education

Department:
Education
PROVINCE OF KWAZULU-NATAL

CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)

LEARNER SUPPORT DOCUMENT

GRADE 11

PHYSICAL SCIENCES

STEP AHEAD PROGRAMME

2021

PREFACE

This support document serves to assist Physical Sciences learners on how to deal with curriculum gaps and learning losses as a result of the impact of COVID-19 in 2020. It also captures the challenging topics in the Grade 10 -12 work. Activities should serve as a guide on how various topics are assessed at different cognitive levels and also preparing learners for informal and formal tasks in Physical Sciences. It will cover the following topics:

Vector- A physical quantity with magnitude and direction. (Example: force, velocity, acceleration, etc.)	Scalars- A physical quantity with magnitude only. (Example: time, charge, work. Energy, distance, speed etc.)
• A vector has a magnitude and direction. • Vectors can be used to represent many physical quantities that have a 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 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.	**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.

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

IMPORTANT NOTE IN THIS SECTION

- Usage of the Protractor.
- Use of the 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 the Protractor, they must ensure that Tail of the vector as at the dot centre of the protractor, and that the line is correctly placed.

PRIOR KNOWLEDGE CURRENT LOOKING FORWARD

GRADE 10	GRADE 11	GRADE 11 – 12
Equality of vectors, negative vectors, addition and subtraction of vectors (in one dimension only). • Defined a resultant vector. • Found 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.	Add co-linear vertical vectors and co-linear horizontal vectors to obtain the net vertical vector (Ry) and net horizontal vector (Rx). • Sketch Rx and Ry on a Cartesian plane. • Determine the magnitude of the resultant using the theorem of Pythagoras. • Find resultant vector	Use these methods to find the resultant of any vector quantity learnt in grades 10, 11 and 12. • Resolve any vector learnt in grades 10, 11 and 12 into its perpendicular components.

• A frame of reference has an origin and a set of directions e.g. East and West or up and down. • Defined one dimensional motion. • Defined position relative to a reference point and understood that position can be positive or negative. • Defined displacement as a change in position. • Displacement is a vector quantity that points from initial to final position	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

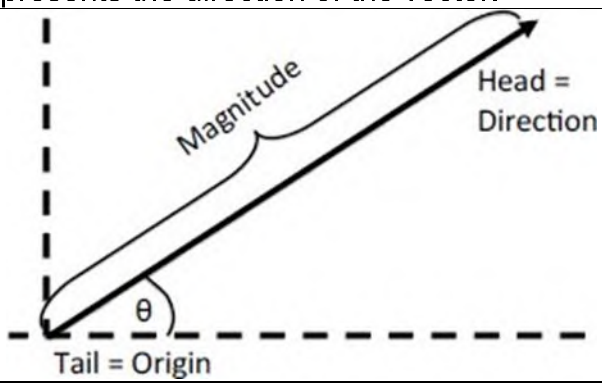
- Vector – physical quantity having magnitude and direction.
- Scalar – physical quantity having magnitude only.

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

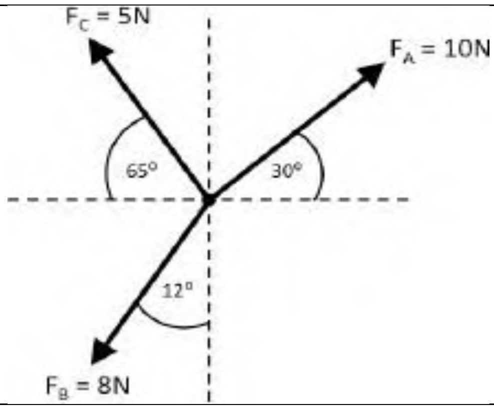
a) right is + ⟶ + 5 N

b) left is – ⟵ - 3 N

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 30° above the positive x- axis (horizontal axis)

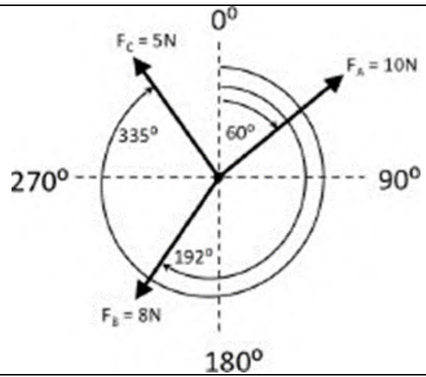
F_B : 8 N at 12o left of the negative y- axis (vertical axis)

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**



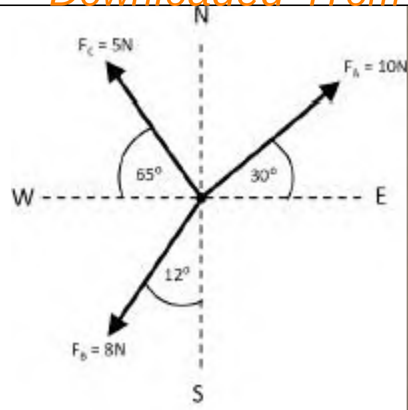
F_A : 10 N on a bearing of 60°

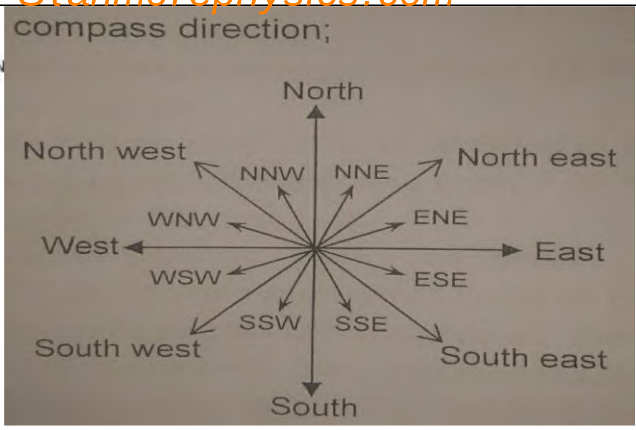
F_B : 8 N on a bearing of 192°

F_C : 5 N on a bearing of 335°

F_A : 10 N on a bearing of 60°

Compass (Cardinal points or directions)





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

F_A : 10 N at 30° North of East

F_B : 8 N at 12° West of South

F_C : 5 N at 65° 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)

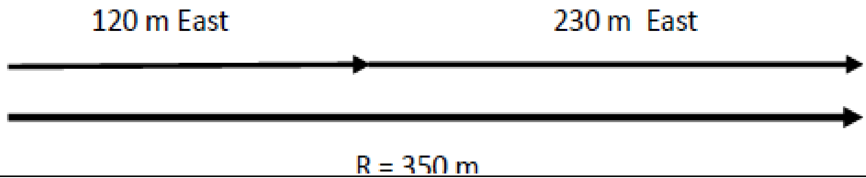
A girl walks 120m due East and then 230m in the same direction. What is her resultant displacement?

1. By calculation:

Sign of direction: Take to East to be +

R = 120m + 230m = 350m East

2. By construction:

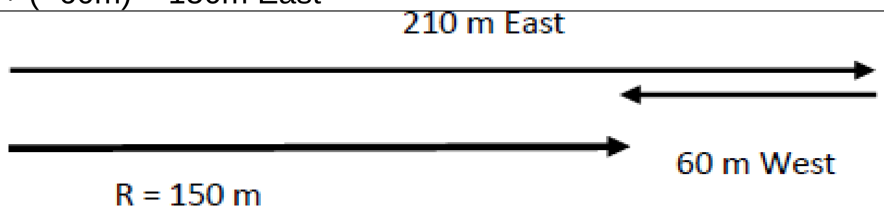


B. Two vectors acting in opposite direction (one dimension)

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

By calculation: (taking East as positive)

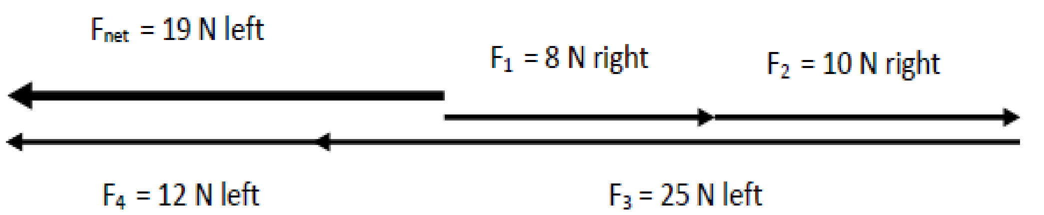
R = 210m + (- 60m) = 150m East



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 to the right be **positive**

