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PROVINCE OF KWAZULU-NATAL



CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)



LEARNER SUPPORT DOCUMENT

GRADE 11

PHYSICAL SCIENCES

STEP AHEAD PROGRAMME

2022

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PREFACE

This support document serves to assist Physical Sciences learners on how to deal with curriculum gaps and learning losses because of the impact of COVID-19 in 2021. It also addresses the challenging topics in the Grade 11 curriculum in Term 1 and Term 2.

Activities serve as a guide on how various topics are assessed at different cognitive levels and preparing learners for informal and formal tasks in Physical Sciences. It covers the following topics:

No.	Topic	Page
1.	Newton's Laws	03
2.	Atomic combinations	24
3.	Vectors and Scalars	32
4.	Electrostatics	55
5.	Quantitative Aspects of Chemical Change	74



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PHYSICAL SCIENCES GRADE 11 TERM 1

NEWTON'S LAWS OF MOTION

FORCES

A force is a push or a pull action exerted on an object. This action can be exerted while objects are in contact (contact force) or over a distance (non-contact force).

Because forces have magnitude and direction, they are vectors. Force is measured in Newton (N). 1 N is the force required to accelerate a 1 kg object at 1 $m \cdot s^{-2}$ in the direction of the force. We can therefore say that 1 N = 1 $kg \cdot m \cdot s^{-2}$.

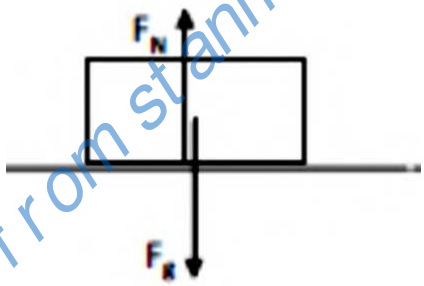
Non-contact force: A force exerted between objects over a distance without physical contact.	**Contact force:** A force exerted between objects that are in contact with each other.
Electrostatic force	Applied force (F_A)
Gravitational force (W/F_g)	Tension (T or F_T)
Magnetic force	Friction (F_f or f_s/f_k)
	Normal force (N/F_N)

Normal force (F_N)

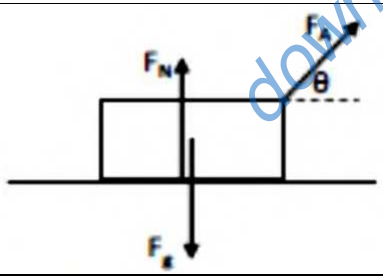
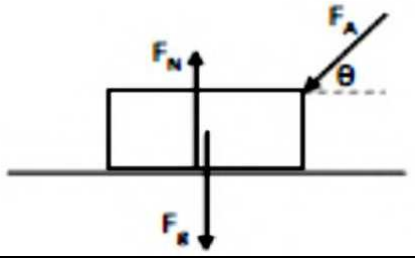
The perpendicular force exerted by a surface on an object in contact with it.

The normal force is equal to the **perpendicular component** of gravity **if there are no other forces acting on the object**.

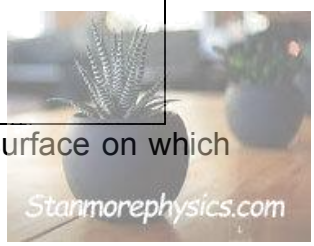
$F_N = F_g$



If alternative forces act on the object, the normal force will change depending on the direction and magnitude of the applied force.

	
$F_N + F_{Ay} + F_g = 0$ $F_N + F_A \sin\theta = F_g$	$F_N + F_{Ay} + F_g = 0$ $F_N = F_g + F_A \sin\theta$

Objects suspended from a rope/string/cable have no normal force, as there is no surface on which the object rests.



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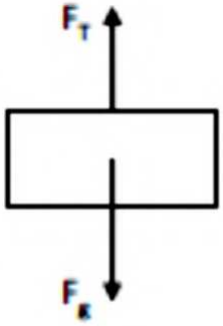
The tension is equal to the **perpendicular component** of gravity **if there are no other forces acting on the object**.

$F_T = F_g$



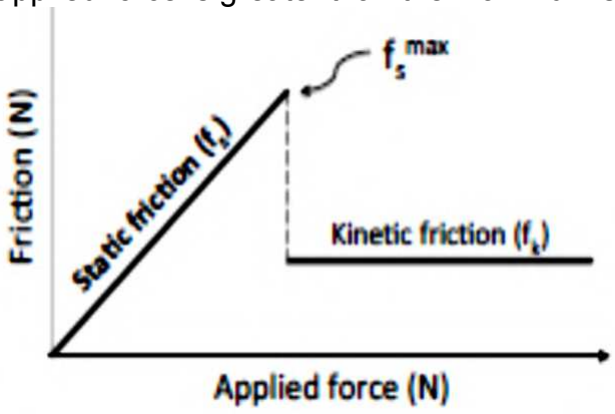
Friction (F_f or f_s/f_k)

Frictional force due to a surface is the force that opposes the motion of an object in contact with it.

Friction is the parallel component of the contact force on an object by the surface on which it rests. The friction between the surfaces in contact is determined by the properties of that surface. The coefficient of friction (μ_s/μ_k) is a description of the roughness of the surface. The rougher the surface, the greater the coefficient of friction.

Static friction (f_s)	**Kinetic friction (f_k)**
Static friction is the **frictional force on a stationary object that opposes the tendency of motion of the object**. The magnitude of the static friction will increase as the parallel component of the applied force is increased, until maximum static friction is reached. f_s^{max} is the magnitude of friction when the object just starts to move.	Kinetic friction is the **frictional force on a moving object that opposes the motion of the object**. The magnitude of the kinetic friction is constant for the specific system at all velocities greater than zero, and irrespective of the applied force.
$f_s^{max} = \mu_s F_N$	$f_k = \mu_k F_N$

If the applied force is greater than the maximum static friction, the object will start to move.



Newton's First Law of Motion

An object continues in a state of rest or uniform (moving with constant) velocity unless it is acted upon by a net or resultant force.

Newton's First Law is due to inertia- the resistance of an object to change its state of rest of motion.

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$F_{net} = 0$ N $\qquad\qquad$ $a = 0\ m \cdot s^{-2}$

Importance of wearing safety belts:
According to Newton's First Law, an object will remain in motion at a constant velocity unless a non-zero resultant force acts upon it. When a car is in an accident and comes to a sudden stop, the person inside the car will continue with a constant forward velocity. Without a safety belt, the person will make contact with the windscreen of the car, causing severe head trauma. The safety belt acts as an applied force, preventing the forward motion of the person.

A 3kg object moves up an incline surface at an angle of 15º with a constant velocity. The coefficient of friction is 0,35. Determine the magnitude of the applied force.

Take downwards as positive

$F_{net\perp} = 0$

$F_N + F_{g\perp} = 0$

$F_N = - F_{g\perp}$

$F_N = - mg\cos\theta$

$F_N = - (3)(9,8)\cos 15^o$

$F_N = - 28,40$ N

$\therefore F_N = 28,40$ N up the slope

$F_{net//} = 0$

$F_A + F_{g//} + f_k = 0$

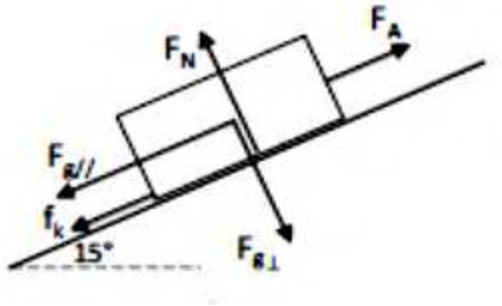
$F_A + mg\sin\theta + \mu_K F_N = 0$

$F_A = - mg\sin\theta - \mu_K F_N$

$F_A = - (3)(9,8)\sin 15^o - (0,35)(28,40)$

$F_A = - 17,55$ N

$\therefore F_A = 17,55$ N



Newton's Second Law of Motion
When a net force is applied to an object of mass, it accelerates in the direction of the net force. The acceleration is directly proportional to the net force and inversely proportional to the mass.

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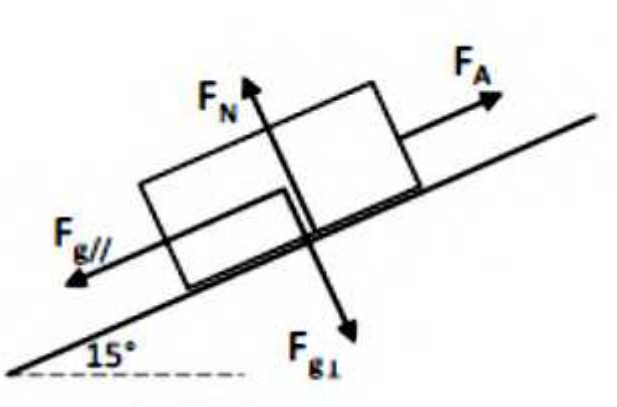
Newton's Second Law is dependent on the resultant force-The vector sum of all forces acting on the same object.

$F_{net} = ma$ $a \neq 0\ m \cdot s^{-2}$

A 20 N force is applied to a 5 kg object. The object accelerates up a frictionless incline surface at an angle of 15º. Determine the acceleration of the object.



Take upwards as positive

$F_{net//} = ma$

$F_A + F_{g// k} = ma$

$20\ (5)(-9,8)\sin 15^o = 5a$

$20 - 12,68 = 5a$

$A = 1,46\ m \cdot s^{-2}$ up the slope

Effect of Newton's Second Law on overloading:
According to Newton's Second Law, the acceleration of an object is directly proportional to the applied force and inversely proportional to the mass of the object. If a vehicle is overloaded, the stopping distance will increase which can lead to serious accidents.
When brakes are applied, the force (friction) remains the same, but the increase in mass causes a decrease in negative acceleration, increasing the time (and distance) it takes for the vehicle to stop.

Newton's Third Law of Motion
When object A exerts a force on object B, object B simultaneously exerts an oppositely directed force of equal magnitude on object A.

Newton's Third Law describes action-reaction force pairs. These are forces on different objects and cannot be added or subtracted.

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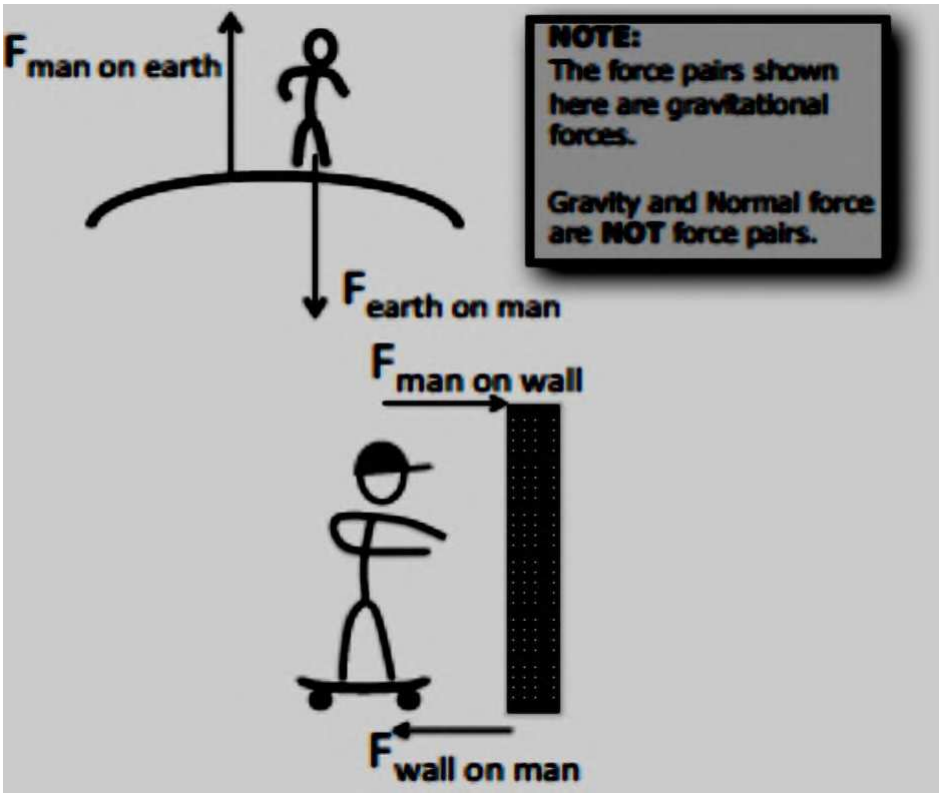
$F_{A \text{ on } B} = F_{B \text{ on } A}$

Newton Force Pairs Properties:

- Equal in magnitude
- Opposite in direction
- Acts on different objects (and therefore **DO NOT CANCEL** each other out)

Newton's Third Law during an accident

According to Newton's Third Law, the force that two objects exert on each other is equal in magnitude but opposite in direction. If two cars are in an accident, they will both exert the same amount of force on each other irrespective of their masses.



NEWTON'S LAWS OF MOTION - APPLICATION

1. Objects Moving Horizontally

The vertical resultant = 0 N.
The horizontal resultant determines acceleration.

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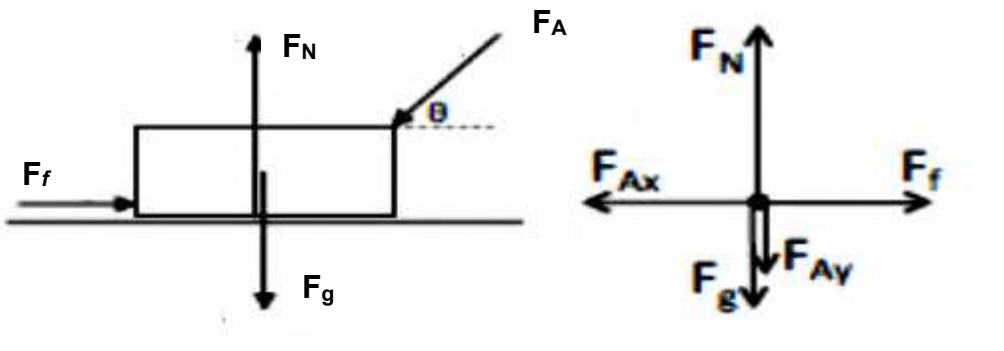
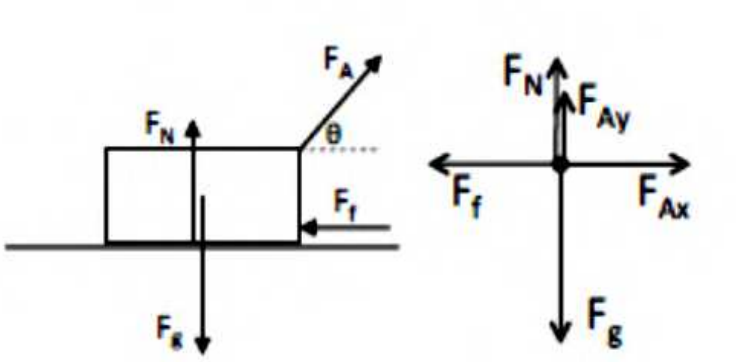
1.1 Pushed at an angle



Horizontal:	**Vertical:**
$F_{net} = ma$	$F_{net} = 0$
$F_{Ax} + (-F_f) = ma$	$F_g + (-F_N) + F_{Ay} = 0$

1.2 Pulled at an angle



Horizontal:	**Vertical:**
$F_{net} = ma$	$F_{net} = 0$
$F_{Ax} + (-F_f) = ma$	$(-F_g) + F_N + F_{Ay} = 0$

2. Object Moving on Slopes or Inclined Planes

The perpendicular (⊥) resultant = 0 N.
The parallel (//) resultant determines acceleration.
REMEMBER: Use components of weight.

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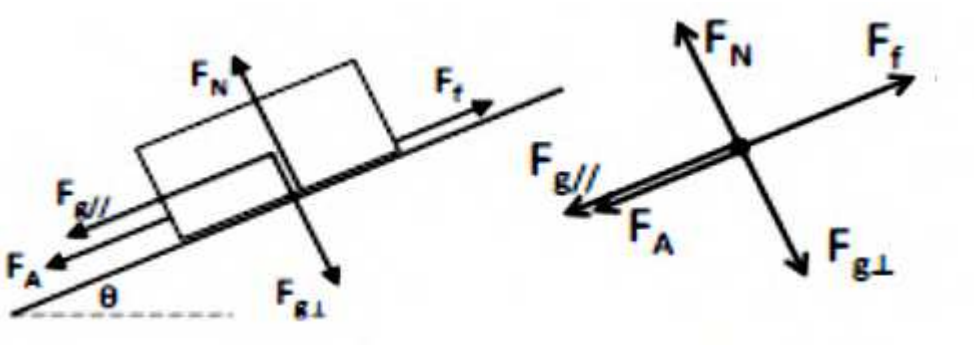
2.1 Force applied down the slope



Parallel:

$F_{net} = ma$

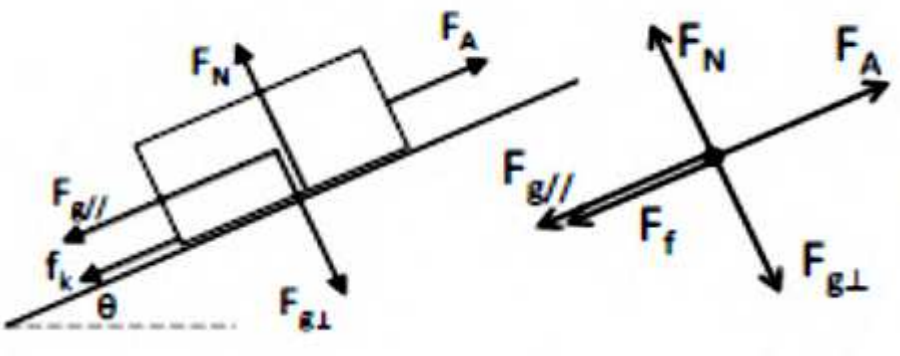
$F_{g//} + F_N + (-F_f) = ma$

Perpendicular:

$F_{net} = 0$

$F_{g\perp} + (-F_N) = 0$

2.2 Force applied up the slope



Parallel:

$F_{net} = ma$

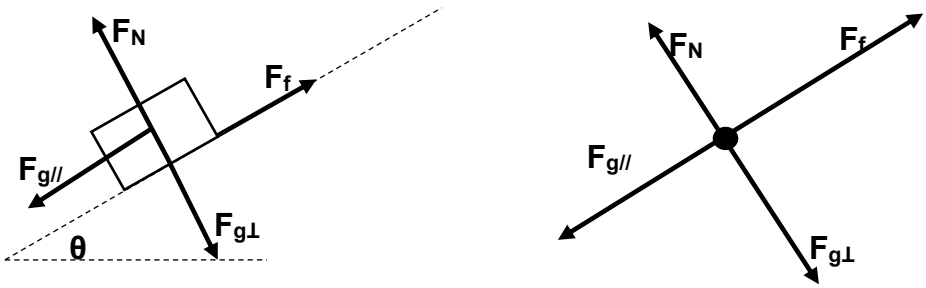
$(-F_{g//}) + F_A + (-F_f) = ma$

Perpendicular:

$F_{net} = 0$

$F_{g\perp} + (-F_N) = 0$

2.3 No force applied



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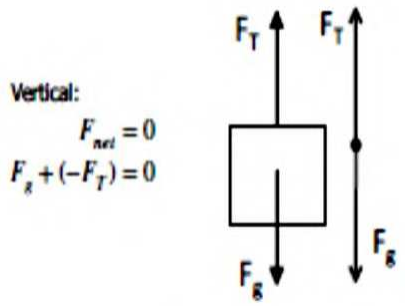
Parallel:	**Perpendicular:**
$F_{net} = ma$	$F_{net} = 0$
$(-F_{g//}) + (-F_f) = ma$	$F_{g\perp} + (-F_N) = 0$

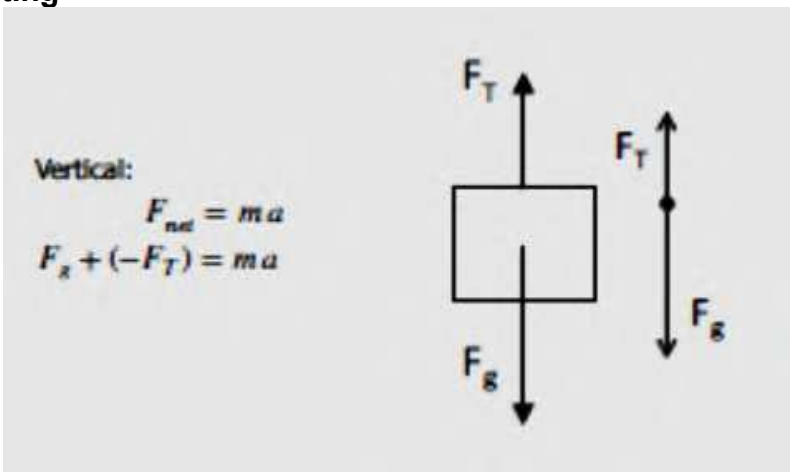
3. Objects Suspended by Strings/Cords

3.1 Lift stationary/constant velocity

Horizontal resultant = 0 N.
Vertical resultant determines acceleration.
REMEMBER: No normal or friction forces.

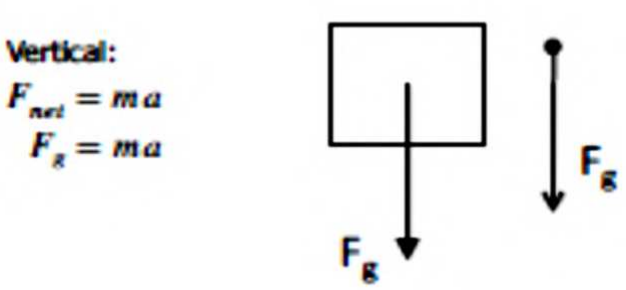


3.2 Lift accelerating



Acceleration will be in the direction of the greatest force.

3.3 Lift in freefall (cable snap)



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4. Connected objects

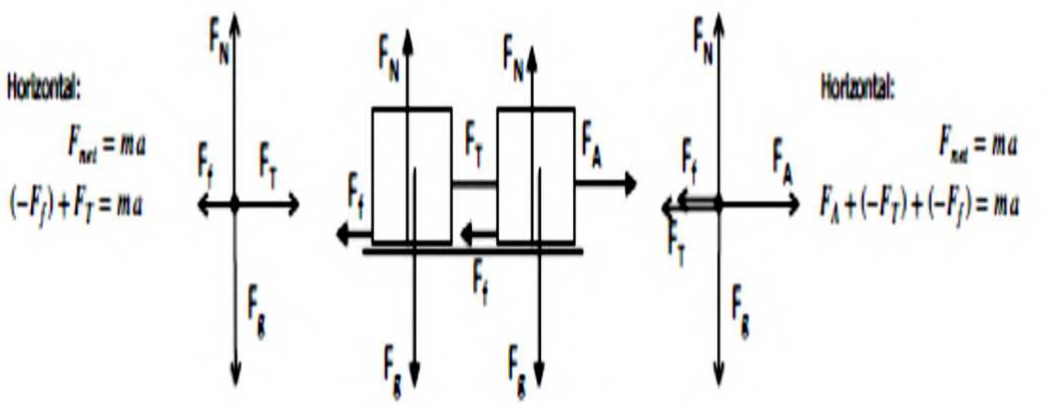
Do separate free body diagrams for each object.
The velocity and acceleration of all objects are equal in magnitude and direction.
Applied forces are applied to only one object at a time.
Simultaneous equations for acceleration and tension are sometimes needed.

