the shorter of the two distances along the track between **A** and **B**, immediately after **A** has completed one lap.

distance = _______________ m **[2]**

An object above the ground is released from rest at time $t = 0$.

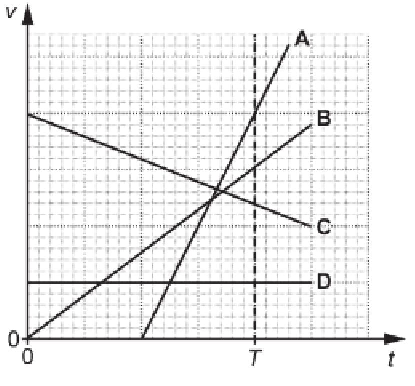
Air resistance is negligible.

What is the distance travelled by the object between $t = 0.20$ s and $t = 0.30$ s?

A 0.20 m
B 0.25 m
C 0.44 m
D 0.49 m

Your answer **[1]**

The velocity v against time t graphs for four objects **A** , **B** , **C** and **D** are shown below.



Which object travels the greatest distance between $t = 0$ and $t = T$?

Your answer **[1]**

A ball is thrown vertically upwards with a speed of 5.0 m s^{-1}.
Ignore air resistance.

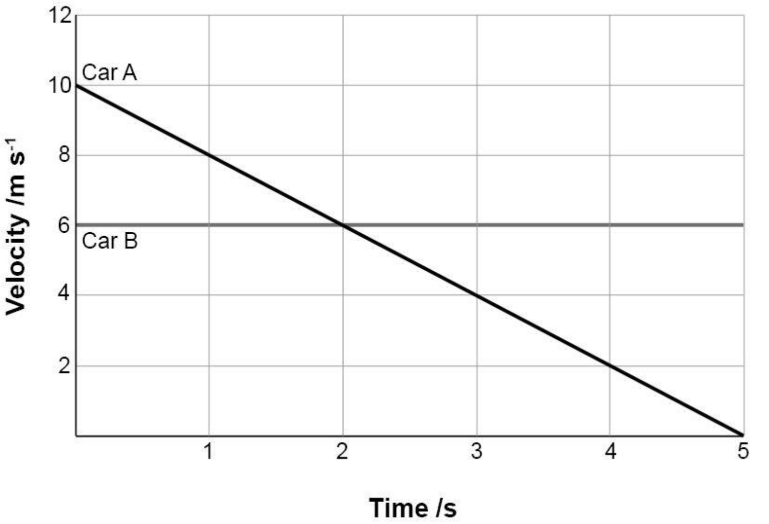
What is the maximum height reached by the ball?

A 0.3 m
B 0.8 m
C 1.3 m
D 2.5 m

Your answer

[1]

The graph below shows the velocity – time graphs of two cars.



At what time have both cars travelled the same distance since $t = 0$?

A 1.0 s

B 2.0 s

C 3.0 s

D 4.0 s

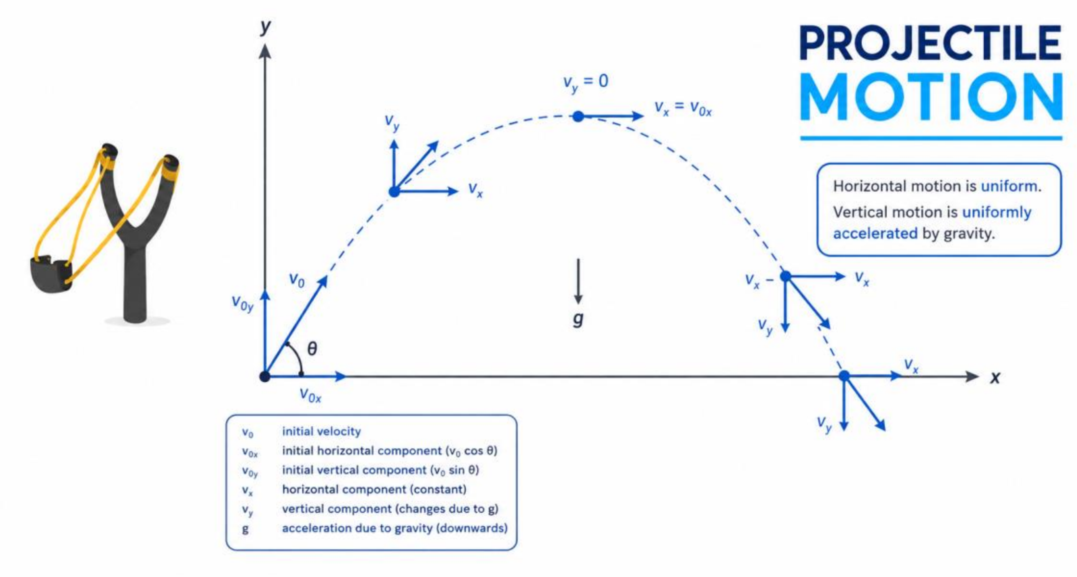
3.1.3 Projectile motion

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) independence of the vertical and horizontal motion of a projectile

(b) two-dimensional motion of a projectile with constant velocity in one direction and constant acceleration in a perpendicular direction.