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

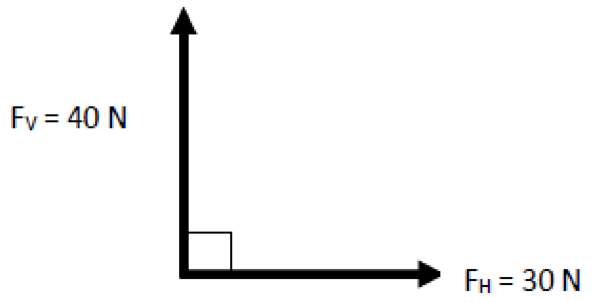


Vectors in Two Dimension`

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 are 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.
- 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

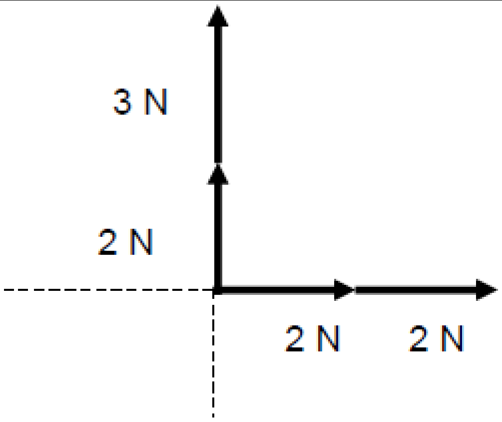
Two forces of 3N and 2N apply an upward force to an object. At the same time, two forces each of 2N act horizontally to the right. Find the resultant force acting on the object.

Step 1: Draw a diagram and calculate the net vertical and net horizontal forces

$R_y = R_{y1} + R_{y2}$

$R_y = 2 + 3$

$R_y = 5\ N\ upwards$

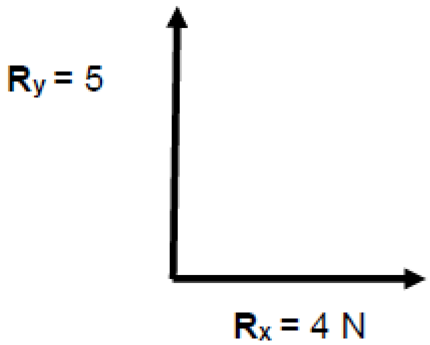


$R_x = R_{x1} + R_{x2}$

$R_x = 2 + 2$

$R_x = 4\ N\ right$

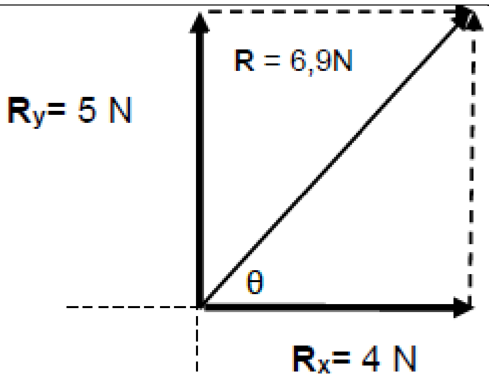
Step 2: Graphical representation of Rx and Ry



Step 3: To find resultant (R) of the above vectors, one can be using **tail-to-tail** drawing of vectors

Tail to tail method or Parallelogram:

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



- Pythagoras theorem is used to calculate the magnitude of the resultant.

- Considering the vector diagram above we can use Pythagoras theorem 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:

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

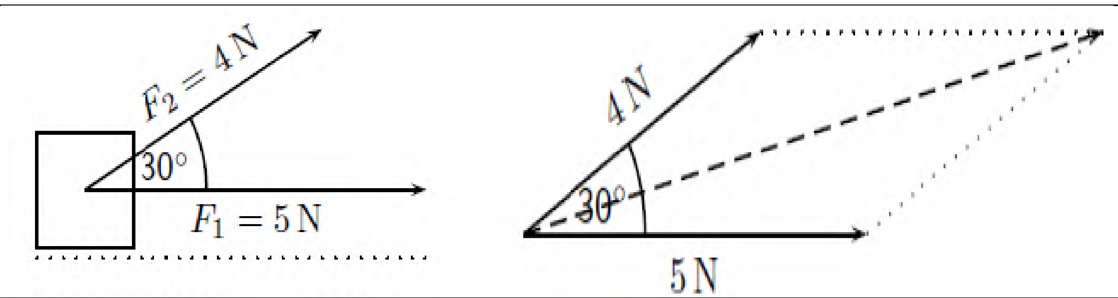
$\theta = 51.24^0$

Worked Example:

A force of F1 = 5N is applied to a block in a horizontal direction. A second force F2 = 4N is applied to the object at an angle of 30º above the horizontal. Determine the resultant of the two forces**, by accurate scale drawing.**

Step 1: Draw rough sketches of the vector diagrams:

Note: Forces are NOT perpendicular



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

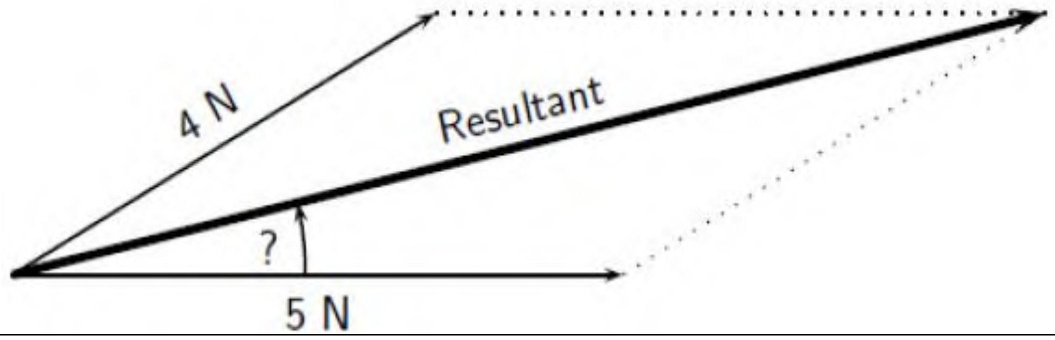
Step 3: Draw the first vector (F1) on the horizontal, according to the scale.

Step 4: Draw the second scaled vector (F2) 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 the suitable scale e.g. 10mm: 10N
- 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 tip 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.
- Always add arrow heads to vectors to indicate the direction.
- Measure the length and direction of the resultant vector.

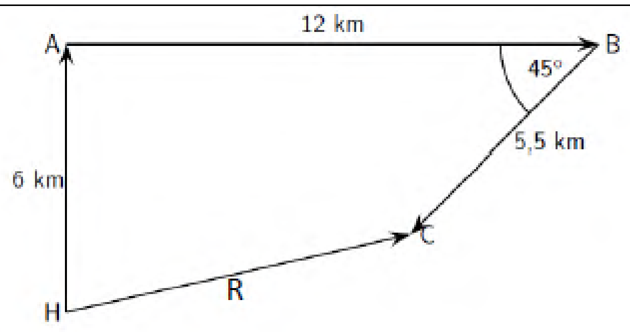
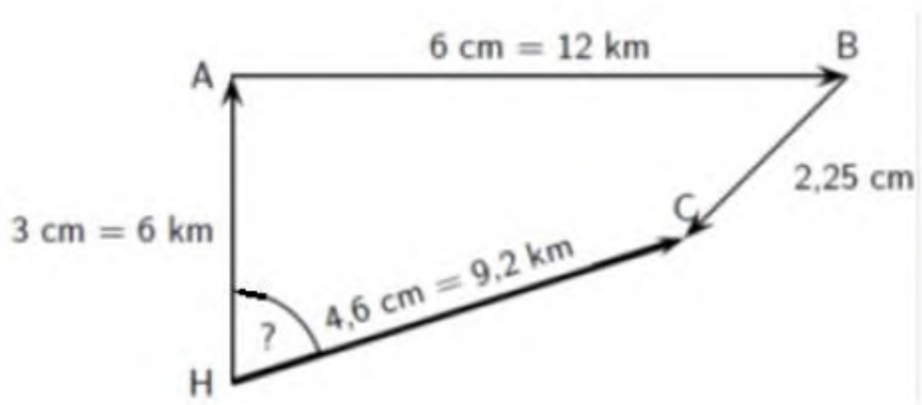
Use the scale to determine the real magnitude of the resultant.

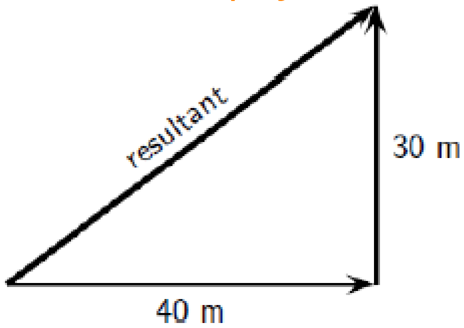
Worked Example 1:

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 restaurant displacement using the tail-to-head technique.