REMEMBER:
Ropes/cables- The tension forces on the objects are the same in magnitude but opposite in direction.
Touching objects- Newton's Third Law

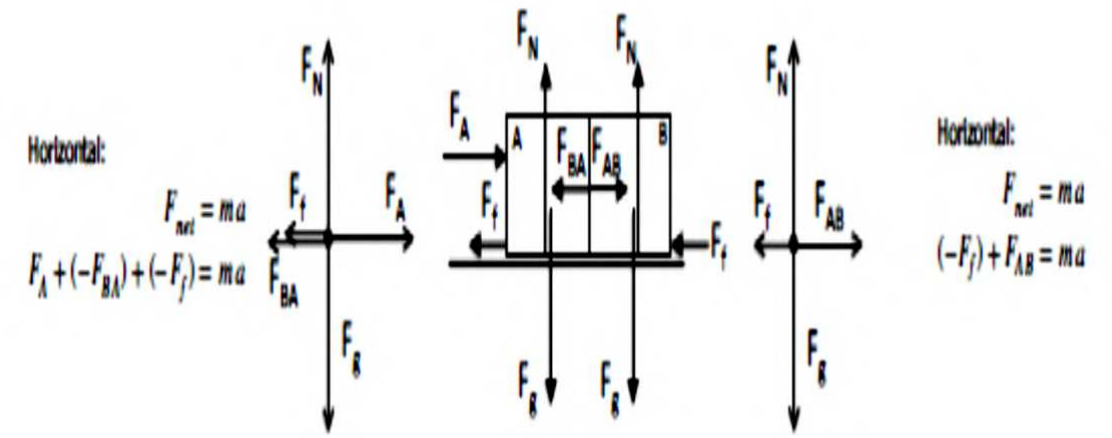
4.1 Same axis

Can be horizontal (multiple objects on a surface) or vertical (multiple suspended objects).
The velocity and acceleration of all objects are equal in magnitude and direction.

4.1.1 Objects attached by rope/cable



4.1.2 Objects in contact



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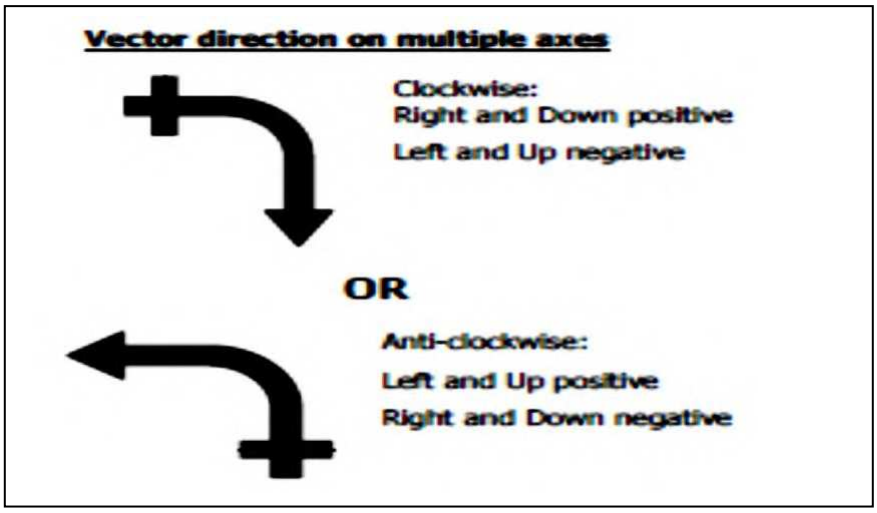
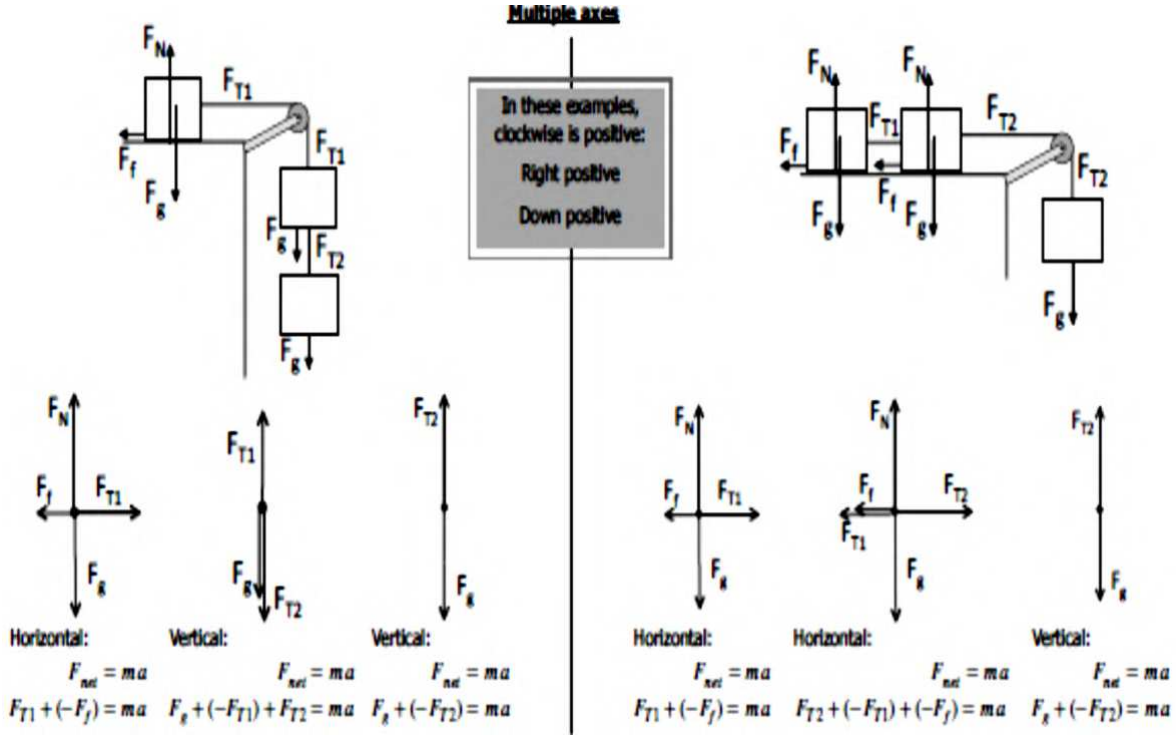
4.2 Multiple axes

Horizontal (objects on a surface) **AND** vertical (suspended objects).



The velocity and acceleration of all objects are equal in magnitude NOT DIRECTION.



Universal Law of Gravitation

Every particle in the universe attracts every other particle with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres (or between them).

OR

Every body in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

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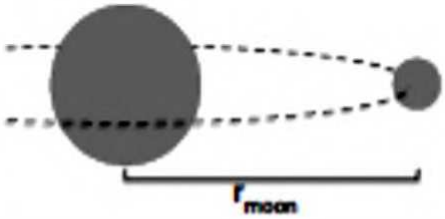
$$F = \frac{Gm_1m_2}{r^2}$$

F = force of attraction between objects (N)
G = universal gravitational constant ($6,7 \times 10^{-11}$ N·m²·kg⁻²)
m = object mass (kg)
r = distance between object centers (m)

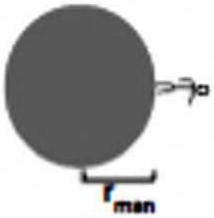
A uniform sphere of matter attracts a body that is outside the shell as if all the sphere's mass was concentrated at its centre.



Thus, the distance is determined between the centres of the two bodies.



NOTE:
The radius of the earth is added to the distance between the earth and the moon.



NOTE:
The radius of object (man) on the earth is negligibly small.

KNOW THE DIFFERENCE!

g vs G

g: Gravitational acceleration (9,8 m·s^{-2} on Earth)
g is the acceleration due to gravity on a specific planet.
G: Universal gravitational constant ($6,7 \times 10^{-11}$ N·m^2·kg^{-2}) , proportionality constant which applies everywhere in the universe.

Mass vs Weight

Mass (kg)
A scalar quantity of matter which remains constant everywhere in the universe.
Weight (N)
Weight is the gravitational force the Earth exerts on any object. Weight differs from planet to planet. F_g = mg. Weight is a vector quantity.

RATIOS

1. Write out the original formula.
2. Manipulate unknown as subject.
3. Substitute changes into formula (Keep symbols!).
4. Simplify ratio number.

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5. Replace original formula with unknown symbol.

EXAMPLE:

Two objects, m_1 and m_2, are a distance r apart and experience a force F. How would this force be affected if:

a) One mass is doubled and the distance between the masses is halved?

$$F = \frac{Gm_1m_2}{r^2}$$ Write out the formula

$$= \frac{G(2m_1)m_2}{(\frac{1}{2}r)^2}$$ Substitute changes into formula

$$= \frac{2\,Gm_1m_2}{\frac{1}{4}\,r^2}$$ Simplify ratio number

$$= 8\left(\frac{Gm_1m_2}{r^2}\right)$$

$$\therefore F_{new} = 8\,F$$ Replace original formula

b) Both the two masses as well as the distance are doubled?

$$F = \frac{Gm_1m_2}{r^2}$$ Write out the formula

$$= \frac{G(2m_1)(2m_2)}{(2r)^2}$$ Substitute changes into formula

$$= \frac{4\,Gm_1m_2}{4\,r^2}$$ Simplify ratio number

$$= 1\left(\frac{Gm_1m_2}{r^2}\right)$$

$$\therefore F_{new} = 1\,F$$ Replace original formula

DETERMINING GRAVITATIONAL ACCELERATION (g)

$$F = m_{object}g \quad \text{and} \quad F = \frac{Gm_{object}m_{planet}}{r^2_{planet}}$$

$$m_o g = \frac{Gm_o m_p}{r_p^2}$$

$$g = \frac{G\cancel{m_o}m_p}{\cancel{m_o}r_p^2}$$

$$\therefore g = \frac{Gm_p}{r_p^2}$$

Therefore, the gravitational acceleration of an object only depends on the mass and radius of the planet. **Object mass is irrelevant!**

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EXAMPLE:
The Earth with a radius of 6,38 x 10^3 km is 149,6 x 10^6 km away from the sun with a radius of 696 342 km. If the Earth has a mass of 5,97 x 10^{24} kg and the sun has a mass of 1,99 x 10^{30} kg, determine the force between the two bodies.

$$r = 6{,}38 \times 10^3 \text{ km} + 149{,}6 \times 10^6 \text{ km} + 696\ 342 \text{ km}$$
$$= 6{,}38 \times 10^6 \text{ m} + 149{,}6 \times 10^9 \text{ m} + 696\ 342 \times 10^3 \text{ m}$$
$$= 1{,}5 \times 10^{11} \text{ m}$$

$$F = \frac{Gm_1m_2}{r^2}$$
$$F = \frac{6{,}7 \times 10^{-11}(5{,}97 \times 10^{24})(1{,}99 \times 10^{30})}{(1{,}50 \times 10^{11})^2}$$
$$F = 3{,}54 \times 10^{22} \text{ N attraction}$$

The force of gravitational attraction is a vector, therefore all vector rules can be applied:
• Direction specific
• Can be added or subtracted



Take right as positive:

$$F_{net\ on\ satellite} = F_{m\ on\ s} + F_{e\ on\ s}$$
$$= -\left(\frac{Gm_m m_s}{r_{ms}^2}\right) + \left(\frac{Gm_e m_s}{r_{es}^2}\right)$$



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ACTIVITIES

EXAMINATION TYPE QUESTIONS

Various options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 E.

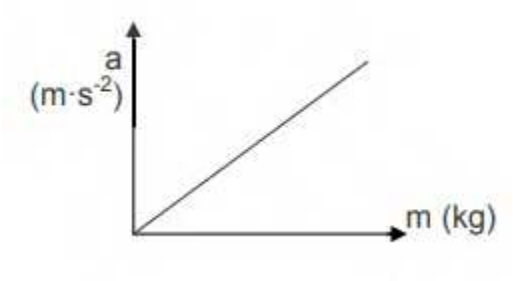
1.1 Which ONE of the following statements regarding inertia of an object is CORRECT?

The inertia of an object …

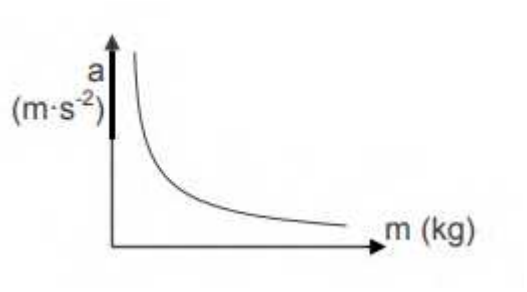
A is the resistance to any change in its state of motion.
B increases as the frictional force on the object increases.
C increases as the applied force on the object increases.
D B C D is greater if its mass is smaller. (2)

1.2 Which ONE of the following graphs represents the relationship between acceleration and mass of an object if a constant net force acts on it?

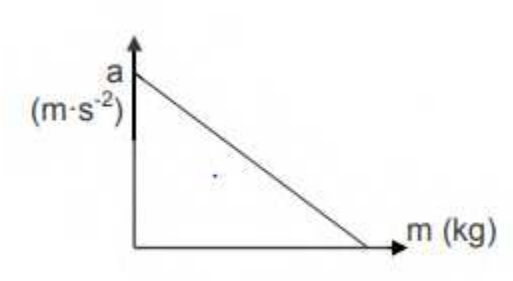
A



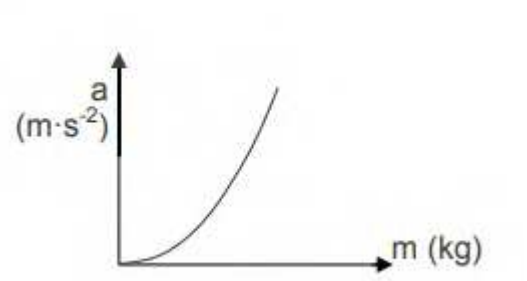
B



C



D



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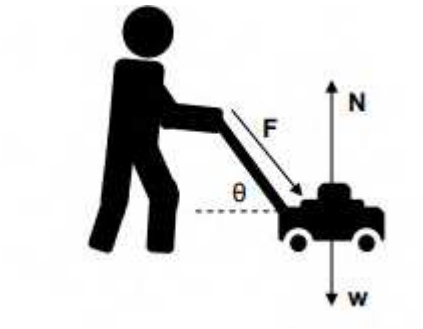
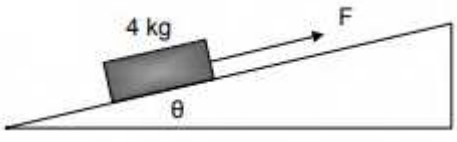
1.3 A lawnmower is pushed across the ground with a force of F at an angle of θ with the horizontal. The weight of the lawnmower is w



The normal force, in N, on the lawnmower is … A B C D

A w
B $w + F_X$
C $w - F_Y$
D $w + F_Y$ (2)

1.4 A block with a mass of 4 kg is pulled upwards along a frictionless slope, inclined at an angle θ, with a force F, as shown in the sketch below.



Which ONE of the following equations can be used to calculate the magnitude of the normal force (N)?

A N = (4) (9,8) Cos θ
B N = F + (4) (9,8) Cos θ
C N = F - (4) (9,8) Cos θ
D N = (4) (9,8) Sin θ (2)

1.5 A free-moving block slides down an inclined plane at a CONSTANT VELOCITY. This means that the …

A component of weight parallel to the plane is greater than the frictional force
B net force acting on the block is zero
C net force acting on the block is in the direction down the slope of the plane
D frictional force acting on the block is zero (2)

1.6 The mass of a man on Earth is 85 kg. What will be the mas of the same man on the surface of a planet which has the same mass as earth but half the radius of earth?

A 85 kg
B 42,5 kg
C 21,25 kg
D 340 kg (2)

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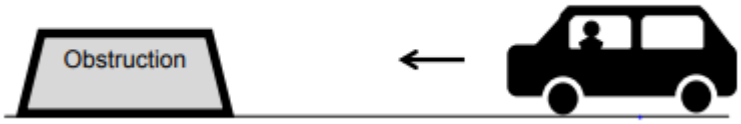
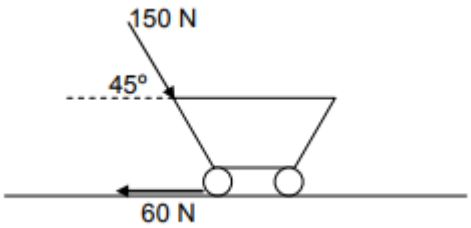
1.7 A car is travelling along a road. The driver has his seat belt on. The driver sees an obstru the road ahead and suddenly applies the brakes.



An action-reaction pair is the force of the seat belt on the driver and the force of the …

A wheels on the road.
B driver on the seat belt.
C seat belt on the seat.
D driver on the seat. (2)

1.8 A trolley is pushed along a horizontal surface with a force of 150 N at an angle of 45º to tl horizontal. The trolley experiences a constant frictional force of 60 N.



The NET FORCE acting on the trolley:

(i) Causes the trolley to accelerate horizontally
(ii) Is equal to the applied force
(iii) Is horizontally forward

Which of the statements above are CORRECT?

A (i) and (ii)
B (ii) and (iii)
C (i) and (iii)
D (i), (ii) and (iii) (2)

1.9 A satellite orbits Earth at a height where the gravitational force is a quarter (¼) of the force it experiences on the surface of the Earth. If the radius of Earth is R, the height of the satellite ABOVE THE SURFACE of Earth is …

A 4R
B 2R
C R
D ½ R (2)

1.10 A man in a lift is moving upwards at a CONSTANT SPEED. The weight of the man is W. According to Newton's Third Law, the reaction force of the weight W is the force of …

A the man on Earth.
B the man on the floor
C Earth on the man.
D the floor on the man. (2)

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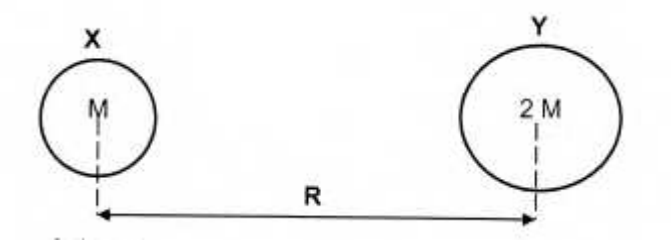
1.11 Two bodies, X and Y, of mass M and 2 M respectively exert a force F on each other when their centres are R metres apart.



The mass of object Y is reduced to 0,5 M and the distance between their centre is reduced to 0,25 R.

What is the new force that the bodies exert on each other, in terms of F?

A 16F
B 2F
C 4F
D 8F (2)

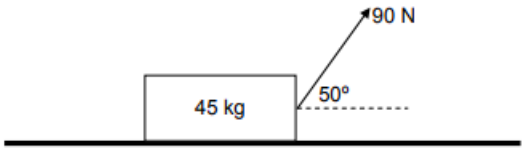
QUESTION 2

A box, mass 5 kg, rests on a plane inclined 30° to the horizontal. A force F (30 N) acts on the box parallel to the plane, and upwards.

2.1 Draw a free body diagram of this situation, including all relevant info.
2.2 Find the force of friction and the normal force acting on the box.

QUESTION 3 (QUESTION 3 DBE Nov 2018)

A box, with a mass of 45 kg, is pulled with a force of 90 N at an angle of 50^0 to the horizontal. The box moves at a CONSTANT VELOCITY.



3.1 Define the term kinetic frictional force.
3.2 State Newton's First Law of Motion in words.
3.3 Calculate the magnitude of the horizontal component of the applied force.

3.4 Calculate the magnitude of the normal force.
3.5 Calculate the coefficient of kinetic friction.
3.6 Will the coefficient of kinetic friction change if the angle of the applied force is decreased? Write only YES or NO and give a reason.

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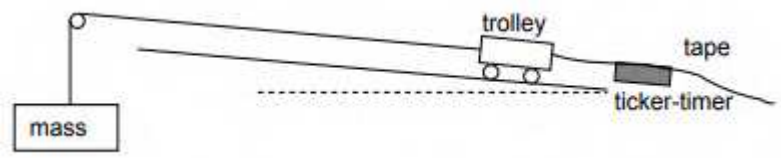
QUESTION 4 (QUESTION 3 DBE NOV 2017)

Learners investigate the relationship between net force and acceleration by pulling a trolley across a surface which is slightly inclined to compensate for friction. The trolley is connected to different masses by a string of negligible mass. The string passes over a frictionless pulley. Refer to the diagram below.



Ticker tape attached to the trolley passes through the ticker-timer. The acceleration of the trolley is determined by analysing the ticker tape. The results of the net force produced by the different masses and the acceleration of the trolley were recorded in the table below.

NET FORCE (N)	a ($m.s^{-2}$)
0,3	0,36
0,6	0,73
0,9	1,09
1,2	1,45

4.1 Write down a hypothesis for this experiment. (2)

4.2.1 Identify the independent variable. (1)

4.2.2 Identify the controlled variable. (1)

4.3 Use the graph paper on the ANSWER SHEET and draw a graph of the acceleration versus net force. (4)

4.4 Calculate the gradient of the graph. (3)

4.5 Use the gradient of the graph calculated in QUESTION 4.4 to determine the mass of the trolley (2)

[13]

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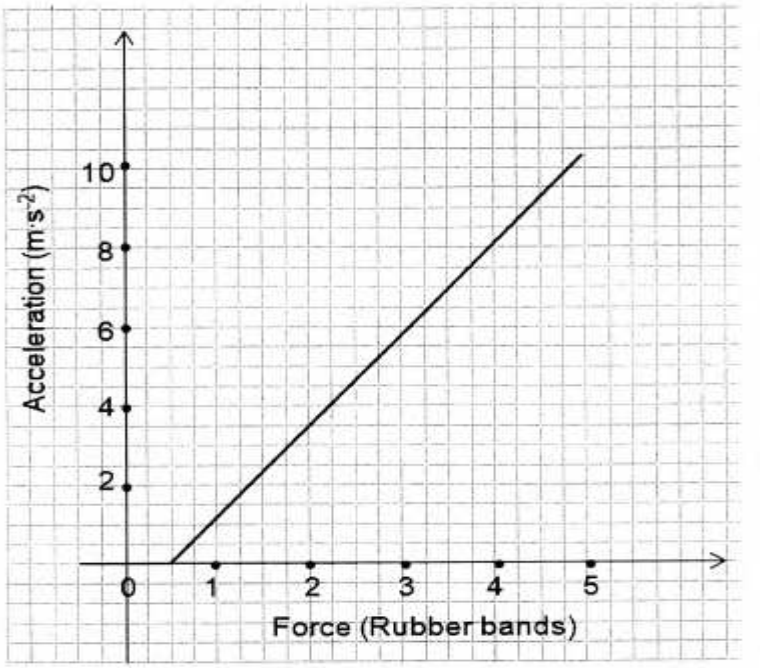
QUESTION 5 (QUESTION 3 KZN March 2020)

The graph below was obtained from an experiment used to determine a relationship between the acceleration of a trolley and the force applied on the trolley. The mass of the trolley was kept constant during the experiment.



5.1 State Newton's Second Law of motion (2)

5.2 What is the acceleration of the trolley when two rubber bands are used (1)

5.3 Why does the graph not start at the origin? (1)

5.4 What is the magnitude of the frictional force acting on the trolley? (2)

5.5 Calculate the mass of the trolley if the gradient of the graph is 2,286 (2)

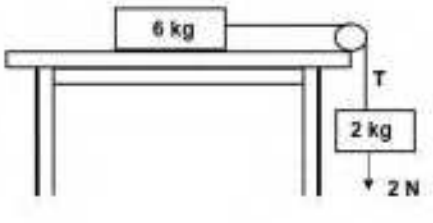
5.6 What change should be made to the experiment setup to verify the relationship between NET FORCE and ACCELERATION? (2)

5.7 The frequency of the ticker timer used in this experiment is 50 Hz. How would the gradient of the graph be affected if the frequency of the ticker timer was reduced to 20 Hz?
Choose from INCREASES, DECREASES, or REMAINS THE SAME. (1)

[11]

QUESTION 6 (QUESTION 5 Grade 11Exam Prep. Touch tutor)

A 6 kg block on a rough horizontal surface is joined to a 2 kg block by a light, inelastic string runn over a frictionless pulley. The frictional force between the 6 kg block and the table is 11,76 N. A downward force of 2 N is applied to the 2 kg block as indicated in the diagram below.



6.1 Draw a free-body diagram showing all forces on the 6 kg block. (4)

6.2 Calculate the magnitude of the acceleration of the 6 kg block (5)

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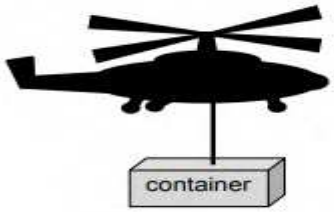
6.3 Calculate the magnitude of the tension (T) in the string connecting the two blocks. (3)

QUESTION 7 (QUESTION 3 DBE NOV 2016)

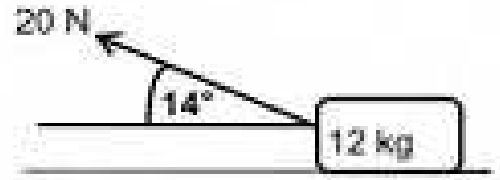
A hovering rescue helicopter has a container of supplies, with a weight of 1 960 N, hanging from a cable. The tension in the cable is 2 100 N.