All objects fall at the same rate(acceleration).

This value is $9.81 m/s^2$. Which means each second the objects falls for it gains a velocity of 9.81m/s.

Velocity (m/s)	Time(s)
0	0
	1
	2
	3
	4

Acceleration is caused by a force. When an object falls due to gravity. What force is causing this and in which direction?

How does a horizontal force being applied to an object affect the previously mentioned force?

A skydiver jumps from a plane. He has been told to pull his parachute after 10s of falling. Calculate the distance travelled by the parachutist in this time.

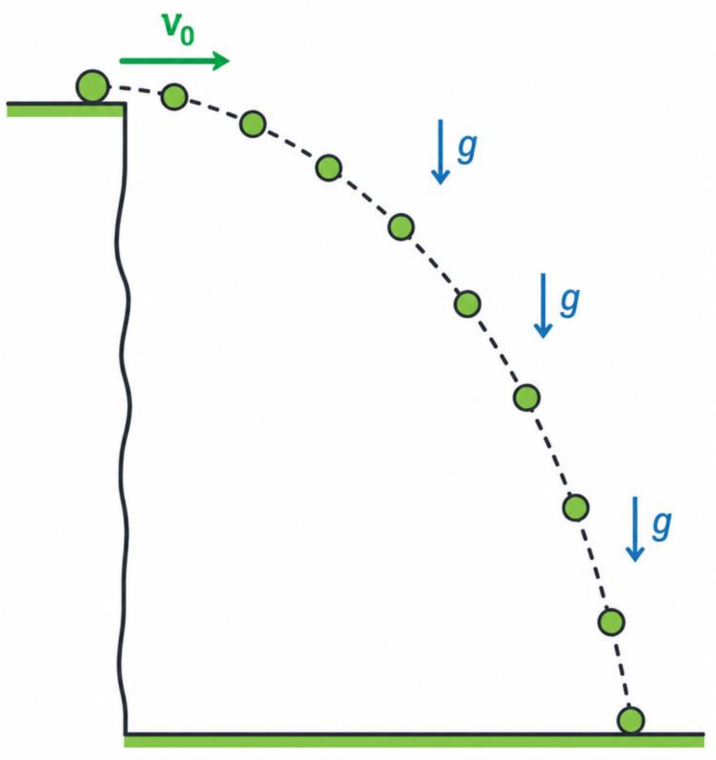
A ball is thrown vertically upwards with a velocity of 12m/s. Calculate the maximum height of the ball and the time it takes to reach that height.

KEY POINTS

If something is moving up in the air it is working against gravity, Therefore, $g= -9.81 m/s^2$.

Something moving into the air will be slowing down, this means the final velocity will eventually become 0.

The time it takes to go up will be the time it takes to come down (provided distance is the same).



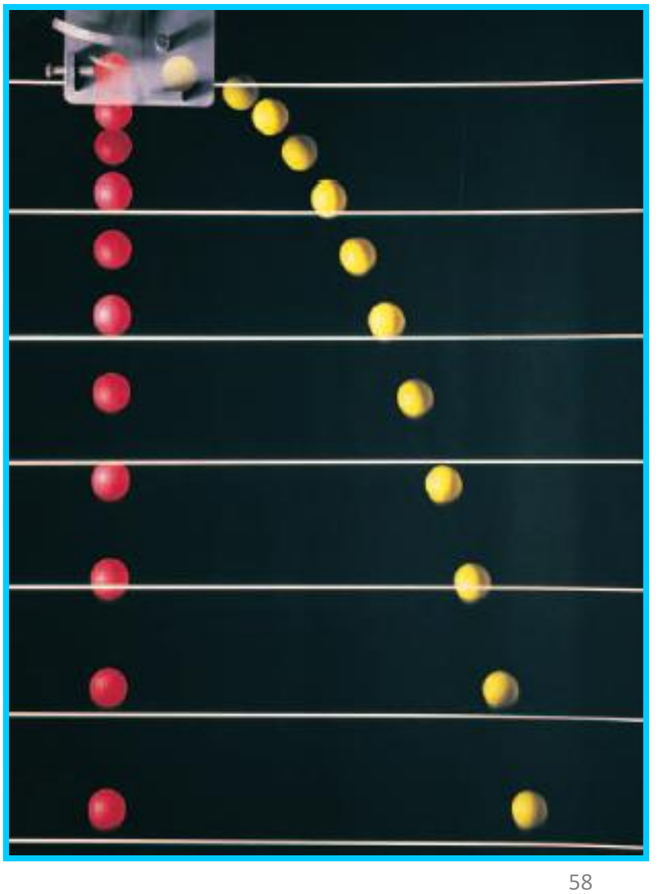
Projectile motion is free fall with an initial horizontal velocity.