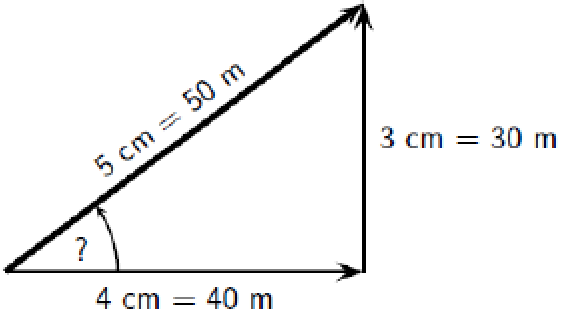
Rough sketch:

		
	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.	
	Example 2:	
	A man walks 40m East, then 30m North. Use a scale of 1 cm: 10 m and answer the following questions:	
	1. What was the total distance he walked?	
	2. Determine by construction his resultant displacement?	
	3. Calculate determine the direction of the resultant.	
	4. Calculate the magnitude of resultant displacement	
	Solutions:	
	1. Rough sketch	



Total distance = 40m + 30m
= 70 m

2. Scale: 1cm: 10m



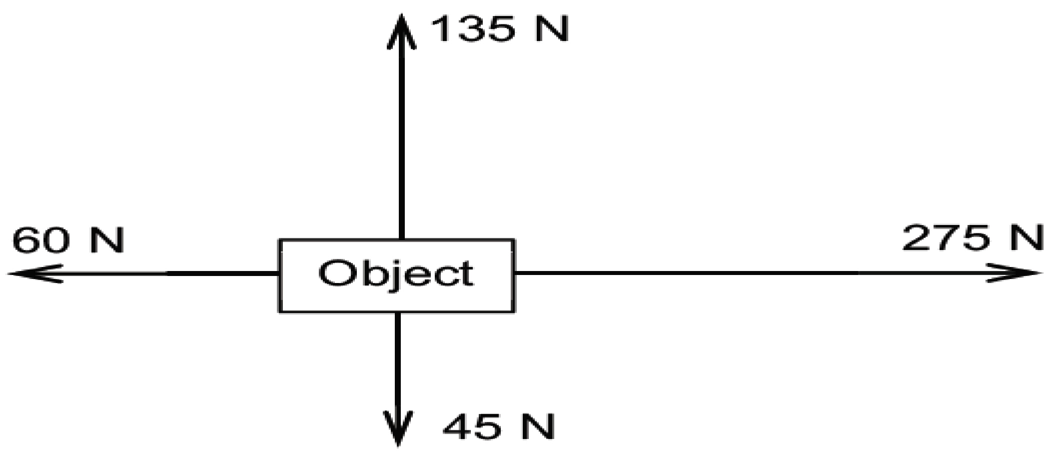
The resultant is 50m, 37º from the horizontal

Tan Φ= $\frac{30}{40}$
Φ=36,87º

$R^2 = x^2 + y^2$
$= 40^2 + 30^2$
= 2500
R = 50m

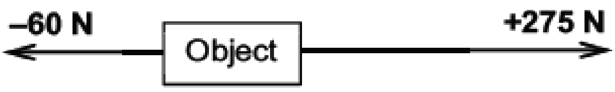
CO-LINEAR VECTORS

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.

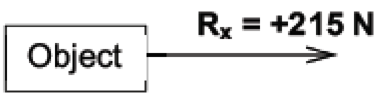


The 60 N and 275 N force vectors act along the horizontal axis (x-axis). It is essential to use signs (+ and -) to indicate the direction of vectors which act in the same line.

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: $\boldsymbol{R_x}$ **= (+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.

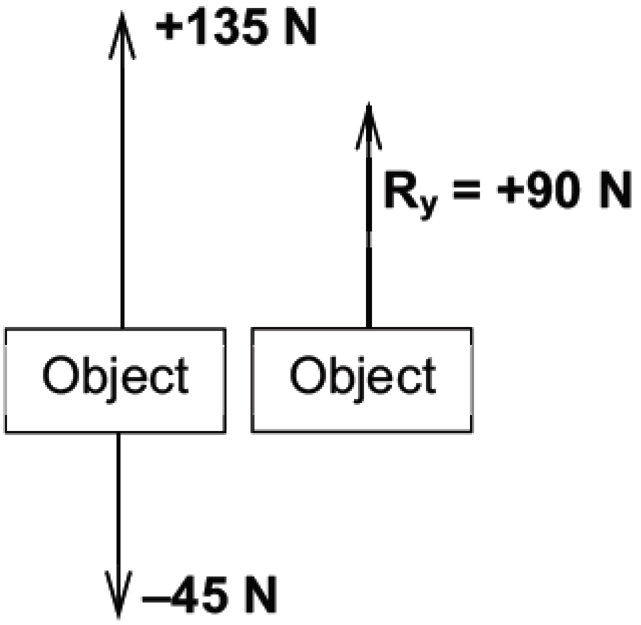


The 135 N and 45 N forces act in the vertical direction (y-axis). In the Cartesian plane, up is positive (+) and down is negative (–). The 135 N force acts upwards and is therefore

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.

$\boldsymbol{R_x}$ **= (+135) +(- 45) = + 90 N**

R_y = *90N Upwards*



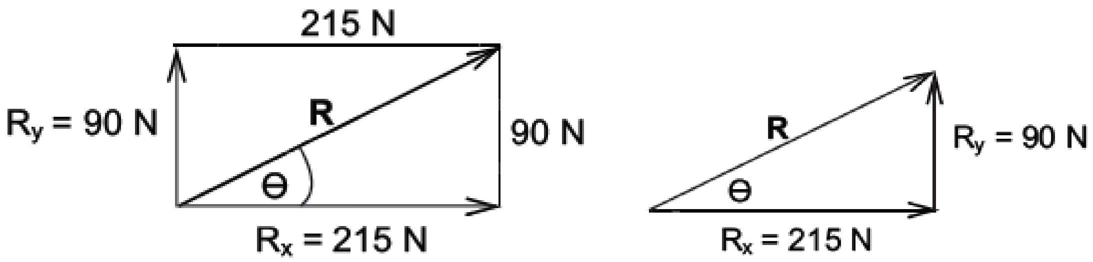
CONCEPT

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 in the diagonal of the parallelogram. The diagonal MUST start from the TWO TAILS of the given forces.

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

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

$\mathbf{R^2 = 90^2 + 215^2}$

$\mathbf{R^2 = 54325}$

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

This is the magnitude of the resultant force.

We now need to find the direction of the resultant force. Place a θ into your vector diagram to represent the angle between the resultant force and the horizontal plane.

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

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°** above 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).

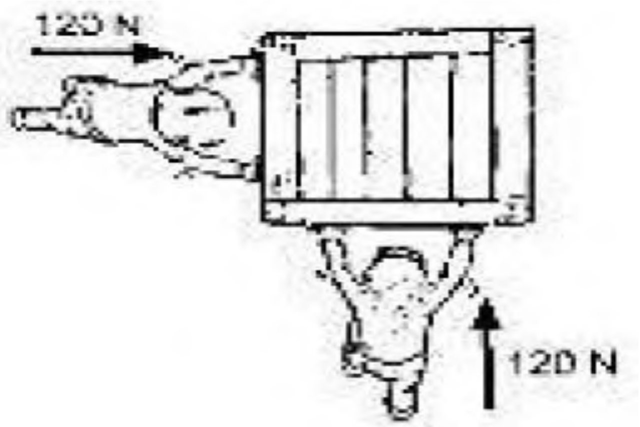
C. When left with perpendicular vectors, decide on the method to use (tail-to-tail method, etc.)

D. Draw a neat vector diagram of the perpendicular vectors.

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

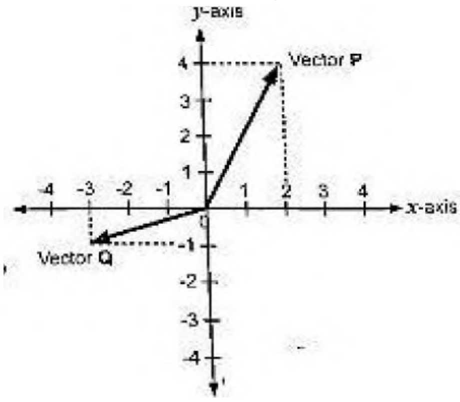
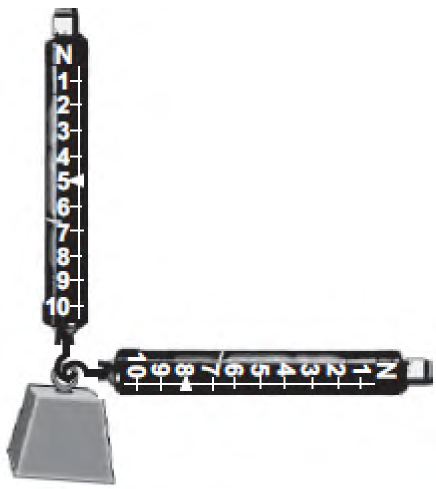
ACTIVITY 2

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 a Cartesian plane

1.2 Use a scale of 10mm: 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	The magnitude of vector P in force units ____ ____
2.2	The direction of vector Q, measured clockwise from positive y-axis ____ ____
3.	Two Newton spring 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 plan.