7.1 State Newton's First Law of Motion in words. (2)
7.2 Draw a labelled force-diagram of ALL the forces acting on the container. (2)

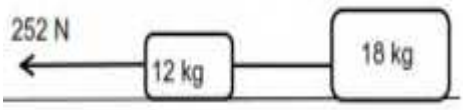
QUESTION 8 (QUESTION 9 Grade 11Exam Prep. Touch tutor)

A 12 kg block is pulled across a smooth horizontal surface with a force of 20 N at an angle of 14° to the horizontal



8.1 State Newton's Second Law of Motion in words. (2
8.2 Draw a labelled free body diagram showing all forces acting on the block. (3)
8.3 Calculate the magnitude of the block's acceleration. Ignore friction. (3)

Another block of mass 18 kg is joined to the 12 kg block by a light inextensible string, both on a ROUGH horizontal surface. The two blocks move under the influence of a force of 252 N as shown. The coefficients of kinetic friction between the surface and the 12 kg and 18 kg blocks are 0,1 and 0,15 respectively.



8.4 Draw a labelled free body diagram showing all forces on the 12 kg block (5)
8.5 Determine the tension, T, in the string.

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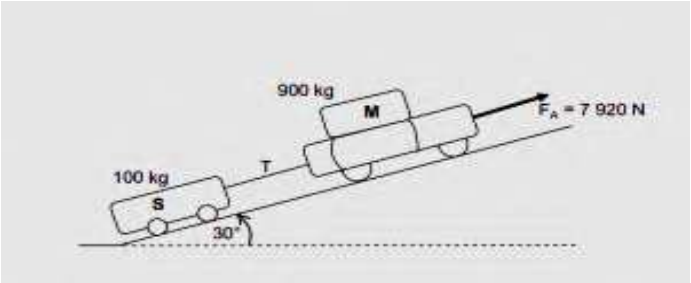
QUESTION 9 (QUESTION 10 Grade 11Exam Prep. Touch tutor)

Car M, with a mass of 900 kg, tows trailer S, of mass 100 kg, up a slope of 30° with the horizontal as shown in the diagram below. The engine of the car exerts a force of 7 920 N. The car and the trailer experience kinetic frictional forces of 1 800 N and 200 N respectively. The rope connecting the car with the trailer is inelastic and of negligible mass.



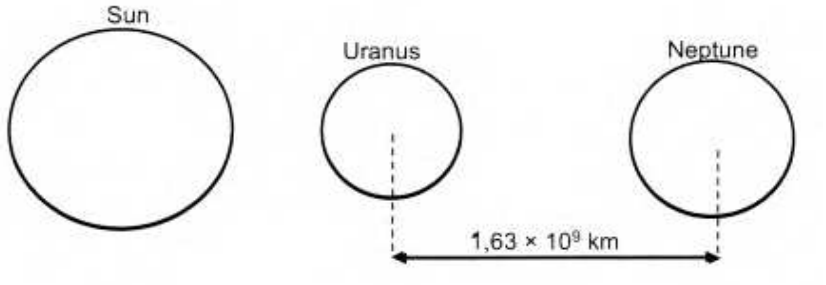
9.1 Draw a labelled free body diagram showing all forces acting on car M. (5)

9.2 Calculate the magnitude of the tension T in the rope if the system accelerates up the slop at 3 $m \cdot s^{-2}$. (4)

9.3 The car suddenly comes to a stop and a passenger in the car who is not wearing a seatbe continues to move forward. Write down the name of the law of motion that explains why th passenger continues to move forward (1)

QUESTION 10 (QUESTION 5 March 2020)

The diagram below represents the planets Neptune, Uranus, and the Sun in a straight line. Neptune and Uranus and the Sun in a straight line. Neptune is 1,63 $\times 10^9$ km from Uranus.



The data below provides relevant information concerning the above planetary bodies.

Mass of the Sun	1,99 $\times 10^{30}$ kg
Mass of Uranus	8,73 $\times 10^{25}$ kg
Mass of Neptune	1,03 $\times 10^{26}$ kg
Mean distance of Uranus to the Sun	2,87 $\times 10^{12}$ m
Mean distance of Neptune to the Sun	4,50 $\times 10^{12}$ m

10.1 Calculate the magnitude of the force of attraction that Uranus exerts on Neptune. (5)

10.2 Write down the magnitude and direction of the force that Neptune exerts on Uranus. (2)

10.3 The magnitude of the force the Sun exerts on Uranus in 1,41 $\times 10^{21}$ N. Calculate the net force experience by Uranus due to the Sun and Neptune. (2)

[9]

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ATOMIC COMBINATIONS

DEFINITIONS

- Intramolecular bond: bond which occurs between atoms within molecules
- Electronegativity: a measure of the tendency of an atom to attract a bonding pair of electrons
  Covalent bond: a sharing of at least one pair of electrons by two atoms
- Non - polar covalent (pure covalent): an equal sharing of electrons
- Polar covalent: unequal sharing of electrons leading to a dipole forming
- Ionic bond: a transfer of electrons and subsequent electrostatic attraction
- Metallic bond: Being between a positive kernel and a sea of delocalised electrons

MOLECULAR STRUCTURE

The structure mainly depends on the type of chemical bond (force) that exist between the atoms that the molecule consists of.

CHEMICAL BONDS

Chemical bond is the net electrostatic force that two atoms sharing electrons exert on each other.

- Bonding occurs when valence electrons are shared between two atoms or transferred from one atom to another
- Valence electrons correspond to the group number of an element on the Periodic table
- Valence electrons: Electrons in the outermost energy level of an atom that take part in bonding.
- The type of bond that forms is dependent on the difference in electronegativity (ΔEN) between the atoms.
- Electronegativity is the tendency of an atom to attract a shared electron pair during bonding. If one atom has a greater electronegativity than another, the electrons will be pulled more towards one atom than another. Such a shift of electrons creates negative and positive charge distributions inside the molecule.
  - ΔEN = 0: Non-polar (pure) covalent (an equal sharing of electrons)
  - ΔEN < 1: Weak polar
  - ΔEN ≤ 2,1: Polar covalent (unequal sharing of electrons leading to a dipole forming)
  - ΔEN > 2,1: Ionic (transfer of electrons and subsequent electrostatic attract

Polar bond: An unequal distribution of electrons between two atoms during bonding.

Example: H-Cl

Non-polar bond: An equal distribution of electrons between two atoms during bonding.

Example: H -H

EN (Cl) > EN (H): Electrons shift towards chlorine. Chlorine is slightly negative (δ−) and hydrogen is slightly positive (δ+). EN (H) = EN (H): Bonding electrons are evenly shared. Charge is evenly distributed and no dipole formed

Polar molecule: A molecule over which charge is distributed unevenly.

Example: H_2O

Non-polar molecule: A molecule over which the charge is evenly distributed.

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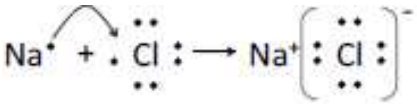
Example: Cl_2

Covalent Bonding (Between non-metals)

- Covalent bonding is the sharing of at least one pair of electrons by two atoms.
- Non-polar (pure) covalent: An equal sharing of electrons
  E.g. H-P bond: ΔEN = EN(P) - EN(H) = 0
- Weak polar covalent
  E.g. H - Br bond: ΔEN = EN(Br) - EN(H) = 0,7
- Polar covalent: An unequal sharing of electrons leading to a dipole forming
  Eg. H - O bond: ΔEN = EN(O) - EN(H) = 1.4

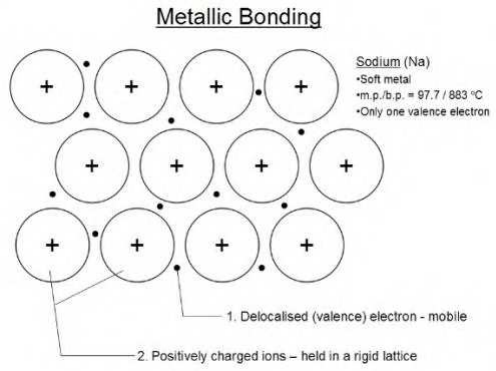
Ionic Bonding (between metals and non-metals)
Ionic bonding is a transfer of electrons and subsequent electrostatic attraction.
1. Involves a complete transfer of electron(s).
2. Metal atom gives electrons to non-metal.
3. Metal forms a positive cation.
4. Non-metal forms a negative anion.
5. Electrostatic attraction of ions leads to formation of giant crystal lattice.

Ionic bonding takes place in two steps.
1. Transfer of electron(s) to form ions
2. Electrostatic attraction.



Metallic Bonding (between metals)

- Metallic bonding is the bond between the positive metal kernels and the sea of delocalized electrons.
- The metal atoms release their valence electrons to surround them.
- There is a strong but flexible bond between the positive metal kernels and a sea of delocalised electrons



BOND ENERGY

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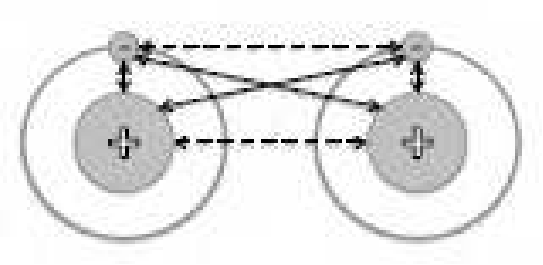

- There are various attractive and repulsive forces at play between the two atoms during bonding.
- Attractive forces between the protons of one atom and the electrons of another.
- A repulsive force between the protons from each atom.
- A repulsive force between the electrons from each atom.
- The net electrostatic forces will determine bond strength, which can be quantified as the bond energy. This is the energy required to break the bond, or energy released when bonds are formed.
- Bond energy is the amount of energy required to break one mol of a specific covalent bond in gaseous phase.

FACTORS INFLUENCING BOND STRENGTH

Bond strength is determined by:

Bond length

The shorter the length of the bond, the stronger the bond.

Atom size

The smaller the atoms, the stronger the bond.

Bond order

The more bonds (double, triple bonds etc.) between the atoms, the stronger the bond.

BOND LENGTH

Bond length: The average distance between the nuclei of two bonded atoms.

As the atoms get closer, the attractive forces get stronger until the minimum possible potential energy is reached (bond energy). The distance between the nuclei of the atoms at the minimum potential energy is

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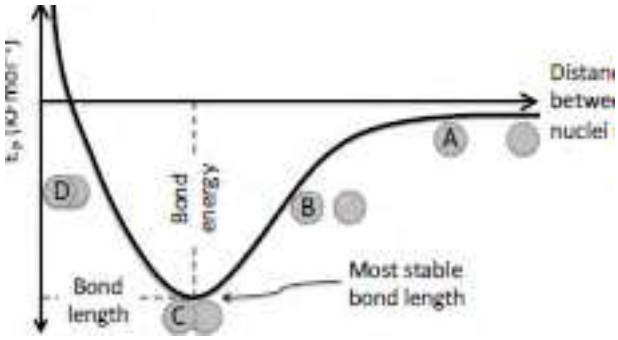
the bond length. If the two atoms get closer than the bonding length, they will be forced apart by the repulsive forces, increasing the potential energy.

FACTORS INFLUENCING BOND LENGTH Bond length is determined by:

1. Atom size
   The smaller the atoms, the shorter the bond.
2. Bond order
   The more bonds (double, triple bonds etc.) between the atoms, the shorter the bond.
3. Difference in electronegativity (ΔEN) The greater the ΔEN, the shorter the bond.

Process of bond formation

A: Atoms are infinitely separated; potential energy is nearly zero.
B: as the atoms move closer, the forces of attraction and repulsion increase until the forces of attraction dominate.
C: the lowest, most stable energy state reached, chemical bond forms.
D: Atoms move too close, forces of repulsion increase, potential energy increases



ACTIVITIES – ATOMIC COMBINATIONS

QUESTION 1	

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Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number.		
1.1	The type of bond formed between a H^+ ion and H_2O is called a/an … A. hydrogen bond. B. dative covalent bond C. ionic bond. D. covalent bond	(2)
1.2	The bond energy of a C–Cℓ bond is 338 $kJ.mol^{-1}$ whereas the bond energy of a C–I bond is 238 $kJ.mol^{-1}$. The difference in bond energy exists because … A. the bond length of the C–Cℓ bond is greater than that of the C–I bond. B. chlorine is more electronegative than iodine. C. the bond length of the C–I bond is greater than that of the C–Cℓ bond. D. the chlorine atom is bigger than the iodine atom.	(2)
1.3	Which ONE of the following pairs of atoms is most likely to form an ionic bond? A. C and F B. Na and F C. N and F D. O and F	(2)
1,4	Which ONE of the following best describes the bond formed between an H^+ ion and a NH3 molecule? A. Covalent bond B. Dative covalent bond C. Ionic bond D. Hydrogen bond	(2)
1.5	Which one of the following statements concerning the length of carbon-carbon single, double and triple covalent bond is true?	

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	A. The carbon-carbon single bond is shorter than either the carbon-carbon double or triple bond. B. The carbon-carbon double bond is shorter than either the carbon-carbon single or triple bond. C. The carbon-carbon triple bond is shorter than either the carbon-carbon single or double bond. D. The carbon-carbon single, double, and triple bonds all have the same length.	(2)
1.6	Which molecule is the most polar? A. HBr B. HI C. HCl D. HF	(2)
1.7	If the total bond enthalpy for methane (CH_4) is 1652 kJ mol^{-1} and ethane (C_2H_6) is 2826 kJ mol^{-1}, what is the strength of a C–C bond? A. 1.71 kJ mol–1 B. 348 kJ mol–1 C. 1174 kJ mol–1 D. 4478 kJ mol–1	(2)
1.8	Consider the reaction represented by the equation below: $2H(g) + O_2(g) \rightarrow 2H_2O(g)$ ΔH= - 469kJ/mol The total energy absorbed when bonds are broken in TWO moles of H_2 and ONE mole of O_2 is 1 371 kJ/mol. What is the bond energy in kJ/mol for each O–H bond in the water molecule? A. 920 B. 499 C. 460 D. 184	(2)
QUESTION 2		
Electronegativity of atoms may be used to explain the polarity of bonds.		
2.1	Define the term electronegativity.	(2)
2.2	Draw the Lewis diagram of an oxygen difluoride molecule.	(2)
2.3	Calculate the electronegativity difference between O and F in oxygen difluoride and predict the polarity of the bond.	(2)



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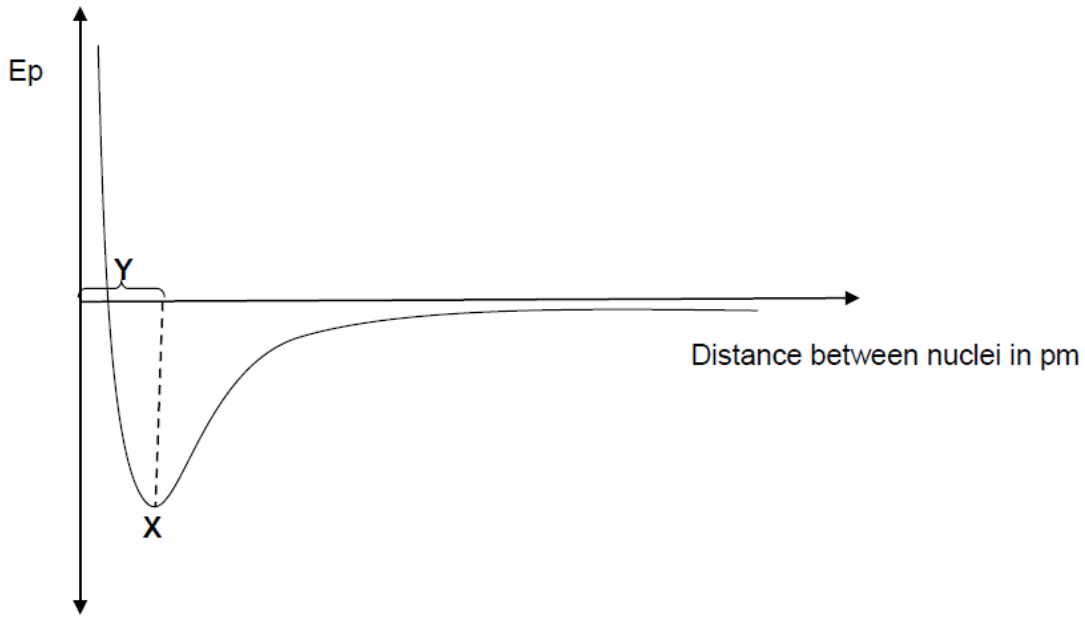
2.4	The diagram below shows the energy change that takes place when two atoms move towards each other  	
2.4.1	What does X and Y represent?	(2)
2.4.2	Define the concept represented by X.	(2)
2.4.3	Explain the relationship between bond order, bond length and bond energy.	(3)
QUESTION 3		
Molecules such as CO_2 and H_2O are formed through covalent bonding		
3.1	Define the term covalent bonding.	(2)
3.2	ONE of the above molecules has lone pairs of electrons on the central atom. Draw the Lewis diagram for this molecule.	(2)
3.3	H_3O^+ is formed when H2O forms a dative covalent bond with an H+ ion.	
3.3.1	Draw the Lewis diagram for H_3O^+.	(1)
3.3.2	State TWO conditions for the formation of such a bond.	(2)
3.4	The polarity of molecules depends on the DIFFERENCE IN	

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	ELECTRONEGATIVITY and the MOLECULAR SHAPE.	
3.4.1	Define the term electronegativity.	(2)
3.4.2	Calculate the difference in electronegativity between:	
3.4.2.1	C and O in CO_2	(1)
3.4.2.2	H and O in H_2O	(1)

VECTORS AND SCALARS

VECTORS IN 2D NOTES GR 11

	Vector- A physical quantity with	*Scalars- A physical quantity with*		

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magnitude and direction. (Example: force, velocity, acceleration, etc.)	*magnitude only. (Example: time, charge, work. Energy, distance, speed etc.)*

- *A vector has magnitude and direction.*
- *Vectors can be used to represent physical quantities that have magnitude and direction, like forces.*
- *Vectors may be represented as arrows where the length of the arrow indicates the magnitude and the arrowhead indicates the direction of the vector.*
- *Vectors in two dimensions can be drawn on the Cartesian plane.*
- *Vectors can be added graphically using the head-to-tail method or the tail-to-tail method.*
- *A closed vector diagram is a set of vectors drawn on the Cartesian plane using the tail-to-head method and that has a resultant with a magnitude of zero.*
- *Vectors can be added algebraically using Pythagoras' theorem or using components.*
- *The direction of a vector can be found using simple trigonometric calculations.*
- *The components of a vector are a series of vectors that, when combined, give the original vector as their resultant.*
- *Components are usually created that align with the Cartesian coordinate axes.*

*A **resultant** is that single vector which has the same effect on a body as the two or more vectors that are actually acting on that*

Resources

1. Relative Velocity Vectors
http://cnx.org/content/m14030/latest/
A resource on relative velocity in two dimensions.
http://www.examsolutions.net/math s revision/mechanics/vectors/relative velocity/tutorial-1.php
A video introducing relative velocity.

2. Vectors of Relative Motion
https://www.youtube.com/watch?v= nxF47gTE2yU
This video discusses relative motion.
http://www.physicstutorials.org/hom e/mechanics/1d-kinematics/relative motion
Relative motion with examples.

3. Forces in Equilibrium
http://fiziknota.blogspot.com/2009/0 5/analysing-forces-inequilibrium.html
Analysing forces in equilibrium.
https://www.uwstout.edu/physics/up load/Force-Equilibrium.pdf

A laboratory activity demonstrating the conditions under which an object is held in static equilibrium due to concurrent forces.
http://www.physics.arizona.edu/physics/ resources/documents/03_Ve ctors.pdf
A study of vectors in the context of force

4. Calculating Vectors using Pythagoras
http://www.mathsisfun.com/algebra/ vectors.html
All about calculating vectors.

5. Resolution of Vectors into Components
http://www.wikihow.com/Resolve-aVector-Into-Components
How to resolve components can be resolved as horizontal and vertical components.

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body. It starts at the beginning of the first vector and ends at the end of the last one.

*An **equilibrant** is one vector, which cancels out the effect that the two or more vectors actually have on a body. It is equal in size to the resultant but opposite in direction.*

Positive (+) and negative (-) signs are used to indicate direction in vectors (Not their magnitude).

Arrows are used in vectors to give magnitude (length of arrow) and direction (head of arrow).

RESULTANT VECTORS CAN BE DETERMINED BY CALCULATION, USING MATHEMATICAL KNOWLEDGE, OR BY ACCURATE CONSTRUCTIONS.

IMPORTANT NOTES WHEN USING ACCURATE CONSTRUCTIONS:

- *Protractor must be used correctly.*
- *Use of an appropriate, correct scale.*
- *Understanding the difference between The Tail to Tail and The Tail to Head Method.*
- *Measuring the Angles from the reference line to the Vector.*

When the Learners are using a Protractor, they must ensure that the Tail of the vector is at the dot centre of the protractor, and that the line is correctly placed.