There is only one force acting on the object.

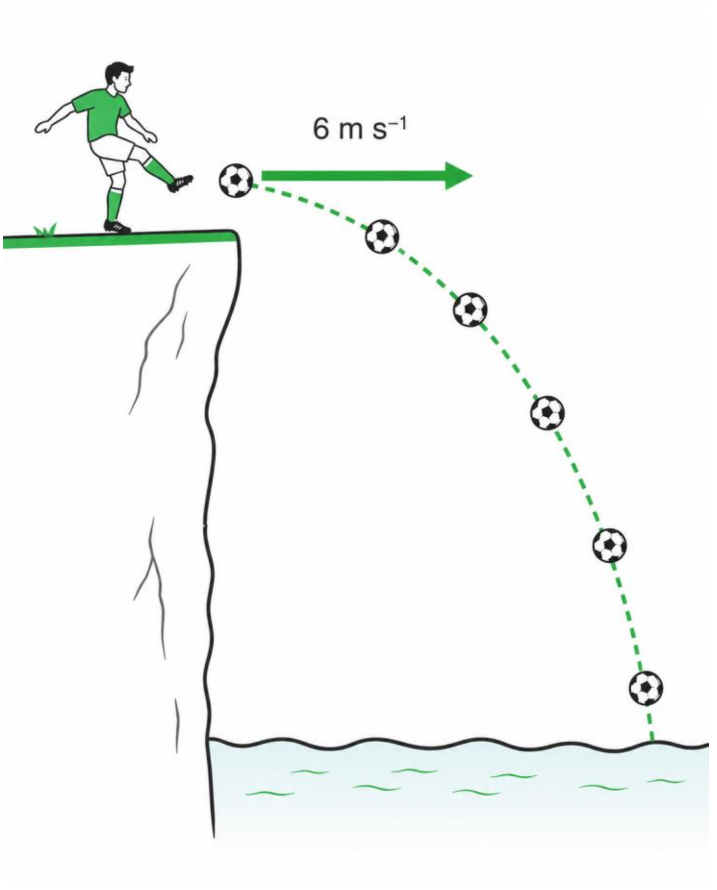
Therefore the object will not accelerate in the horizontal direction. Only downwards.

Caught by slow motion camera:

The yellow ball is given an initial horizontal velocity and the red ball is dropped. Both balls fall **at the same rate**.



Projectile example



A ball is kicked from a cliff of vertical height 30m.

Calculate

- Time taken to reach the ground
- Horizontal range of the ball

How would these values change if the ball was kicked at an angle above the horizontal?

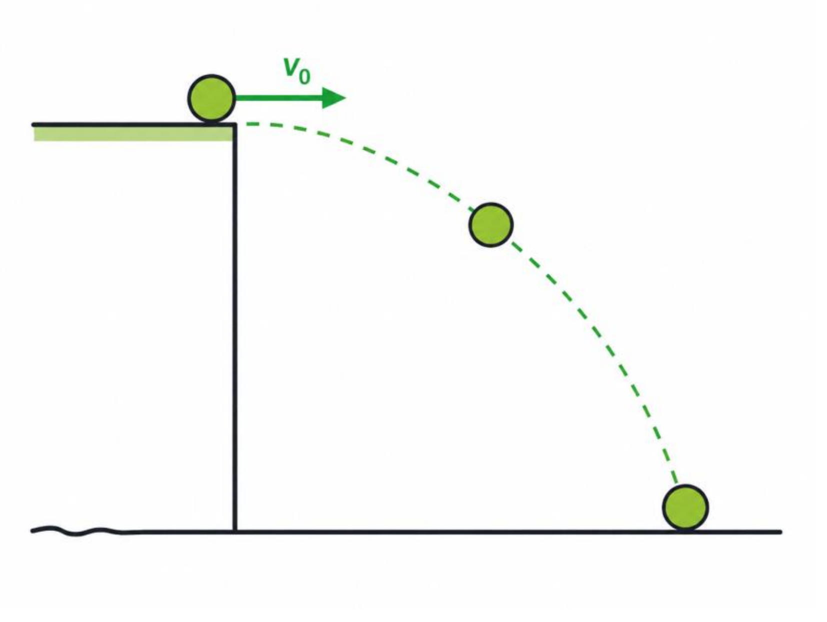
A projectile launched from the end of a cliff with initial velocity ‘u’. Which statement is correct.