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

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

____

____

____

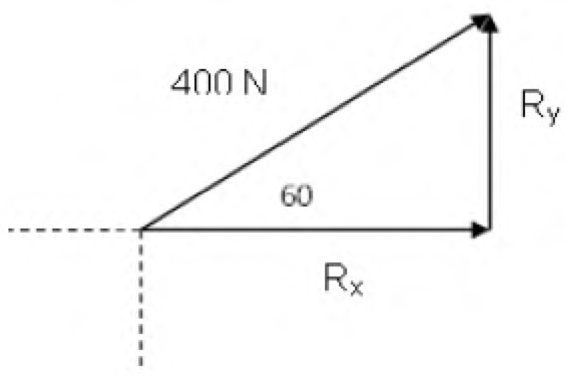
____

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.

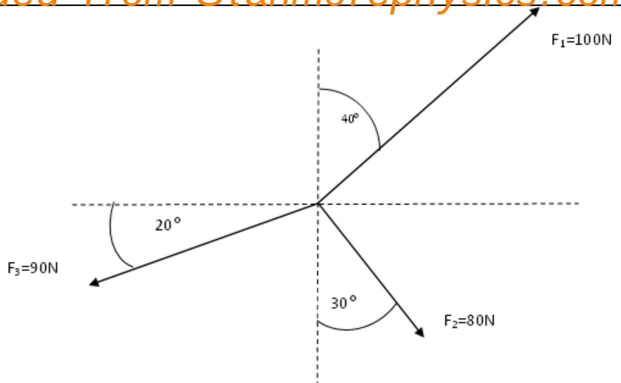
Worked Example

A force of 400N acts at an angle 600 to the horizontal.



Horizontal component	**Vertical component**
CosΘ= Adjacent /Hypotenuse $Cos60^0$= Rx/400 Rx = 200N	SinΘ= opposite/hypotenuse Sin600= Ry/400 Ry = 346.41N

Finding resultant of vectors acting at angles (using component method)

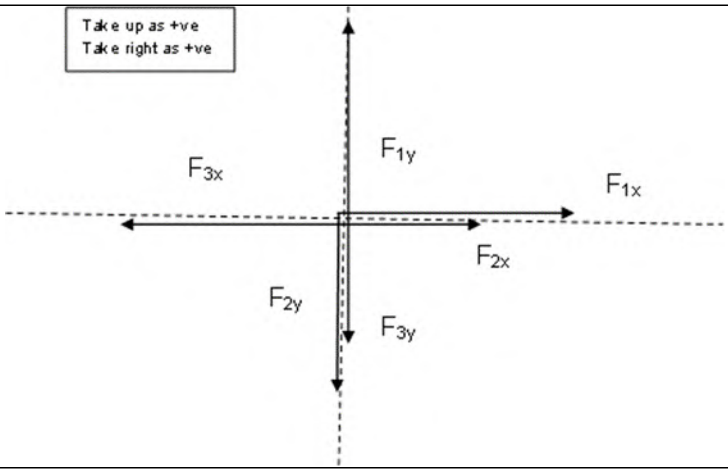


Step 1: Find horizontal and vertical components of each force

Components of F1: Horizontal (Fx)	**Components of F2: Horizontal**	**Components of F3: Horizontal (Fx)**
(Fx) = F1cosΦ = 100 cos(90^o- 40^0) = 64,28N (right	(Fx) = F2cosΦ = 80 cos(90^0-30^0) = 40N (right)	(Fx) = F3 cosΦ = 90 cos20^o = 84,57N (left)
(Fy) = F1 sinΦ = 100 sin(90^o- 40^0) = 76,60N (up	(Fy) = F2 sinΦ = 80 sin($90^{0-}30^0$) = 69,28N (down)	(Fy) = F3 sinΦ = 90 sin20^o = 30,78N (down)

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

Step 2: Hence, the new situation is:



Step 3: Thus, the sum of horizontal components

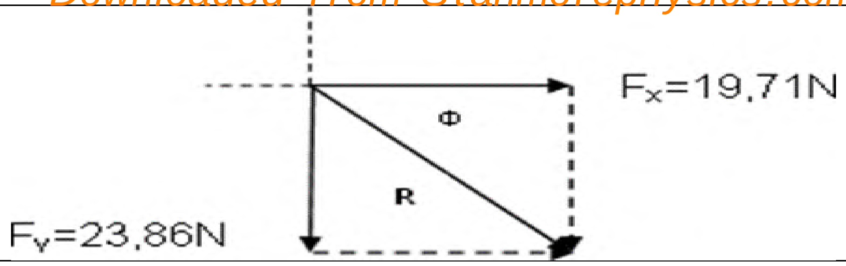
= 64,28+40+ (-84,57)

= 19,71N to the right

And the sum of vertical components = 69,28+30,78+ (76,20)

= 23,46N downwards

Step 4:



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

$\mathbf{R}^2 = Rx^2 + Ry^2$

$= 19{,}71^2+23{,}86^2$

= 30,64N

tan Φ = 23,86/19,71

Φ = 50,47º

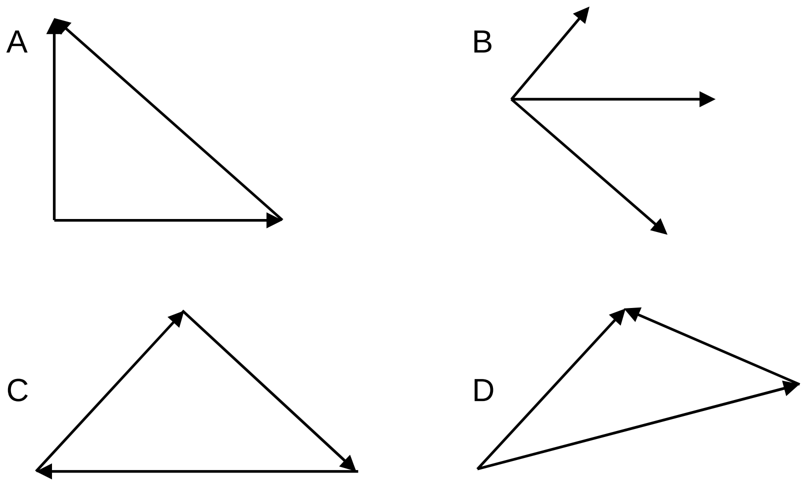
Thus, the resultant of the three forces is 30,95N in a bearing of 50,47º from the horizontal.

Exam MCQ questions

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

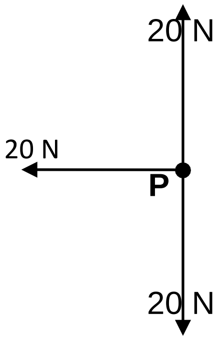
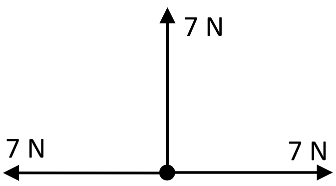
Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

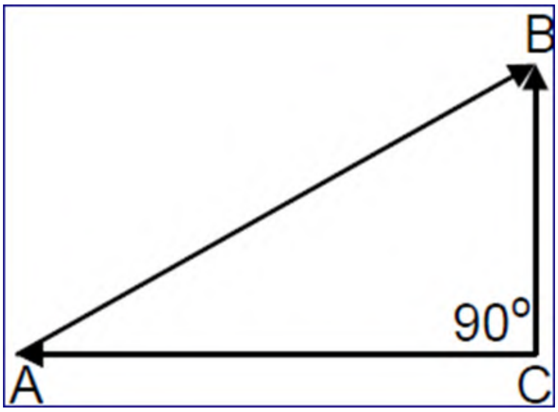
1.1 Consider the following vector diagrams. Which ONE of these vector diagrams represents a zero resultant



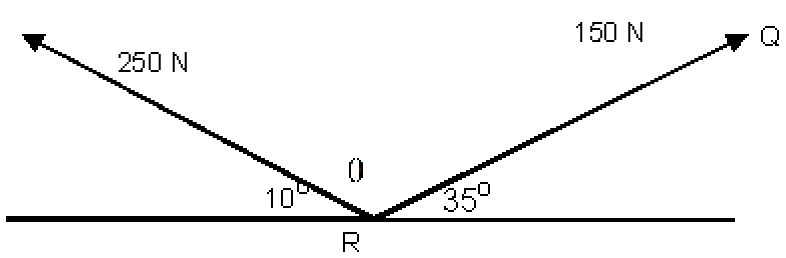
(2)