PRIOR KNOWLEDGE FROM GRADE 10

- *Define and understand one dimensional vectors. (vectors acting along one axis only)*
- *Equality of vectors, negative vectors, addition and subtraction of vectors (in one dimension only).*
- *Define a resultant vector.*
- *Find the resultant vector graphically using the tail-to head method as well as by calculation for a maximum of four force vectors in one dimension only.*



GRADE 11 ASSESSMENT GUIDELINES

- *Add co-linear vertical vectors and co-linear horizontal vectors to obtain the net vertical vector (Ry) and net horizontal vector (Rx).*

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- *Sketch Rx and Ry on a Cartesian plane.*
- *Determine the magnitude of the resultant using the Theorem of Pythagoras.*
- *Find resultant vector graphically using the tail-to head method as well as by calculation (by component method) for a maximum of four force vectors in both 1-dimension and 2-dimensions.*
- *Understand what is a closed vector diagram.*
- *Determine the direction of the resultant using simple trigonometric ratios.*
- *Resolve a 2-dimensional vector into its perpendicular components.*

Vectors in One Dimension – Revision

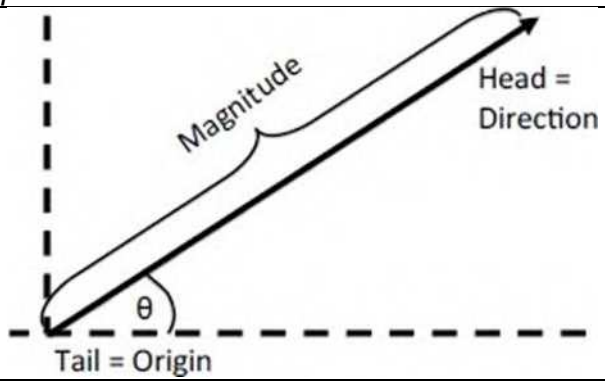
- *Vector – physical quantity having magnitude and direction.*
- *Scalar – physical quantity having magnitude only.*

Examples:

Vector	Scalar
Force	Time
	Energy
Weight	Mass
Velocity	Speed
Displacement	Distance
Acceleration	

Graphical Representation of a vector

- *Vector is represented by an arrow*
- *The length of an arrow represents the size (magnitude) of the vector*
- *The arrow-head represents the direction of the vector.*



Direction of a horizontal or vertical vector

- *A positive sign (+) or a negative sign (–) is used to indicate the direction of a vector that are either horizontal or vertical. For each example you must select the sign.*

Examples

a) right is + ⟶ *+ 5 N*

b) left is – ⟵ *- 3 N*

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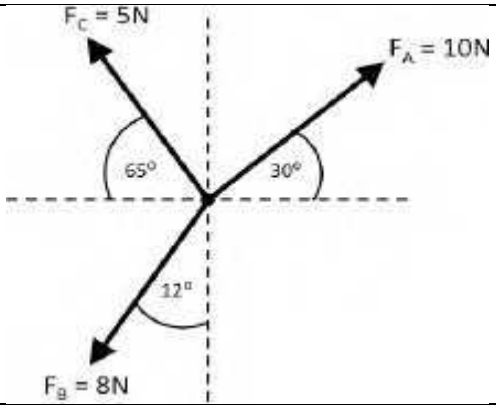
Three methods to describe the direction of a vector that is not horizontal or vertical

1. ***X and Y axes***
2. ***Bearing***
3. ***Compass Reading***

On a graph



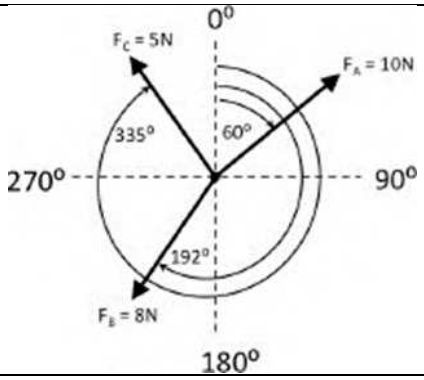
FA : 10 N at 30º above the positive x- axis (horizontal axis)

F_B : 8 N at 12o left of the negative y- axis (vertical axis)

F_C : 5 N at 65o above the negative x- axis (horizontal axis)

Bearing

- *Only for vectors in the horizontal plane i.e. parallel to the surface of the Earth.*
- *Use North as 0° and always measure* ***clockwise***



F_A : 10 N on a bearing of 60º (or 60º east of north, or 30º north of east)

F_B : 8 N on a bearing of 192º (or 12º west of south, or 78º south of west)

F_C : 5 N on a bearing of 335º (or 65º north of west, or 25º west of north)

Compass (Cardinal points or directions)

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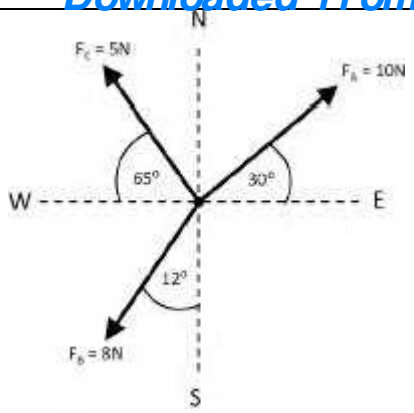
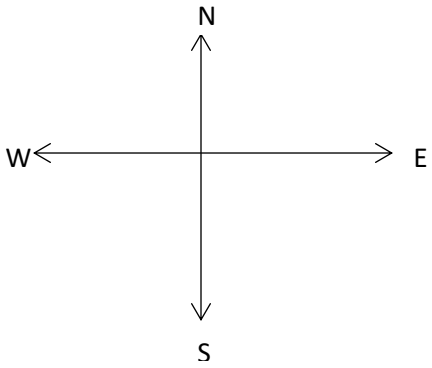




NB: The 30^0 N of E means you start from east and move 30^0 towards the North

F_A : 10 N at 30º North of East

F_B : 8 N at 12º West of South

F_C : 5 N at 65º North of West

RESULTANT OF VECTORS

Define a resultant *as the vector sum of two or more vectors, i.e. a single vector having the same effect as two or more vectors together.*

Resultant vector is greatest when vectors are in the same directions

Resultant vector is smallest when vectors are in the opposite directions

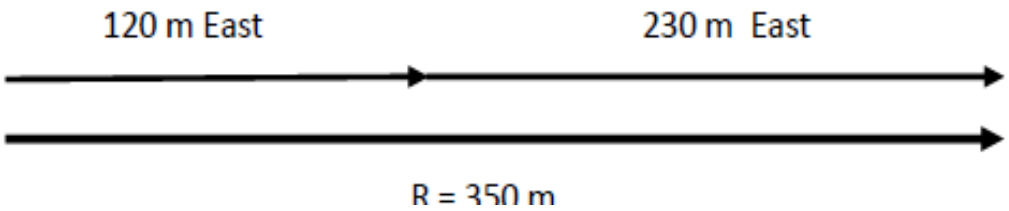
A. Two vectors acting in the same direction :(one dimension)

A girl walks 120m due East and then 230m in the same direction. What is her resultant displacement?

1. By calculation:

Sign of direction: Take to East to be +
R = 120m + 230m = 350m East

2. By construction:



B. Two vectors acting in opposite direction (one dimension)

A boy walks 210m due East. He then turns and walk 60m due West. Determine his resultant displacement.

By calculation: (taking East as positive)

R = 210m + (- 60m) = 150m East

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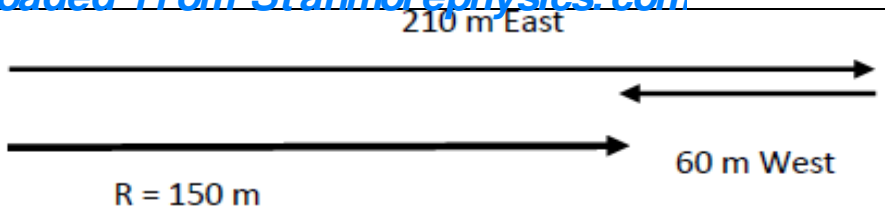
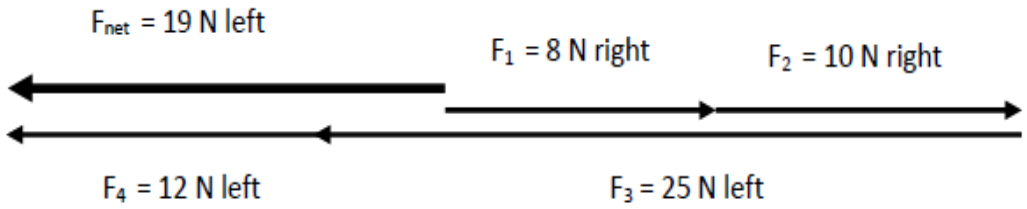


C. *Multiple vectors acting in different directions (one dimension)*

Determine the resultant(net) force when 8 N force acts to the right, a 10 N force acts to the right, a 25 N force acts to the left and a 12 N force acts to the left
Let the direction to the right be ***positive***

By Calculation: $F_{net} = F1 + F2 + F3 + F4$
$= 8 + 10 + (-25) + (-12)$
$= -19\ N$
$F_{net} = 19\ N\ left$

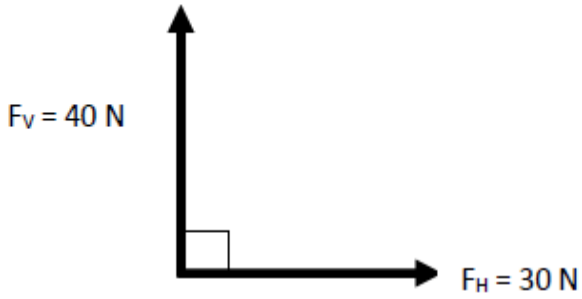


Vectors in Two Dimension`

Resultant of perpendicular vectors

- ***Perpendicular vectors*** *are at right angles to each other*
- *A horizontal force of 30 N and a vertical force of 40 N that act on an object is an example of two forces that are perpendicular to each other.*

Diagram



Adding co-linear vectors

- *Co-linear vectors are simply vectors that lie in the same straight line.*

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- *The net x-component (Rx) is the sum of the vectors parallel with the x-direction:* $R_x = R_{x1} + R_{x2}$

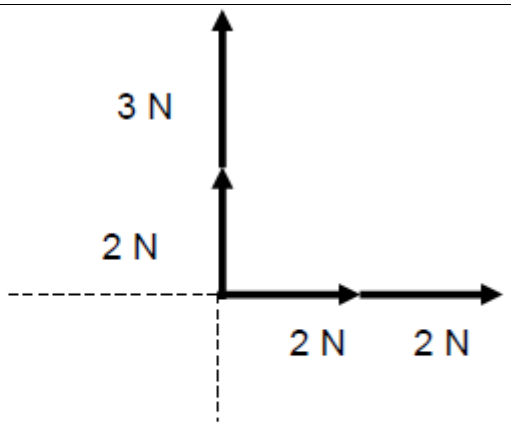
- *The net y-component (Ry) is the sum of the vectors perpendicular to the x-direction:* $R_y = R_{y1} + R_{y2}$

Worked Example 1

Two forces of 3N and 2N act in a northerly direction on an object. At the same time, two forces each of 2N act in an easterly direction. Find the resultant force acting on the object.

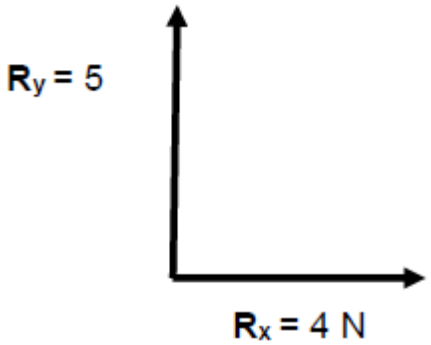
Step 1: *Draw a diagram and calculate the net force acting north (along the y axis) and the net force acting east (along the x axis).*

$$R_y = R_{y1} + R_{y2}$$
$$R_y = 2 + 3$$
$$R_y = 5\ N \quad \text{North}$$



$$R_x = R_{x1} + R_{x2}$$
$$R_x = 2 + 2$$
$$R_x = 4\ N \quad \text{East}$$

Step 2: *Graphical representation of Rx and Ry*



Step 3: *To find resultant (R) of the above vectors, one can use the* ***tail-to-tail*** *method.*

Tail to tail method (Using a Parallelogram):

Note: *When vectors are drawn tail-to-tail, a parallelogram must be completed in order to determine their resultant.*

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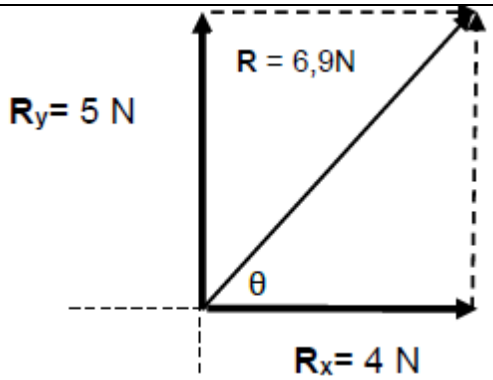


- *If the two vectors are at right angles to each other, as above, a rectangle with two right-angled triangles are formed. The Theorem of Pythagoras is then used to calculate the magnitude of the resultant.*

- *Considering the vector diagram above we can use the Theorem of Pythagoras as follows:*

$R^2 = R_x^2 + R_y^2$

$R^2=4^2+5^2$

$R=\sqrt{4^2+5^2}$

$R=6,40\ N$

- *Use trigonometry to find the direction of the resultant as follows:*

$tan\theta=\frac{R_y}{R_x}=\frac{5}{4}$

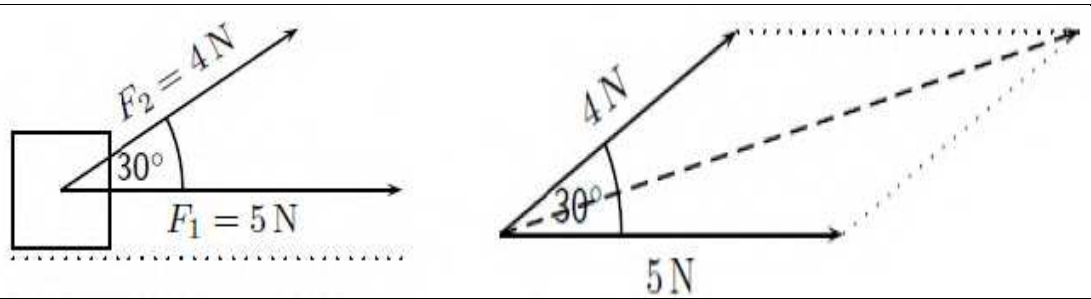
$\Theta = 51.24^0$ *North of East*

Worked Example 2:

A force F_1 = 5N is applied to a block in a horizontal direction. A second force F_2 = 4N is applied to the object at an angle of 30º to the horizontal. Determine the resultant of the two forces, ***by accurate scale drawing.***

Step 1: *Draw rough sketches of the vector diagrams:*

Note: *The forces are NOT perpendicular*



Step 2: *Choose the suitable scale. e.g. 1cm represents 1N*

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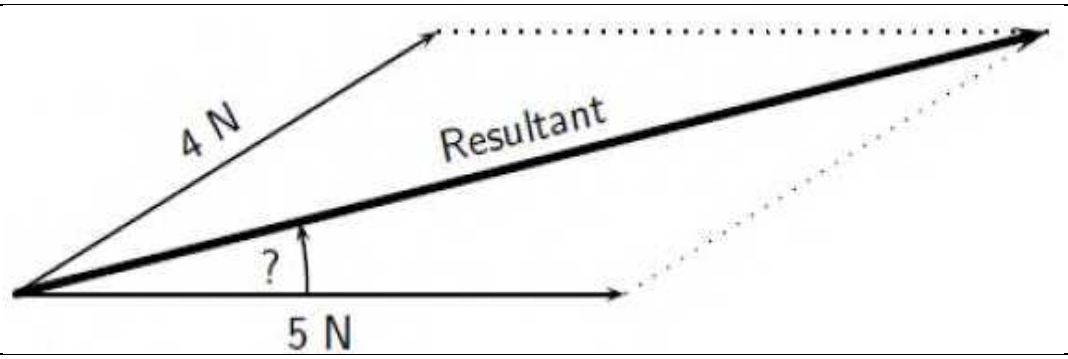
	Step 3: *Draw the first vector (F_1) on the horizontal, according to the scale.*	
	Step 4: *Draw the second scaled vector (F_2) 30º above the horizontal.*	
	Step 5: *Complete the parallelogram and draw the diagonal (which is the resultant).*	
	Step 6: *Use the protractor to measure the angle between the horizontal and the resultant*	
	Step 7: *Apply scale and convert the measured length to the actual magnitude.*	
		
	The resultant is 8,7N, 13,3º above the horizontal.	
	GRAPHICAL DETERMINATION OF THE RESULTANT VECTOR	
	Tail-to-head method *is used to find the resultant of two or more consecutive vectors (vectors that are successive).*	
	Steps to be followed:	
	• *Choose a suitable scale e.g. 10mm represents 10N*	
	• *Always add arrow heads to vectors to indicate the direction.*	
	• *Accurately draw the first vector as an arrow according to chosen scale and in the correct direction*	
	• *Draw the second vector by placing the tail of the second vector at the head of the first vector (tail – to – head method)*	
	• *Complete the diagram by drawing the resultant from the tail of the first vector to the head of the last vector.*	
	• *Make sure that you measure the angles correctly with a protractor.*	

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- *Measure the length and direction of the resultant vector.*

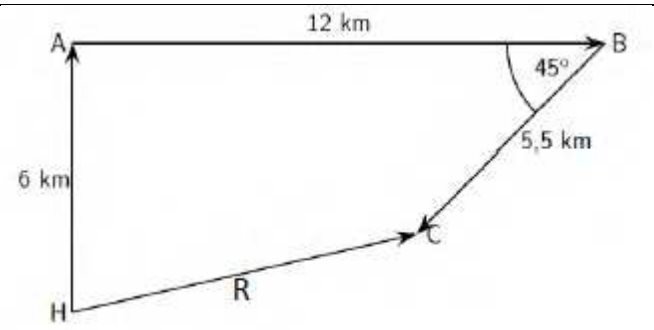
Use the scale to determine the real magnitude of the resultant.

Worked Example 1:

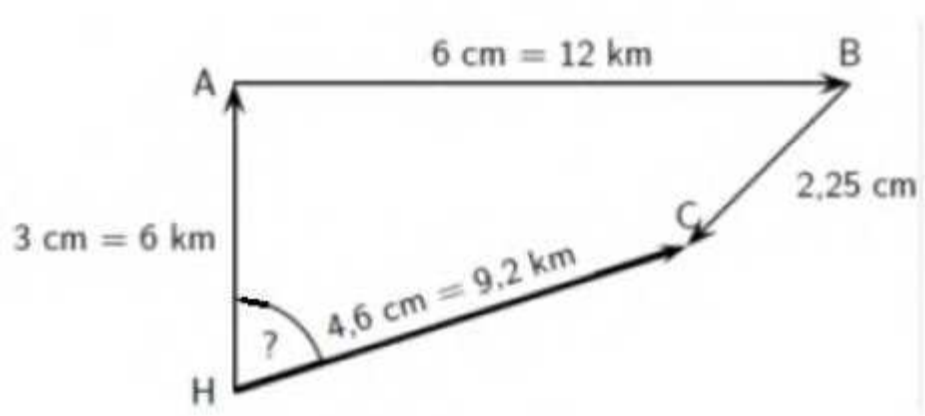
A ship leaves a harbour H and sails 6km north to port A. From here the ship travels 12 km east to port B, before sailing 5,5 km at 450 south-west to port C.

Determine the ship's resultant displacement using the tail-to-head technique.

Rough sketch:



Using a scale 1cm: 2km, the accurate drawing of vectors is:



Measure the angle between the North line and the resultant with a protractor to find that the direction of the resultant displacement:

Resultant displacement of the ship is 9,2 km on a bearing of 72, 3º.

CO-LINEAR VECTORS

Co-linear vectors are simply vectors that lie in the same straight line. They either act in the same direction or in the opposite direction, e.g. vectors pointing east or west are co-linear; vectors pointing north and west are not co-linear because they act at an angle (90°) to each other. Draw the diagram alongside, on the board, of four forces acting on an object.

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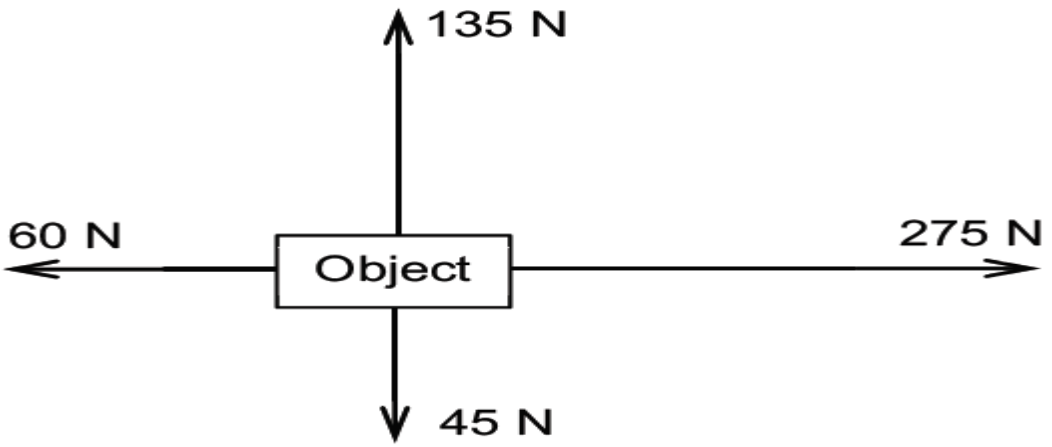
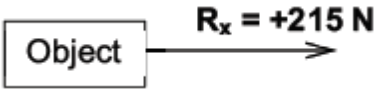


The 60 N and 275 N force vectors act along the horizontal axis (x-axis). It is essential to use signs (+ and -) to indicate the direction of vectors which act in the same line.

In the Cartesian plane, right is positive (+) and left is negative (–). The 275 N force acts to the right and is therefore represented as +275 N. The 60 N force acts to the left and is therefore represented as –60 N.



The resultant horizontal force (Rx) is the vector sum of the forces acting along the horizontal (or x-) axis: ***R_x = (+275) + (- 60) = +215 N****. The positive sign (+) in the answer indicates that the resultant horizontal force acts to the right: Rx = 215 N to the right.*



The 135 N and 45 N forces act in the vertical direction (y-axis). In the Cartesian plane, up is positive (+) and down is negative (–). The 135 N force acts upwards and is therefore

represented as +135 N. The 45 N force acts downwards and is therefore represented as –45 N. The resultant vertical force (Ry) is the vector sum of the forces acting in the vertical direction.

R_x = (+135) +(- 45) = + 90 N

R_y = 90N Upwards

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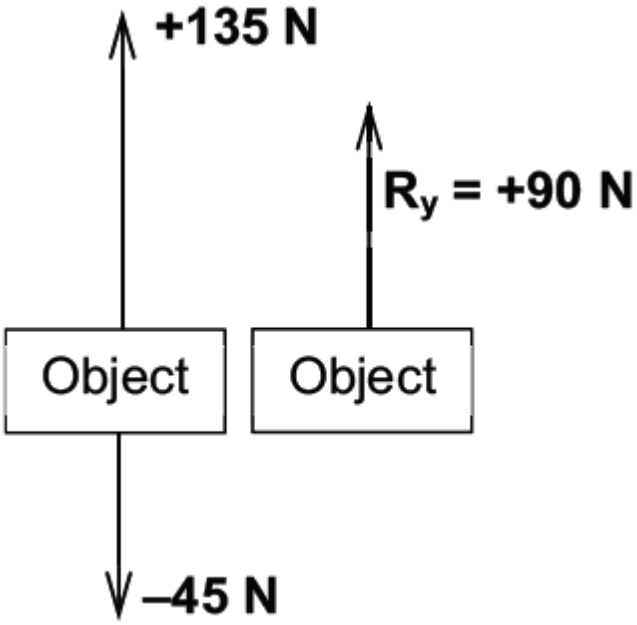
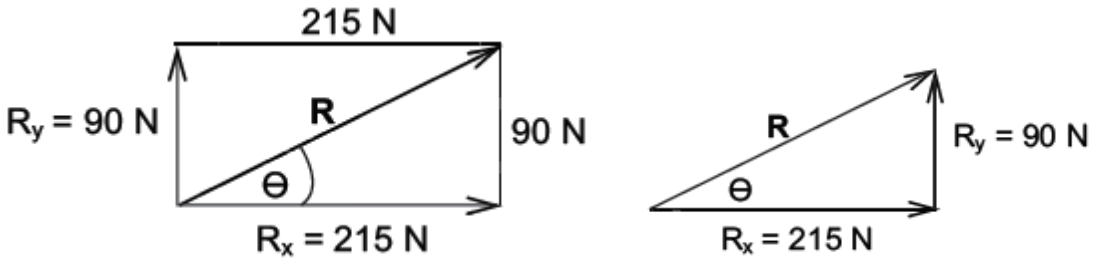


CONCEPT

We have now simplified the given force diagram to just two perpendicular force vectors. The resultant force can be found by drawing a neat vector diagram using the tail-to-tail method or the tail-to-head method.

Tail-to-tail method

Place the tails of the two vectors together (tail to-tail) in the Cartesian plane and complete the parallelogram by drawing in the opposite sides. The opposite sides are PARALLEL and EQUAL IN LENGTH to each other.



Tail to Tail ***Tail to Head***

The resultant force (R) is the diagonal of the parallelogram. Draw this diagonal. The diagonal MUST start from the TWO TAILS of the given forces.

We now have two right-angled triangles to work with.

Use the Theorem of Pythagoras to calculate the magnitude of the resultant force (R).

$R^2 = 90^2 + 215^2$

$R^2 = 54325$

$R = \sqrt{54325} = 233.07N$

This is the magnitude of the resultant force.

We now need to find the direction of the resultant force. Let θ be the angle between the resultant force and the horizontal plane.