A) The final horizontal velocity of the projectile is greater than ‘u’.

B) The initial vertical velocity of the projectile is also ‘u’.

C) The final horizontal velocity of the projectile is ‘u’.

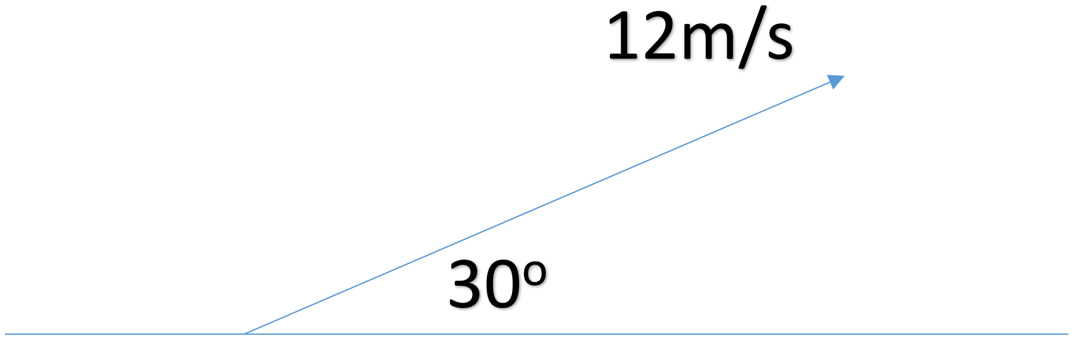
D) The projectile will increase its horizontal velocity at a rate of 9.81 m/s^2.

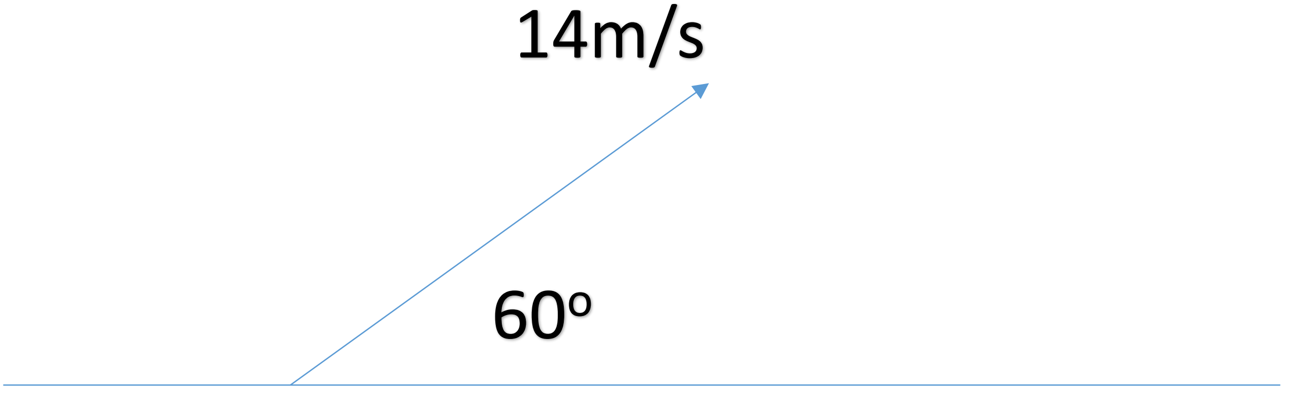


The diagram above shows a ball being hit off a cliff.
The initial horizontal velocity of the ball is measured to be 11m/s and the cliff is 120m high.

1. Explain the motion of the ball and any forces that the ball experiences throughout the journey.
2. Calculate the time taken for the ball to reach the ground.
3. Calculate the horizontal distance from where the ball lands to the base of the cliff.