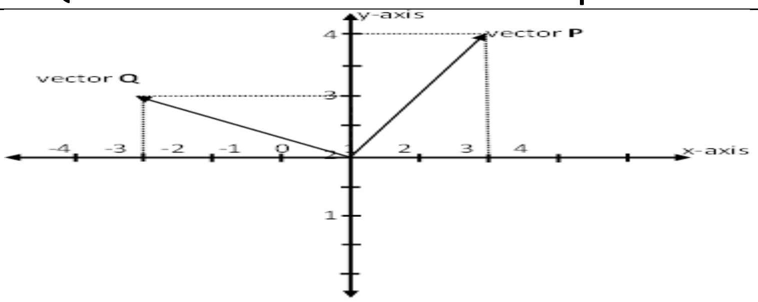
1.2 Two forces of magnitudes 3 N and 4 N respectively act on a body. The maximum magnitude of the resultant of

	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.  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	Three forces, each of magnitude 7 N, act on object **P** as shown.  The resultant force on object P is … A zero B 7 N to the left. C 7 N upwards. D 7 N downwards.	(2)

1.6	Two forces of magnitude 50 N and 70 N respectively act on a body. The maximum magnitude of the resultant force on the body is ... A 20 N. B 60 N. C 120 N. D 140 N.	(2)
1.7	Two forces of magnitudes 8 N and 6 N are added to each other. Which of the following values CANNOT be a resultant of these two forces? A 2 N B 3 N C 14 N D 16 N	(2)
1.8	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)
1.9	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)

STRUCTURED QUESTIONS

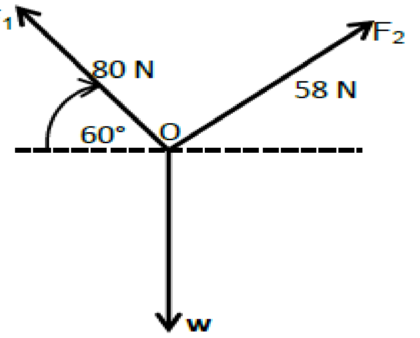
	QUESTION 1 (Grade11 KZN MARCH 2015)	
	The diagram below shows TWO forces P and Q of magnitude 250 N and 150 N respectively acting at a point R.	
		
1.1	Calculate the horizontal and vertical components of vector P.	**(4)**
1.2	Calculate the vector sum of horizontal components of P and Q.	**(3)**
1.3	The 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 Q	(2)
	2.2.4	Resultant of vectors **P** and **Q**.	(6)

			[13]

QUESTION 3 (Fs CONTROL TEST TERM 1 – 2015)

Three forces, **F1**, **F2** 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 **F1**. Use a scale where 10 N is represented by 10 mm.		(5)
3.3	The horizontal and vertical components of F2 are equal to 40 N and 42 N 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]

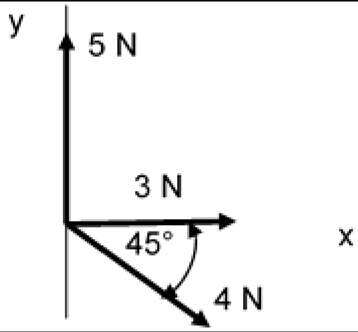
ADDITIONAL ACTIVITIES

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 – 1.10) 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)
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.	

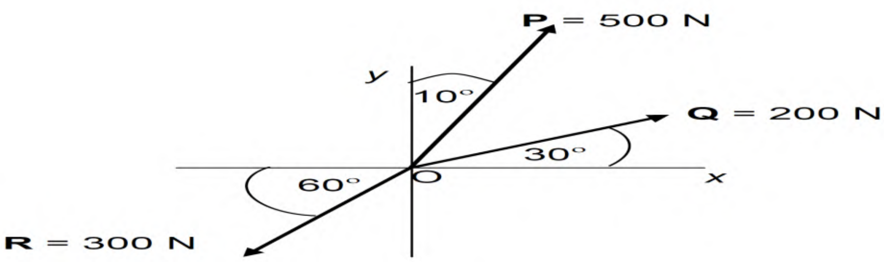


Calculate the:

2.1	Magnitude of the resultant force acting on the object.	(10)
2.2	Direction of the resultant force.	(3)

November 2015 National

	Vector **P** and vector **–P** are acting on a common point **O**. The angle between the two vectors is ...	
1.1	A. 0º	
	B. 90º	
	C. 180º	
	D. 270º	
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.		

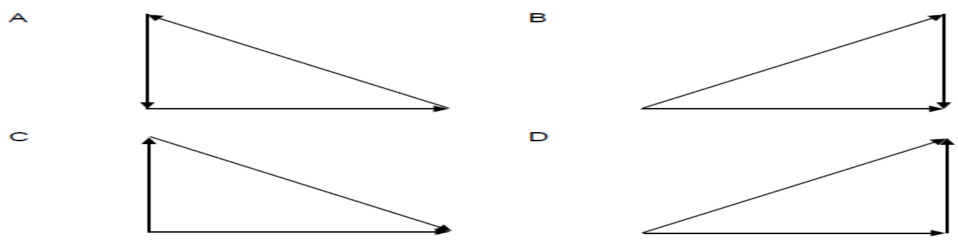


2.1	Refer to the information in the diagram above and give a reason why	(2)

	forces **P**, **Q** and **R** are classified as vectors.	
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]

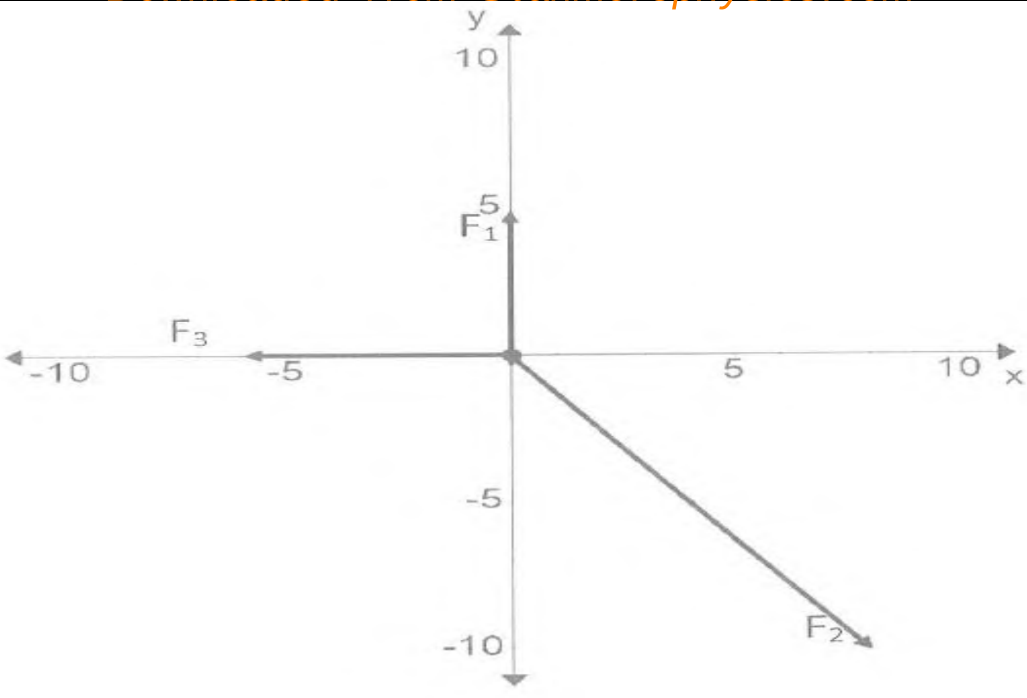
November 2017 National

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

1.1	Which ONE of the following pairs of physical quantities is 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?	
		**(2)**

MARCH 2018

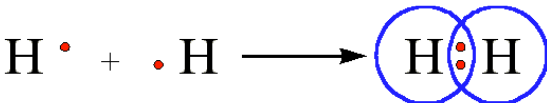
QUESTION 2
Three forces F_1, F_2 and F_3 act at a point , as shown on the Cartesian plane in the diagram below.



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]

MATTER AND MATERIALS
Intermolecular forces

The ***covalent bond*** occurs when atoms of non-metal elements share unpaired valence electrons to achieve noble gas electron configuration.
Example:

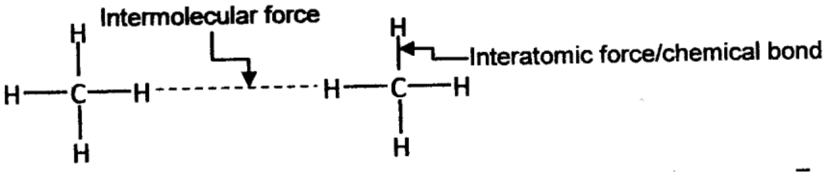


The covalent bond is an interatomic force and the result product is a ***molecule.***
The covalent bonds are very strong and one requires a large amount of energy to break them i.e. to separate the atoms of the molecule.