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Use a trig. ratio to find the angle θ: $\tan \Theta = \frac{opposite}{adjacent} = \frac{90}{215}$ $\theta = 22.71\ N$

Tail to Head Method

Draw the horizontal vector Rx on your page, then draw the vertical vector Ry so that its TAIL is touching the HEAD of Rx. The resultant force (R) MUST be drawn from the TAIL of the first vector to the HEAD of the second vector. As shown in the previous method, use Pythagoras to calculate the ***magnitude*** *of the resultant force (R) and a trig. ratio to find the* ***direction*** *of the resultant force.*

R = 233,08 N at 22,71° *to the horizontal axis (positive x-axis).*

STEPS TO FOLLOW

A. *Draw a neat-labelled vector diagram.*

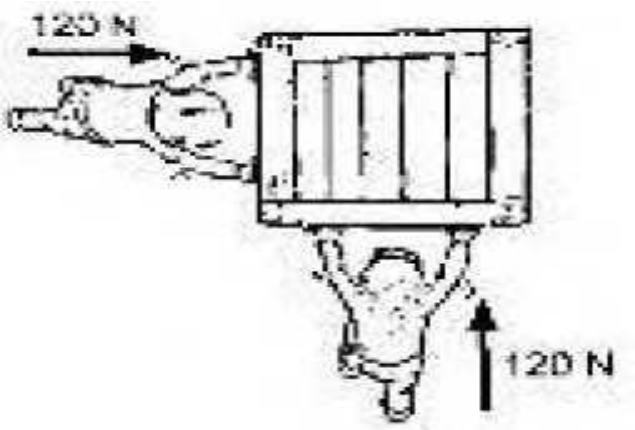
B. *Simplify the problem by first finding the resultant of vectors in the same and opposite directions (co-linear vectors).*

C. *When left with perpendicular vectors, draw a neat vector diagram of the perpendicular vectors, and indicate the resultant vector.*

D. *Use the theorem of Pythagoras and trig. ratios to find the magnitude and direction of resultant.*

ACTIVITY 2

1. *Two forces of 120N each are exerted on a crate simultaneously as shown in the figure*



1. 1 *Plot a sketch of force vectors on the Cartesian plane.*

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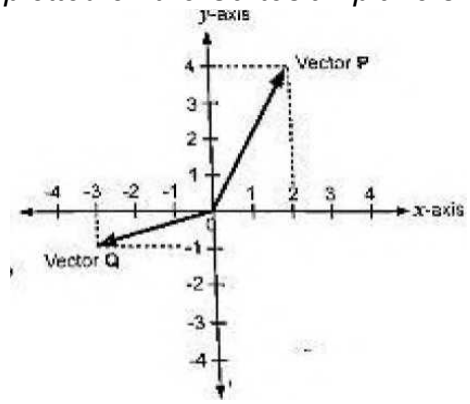
1.2	*Use a scale of 10mm represents 20N and the tail-to-tail method to determine magnitude and direction of the resultant.*	
2	*Force vectors P and Q are plotted on the Cartesian plane shown below* 	
2.1	*Determine the magnitude of vector P in force units* _____ _____	
2.2	*Determine the direction of vector Q, measured clockwise from the positive y-axis* _____ _____	
3.	*Two Newton springs are used to exert forces on a wooden block as shown in the figure* 	
3.1	*Take the readings of the individual forces exerted on the spring balances and plot them on a Cartesian plane.*	

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3.2 *Plot a vector sketch diagram (not according to scale)*

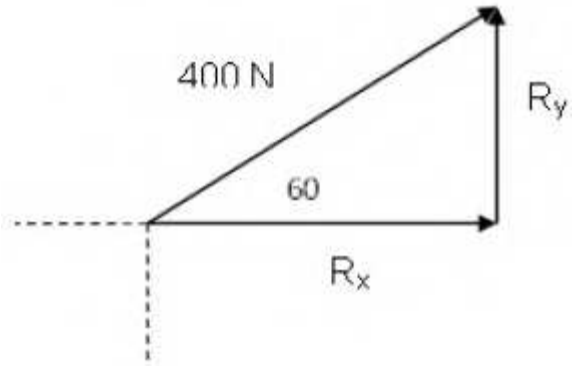
3.3 *Calculate the magnitude and direction of the resultant of the two forces.*

RESOLUTION OF A VECTOR INTO ITS PARALLEL AND PERPENDICULAR COMPONENTS

- *The process of breaking down the vector quantity into its components that are at right angles to each other is known as **resolving a vector** into its components.*

Worked Example

A force of 400N acts at an angle 60º to the horizontal.



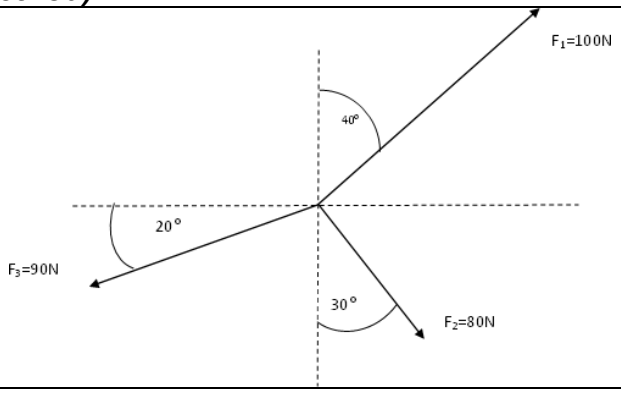
Horizontal component (x-component, R_x)	***Vertical component (y-component, Ry)***
Cos Θ= Adjacent /Hypotenuse *Cos 60^0= Rx/400* *R_x = 200N*	*Sin Θ = opposite/hypotenuse* *Sin 60 = Ry/400* *R_y = 346.41N*

Formulae to calculate the x- and y-components:

R_x = R Cos θ** and **R_y = R Sin ϑ

Where θ is the angle between the x-axis and the force

Finding the resultant of vectors acting at some angle to each other (using component method)



***Step 1:** Find horizontal and vertical components of each force*

Components of F_1: Horizontal (F_{1x})	***Components of F_2: Horizontal (F_{2x})***	***Components of F_3: Horizontal (F_{3x})***
(F_{1x}) = F_1cos θ	*(F_{2x}) = F_2cos θ*	*(F_{3x}) = F_3 cos θ*

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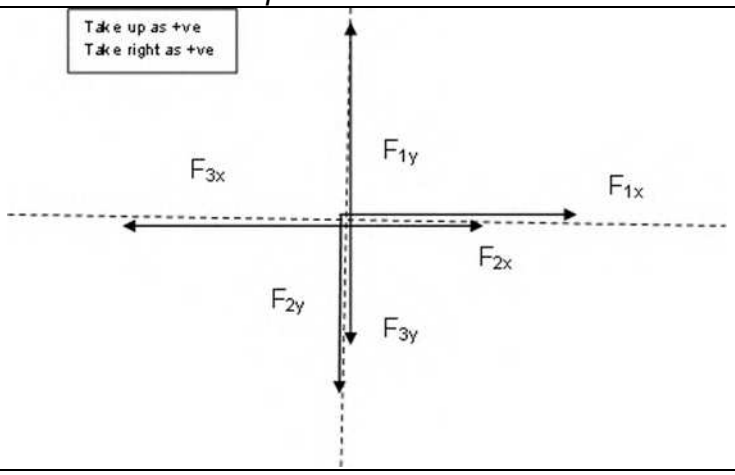
= 100 cos(90º- 40^0) = 64,28N (right)	= 80 cos(90^0 - 30^0) = 40N (right)	= 90 cos20º = 84,57N (left)
(F_{1y}) = F_1 sin θ = 100 sin(90º- 40^0) = 76,60N (up)	(F_{2y}) = F_2 sin θ = 80 sin(90^0 - 30^0) = 69,28N (down)	(F_{3y}) = F_3 sin θ = 90 sin20º = 30,78N (down

NB : The angle θ is between the Horizontal axes and the Force.

Step 2: The three vectors can now be represented as:



Step 3: *Thus, the sum of horizontal components*

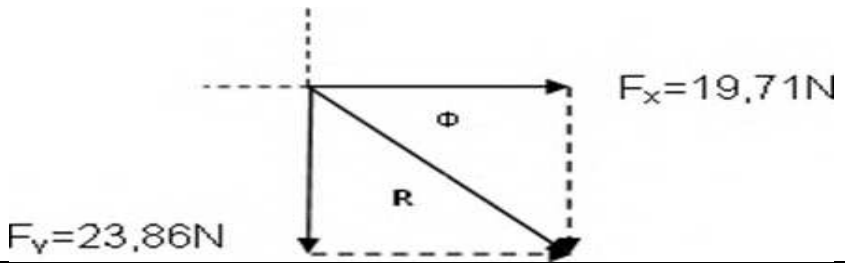
= 64,28 + 40 + (-84,57)

= +19,71N

= 19,7 N to the right

And the sum of vertical components = (- 69,28) + (-30,78) + (76,20)
= - 23,46 N
= 23,46 N downwards

Step 4:



The resultant of the two vectors (at right angles to each other) is:

R^2 = R_x^2 + R_y^2
= 19,71^2+23,86^2
= 30,64N

tan θ = 23,86/19,71
θ = 50,47º

Thus, the resultant of the three forces is 30,64 N in a bearing of 90º + 50,47º = 140,47º.

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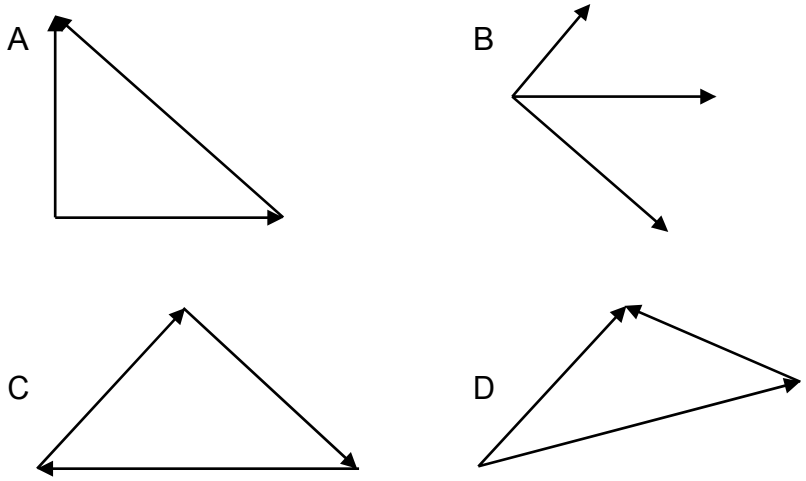
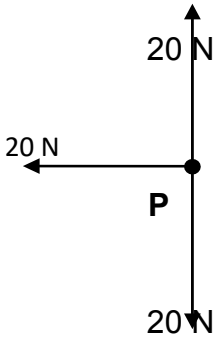
	Exam MCQ questions	
	QUESTION 1: MULTIPLE-CHOICE QUESTIONS	
	Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (1.1–1.6) in the ANSWER BOOK.	
1.1	Consider the following vector diagrams. Which ONE of these vector diagrams represents a zero resultant 	(2)
1.2	Two forces of magnitudes 3 N and 4 N respectively act on a body. The maximum magnitude of the resultant of these forces is … A 12 N. B 7N C 5N D 1N	**(2)**
1.3	Three forces of magnitude 20 N each act on object **P** as shown below. 	

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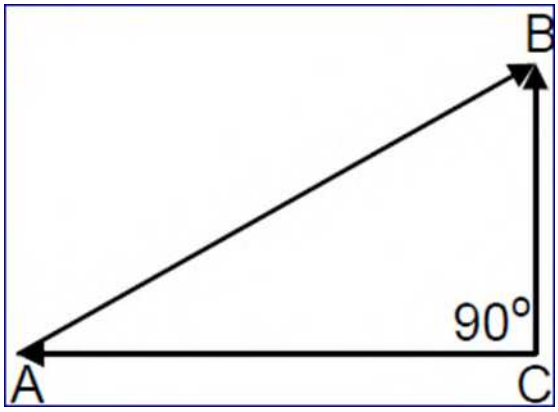
	The resultant force on object P is … A zero. B 20 N to the left. C 20 N upwards. D 20 N downwards.	**(2)**
1.4	Two forces of magnitudes 15 N and 20 N act at a point on an object. Which one of the following magnitudes CANNOT be the resultant of these forces? A. 35 N B. 10 N C. 4 N D. 18 N	(2)
1.5	You can replace two forces, P and Q, with a single force of 7 N. If the magnitude of force P is 3 N, which one of the following can be the magnitude of force Q? A 2 N B 3 N C 8 N D 13N	(2)
1.6	Consider the following vector diagram:  The vector which represents the resultant of the other two, is … A AB. B AC. C CB. D BA.	(2)

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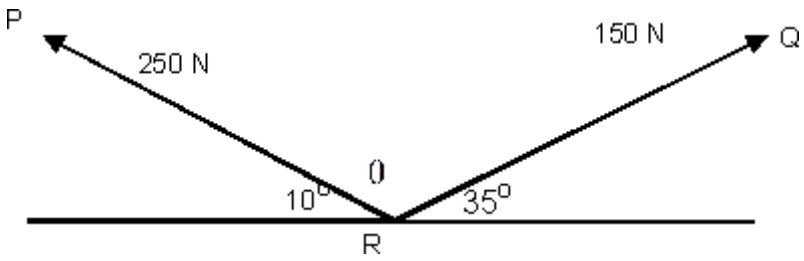
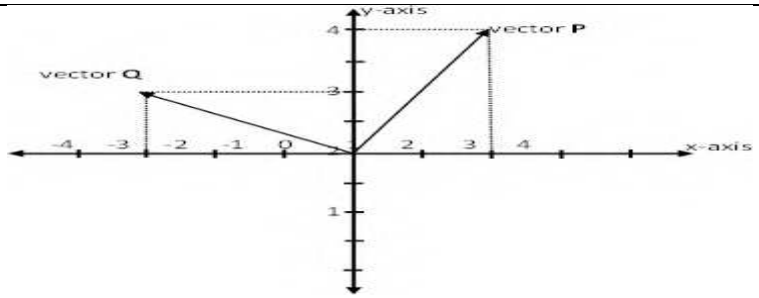
STRUCTURED QUESTIONS

	QUESTION 1 (Grade11 KZN MARCH 2015)	
	The diagram below shows TWO forces P and Q of magnitude 250 N and 150 N respectively acting at a point R.	
		
1.1	Calculate the horizontal and vertical components of vector P.	**(4)**
1.2	Calculate the vector sum of horizontal components of P and Q.	**(3)**
1.3	The vector sum of the vertical components of these forces is 129,45 N. Using the vector sums of the horizontal and vertical components of P and Q, draw a labelled force vector diagram to show the resultant force acting on the point R.	**(3)**
1.4	Calculate the magnitude of the resultant of forces P and Q.	**(3)**
1.5	Calculate the direction (measured clockwise from the positive Y axis) of the resultant of vectors P and Q.	**(3)**
1.6	If vector P was fixed but the direction of vector Q could be changed, for which value of Θ will the resultant force have a maximum value?	**(1)**
		17

	QUESTION 2 (FS CONTROL TEST TERM 1 – 2014)		
	Force vectors P and Q were drawn to scale on the Cartesian plane shown below.		
			
2.1		Define the term resultant of a vector.	(2)
2.2		From the graph, without using a scale drawing, CALCULATE the (no units are required):	
	2.2.1	Magnitude of the horizontal component of vector **P**	(1)
	2.2.2	Magnitude of the horizontal component of the resultant of vectors **P** and **Q**	(2)
	2.2.3	Magnitude of the vertical component of the resultant of vector P and	(2)

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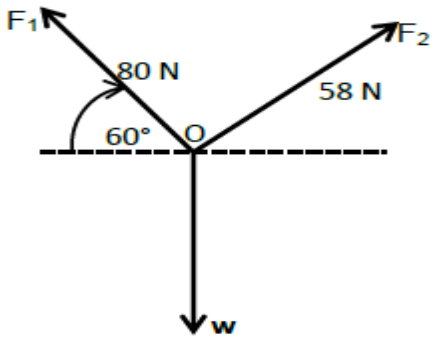
		Q	
	2.2.4	Resultant of vectors **P** and **Q**.	(6)
			[13]

QUESTION 3 (Fs CONTROL TEST TERM 1 – 2015)

Three forces, $\mathbf{F_1}$, $\mathbf{F_2}$ and **w**, act on point **O** as shown in the diagram below.



3.1		Define the term *resultant of forces*.	(2)
3.2		By means of an accurate scale drawing, determine the vertical component of $\mathbf{F_1}$. Use a scale where 10 N is represented by 10 mm.	(5)
3.3		The horizontal and vertical components of F_2 are equal to 40 N and 42N respectively.	
	3.3.1	Prove with calculations that the horizontal components of the forces are in equilibrium.	(3)
	3.3.2	Calculate the magnitude and direction of force **w**.	(2)
			[12]

ADDITIONAL ACTIVITIES

JUNE 2014 LIMPOPO

	QUESTION 1
	Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A – D) next to the question number (1.1 – 1.2) in the ANSWER BOOK.
1.1	Which of the following pairs can be classified as vectors?
	A. Friction and mass
	B. Mass and inertia
	C. Inertia and weight
	D. Weight and Friction (2)

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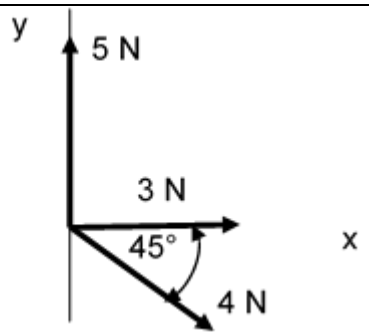
1.2	Which one of the following represents a closed vector diagram?
	 (2)

QUESTION 2		
The diagram below shows three forces of 5 N, 4 N and 3 N acting on an object in the same Cartesian plane.		
		
Calculate the:		
2.1	Magnitude of the resultant force acting on the object.	(10)
2.2	Direction of the resultant force.	(3)

November 2015 National Exams

QUESTION 1		
Vector **P** and vector **–P** are acting at a common point **O**. The angle between the two vectors is ...		
A	0°	
B	90°	
C	180°	
D	270°	
QUESTION 2		
Three forces, **P**, **Q** and **R**, of magnitudes 500 N, 200 N and 300 N respectively, act on a point **O** in the directions shown in the diagram below.		
The forces are NOT drawn to scale.		

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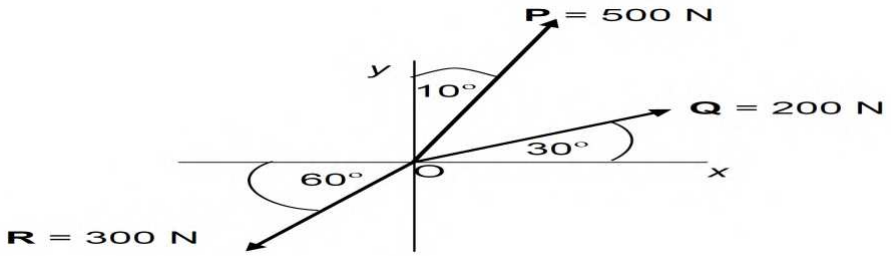
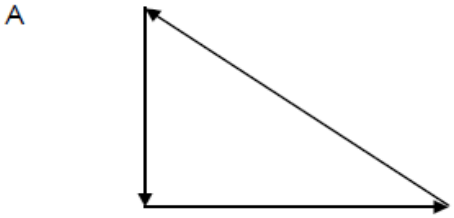
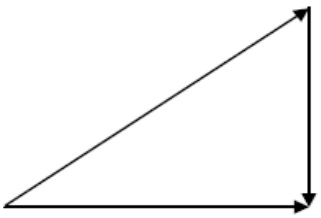
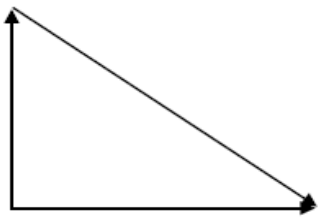
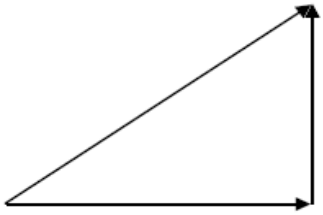


2.1	Refer to the information in the diagram above and give a reason why forces **P**, **Q** and **R** are classified as vectors.	(2)
2.2	Determine the magnitude and direction of the resultant force, either by CALCULATION or by ACCURATE CONSTRUCTION AND MEASUREMENT. (Use scale 10 mm = 50 N.)	(8)
		[10]

November 2017 National Exam

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

1.1	Which ONE of the following pairs of physical quantities are vector quantities?	
	A. Force and distance	
	B. Velocity and speed	
	C. Charge and electric field	
	D. Electric field and force	**(2)**
1.2	Which ONE of the following vector diagrams represents three forces acting on an object simultaneously while the object moves at CONSTANT VELOCITY?	
	A  B  C  D 	**(2)**

MARCH 2018

QUESTION 2
Three forces F_1, F_2 and F_3 act at a point , as shown on the Cartesian plane in the diagram below.

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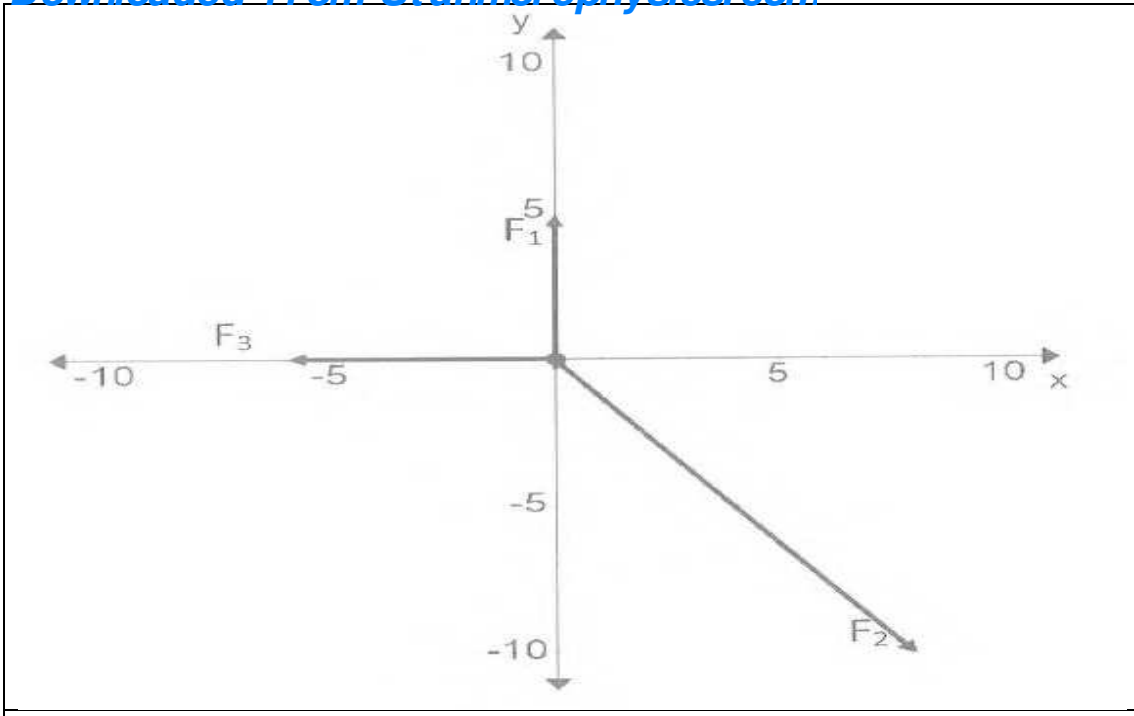

Scale : 1 square unit represents 1N

2.1	Define the "resultant vector"	(2)
2.2	Write down the X-component and Y-component for force F_2	(2)
2.3	Calculate the NET horizontal component for the forces F_1, F_2 and F_3	(1)
2.4	Calculate the NET vertical component for the forces F_1, F_2 and F_3	(1)
2.5	Calculate the magnitude and direction of the resultant force of these three forces.	(4)
		[10]

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ELECTROSTATICS

Principle of conservation of charge.

$$Q_{new} = \frac{Q1 + Q2}{2}$$

Principle of charge quantization.

$$n = \frac{Q}{q_e}$$

Prefix	Conversion
centi− (cC)	$\times 10^{-2}$
milli− (mC)	$\times 10^{-3}$
micro− (μC)	$\times 10^{-6}$
nano− (nC)	$\times 10^{-9}$
pico− (pC)	$\times 10^{-12}$

COULOMB'S LAW

The electrostatic force between two point charges is directly proportional to the product of the two charges and inversely proportional to the square distance between them.

Mathematical representation: $F \alpha Q_1Q_2$, $F\alpha 1/r^2$

Then $F \alpha Q_1Q_2/r^2$

$F = k\frac{Q_1Q_2}{r^2}$

F = force of attraction between objects (N)S
k = Coulomb's constant (9×10^9 $N\cdot m^2\cdot C^{-2}$)
Q = object charge (C)
r = distance between objects (m)

EXAMPLES:
Two charges experience a force F when held a distance r apart. How would this force be affected if one charge is doubled, the other charge is tripled and the distance is halved?