Resolve these vectors into X and Y components





Projectiles (Guide)

This is the method for solving the type 3 questions:

1. Draw a diagram
2. Define upwards as the positive direction
3. Write down all the equations
4. List what you have in the horizontal direction
5. List what you have in the vertical direction
6. Gravity, $a = +/-9.81 m/s^2$, only in the vertical direction
7. Gravity, $a = 0$, in the horizontal direction
8. Highlight what you need
9. Pick the equation that you need
10. Remember that time is the same in both directions!

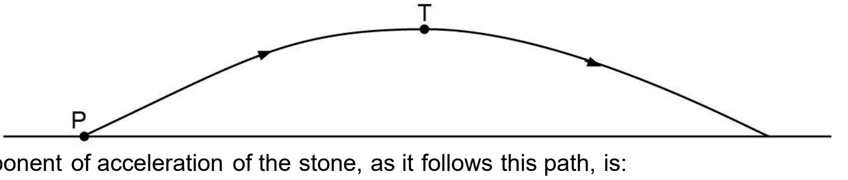
Example 1

A ball is kicked off a cliff 100m above the sea with an initial horizontal velocity of $10ms^{-1}$. Assuming that there is no air resistance, calculate the time it takes for the ball to reach the sea and the horizontal distance it travels.

Example 2

A projectile is launched at an angle of 45° to the horizontal with a velocity of 30m/s. Calculate the maximum height reached by the ball and the horizontal distance that it travels when it reaches this maximum height.

In the absence of air resistance a stone is thrown from **P** and follows a parabolic path, as shown, in which the highest point reached is **T**.



The vertical component of acceleration of the stone, as it follows this path, is:

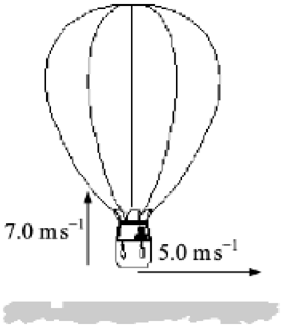
A zero at **T**

B greatest at **T**

C greatest at **P**

D The same at **P** as at **T**

When a sandbag is dropped from a balloon hovering 1.3 m above the ground, it hits the ground at 5.0 ms^{-1}.
On another occasion, the sandbag is released from the balloon which is rising at 7.0 ms^{-1} when 1.3 m above the ground. There is also a crosswind of 5.0 m s^{-1}.



At what speed does the sandbag hit the ground?

A. 2.0 ms^{-1}

B. 5.4 ms^{-1}

C. 10 ms^{-1}

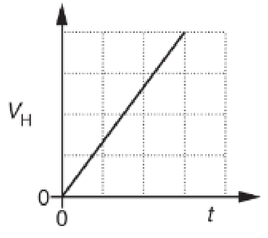
D. 13 ms^{-1}

Your answer

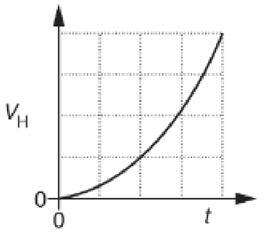
A projectile is fired in a horizontal direction at time $t = 0$.
Ignore air resistance.

Which graph correctly shows the horizontal component of the velocity V_H of the projectile against time t?

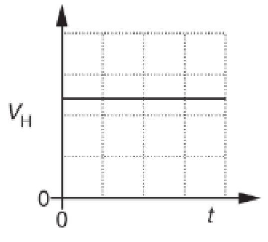
A



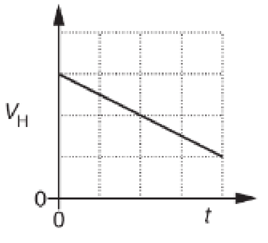
C



B



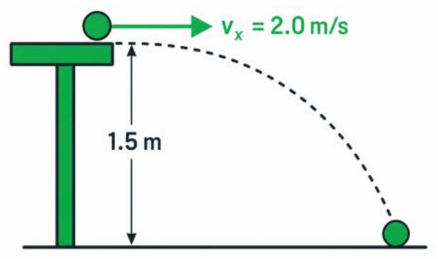
D



A golf ball is struck horizontally from a 200m high cliff at 12m/s. Calculate the time taken to reach the ground and the distance travelled by the ball.

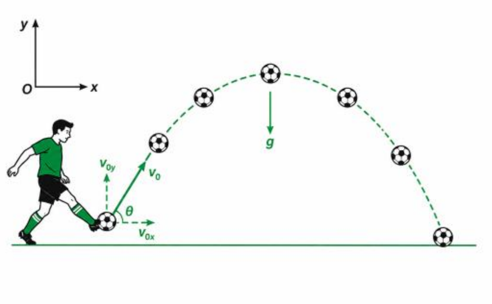
A projectile is launched from the ground at an angle of 30° to the horizontal with a velocity of 20m/s. Calculate the horizontal distance it travels before it hits the ground again.