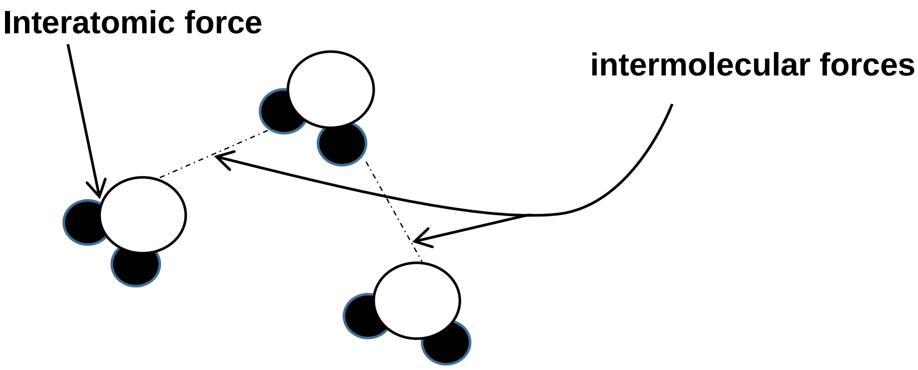
The ***intermolecular forces*** are the forces of attraction that exist between molecules of a chemical substance in a solid or liquid form..
The intermolecular forces are ***weaker*** than interatomic forces.

Examples

1.



2.



The strength of intermolecular forces determines the physical properties (boiling points, melting point, evaporation, etc.) of a molecular substance.

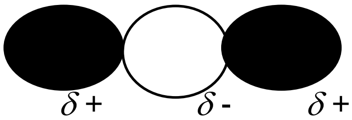
Molecules can be **polar** or **non-polar**.

The polarity of a molecule is determined by two factors :

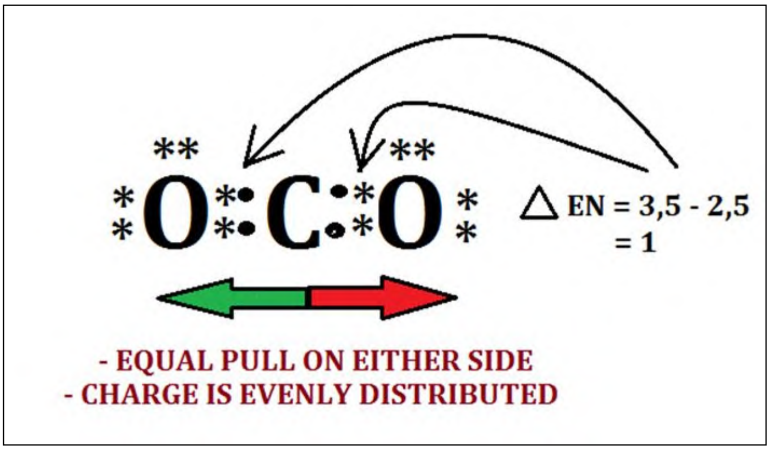
- ✓ The difference in electronegativity between the bonding atoms.

✓ The geometry (shape) of a molecule.

Non-polar molecules have no dipoles (positive and negative ends) e.g. *CO_2*

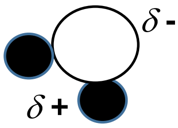


Difference in electronegativity (ΔEN) = 3,5 – 2,5 = 1,0 → bond between C and O is polar but both ends of CO_2 are ∂+ and the molecule is linear. The molecule is therefore non-polar.



Polar molecule

In polar molecule there are ∂+ and ∂- ends e.g. H_2O and the geometry of the molecule is angular (bent)

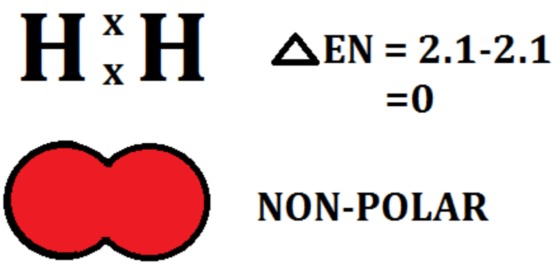


ΔEN = 3,5 – 2,1 = 1,4. The two bonds (between H and O atoms) are polar.

H_2O molecule has H-end being ∂+ and O-end being ∂-, they are called **dipoles.** The molecule is polar

Non-polar bonds:

- H_2 is non-polar because the two atoms are identical, there is even or symmetrical distribution of charge, this makes H_2 a non-polar molecule.
- The electro-negativity between the two atoms is zero, this explains why the interatomic bond in Hydrogen molecule is non-polar



TYPES OF INTERMOLECULAR FORCES

1. Van der **Waals forces:**

   van der Waals force is a weak attraction between molecules The force of attraction is between polar and non-polar molecules

   (a) Dipole-dipole force is an attraction between polar molecules.

   Examples: 1: between molecules of HCℓ

Example: 2. When HCℓ dissolves in water

Dipole-dipole forces are the strongest intermolecular forces

(b) Dipole-induced dipole force is a weak force of attraction that exist when a polar causing a distortion in arrangement of electrons in a non-polar molecule. Temporary dipoles are induced in a non-polar molecule e.g. mixture of HCℓ and argon.

(c) Induced dipole forces (London forces) occurs between atoms or molecules of non-polar substances e.g.
Between atoms of noble gases, molecules of diatomic molecules (H_2; N_2; O_2; F_2; $Cℓ_2$), non-polar compounds (CH_4; $CCℓ_4$; BF_3), between molecules of CO_2(s) – dry ice
Induced dipole forces are the **weakest** van der Waals forces

2. **Hydrogen bond** is a special type of dipole-dipole force. Hydrogen bond is a force attraction between a hydrogen atom bonded to oxygen, nitrogen or fluorine in a molecule to a lone pair of an adjacent molecules e.g. between H_2O molecules, between HF molecules.
   Hydrogen bonds are the **strongest** intermolecular forces.

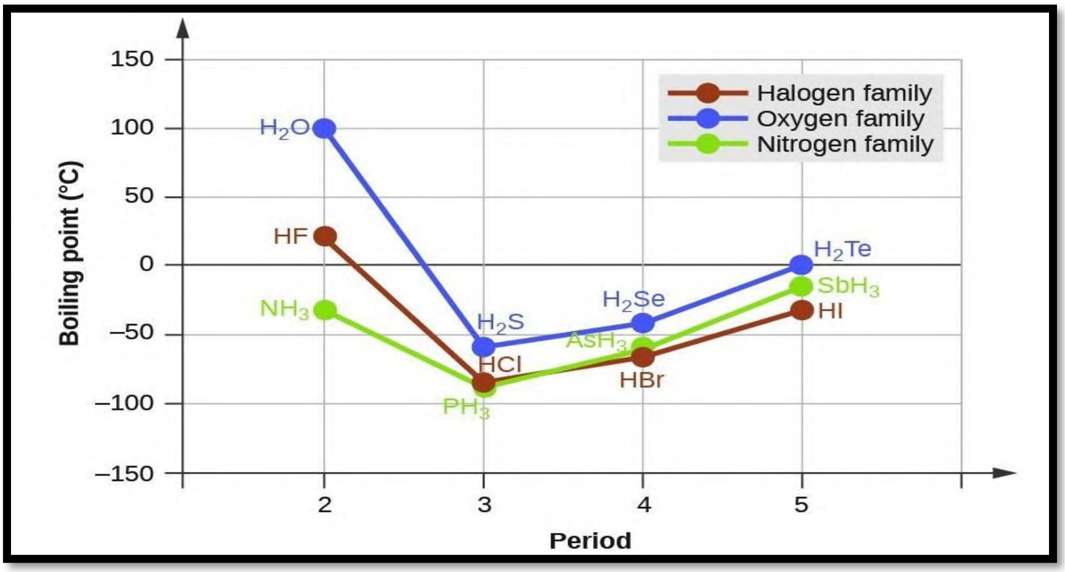
3. **Ion-dipole force** is the attraction of an ion with a positive or negative charge and the oppositely charged end of the dipole of polar molecule e.g. NaCℓ dissolved in water

4. **Ion-induced dipole force** is an attraction between an ion and a non-polar molecule. As an ion approaches a non-polar molecule, it causes a distortion in the arrangement of the arrangement of the electrons of non-polar molecules. Momentary dipoles are induced in non-polar molecules e.g. dissolving NaCℓ in hexane (C_6H_{14})

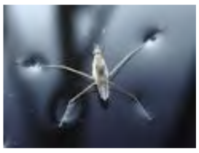
PHYSICAL STATE AND DENSITY EXPLAINED IN TERMS OF THESE INTERMOLECULAR FORCES

Boiling Point
The hydrogen bonds between highly polar water molecules are stronger than normal dipole-dipole forces and more energy is needed to break these bonds. Energy needed for molecules to evaporate, is called

heat of vaporization. 40,7 kJ·mol^{-1} energy is needed for water molecules to evaporate – hence the higher than expected boiling point.