$F = k\frac{q_1q_2}{r^2}$

$F_{new} = k\frac{2q_13q_2}{(\frac{1}{2}r)^2}$

$F_{new} = 24k\frac{q_1q_2}{r^2}$
$F_{new} = 24F$

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2. Two charges experience a force F when held a distance r apart. How would this force be affected if BOTH charges are doubled, and the distance is halved?

$F = k\frac{q_1 q_2}{r^2}$

$F_{new} = k\frac{2q_1 2q_2}{(\frac{1}{2}r)^2}$

$F_{new} = 16k\frac{q_1 q_2}{r^2}$

$F_{new} = 16F$

3. Two charges experience a force F when held a distance r apart. How would this force be affected if one charge is halved, and the distance is doubled?

$F = k\frac{q_1 q_2}{r^2}$

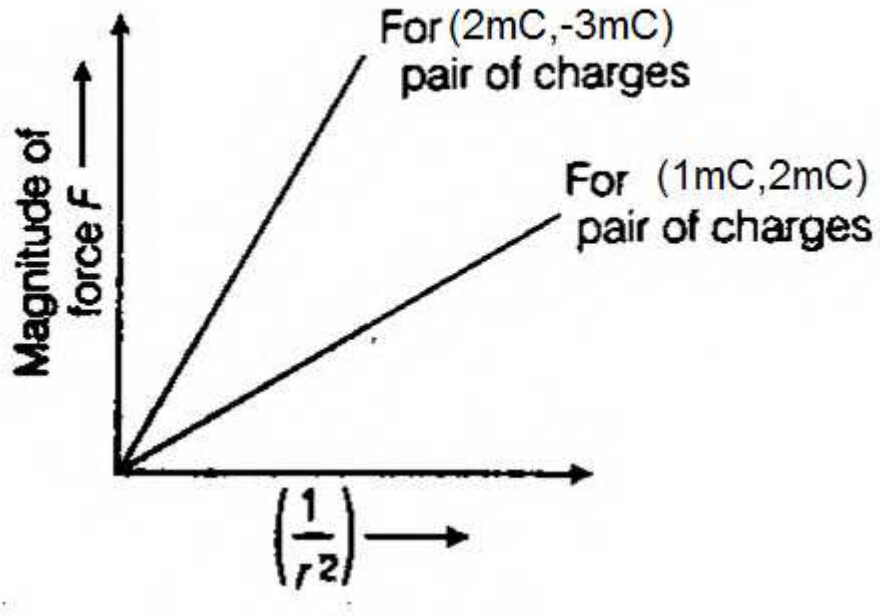
$F_{new} = k\frac{1/2 q_1 q_2}{(2r)^2}$

$F_{new} = 1/4k\frac{q_1 q_2}{r^2}$

$F_{new} = 1/4F$

Graphical representation of Coulombs law:

Electrostatic force and 1/d2



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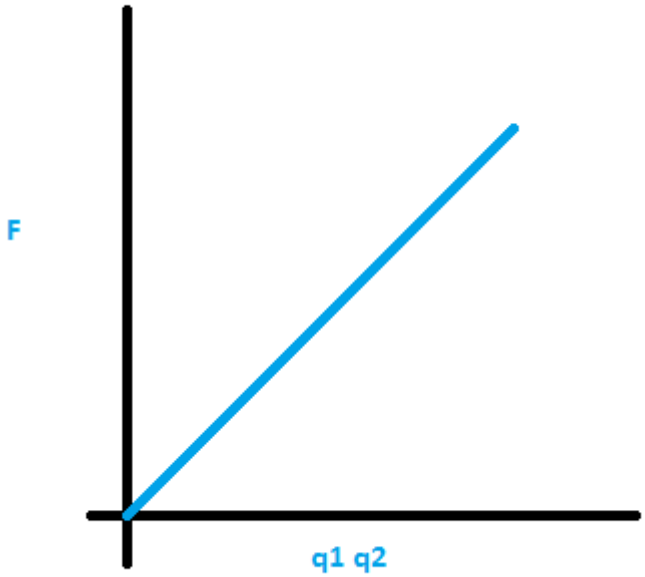


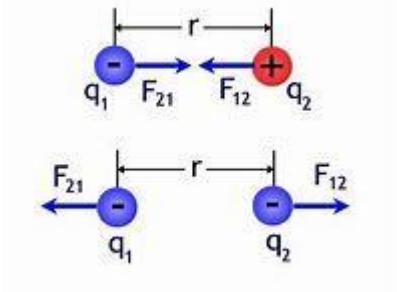
Electrostatic force vs product of charges

CALCULATIONS- Electrostatic force

Electrostatic force is a vector quantity, therefore all vector rules can be applied:
• Direction specific
• Can be added or subtracted.
The force can be calculated using

$$F = k\frac{q_1 q_2}{r^2}$$

• Substitute charge magnitude only.
• Direction determined by charge (like charges repel, unlike charges attract).



• Both objects experience the EQUAL but opposite forces (Newton's Third Law of Motion).

1-Dimensional
Determine the resultant electrostatic force on Q_B.

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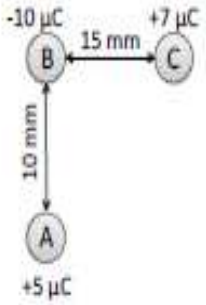
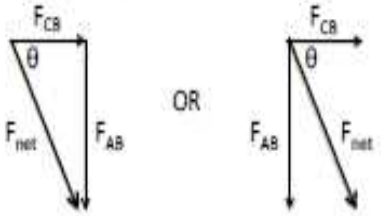
2-Dimensional

Determine the resultant electrostatic force on Q_B.



$$F_{AB} = \frac{kQ_AQ_B}{r^2}$$
$$= \frac{9\times10^9(5\times10^{-6})(10\times10^{-6})}{(10\times10^{-3})^2}$$
$$= 4\,500\text{ N down (A attracts B)}$$

$$F_{CB} = \frac{kQ_CQ_B}{r^2}$$
$$= \frac{9\times10^9(7\times10^{-6})(10\times10^{-6})}{(15\times10^{-3})^2}$$
$$= 2\,800\text{ N right (C attracts B)}$$



PYTHAGORAS:

$$F_{net}^2 = F_{AB}^2 + F_{BC}^2$$
$$F_{net} = \sqrt{4\,500^2 + 2\,800^2}$$
$$F_{net} = 5\,300\text{ N}$$

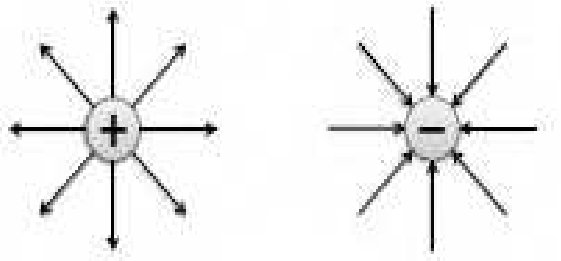
$$\tan\theta = \frac{o}{a}$$
$$\theta = \tan^{-1}\frac{F_{AB}}{F_{CB}}$$
$$\theta = \tan^{-1}\frac{4\,500}{2\,800}$$
$$\theta = 58{,}11°$$
$$\therefore F_{net} = 5\,300\text{ N at } 58{,}11° \text{ below the positive } x-\text{axis}$$

ELECTRIC FIELDS

An electric field is a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge (+1C) would move if placed at that point.

ELECTRIC FIELD LINE PATTERNS

Field lines around the single point charge



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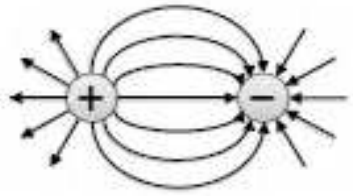
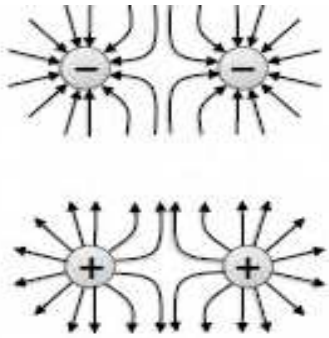
Field lines between two unlike charges



Electric Field Lines between the two like charges

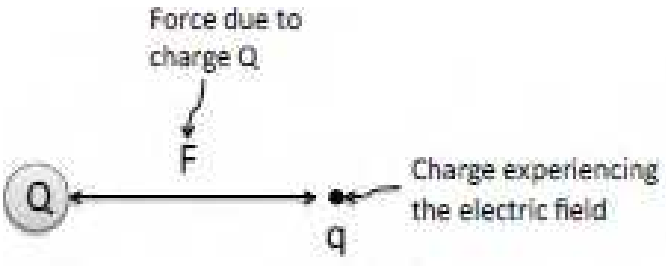


ELECTRIC FIELD STRENGTH

Electric field strength at any point in space is the electrostatic force per unit positive charge experienced by a positive test charge at that point.

$$E = \frac{F}{q}$$

E = electric field strength ($N \cdot C^{-1}$)
F = force (N)
q = charge (C)
q is the charge that experiences the force.



EXAMPLE:

Charge B experiences a force of 2 N due to charge A.
Determine the electric field strength at point B.

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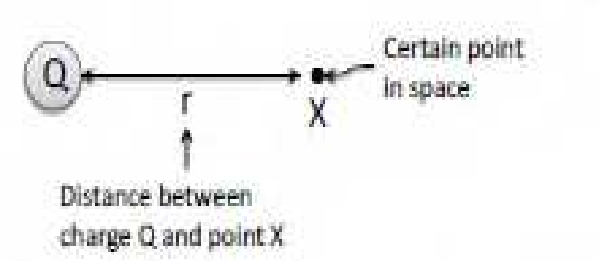
DIRECTION:
Direction that point in space (X) would move IF it was positive.

$$E = k\frac{Q}{r^2}$$

E = electric field strength ($N \cdot C^{-1}$)
k = Coulomb's constant ($9 \times 109\ N \cdot m^2 \cdot C^{-2}$)
Q = object charge (C)
r = distance between objects (m)

Q is the charge that creates the electric field.



WORKED EXAMPLE:

Determine the electric field strength at point P due to charge Q.



$$E = \frac{kQ}{r^2}$$
$$= \frac{9\times 10^9(3\times 10^{-6})}{(5\times 10^{-3})^2}$$
$$= 1{,}08\times 10^9\ N\cdot C^{-1} \text{ to the right}$$

DIRECTION:

Direction that point in space (X) would move IF it was positive.

NOTE:
Electric field strength is a VECTOR. All vector rules and calculations apply. (linear addition, 2D arrangement, resultant vectors, etc.)

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WORKSHEET 1 (20 Min)

1.1 Two identical small metal spheres on insulated stands carry equal charges and are a distance *d* apart. Each sphere experiences an electrostatic force of magnitude F. **(2)**

The spheres are now placed a distance *d* apart.

The magnitude of the electrostatic force each sphere now experiences is:

A. 1/2F

B. F

C. 2F

D. 4F

1.2 Two charged objects on insulated stands have charges of **3Q** and **5Q** respectively. The **(2)**

Objects are a distance **R** apart and exert a force **F** on each other. They are moved so that they are now 1/3 **R** apart. What is the new force that they exert on each other?

A. F

B. 1/3 **F**

C. 3**F**

D. 9**F**

2

Calculate the new charge on each of the spheres in the following diagram after they have touched.



_____

(3)

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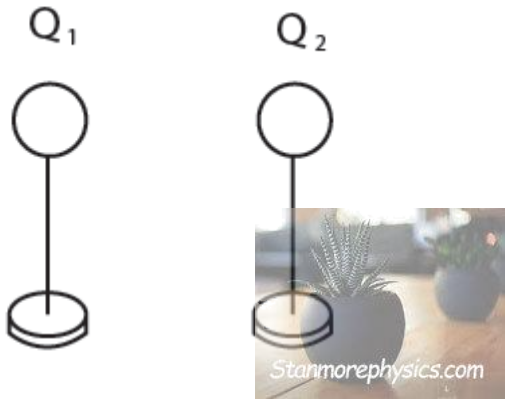
3. Two metal spheres Q1 and Q2 on insulated stands, carry charges of +4nC and −12nC respectively.



3.1 Using free body diagrams, show the electrostatic force on each sphere.

3.2 State the Principle of conservation of charge. (2)



(2)

4 4.1 A neutral object obtains a charge by gaining 1 800 electrons. What is the charge that the object obtains? (2)

4.2 Two metal spheres Q1 and Q2 on insulated stands, carry charges of +8nC and −10nC respectively. The two spheres are now brought together to touch each other. They are then placed back in their original positions.

(3)

4.2.1 Calculate the new charge on each sphere.

4.2.2 What quantity of charge is transferred between the two spheres during contact? (2)

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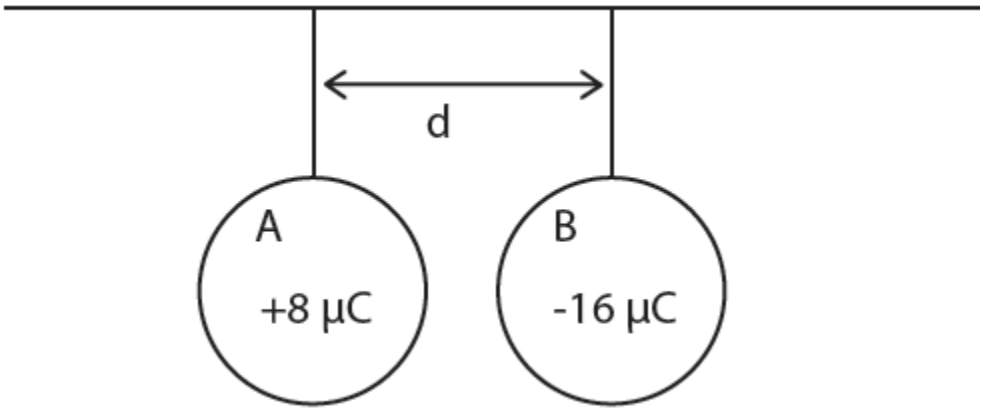
WORKSHEET 2 - COULOMB'S LAW (30min)

1. Two identical metal spheres, **A** and **B** have charges of +8μC and -16μC respectively.

They are suspended from a horizontal wooden pole and placed a distance *d* apart from each other, as shown below.



1.1 Sphere **B** experiences an electrostatic force. In which direction does the force act?

(1)

2. The spheres are touched together and then separated and placed the same distance *d* apart from each other.

(2)

2.2.1 When they touched each other, were electrons removed from or added to **A**?

Give a reason for your answer.

2.2.2 Sphere **B** now experiences a force of 1,6 N. Calculate the distance *d*.

(3)

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3. The centers of two identical metallic spheres, each carrying a charge Q, are placed a distance r apart. Which ONE of the following pairs of changes (that are made simultaneously) will double the electrostatic force that one charged sphere exerts on the other?

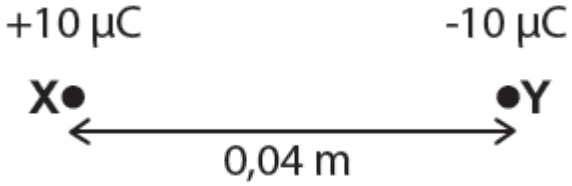
A.	Decrease the distance to $\frac{r}{2}$	Double the charge on each sphere
B.	Decrease the distance to $\frac{r}{2}$	Reduce the charge on one sphere to $\frac{Q}{2}$
C.	Double the distance to 2r	Double the charge on each sphere
D.	Decrease the distance to $\frac{r}{2}$	Reduce the charge on both spheres to $\frac{Q}{2}$

(2)

4. 4.1 Two small metal spheres have charges of +2pC and +5pC respectively. If the force between the two charges is 9 x 10^{-12} N, calculate the distance between them. (4)

5. Two charged spheres X and Y are placed 0,04m apart, as shown in the diagram below.

.



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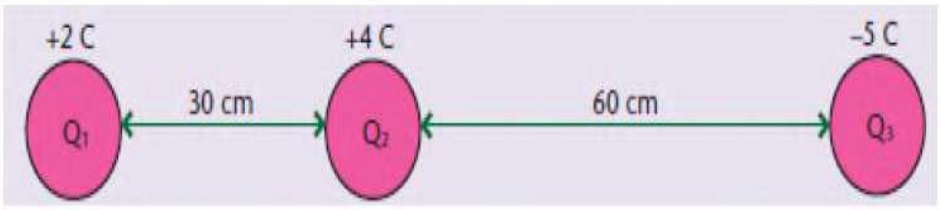
5.1 Calculate the electrostatic force that **Y** experiences due to charge **X** (4)

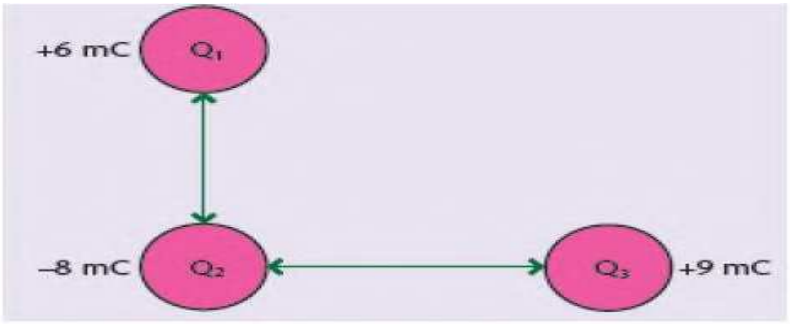
5.2 Thus state the force that **X** experiences due to **Y** (2)

6 Three point charges are in a straight line. The charges and distances between them are shown.



6.1. What is the resultant electrostatic force on Q_2 as a result of the other two charges?

7. Three point charges are placed in close proximity to one another. The charges and distances between them are shown. What is the resultant electrostatic force on Q_2 as result of the other two charges?



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WORKSHEET 3 - **THE ELECTRIC FIELD (25min)**

1. Define an electric field at a point.

(2)

2. 2.1 Draw the electric field pattern for a single positive point charge.

(2)

2.2 Draw the resultant electric field pattern of the following charges



3. A charge of 5nC experiences a force of 4 x10^{-6} N at a point in an electric field. Calculate the strength of the electric field.

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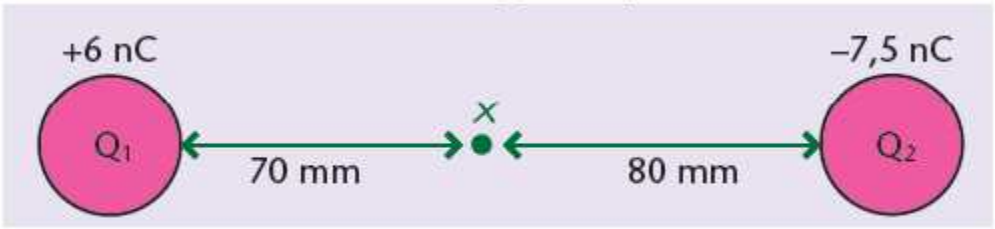
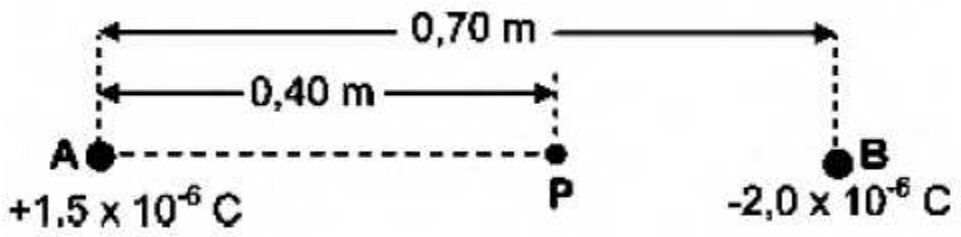
(3)

4. Two charges, Q_1 of +6nC and Q_2 of -7,5nC are separated by a distance of 150 mm. What is the electric field strength at point X, which is 70 mm from Q1 and 80 mm from Q2?



(6)

5. **A** and **B** are two small spheres separated by a distance of 0,70 m. Sphere **A** carries a charge of +1,5 x 10-6 C and sphere **B** carries a charge of -2,0 x 10-6 C. **P** is a point between spheres **A** and **B** and is 0,40 m from sphere **A**, as shown in the diagram below.



5.1 Calculate the magnitude of the net electric field at point P. (3)

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5.2 A point charge of magnitude 3,0 x 10-9C is now placed at point **P**.

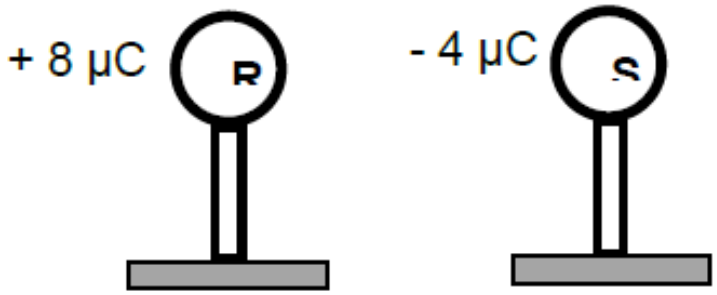
Calculate the magnitude of the electrostatic force experienced by this charge.

(4)

ADDITIONAL ACTIVITIES

QUESTION 1

The diagram shows two small identical metal spheres, **R** and **S**, each placed on a wooden stand. Spheres **R** and **S** carry charges of + 8μC and - 4μC respectively. Ignore the effects of air.



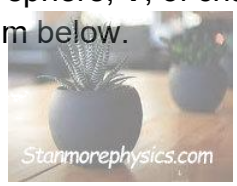
1.1 Explain why the spheres were placed on wooden stands. (1)

Spheres **R** and **S** are brought into contact for a while and then separated by a small distance.

1.2 Calculate the net charge on each of the spheres. (2)

1.3 Draw the electric field pattern due to the two spheres **R** and **S**. (3)

After **R** and **S** have been in contact and separated, a third sphere, **T**, of charge +1μC is now placed between them as shown in the diagram below.



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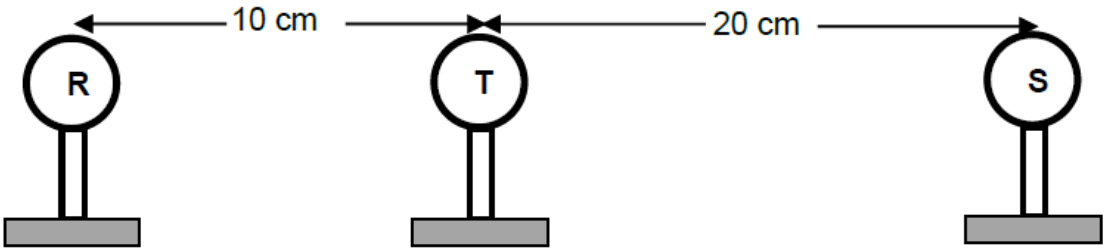


1.4 Draw a free-body diagram showing the electrostatic forces experienced by sphere **T** due to spheres **R** and **S**. (2)

1.5 Calculate the net electrostatic force experienced by **T** due to **R** and **S**. (6)

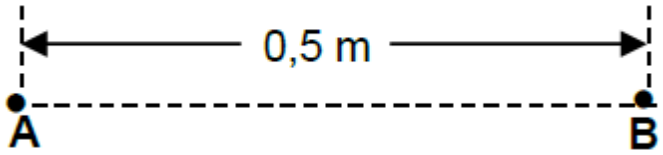
1.6 Define the *electric field at a point*. (2)

1.7 Calculate the magnitude of the net electric field at the location of **T** due to **R** and **S**. (Treat the spheres as if they were point charges.) (3)

[19]

QUESTION 2

Two identical negatively charged spheres, **A** and **B**, having charges of the **same magnitude**, are placed 0,5m apart in vacuum. The magnitude of the electrostatic force that one sphere exerts on the other 144 X1



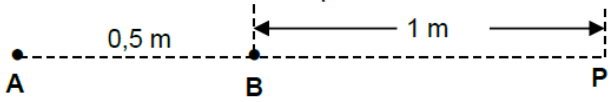
2.1 State Coulomb's law in words. (2)

2.2 Calculate the:

2.2.1 Magnitude of the charge on each sphere (4)

2.2.2 Excess number of electrons on sphere **B** (3)

2.3 **P** is a point at a distance of 1 m from sphere **B**.