Starting



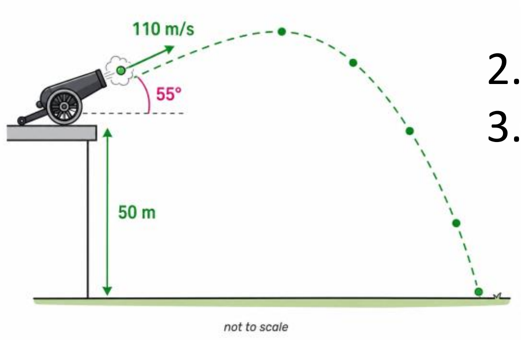
1. Calculate the flight time and range of this projectile.
2. State the final horizontal velocity of the projectile.

Securing



1. Assuming the ball leaves the players foot at 19m/s at an angle of 35°. Calculate the total flight time and range of this projectile.
2. Describe the shape of the path the projectile takes.

Extending



1. Calculate the total flight time of the projectile.
2. Calculate the range of the projectile.
3. Calculate the final velocity of the projectile including the angle at which the projectile enters the ground.

TIP: Find the vertical and horizontal final velocities to do this.

Challenging

Explain why the horizontal velocity of a projectile remains constant throughout its journey.

Using equations of motion and ideas of projectile motion, show that:

$$x \propto u^2$$

Here x is the horizontal distance travelled by a projectile and u is the initial velocity. Assume the projectile travels in a similar way to the securing question of this worksheet.

Note: State any and all assumptions make in your answers.

Starting

A child throws a ball vertically upwards, then catches it again. Taking the initial velocity to be $10\ \mathrm{ms^{-1}}$, g to be $9.8\ \mathrm{ms^{-2}}$ and ignoring the effects of air resistance, calculate:

a) The time of flight of the ball.

b) The maximum height it reaches above the ground.

Securing

A tennis ball is dropped from height h, and bounces so that the speed immediately after each bounce is half the speed just before the bounce.

Sketch the following, treating the upward direction as positive:

a) A velocity-time graph for the first 3 bounces

b) A displacement-time graph for the first 3 bounces.

Extending

A netball player of height 1.6 m makes a pass to their 1.4 m tall teammate. Assuming the first player makes the throw at 3.5 $\mathrm{ms^{-1}}$, and the second player catches the ball calculate the separation of the two players if:

a) The ball does not bounce.

b) The ball bounces once, having a vertical velocity 80 % of the impact velocity.

Challenging

During the Apollo 14 mission, Alan Shepard became the first human to play golf on another astronomical body. The golf ball he hit left the lunar surface with a velocity of 40 $\mathrm{ms^{-1}}$, at an angle of 40^{o} to the vertical, and landed in the Daedalus crater at a depth of $3.0\ \mathrm{km}$. Lunar g is 16% of that on earth, and the shot was made 300 m from the lip of the crater.

Calculate:

a) The range of the shot.

b) The velocity of the ball when it lands.

c) The maximum height of the ball above the lunar surface.

Fig. 4.1 shows the path of a tennis ball after bouncing on the ground at **A** and hitting a vertical wall at **B**.

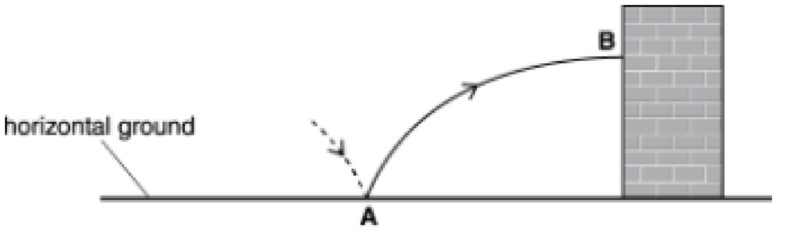


Fig. 4.1

The ball is travelling horizontally as it hits the wall at B. Air resistance has negligible effect on the motion of the ball.

i. Explain why the horizontal component of the velocity of the ball remains constant as it moves from **A** to **B**.

-- **[1]**
----

ii. The ball loses some of its kinetic energy when it hits the wall at **B**. It leaves the wall horizontally.