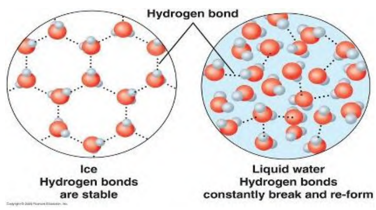
Surface tension



- The surface of a liquid may be considered as an elastic film or skin. As a result of this surface phenomenon, it is possible for insects to walk on the surface of a liquid.
- The curved surfaces (menisci) of liquids, most noticeable in narrow tubes, and the fact that a water drop is always spherical, are properties which are linked to surface tension.
- Surface tension can be defined as the resistance that a liquid offers to a force which tries to increase its surface area.

Density

- The common statements that mercury is "heavier" than water or that iron is "heavier" than aluminium are actually not correct. It is not the mass of the substances that is compared, but the mass per unit volume, which is known as the **density**.
- The density of a substance is independent of the amount and size of the sample and can therefore be used as an aid to distinguish one pure substance from another. Stronger intermolecular forces will result in substances having greater densities.
- According to the kinetic molecular theory, particles in a gas are far apart with no regular motion. Particles in a liquid are close together with no regular arrangement. Particles in a solid are close together, usually in a regular pattern.
- It implies that the number of particles per unit volume will decrease from the solid to the liquid state. (Refer to diagram).



- The density of a substance **increases** as it changes from the gas to the liquid and solid state, because the intermolecular forces **increase** as substances changes from the gas to the solid state.
- Note: The density of most substances known, decreases as the temperature rises. However, the density of water increases as the temperature is raised from 0 ^{0}C to 4 ^{0}C. (Refer to the lesson: Macroscopic properties of the three phases of water related to their microscopic structure)

KINETIC ENERGY AND TEMPERATURE

- Temperature is directly proportional to average kinetic energy of the particles. An increase in T increases K. K = ½mv^3
- The mass of the particles remains constant – motion increases.
- T (Temperature is directly proportional to average kinetic energy of the particles).
- The molar masses of the particles increase in the following order: F2 Cℓ2 Br2. The London forces between the non-polar molecule increase with an increase in molar mass. At the same temperature, the forces between F2 molecules are weaker than between $Cℓ_2$ molecules etc.
- An increase in temperature decreases the bond strength between the molecules. The particles are further apart and the substance becomes less dense.
- Thermometers work by using thermal expansion of a liquid to measure temperature; construction (bridges); it can also be used in loosening nuts and bolts; a hot-air balloon uses the thermal expansion of air to generate lift.

  - **Thermal expansion** is the expansion of a liquid on heating.
  - **Thermal conductivity** is a measure of how much a material conducts heat.

Kinetic energy of particles and temperature change

- Heat is a form of energy. During the heating process, the particles of the substance absorb energy that allows them to vibrate in all directions and collide with each other. Energy that causes motion is called kinetic energy. All the particles do not gain the same amount of energy and they also transfer energy to other particles when they collide with each other.
- An increase in the temperature of gas particles increases the average kinetic energy of the particles and they will move faster (K = ½mv2). The average kinetic energy is directly proportional to the temperature of the particles.

Thermal expansion

- The most easily observed examples of thermal expansion are size changes of materials as they are heated or cooled. Almost all materials (solids, liquids, and gases) expand when they are heated, and contract when they are cooled. Increased temperature increases the frequency and magnitude of the molecular motion of the material and produces more energetic collisions. Increasing the energy of the collisions forces the molecules further apart and causes the material to expand.
- Different materials expand or contract at different rates. In general, gases expand more than liquids, and liquids expand more than solids.

Example:

- Because the liquid expands at a faster rate than the tube, it rises as the temperature increases and drops as the temperature decreases.
- The first step in producing a thermometer scale is to record the height of the liquid at two known temperatures (i.e. the boiling point and freezing point of water). The difference in fluid height between these points is divided into equal increments to indicate the temperature at heights between these extremes.

CHEMISTRY OF WATER

- The atoms in a water molecule are held together strongly by covalent bonds to for angular molecule. The electrons are not evenly around the molecule. Oxygen has a higher electronegativity than hydrogen and the oxygen side of the water molecule is partially negative, while the hydrogen is partially positive. So water molecules are polar and the form dipoles.

- The water molecules are strongly attracted to one another through **hydrogen bonds**. At the Temperature below 0◦C at the atmospheric pressure, water is a solid (ICE), at that stage water molecules are arranged in a regular pattern to form ice crystals.
- When you heat the ice, the water molecules start to vibrate faster and the kinetic energy of water molecules increases. At 0◦C, the particles are moving vigorously to break the lattice pattern.

(More notes on Study and master)

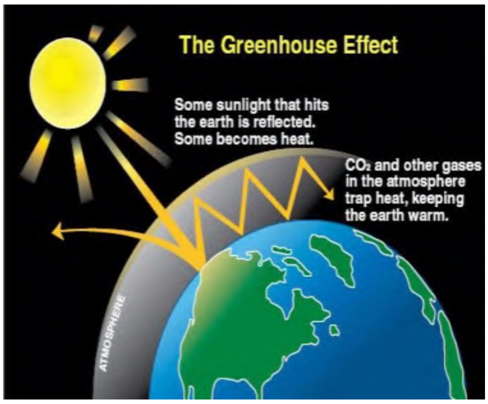
- At solid state – water molecules are closely parked together where hydrogen bond is very strong where they do not move (no kinetic energy)
- Liquid state – water molecules can now vibrate and move (there is kinetic energy)
- Gaseous state – water molecules are scattered free to move (more kinetic energy) resulting in a very week hydrogen bonds (others they even say at this stage there no hydrogen bonds

- So water has a very high specific heat capacity of 4 200 $kJ.kg^{-1}.K^{-1}$.to rise the temperature of water we need first to break many intermolecular forces (Hydrogen bonds). Therefore water molecules absorb lots of heat while its temperature rises slightly. The opposite also true – water molecule can give off much heat with only slight decrease in its temperature.

- The polar water molecules vibrate, which enable them to absorb heat from the sun. The water in lakes and oceans can absorb large amount heat in summer and give off heat in winter, with only small changes in the temperature of the water. This effect moderates the climate of adjacent land masses. In short, oceans act as reservoirs of heat and ensure that the Earth has a moderate climate.

Water vapour ($H_2O(g)$) and carbon dioxide ($CO_2(g)$) in the atmosphere provide a temperature buffer (greenhouse effect) which helps maintain a relatively steady surface temperature.

The polarity of the covalent bonds in H_2O-molecules and the strong hydrogen bond between the molecules that vibrates at the same frequency as infrared light are responsible for the fact that water absorbs sunlight.



INVESTIGATE PHYSICAL PROPERTIES OF WATER (H_2O)

1. **INVESTIGATE SPECIFIC HEAT CAPACITY**

Specific heat capacity is the amount of energy needed to raise the temperature of 1kg of a substance by 1ºC.

Water has high specific heat capacity of 4200J.kg^{-1}. ºC^{-1}

A high specific heat capacity requires more energy for the temperature to change. This means water absorbs a lot of heat energy to increase the temperature of 1kg by 1ºC.

Water has higher specific heat capacity than oil because te rate at which temperature of water increases is less than that of oil with the same amount of heat added.

Melting point and boiling point of water

Melting point is the temperature at which the solid and liquid phases of a substance are in equilibrium.

The stronger the intermolecular forces, the higher the melting point.

The boiling point is the temperature at which the vapour pressure of a substance equal atmospheric pressure.

Melting point of water is 0^0C *and its boiling point is* 100^0C

When the boiling point of water is measured at sea level(e.g. towns like Cape town and Durban),it is often very close to 100^0C since atmospheric pressure is almost the same as standard pressure.

If you measure boiling point of water in a town at a higher altitudes (e.g. Johannesburg or Polokwane) it will have a slightly lower boiling point.

2 .WATER AS A SOLVENT

A solvent is the substance that dissolves a solute to produce a homogeneous mixture.