2.3.1 What is the direction of the net electric field at point **P**? (1)

2.3.2 Calculate the number of electrons that should be removed from sphere **B** so that the net electric field at point **P** is $3 \times 10^4\ N \cdot C^{-1}$ to the right. (8)

[18]

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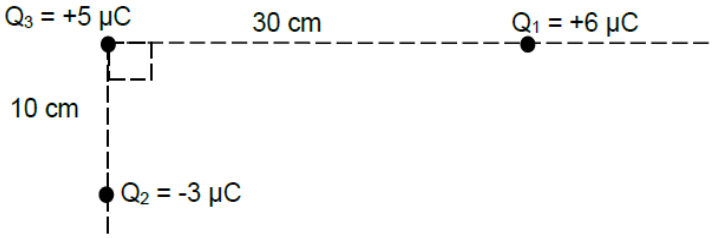
QUESTION 3

Three point charges, Q_1, Q_2 and Q_3, carrying charges of +6 µC, -3 µC and +5 µC respectively, are arranged in space as shown in the diagram below. The distance between Q_3 and Q_1 is 30 cm and that between Q_3 and Q_2 is 10 cm.



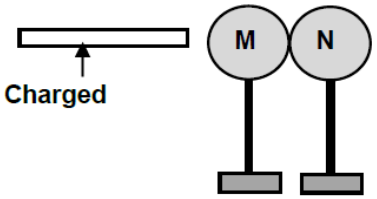
3.1 State Coulomb's law in words. (2)

3.2 Calculate the net force acting on charge Q_3 due to the presence of Q_1 and Q_2. (7)

[9]

QUESTION 4

Two identical neutral spheres, **M** and **N**, are placed on insulating stands. They are brought into contact and a charged rod is brought near sphere **M**.

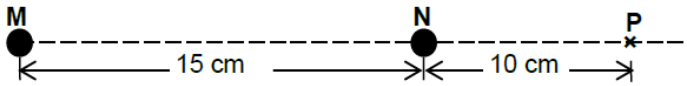


When the spheres are separated it is found that 5 x 10^6 electrons were transferred from sphere **M** to sphere **N**.

4.1 What is the net charge on sphere **N** after separation? (3)

4.2 Write down the net charge on sphere **M** after separation. (2)

The charged spheres, **M** and **N**, are now arranged along a straight line, in space, such that the distance between their centres is 15 cm. A point **P** lies 10 cm to the *right* of **N** as shown in the diagram below.



4.3 Define the *electric field* at a point. (2)

4.4 Calculate the net electric field at point **P** due to **M** and **N**. (6)

[13]

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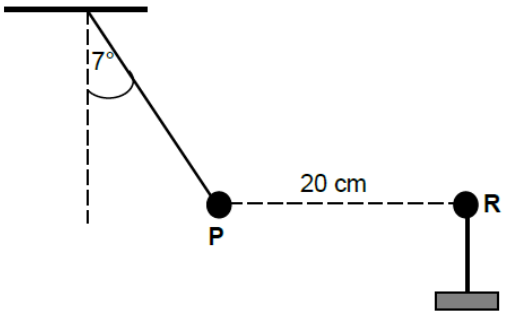
QUESTION 5



A very small graphite-coated sphere **P** is rubbed with a cloth. It is found that the sphere acquires a charge of + 0,5 µC.

5.1 Calculate the number of electrons removed from sphere **P** during the charging process. (3)

Now the charged sphere **P** is suspended from a light, inextensible string. Another sphere, **R**, with a charge of – 0,9 µC, on an insulated stand, is brought close to sphere **P**.

As a result sphere **P** moves to a position where it is 20 cm from sphere **R**, as shown. The system is in equilibrium and the angle between the string and the vertical is 7°.

5.2 Draw a labelled free-body diagram showing ALL the forces acting on sphere **P**. (3)

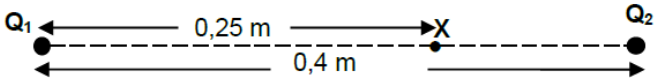
5.3 State Coulomb's law in words. (2)

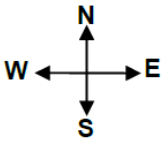
5.4 Calculate the magnitude of the tension in the string. (5)

[13]

QUESTION 6

Two charged particles, Q_1 and Q_2, are placed 0,4 m apart along a straight line. The charge on Q_1 is + 2 x 10^{-5} C, and the charge on Q_2 is – 8 x 10^{-6} C. Point **X** is 0,25 m **east** of Q_1, as shown in the diagram below.





Calculate the:

6.1 Net electric field at point **X** due to the two charges (6)

6.2 Electrostatic force that a – 2 x 10^{-9} C charge will experience at point **X** (4)

The – 2 x 10^{-9} C charge is replaced with a charge of – 4 x 10^{-9} C at point **X**.

6.3 **Without any further calculation**, determine the magnitude of the force that the – 4 x 10^{-9} C charge will experience at point **X**. (1)

[11]

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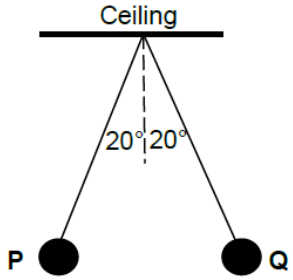
QUESTION 7

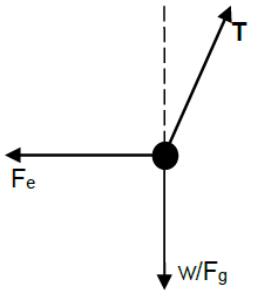


Two identical spherical balls, **P** and **Q**, each of mass 100 g, are suspended at the same point from a ceiling by means of identical light, inextensible insulating strings. Each ball carries a charge of +250 nC. The balls come to rest in the positions shown in the diagram.

7.1 In the diagram, the angles between each string and the vertical are the same. Give a reason why the angles are the same. (1)

7.2 State Coulomb's law in words. (2)

7.3 The free-body diagram, not drawn to scale, of the forces acting on ball **P** is shown alongside. Calculate the:



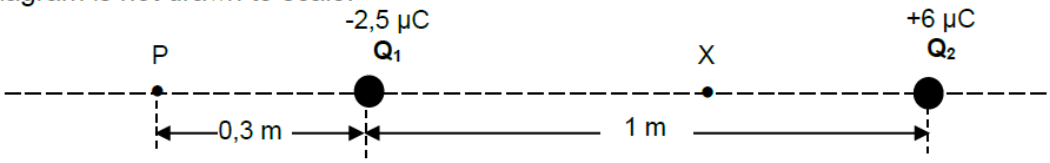
7.3.1 Magnitude of the tension (T) in the string (3)

7.3.2 Distance between balls **P** and **Q** (5)

[11]

QUESTION 8

A sphere Q_1, with a charge of -2,5 µC, is placed 1 m away from a second sphere Q_2, with a charge +6 µC. The spheres lie along a straight line, as shown in the diagram below. Point **P** is located a distance of 0,3 m to the left of sphere Q_1, while point **X** is located between Q_1 and Q_2. The diagram is not drawn to scale.



8.1 Show, with the aid of a VECTOR DIAGRAM, why the net electric field at point **X** *cannot be zero.* (4)

8.2 Calculate the net electric field at point **P**, due to the two charged spheres Q_1 and Q_2. (6)

[10]

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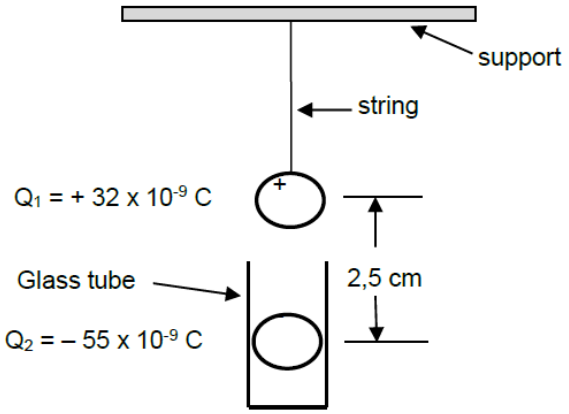
QUESTION 9

A small sphere, Q_1, with a charge of + 32 x 10^{-9} C, is suspended from a light string secured to a support. A second, identical sphere, Q_2, with a charge of – 55 x 10^{-9} C, is placed in a narrow, cylindrical glass tube vertically below Q_1. Each sphere has a mass of 7 g. Both spheres come to equilibrium when Q_2 is 2,5 cm from Q_1, as shown in the diagram. Ignore the effects of air friction.



9.1 Calculate the number of electrons that were removed from Q_1 to give it a charge of + 32 x 10^{-9} C. Assume that the sphere was neutral before being charged. (3)

9.2 Draw a labelled free-body diagram showing all the forces acting on sphere Q_1. (3)

9.3 Calculate the magnitude of the tension in the string. (5)

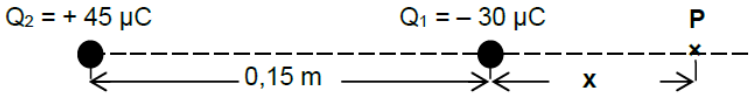
[11]

QUESTION 10

10.1 Define *electric field at a point* in words. (2)

10.2 Draw the electric field pattern for two identical positively charged spheres placed close to each other. (3)

10.3 A – 30 µC point charge, Q_1, is placed at a distance of 0,15 m from a + 45 µC point charge, Q_2, in space, as shown in the diagram below. The net electric field at point **P**, which is on the same line as the two charges, is zero.



Calculate **x**, the distance of point **P** from charge Q_1. (5)

[10]

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Content area: Matter and Materials

Topic: Quantitative Aspects of Chemical

In this unit we will focus on the following concepts and skills:

- **Gases and solutions**
- **Stoichiometric calculations**
- **Volume relationships in gaseous reactions**

QUANTITATIVE ASPECT OF CHEMICAL CHANGE

- The mole is the SI unit for the amount of substance (describe a mole)
- The Mole is a name for a specific number. The Mole is the SI unit for quantity of substance
- One mole is the amount of a substance having the same number of particles as there are atoms in 12 g carbon-12. (define a mole)

Abbreviation of units – the official SI abbreviation of the unit mole is mol.
The mole - mass relationship is summarised if the formula:

$$n = \frac{m}{M}$$

Where: n – number of moles of substance in mol.
m – mass of sample of substance in g.
M – molar mass of substance in $g.mol^{-1}$.

Example 1

1. Calculate the number of moles of water in 100 g of water

$$n = \frac{m}{M} = \frac{100}{16+(2\times1)} = 5{,}56\ mol$$

Example 2

2. What is the molar mass of a substance if 5 moles of the substance have a mass of 295,5g

$$n = \frac{m}{M}$$

$$\therefore 5 = \frac{295{,}5}{M}$$ (Cross multiply and let M be the subject of the formula)

$$M = \frac{295}{5}$$

$M = 58, 5\ g.mol^{-1}$

The mole and Avogadro constant

- The mole is defined as the number of particles or atoms in 12,0 g of Carbon -12
- A mole of particle is an amount of $6, 02 \times 10^{23}$ particle.
- $6, 02 \times 10^{23}$ is known as Avogadro's number N_A.

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WORKED EXAMPLES

1. Calculate the number of moles in:

(i) 2,5g of NH_3

(ii) 213 of Cl_2

Solutions

(i) Molar mass of NH_3

M_{NH3}= 14 + 3(1)

= 17g.mol^{-1}

$n = \frac{m}{M}$

$n = \frac{m}{M} = \frac{2.5}{17}$ = 0.15mol

(ii) Molar mass of Cl_2

M(Cl_2) = 35,5(2) = 71g.mol^{-1}

$n = \frac{m}{M} = \frac{213}{71}$ = 3 mol

Practise exercise

1. Calculate the number of moles in:

(i) 213g of Cl_2
(ii) 128g of SO_2
(iii) 39,5g $KMnO_4$
(iv) 20,5g of $Ba(OH)_2$

2. Calculate the mass of:
(i) 0,2 mol of NH_3
(ii) 0.7 mol of O_2
(iii) 2,5 mol of $Mg(OH)_2$
(iv) 3,5 mol of Fe

3. Calculate the molar mass for each of the following:
(i) Ca
(ii) $MgCl_2$
(iii) CO_2
(iv) $CaCO_3$

Relationship derived from Balanced Chemical Equation

$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

Iron + oxygen → iron(iii)oxide

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4 atoms Fe	**+**	**3 molecules O_2**	**→**	**2 formula units of Fe_2O_3**
4 mol Fe	**+**	**3 mol O_2**	**→**	**2 mol of Fe_2O_3**
223,4g Fe	**+**	**96 g O_2**	**→**	**319g of Fe_2O_3**
319,4 reactants			**→**	**319,4g products**

- **The Mole and the Gases**

AVOGADRO'S LAW:

- Avogadro also determine that: One mole of any gas occupies the same volume at the same temperature and pressure.

  <u>1 mole of ANY gas at STP is occupies a volume of 22,4 dm^3</u>

  For the reactions at STP gas volumes will be according to their molar ratio.

N_2	+	$2O_2$	→ $2NO_2$
1mol	+	2mol	→ 2mol
1(22,4dm^3)	+	2(22,4dm^3)	→ 2(22,4dm^3)

- The Molar volume of ANY gas at STP is given the symbol V_m **(V_m = 22,4 dm^3mol^{-1})**

  NOTE:STP stands for Standard Temperature and Pressure is 273K(0^0C) and 1,01×10^5Pa

- For any gas at STP **n** = $\frac{\mathbf{v}}{\mathbf{v}_m}$
- Where : n - number of moles of gas
  V – Volume of gas sample
  V_m – molar Volume of gas (22, 4 $dm^{-1}.mol^{-1}$)
- The Volume of the gas sample (V) must always be measured in **dm^3 (1 dm^3 = 0,001 m^3 = 1000 cm^3 = dm^3 100ml = 1 litre)**

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WORKED EXAMPLES

1. Determine the volume of 0,2 moles of H_2 at STP.
2. Determine the mass of 60 cm^3 of NH_3 at STP.

Solutions

1. $n = \frac{V}{Vm}$
   $V = 0{,}2X22.4$= 0,448 dm^3

2. [convert units first]
   V=60/1000 =0.06dm^3
   $n = \frac{V}{Vm} = \frac{0.06}{22.4} = 0.0027\ mol$
   $n = \frac{m}{M}$
   $m = 0.0027X17.03 = 0.046g$

- **The mole and Concentrations of solution.**
  - Solutions are homogeneous (uniform) mixture of solute and Solvent
  - Solute and Solvent can be a Gas, liquid or solid.
  - The most common solvent is liquid water, this is called aqueous solution.
  - **Concentration** – the concentration of solution is the number of mole per unit volume of solution.
  - **c =** $\frac{n}{v}$ concentration can also be calculated with **c =** $\frac{m}{MV}$

Where:
C – concentration (mol.dm^{-3})
n – number of moles (mol)
V – Volume (dm^3)
m – mass in (g)
M – Molar mass (g.mol^{-1})



WORKED EXAMPLES

1. Calculate the concerntration of a solution of calcium chloride made by dissolving 5.55g of dry $CaCl_2$ crystals in enough water to make 750 cm^3 of solution.

2. What mass of copper (II) sulphate must be dissolved in 200ml water to yield a 0.4 mol.dm^{-3} solution?

Solutions

1. $c = \frac{m}{MV} = \frac{5.55}{(111)(0.75)} = 0.067\ mol.dm^{-3}$

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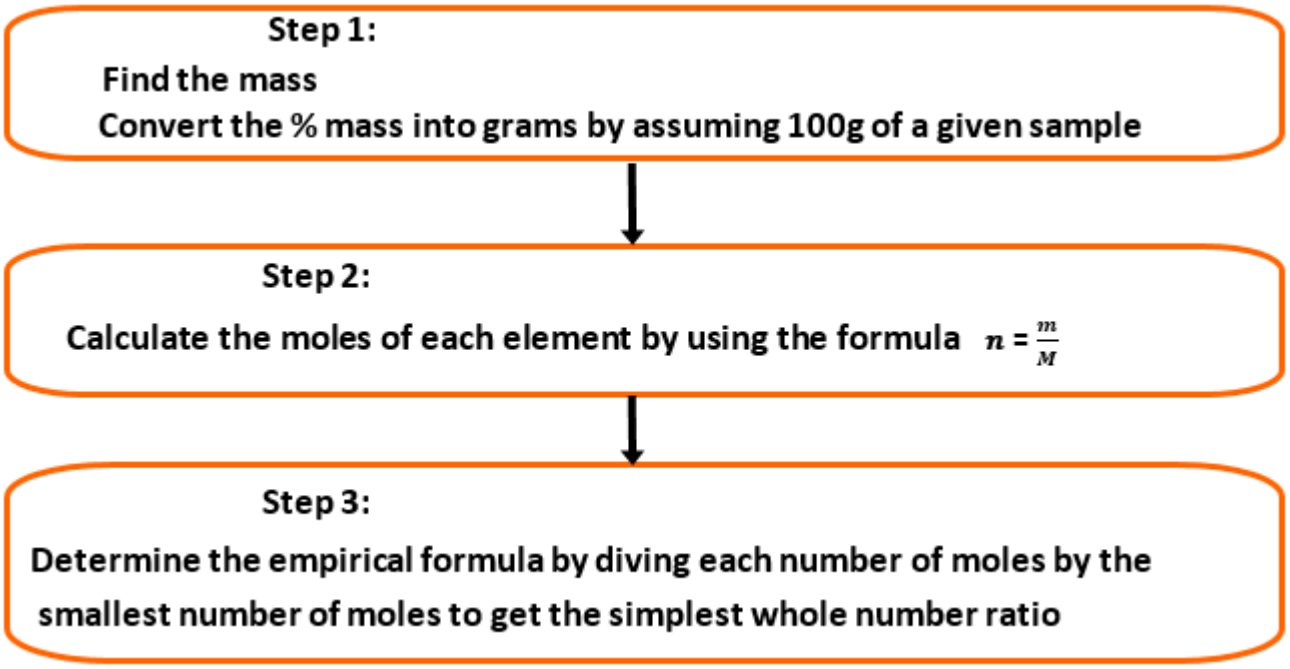
2. $c = \frac{m}{MV}$

$0.4 = \frac{m}{(159.5)(0.2)}$

m = 12,76g

- **The mole and Percentage Composition of Substances**
  - The subscripts in a chemical formula give the mole ratio in which the elements combine.
  - The mole ratio enables one to calculate the percentage composition, of the elements in the compound.
- **The Mole and Empirical formula of compounds.**
  - The empirical formula of a compound gives the simplest mole ratio in which the element of the compound combine.
  - Empirical formula simply tells us the ratio of the different elements in a compound, not number of atoms of each element in molecule.

Steps to find the empirical formula:



EXAMPLE:

E.g. In a combustion reaction 0.48 g of Mg ribbons is burnt. The amount of MgO produced is 0.8g. Calculate the empirical formula for MgO

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Steps	*Magnesium*	*Oxygen*
Step 1 *Mass of element*	*0.48 g*	*0.80- 0.48= 0.32 g*
Step 2 *Mol* ($n = \frac{m}{M}$)	$n = \frac{m}{M} = \frac{0.48}{24} = 0.02$ *mol*	$n = \frac{m}{M} = \frac{0.32}{16} = 0.02$ *mol*
Step 3 *Atom ratio* *(divide by smallest number in ratio)*	$\frac{0.02}{0.02} = 1$	$\frac{0.02}{0.02} = 1$

Therefore the empirical formula is MgO

Worked example 2

The action of bacteria on meat and fish produces a stinking compound called CADAVERINE. The compound has a composition of 58, 77% C; 13,81% H and 27, 42% N by mass.

Determine the empirical formula of CADAVERINE.

In 100 g of compound we have 58,77 g C; 13,81 g H; and 27,40 g N

$n = \frac{m}{M}$

n(C) = $\frac{58,77}{12}$ ✓ = 4,8975 mol C

n(H) = $\frac{13,81}{1}$ ✓ = 13,81 mol H

n(N) = $\frac{27,40}{14}$ ✓ = 1,9571 mol N

Mole ratios = C: H : N

= 2,50 : 7,06 : 1,00✓ x 2

Nearest whole number ratios = 5 : 14 : 2✓

∴ empirical formula is $C_5H_{14}N_2$✓

- **Empirical formula to Molecular formula**
  - Molecular formula is the actual ratio of an atom in a molecular mass.
  - The molecular formula can be calculated from the empirical formula and the relative molecular mass.

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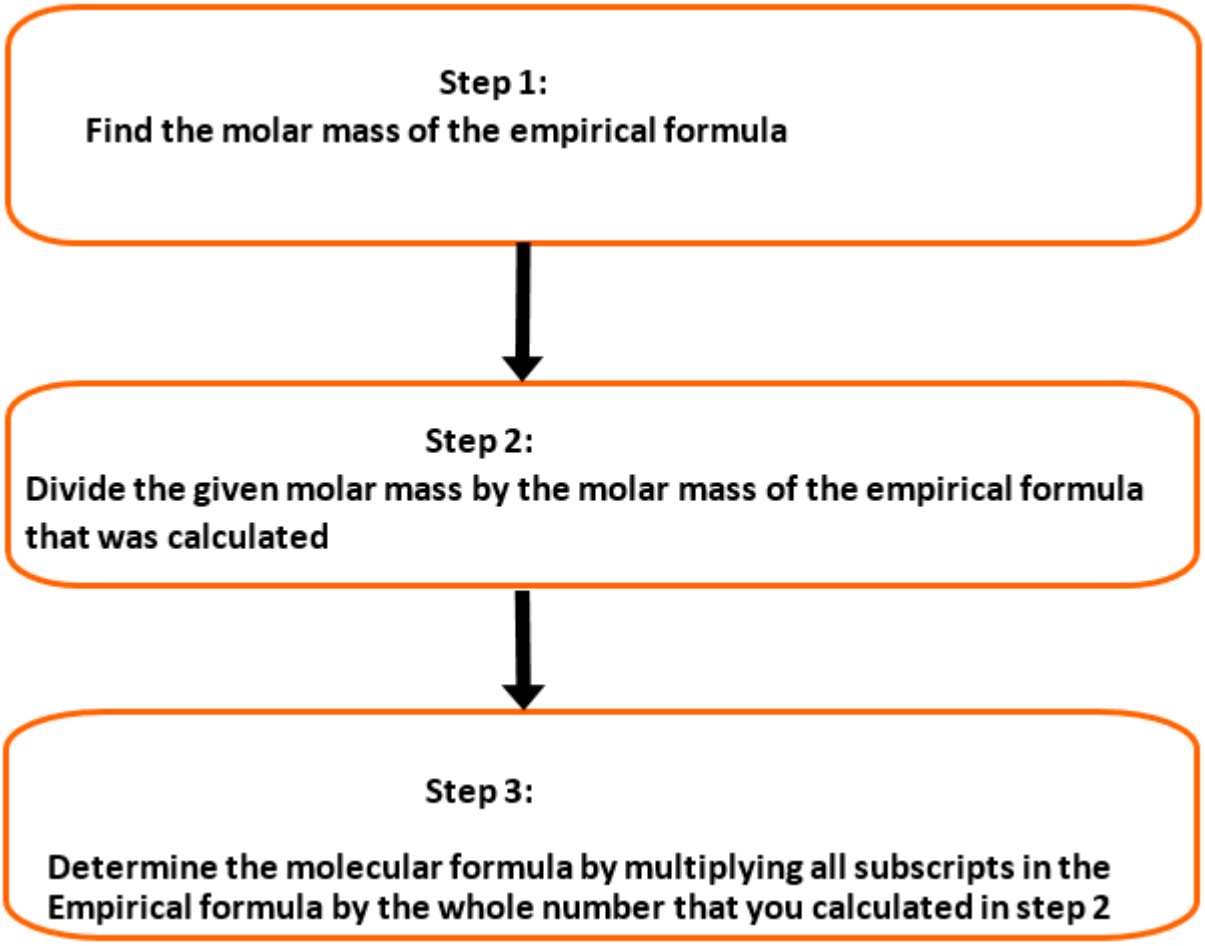
STEPS TO DETERMINE MOLECULAR FORMULA



WORKED EXAMPLE

Butene has the empirical formula CH_2.The molecular mass of butene is 56 g.mol^{-1}
Determine the molecular formula of butene.