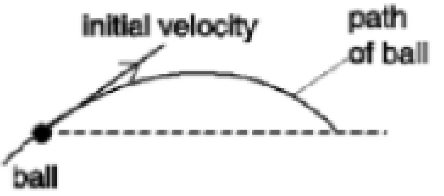
1. On Fig. 4.1, sketch the path of the ball between bouncing at the wall and hitting the ground.

2. Explain how the time taken for the ball to travel from **A** to **B** compares with the time it takes to travel from **B** to the ground.

----

[3]

A ball is thrown with an initial velocity at an angle to the horizontal.



Sketch a graph to show the variation of vertical acceleration against time for the ball.

A ball is launched horizontally at 5 m s^{-1} from the end of a table. The ball is in flight for 0.4 s before it lands on the floor. The ball is now launched from the end of the same table with a horizontal velocity 10 m s^{-1}.

What is the new time of flight of the ball?

A. 0.2 s

B. 0.4 s

C. 0.5 s

D. 0.8 s

Your answer

Fig. 2.1 shows the path of a golf ball which is struck at point **F** on the fairway landing at point **G** on the green. The effect of air resistance is negligible.

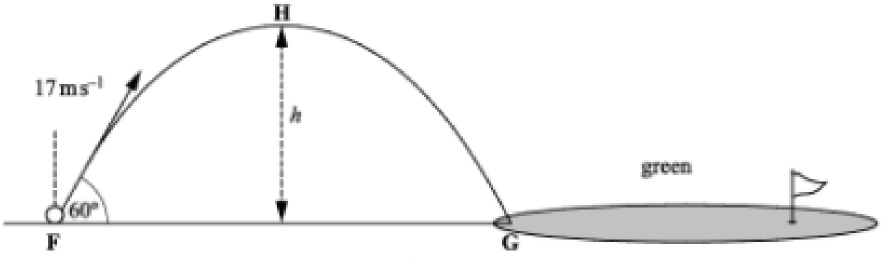


Fig. 2.1

The ball leaves the club at 17 m s^{-1} at an angle of 60° to the horizontal at time t = 0.

Show that the speed of the ball at the highest point **H** of the trajectory is between 8 and 9 m s^{-1}.

speed = ______________________ m s^{-1} **[2]**

Suppose the same golfer standing at **F** had hit the ball with the same speed but at an angle of 30° to the horizontal. See **Fig. 2.2**.

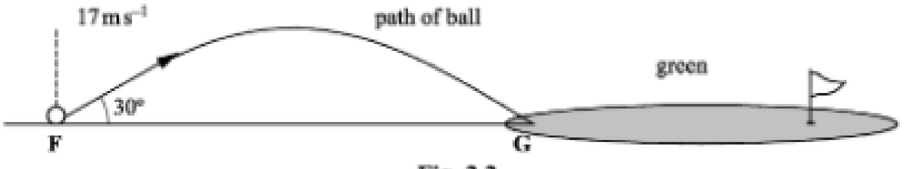


Fig. 2.2

Show that the ball would still land at G.

[3]

Additional note space

CONSOLIDATION QUESTIONS

Answer all questions. Show your working clearly.

1 Scalars and vectors

(a) For each of the following quantities, state whether it is a scalar or a vector.

(i) speed

(ii) displacement

(iii) force

(iv) temperature

(v) momentum

(vi) density

(b) Write down a vector quantity that has the same magnitude but opposite direction to each of the following.

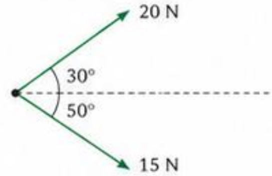
(i) 12 N upwards

(ii) 4.5 m due east

(iii) 7.0 m s^{-1} south-west

2 Vector addition and subtraction

(a) Two forces act on a particle as shown.



Find the magnitude and direction of the resultant force.

(b) A boat moves due east at 6.0 m s^{-1} in still water. The river flows due north at 3.0 m s^{-1}.

(i) Find the speed and direction of the resultant velocity of the boat relative to the river bank.

(ii) If the boat's engine is adjusted so that it now travels due north relative to the river bank, what should the speed and direction of the boat be relative to the water?

3 Vector triangles

Use a scale diagram to find the resultant of the following pairs of coplanar vectors.

(a) $A = 8.0$ N due north, $B = 6.0$ N due east

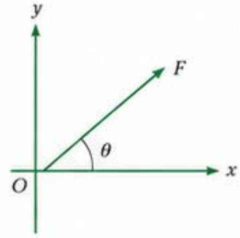
(b) $A = 12$ N at 30° east of north,
$B = 9.0$ N at 20° south of east

(c) $A = 15$ N due west, $B = 10$ N at 60° north of west

Measure the magnitude and direction of the resultant in each case.

4 Resolving vectors

Resolve the following vectors into components parallel to the x-axis and y-axis.



(a) $F = 25$ N at 40° above the x-axis

(b) $F = 18$ N at 135° to the positive x-axis

(c) $F = 30$ N at 20° west of south

5 Kinematics – calculations

(a) A car accelerates uniformly from rest at 2.5 ms^{-2} for 12 s. Find its final velocity and the distance travelled.

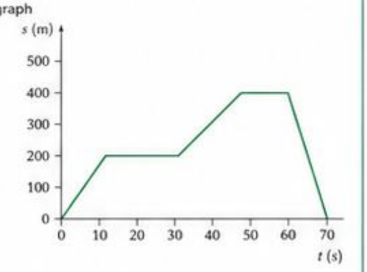
(b) A train travelling at 28 ms^{-1} is uniformly decelerated at 0.7 ms^{-2} to rest. Find the time taken and the distance travelled.

(c) A sprinter runs 100 m in 10.5 s. If her acceleration is uniform for the first 60 m and zero for the rest, find her acceleration and top speed.

(d) A particle moves with uniform acceleration. It is at rest at $t = 0$. Its velocity is 16 ms^{-1} at $t = 6$ s. Find its displacement at $t = 6$ s.

6 Displacement–time graphs

The graph shows the displacement–time graph of a cyclist.



(a) Find the cyclist's velocity during

(i) 0 to 10 s

(ii) 10 to 30 s

(iii) 30 to 50 s

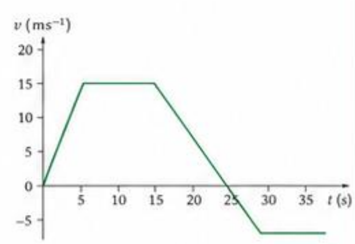
(iv) 50 to 70 s

(b) When is the cyclist stationary?

(c) What is the total distance travelled by the cyclist?

7 Velocity–time graphs

The graph shows the velocity–time graph of a particle.



(a) Find the acceleration during

(i) 0 to 5 s

(ii) 5 to 15 s

(iii) 15 to 25 s

(iv) 25 to 35 s

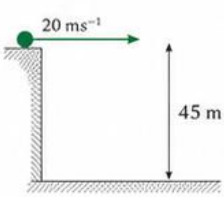
(b) Calculate the displacement of the particle in the first 35 s.

8 Projectile motion

(a) A ball is projected horizontally from a cliff top 45 m above level ground with a speed of 20 ms^{-1}.

(i) Find the time taken to hit the ground.

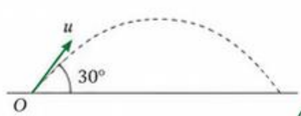
(ii) Find the horizontal distance from the foot of the cliff where the ball lands.



(b) A projectile is fired from level ground with speed u at an angle of 30° above the horizontal.

(i) Find the time of flight in terms of u.

(ii) Find the maximum height reached in terms of u.



Final specification self-check

Read each statement and tick the box that best matches how confident you feel.

2.3.1 Scalars and vectors

	Statement	Not yet	Nearly there	Confident
1	I can distinguish between scalar and vector quantities.	☐	☐	☐
2	I can add and subtract vectors.	☐	☐	☐
3	I can use a vector triangle to find the resultant of two coplanar vectors.	☐	☐	☐
4	I can resolve a vector into perpendicular components using $F_x = F\cos\theta$ and $F_y = F\sin\theta$.	☐	☐	☐

3.1.1 Kinematics

	Statement	Not yet	Nearly there	Confident
1	I understand displacement, instantaneous speed, average speed, velocity and acceleration.	☐	☐	☐
2	I can interpret graphical representations of displacement, speed, velocity and acceleration.	☐	☐	☐
3	I know that on a displacement–time graph, velocity is the gradient.	☐	☐	☐
4	I know that on a velocity–time graph, acceleration is the gradient and displacement is the area under the graph.	☐	☐	☐

3.1.3 Projectile motion

	Statement	Not yet	Nearly there	Confident
1	I understand that the vertical and horizontal motion of a projectile are independent.	☐	☐	☐
2	I can describe projectile motion as constant velocity in one direction and constant acceleration in a perpendicular direction.	☐	☐	☐

My next steps

Which area should I revise first? ______________________________

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Use this page to identify the areas you should revisit before moving on.

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