Step 1 Empirical formula given CH_2.

Step 2 M (CH_2)= 12+2(1) = 14 g.mol^{-1}

Step 3 ratio number = $\frac{molecular\ formula\ mass}{empirical\ formula\ mass}$ = $\frac{56}{14} = 4$

Step 4 $CH_2 \times 4 = C_4H_8$

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- **Limiting Reaction**
  - In a reaction between two substances, one reaction is likely to be used up completely before the other and this limit the amount of product formed.
  - The amount of limiting reactant will determine :
    - ✓ The amount of product formed.
    - ✓ The amount of other (**excess)** reactant used.

  Determining limiting reactants
    - ✓ Calculate the number of moles of each element.
    - ✓ Determine the ratio between reactants.
    - ✓ Determine limiting reactant using the ratio.

NOTE: If one reactant is in excess, it means that there is more enough of it.

If there are only two reactants and one is in excess, it means that the other is the limiting reactant.

WORKED EXAMPLES.

1. A 8,4g sample of nitrogen reacts with 1,5g of hydrogen. The reaction is represented with the unbalanced equation below.

   $N_2(g) + H_2(g) \rightarrow NH_3(g)$

   1.1. Balance the equation.
   1.2. Determine:
   1.2.1. Which reactant is a limiting reactant?
   1.2.2. The mass of ammonia that can be produced.

SOLUTIONS

1.1. $N_2 + 3H_2 \rightarrow 2NH_3$

1.2.1. $\text{n}(N_2) = \frac{m}{M} = \frac{8,4}{28} = 0,3\ mol$

$\text{n}(H_2) = \frac{m}{M} = \frac{1,5}{2} = 0,75\ mol$

N_2	:	H_2	
1	:	3	
0,3	:	x	(cross multiply)

$\therefore x = 0,9\ mol$

If all nitrogen is used, 0,9 mol of hydrogen is needed, however, only 0,75 mol of hydrogen is available. The hydrogen will run out first therefore hydrogen is the limiting reactant.

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1.2.2. Because the hydrogen is the limiting reactant, it will determine the mass of ammonia produced:

H_2 : NH_3
3 : 2
0.75 : x (cross multiply)

∴ x = 0,5 mol

$n(NH_3) = \frac{m}{M}$

m= (0,5)(17)= 8,5g

- **Percentage purity**
  - Sometimes chemicals are not pure and one needs to calculate the percentage purity.
  - Only the pure component of the substance will react.
  - For impure sample of a substance :

Percentage purity = $\frac{\text{Mass of pure substance}}{\text{Mass of impure substance}} \times 100\ \%$

Steps to determine the percentage purity

- ✓ Determine moles of a product.
- ✓ Balance the equation.
- ✓ Determine the ratio between reactants and products.
- ✓ Using the ratio, determine the number of moles of reactants.
- ✓ Determine the mass of pure substance.
- ✓ Calculate the percentage purity of the sample.

- **Percentage Yield**
  - The percentage yield shows how much product is obtained compare to the maximum possible mass.
  - Some of the product may be lost due to evaporation into the surrounding air, or to a little being left in solution. This results in the amount of produced being less than maximum theoretical amount you would expect.
  - We can express this by the percentage yield :

Percentage yield = $\frac{\text{Actual yield}}{\text{Theoritical yield}} \times 100\%$

  - Percentage yield is usually determined using mass, but can also be determined with mol and volume.

STEPS TO DETERMINE THE PERCENTAGE YIELD

- ✓ Determine the moles of reactant
- ✓ Balance the equation.

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- ✓ Using the ratio from the balance equation, determine the numbers of moles of product.
- ✓ Determine the theoretical mass of product.
- ✓ Calculate the percentage yield.

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WORKED EXAMPLE

Emphases that for percentage yield the focus on actual yield and theoretical yield

An excess of $Pb(NO_3)_2$ reacts with 0.75g of KI according to the reaction:
$Pb(NO_3) + KI \rightarrow PbI_2 + KNO_3$
After titration and drying, a mass of 0.583g of PbI_2 is measured.

Determine the percentage yield of PbI_2

SOLUTIONS

Step 1: (balance chemical equation)
$Pb(NO_3) + 2KI \rightarrow PbI_2 + 2KNO_3$
Step 2: (convert all given information to mole)

$$n(KI) = \frac{m}{M} = \frac{0.75}{166} = 4.52X10^{-3}mol$$

Step 3: (use stoichiometric ratio)

From the balance equation

(n)KI	:	(n)PbI_2
2	:	1
$4.52X10^{-3}$	:	?

(n)PbI_2= $\frac{1}{2}(4.52X10^{-3}) = 2.26X10^{-3}\ mol$

Step 4: (convert the number of moles to mass)

$$n = \frac{m}{M}$$

$$2.26X10^{-3} = \frac{m}{461}$$

$$m = 1.04g$$

Step 5: (percentage yield)

$$Percentage\ yield = \frac{actual\ yield\ mass}{theoretical\ yeild\ mass}X100$$

$$Percentage\ yield = \frac{0.583}{1.04}X100$$

$$Percentage\ yield = 56.1\%$$

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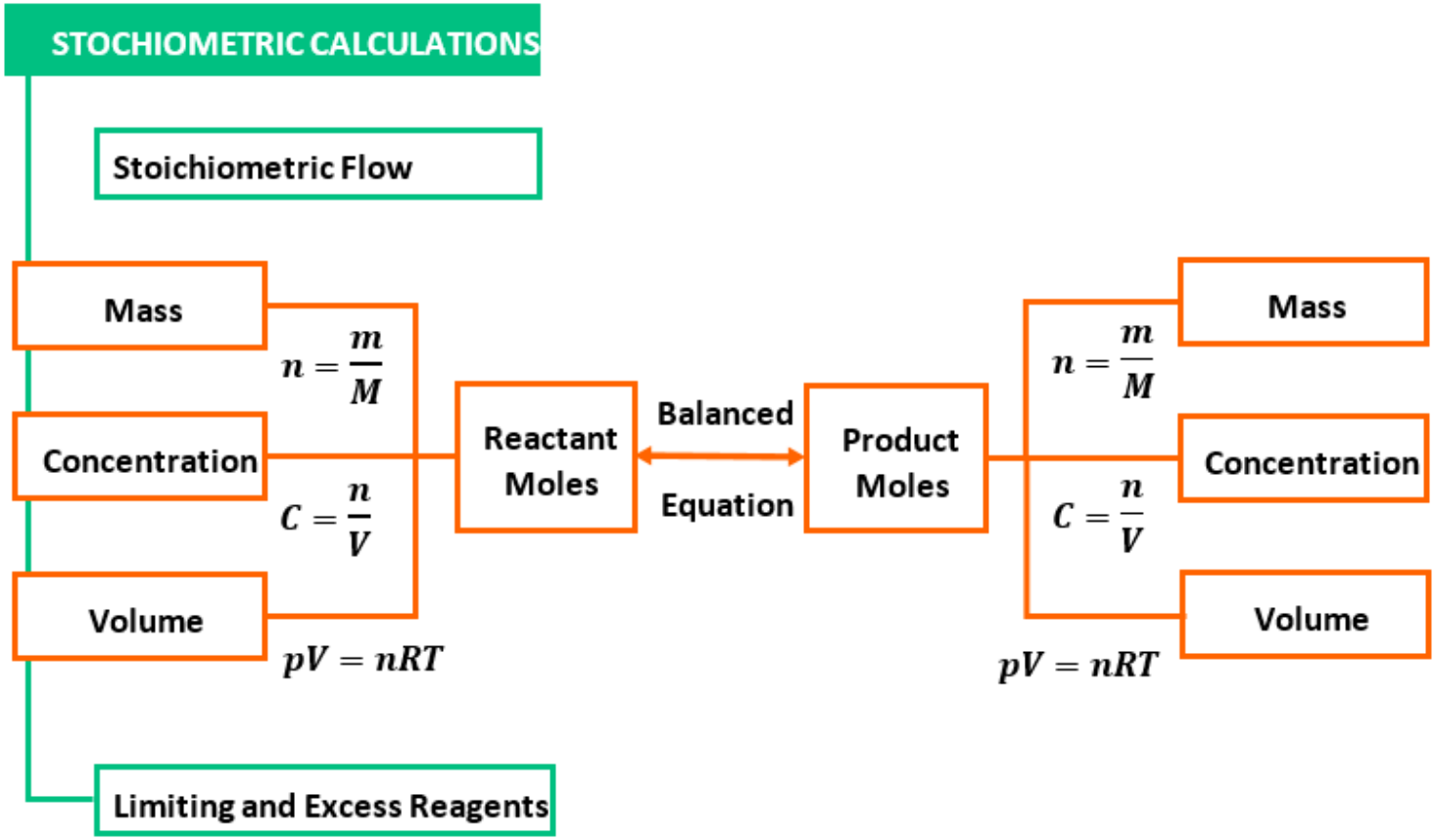

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LESSON 1- REVISION OF GRADE 10 STOICHIOMETRY

1.1	Calculate the molar mass for each of the following:		
	1.1.1	Ca	(1)
	1.1.2	$MgCl_2$	(2)
	1.1.3	H_2SO_4	(2)
	1.1.4	$Ca(NO_3)_2$	(2)
1.2	Determine the percentage composition for each of the following substances:		
	1.2.1	$MgCl_2$	(2)
	1.2.2	$CuSO_4$	(2)
1.3	Given 80 g of NaOH		
	1.3.1	Calculate the number of moles of 80 g of NaOH.	(3)
	1.3.2	Calculate the number of NaOH particles in 80 g of NaOH.	(3)
1.4	Given 0,05 kg of $CaCO_3$.Calculate		
	1.4.1	The number of moles of 0,05 kg of $CaCO_3$.	(2)
	1.4.2	The number $CaCO_3$ particles in 0,05 kg of $CaCO_3$.	(2)
1.5	Given 11,2 dm^3 of nitrogen gas at STP. Calculate		
	1.5.1	The number of moles of 11,2 dm^3 of nitrogen gas at STP.	(2)
	1.5.2	The number of N_2 (g) molecules at STP.	(2)

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	1.5.3	The number of nitrogen(N) atoms at STP	(2)

LESSON 2- MOLAR VOLUME OF GASES

2.1. Choose the correct answer			
	2.1.1	....of a gas is the volume of one mole of a substance at STP. A. Molar mass B. Molar volume C. Atomic weight D. Molar weight	(2)
	2.1.2	Equal volumes of all gases at the same temperature and pressure contain the same number of.. A. Protons B. Neutrons C. Electrons D. Molecules	(2)
2.2			
	2.2.1	Calculate the number of moles of water in 12 dm^3 of water vapour at STP.	(3)
	2.2.2	Calculate the volume of hydrogen gas that combines with 12 cm^3 of chloride.	(3)

LESSON 3- CONCENTRATION

3.1	3.1.1	Calculate the concentration of a solution of calcium chloride made by dissolving 5.55g of dry $CaCl_2$ crystals in enough water to make 750 cm^3 of solution.	(3)
	3.1.2	What mass of copper (II) sulphate must be dissolved in 200ml water to yield a 0.4 $mol.dm^{-3}$ solution?	(3)
3.2			
	3.2.1	How many moles of chloride ions are present in 111 g of calcium chloride?	(2)

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		A 0,5 **B** 2 **C** 1 **D** 1,47	
	3.2.3	What amount of oxygen gas (in moles) contains 1,8 x 10^{22} molecules? **A** 0,03 **B** 33,34 **C** 1,2 X 10^{24} **D** 1,08 X0^{46}	(2)
3.3	A solution of $Mg(OH)_2$ is made up so that it will have a volume of 0,25 dm^3 and a concentration of 0,5 $mol.dm^{-3}$. The solution is made up using distilled water.		(2)
	3.3.1	Define the term *concentration.*	(1)
	3.3.2	Name the solute used to make this solution.	(5)
	3.3.3	Calculate the mass of solid $Mg(OH)_2$ required to make up the solution.	(3)
3.4.	20 cm^3 of a 0,1 $mol \cdot dm^{-3}$ nitric acid solution neutralises 25 cm^3 sodium carbonate solution according to the following balanced equation: $2HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(\ell) + CO_2(g)$		
	3.4.1	Write down the NAME of the salt formed in the reaction.	(5)
	3.4.2	Calculate the mass of sodium carbonate used to prepare 250 cm3 of sodium carbonate solution of this concentration.	(3)
LESSON 4-EMPIRICAL FORMULA			
4.1	Methyl benzoate is a compound used in the manufacture of perfumes. It is found that a 5,325 g sample of methyl benzoate contains 3,758 g of carbon, 0,316 g of hydrogen and 1,251 g of oxygen.		
	4.1.1	Define the term *empirical formula*	(2)
	4.1.2	Determine the empirical formula of methyl benzoate	(5)
	4.1.3	If the molar mass of methyl benzoate is 136 $g.mol^{-1}$, what is its molecular formula?	(3)

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4.2	The action of bacteria on meat and fish produces a stinking compound called CADAVERINE. The compound has a composition of 58, 77% C; 13,81% H and 27, 42% N by mass.		
	4.2.1.	Determine the empirical formula of CADAVERINE.	5
LESSON 5- STOICHIOMETRIC CALCULATIONS			
5.1.	8 g of zinc react completely with an excess hydrochloric acid at STP to form hydrogen gas.		
	5.1.1	Calculate the mass of hydrochloric acid that reacts.	(4)
	5.1.2	Calculate the volume of hydrogen gas that is produced.	(3)
5.2	Sodium thiosulphate, $Na_2S_2O_3(s)$, reacts with 200 cm^3 of a hydrochloric acid solution, $HC\ell(aq)$, of concentration 0,2 $mol \cdot dm^{-3}$ according to the following balanced equation: $$Na_2S_2O_3(s) + HC\ell(aq) \rightarrow NaC\ell(aq) + S(s) + SO_2(g) + H_2O(\ell)$$		
	5.2.1	Define the term *concentration of a solution*	(2)
	5.2.2	Write down the balance chemical equation.	(3)
	5.2.3	Calculate the number of moles of $HC\ell(aq)$ added to the sodium thiosulphate.	(3)
	5.2.4	Calculate the volume of $SO_2(g)$ that will be formed if the reaction takes place at STP.	(3)
LESSON 6- EXPERIMENTAL YIELD			
6.1.	An excess of $Pb(NO_3)_2$ reacts with 0.75g of KI according to the reaction: $Pb(NO_3) + KI \rightarrow PbI_2 + KNO_3$ After titration and drying, a mass of 0.583g of PbI_2 is measured.		
	6.1.1	Determine the percentage yield of PbI_2	(6)
6.2.	It is found that 40 cm^3 of a 0,5 $mol.dm^{-3}$ sodium hydroxide solution is needed to neutralise 20 cm^3 of the vinegar with a mass of 20,8 g. Vinegar is a solution of ethanoic acid in water. The balanced chemical equation for this reaction is: $NaOH + CH_3COOH \rightarrow CH_3COONa + H_2O$		
	6.2.1	Calculate the number of moles of sodium hydroxide that reacted.	(3)
	6.2.2	Calculate the mass of ethanoic acid present in the vinegar.	(4)
	6.2.3	Calculate the percentage (by mass) of ethanoic acid present in the	(2)

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6.3	37 g C react with an excess of oxygen and produce 65 dm3 CO_2 gas at STP. The balanced equation for the reaction is as follows: $C(s) + O_2(g) \rightarrow CO_2(g)$		
	6.3.1	Calculate the percentage purity of the carbon	(5)
6.4	22,5 dm^3 H_2 and 30 dm^3 N_2 is placed in a container and produces 12 dm^3 NH_3. The balanced equation for the reaction is $N_2(g) + 3\ H_2(g) \rightarrow 2NH_3(g)$		
	6.4.1	Calculate the percentage yield for this reaction.	(5)
LESSON 7- REACTING SOLUTIONS- STANDARD SOLUTION			
7.1		25 cm^3 of HCl of concentration 0.12 $mol.dm^{-3}$ reacts with 28.4cm^3 NaOH to form water and NaCl. Calculate the concentration of sodium hydroxide.	(3)
7.2		30 cm^3 of HCl of concentration 0.5 $mol.dm^{-3}$ is diluted with 100ml of water. Calculate the concentration of the diluted solution.	(3)
7.3	25 cm^3 of $BaCl_2$ reacts with 20 cm^3 of a standard solution of 0.05 $mol.dm^{-3}$ sulfuric acid to form barium sulphate and hydrochloric acid.		
	7.3.1	Define the term standard solution.	(2)
	7.3.2	Write down the balanced equation	(3)
	7.3.3	Calculate the concentration of barium chloride solution.	(3)
	7.3.4	Calculate the mass of the precipitate ($BaSO_4$) that is formed.	(3)
7.4		30 ml of an NaOH solution with concentration of 0,2 $mol \cdot dm^{-3}$ is mixed thoroughly with 50 ml of an NaOH solution with a concentration of 0,3 $mol \cdot dm^{-3}$. Calculate the concentration of the final solution.	(5)
7.5		25 g NaCl is added to 100 cm of a NaCl solution with a concentration of 0,5 $mol \cdot dm^{-3}$ and thoroughly mixed. Assume that the volume of the solution does not change. Calculate the concentration of the final solution.	(7)

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LESSON 8-LIMITING REAGENTS

8.1. 50 g of magnesium carbonate is added to 500 cm^3 of hydrochloric acid with a concentration of 0,75 $mol.dm^{-3}$. The equation for the reaction is given below:

$$MgCO_3\,(aq) + 2HCl\,(aq) \rightarrow MgCl_2\,(aq) + CO_2\,(aq) + H_2O$$

The carbon dioxide gas is collected at STP.

8.1.1. What are the standard conditions used when conducting an experiment at STP? (2)

8.1.2. Determine which reactant is the limiting reactant. (6)

8.2. Consider the following balanced chemical reaction:

$$2HNO_3\,(aq) + Ca(OH)_2\,(aq) \rightarrow Ca(NO_3)_2\,(aq) + 2H_2O\,(l)$$

25,0 ml of the nitric acid of concentration of 0,15 $mol.dm^{-3}$ reacts with the calcium hydroxide solution.

8.2.1. How many moles of the acid are used? (2)

8.2.2. What mass of calcium hydroxide reacted with the nitric acid? (3)

8.2.3. 13,6 ml of calcium hydroxide solution was used. What was the concentration of the calcium hydroxide solution? (4)

LESSON 9-MORE COMPLEX STOICHIOMETRIC CALCULATIONS

9.1

9.1.1 Define the term concentration. (2)

9.1.2 Eight (8) grams of $Na_2S_2O_3$ is dissolved in water to prepare 500 cm^3 of solution. Calculate the concentration of the $Na_2S_2O_3$ solution (3)

9.1.3 A 10 g sample of a compound contains 2,66 g of potassium, 3,54 g of chromium and 3,81 g of oxygen.

9.1.3.1 Define the term empirical formula (2)

9.1.3.2 Determine the empirical formula of this compound. (7)

9.2 Zinc reacts with sulphuric acid according to the reaction below.

$$\mathbf{Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(\,g\,)}$$

The mass of zinc is recorded during the experiment and is shown on the graph below. The reaction stops after 2 minutes

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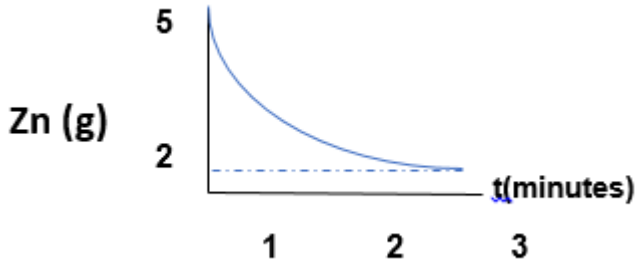


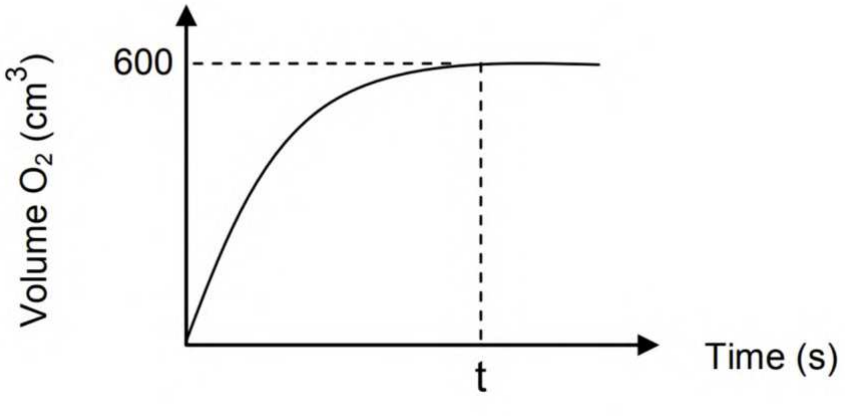
	9.2.1	Name the substance that is the limiting reagent	(1)
	9.2.2	Calculate the initial concentration of the sulphuric acid if 50 cm^3 of the acid was used.	(5)

9.3 Decomposing hydrogen peroxide in the presence of a catalyst at a specific pressure and room temperature is given by the unbalanced chemical equation below:

$$H_2O_2(aq) \rightarrow H_2O + O_2$$

Oxygen gas is collected and the volume is recorded over time(T)

The results are then graphed below.



Take the molar gas volume (V_m) to be 24,45 dm^3 at room temperature and standard pressure.

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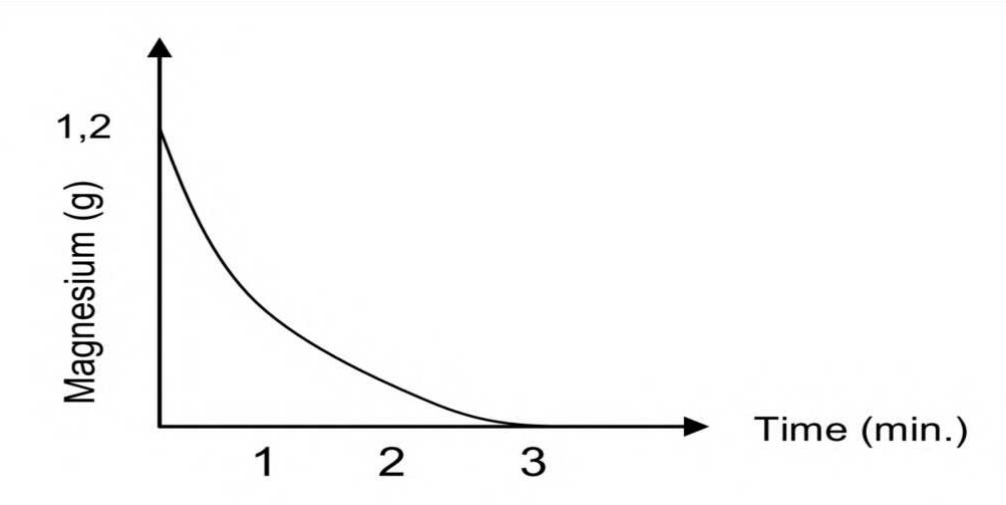
	9.3.1	Balance the equation given above.	(2)
	9.3.2	Using the information from the graph, calculate the mass of hydrogen peroxide that decomposed	(5)
9.4		In an experiment, a learner adds $\mathbf{500}\boldsymbol{cm}^{3}$ of hydrochloric acid (HCℓ) along with a concentration of $\mathbf{0.36}\ \boldsymbol{mol.dm}^{-3}$ to 1, 2 g of magnesium in a test tube.	
		She records the change in the mass of magnesium as the reaction proceeds at regular intervals.	
		The balanced chemical equation for the reaction is: $$\mathrm{Mg}(s) + 2HC\ell(aq) \rightarrow \mathbf{MgCl_2(aq)} + \mathbf{H_2}(\mathrm{g})$$	
		The mass change of magnesium during the reaction is shown on the graph below.	



		Use the graph given above to answer the following questions	
	9.4.1	Identify the limiting agent in the reaction. Give a reason for your answer.	(2)
	9.4.2	Calculate the number of moles of reacted hydrochloric acid in three minutes.	(5)

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