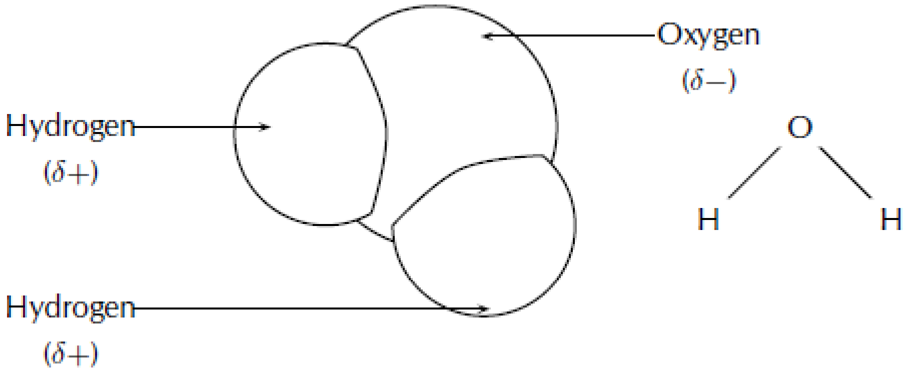
A solute is a substance that dissolves in a solvent to produce a homogeneous mixture.

A solution is a homogeneous mixture of two or more substances.

What makes water a good solvent?

The polarity and the ability to form hydrogen bonds makes water a good solvent.

- The polarity of water allows it to dissolve both ionic bonds and other polar molecules.
- A water molecule is polar because the electric charge is distributed unevenly because the oxygen atom is on one end ,causing it to have slight negative charge and hydrogen atom is on one end causing it to have slight positive charge.



Water molecules are held together by hydrogen bonds. Hydrogen bonds are a much stronger type of intermolecular force than those found in many other substances and affects the properties of water.

3. Investigating Surface tension

- **Intermolecular forces** are forces between neighbouring molecules.
- . **Surface tension** is the energy required to increase the surface area of a liquid.
- Water has strong hydrogen bonds between the molecules. These intermolecular forces hold the particles more strongly together increasing surface tension.

  - The molecules of water attract each other strongly.
  - The drop of water does not spread out easily on the paper and keeps its shape on the wax paper,
  - This shows that there are strong intermolecular forces on between water molecules. The oil particles spread out easily as a result of weak London forces.

4. Density of water

Density is the the mass per unit volume.

Density=$\frac{mass}{volume}$

Another unusual property of water is that its solid phase (ice) is less dense than its liquid phase. This can observed by put ice into the a glass of water .The ice does not sink to the bottom of the glass but floats on top of the liquid. This phenomenon is related to hydrogen bonds between particles of water .While other material contract when they solidify, water expands. The ability of the ice to float is very important in the environment. When a deep body of water cools, floating ice insulates the liquid water below, preventing it from freezing and allowing life under the frozen surface to exist.

LEARNERS WORKSHEET

1. Which intermolecular forces are found in:

1.1 hydrogen fluoride (HF) (1)

____

1.2 methane (CH_4) (1)

____

1.3 potassium chloride in ammonia (KCl in NH_3) (1)

____

1.4 krypton (Kr) (1)

____

2 Given the following diagram:

H—Cl---H—Cl

2.1 Name the molecule and circle it on the diagram (2)

____

2.2 Label the interatomic forces (covalent bonds) (1)

2.3 Label the intermolecular forces (1)

3 Given the following molecules and solutions:

HCl, CO_2, I_2, H_2O, KI(aq), NH_3, NaCl(aq), HF, $MgCl_2$ in CCl_4, NO, Ar, SiO_2

3.1 Complete the table below by placing each molecule next to the correct type of intermolecular force. (11)

Type of force Molecules	Type of force Molecules
Ion-dipole	
Ion-induced-dipole	
Dipole-dipole (no hydrogen bonding)	
Dipole-dipole (hydrogen bonding)	
Induced dipole	
Dipole-induced-dipole	

3.2 In which one of the substances listed above are the intermolecular forces:

3.2.1 strongest (2)

____

3.2.2 weakest (3)

4 Use your knowledge of different types of intermolecular forces to explain the following statements:

4.1 The boiling point of F2 is much lower than the boiling point of NH3 (2)

4.2 Water evaporates slower than carbon tetrachloride (CCl_4). (2)

4.3 Sodium chloride is likely to dissolve in methanol (CH_3OH) (2)

----

5 Calvin and Jason are helping their dad tile the bathroom floor. Their dad tells them to leave small gaps between the tiles. Why do they need to leave these small gaps? (2)

----

6 Hope returns home from school on a hot day and pours herself a glass of water. She adds ice cubes to the water and notices that they float on the water.

6.1 What property of ice cubes allows them to float in the water? (2)

6.2 Briefly describe how this property affects the survival of aquatic life during winter. (2)

----

7 Which properties of water allow it to remain in its liquid phase over a large temperature range? (3)

Explain why this is important for life on earth.

----

8 Give one word or term for each of the following descriptions:

8.1 The attractive force that exists between molecules. (1)

8.2 A molecule that has an unequal distribution of charge. (1)

8.3 The amount of heat energy that is needed to increase the temperature of a unit mass of a substance by one degree. (1)

----

9 Refer to the list of substances below:

HCl, Cl_2, H_2O, NH_3 N_2, HF

Select the true statement from the list below:

a) NH3 is a non-polar molecule

b) The melting point of NH3 will be higher than for Cl2

c) Ion-dipole forces exist between molecules of HF

d) At room temperature N2 is usually a liquid

10 The following table gives the melting points of various hydrides:

Hydride	**Melting point (℃)**
HI	-34
NH_3	-33
H_2S	-60
CH_4	-164

10.1 In which of these hydrides does hydrogen bonding occur?

A. HI only
B. NH_3 only
C. HI and NH_3 only
D. HI, NH_3 and H_2S

10.2 Draw a graph to show the melting points of the hydrides.

10.3 Explain the shape of the graph

10.4 The respective boiling points for four chemical substances are given below:

Hydrogen sulphide	−60 ℃
Ammonia	−33 ℃
Hydrogen fluoride	20 ℃
Water	100 ℃

10.4.1 Which one of the substances exhibits the strongest forces of attraction between its molecules in the liquid state?

10.4.2 Give the name of the force responsible for the relatively high boiling points of hydrogen fluoride and water and explain how this force originates.

10.4.3 The shapes of the molecules of hydrogen sulfide and water are similar, yet their boiling points differ. Explain

----

10.4.4 Susan states that van der Waals forces include ion-dipole forces, dipole-dipole forces and induced dipole forces.

Simphiwe states that van der Waals forces include ion-dipole forces, ion-induced dipole forces and induced dipole forces.

Thembile states that van der Waals forces include dipole-induced dipole forces, dipole-dipole forces and induced dipole forces.

Who is correct and why?

----

11 Jason and Bongani are arguing about which molecules have which intermolecular forces. They have drawn up the following table:

Compound	Compound
Potassium iodide in water (KI(aq))	Potassium iodide in water (KI(aq))
Hydrogen sulfide (H2S)	Hydrogen sulfide (H2S)
Helium (He)	Helium (He)
Methane (CH4)	Methane (CH_4)

11.1 Jason says that hydrogen sulfide (H_2S) is non-polar and so has induced dipole forces. Bongani says hydrogen sulfide is polar and has dipole-dipole forces. Who is correct and why?

11.2 Bongani says that helium (He) is an ion and so has ion-induced dipole forces. Jason says helium is non-polar and has induced dipole forces. Who is correct and why?

11.3 They both agree on the rest of the table. However, they have not got the correct force for potassium iodide in water (KI(aq)). What type of force actually exists in this compound?

11.4 Khetang is looking at power lines around him for a school project. He notices that they sag slightly between the pylons. Why do power lines need to sag slightly?

11.5 Briefly describe how the properties of water make it a good liquid for life on Earth.

QUANTITATIVE ASPECT OF CHEMICAL CHANGE

- The mole is the SI unit for the amount of substance
- The Mole is a name for a specific number. The Mole is the SI unit for quantity of substance

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 wate

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

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.

WORKED EXAMPLES

Calculate the molar mass for each of the following:

(i) Ca

(ii) $MgCl_2$

Solutions

(i) $40\,g \cdot mol^{-1}$

(ii)

$= 24 + (35{,}5 \times 2)$

$= 24 + 71$

$= 95\,g \cdot mol^{-1}$

Calculate the number of moles of:

1. 213g of Cl_2
2. 39.5g of $KMnO_4$

Solutions

1. $n = \frac{m}{M} = \frac{213}{71}$ = 3 mol
2. $n = \frac{m}{M} = \frac{39.5}{158}$ = 0.25 mol

- **The Mole and the Gases**
  - Avogadro also determine that :
    1 mole of ANY gas at STP is occupies a volume of 22,4 dm^3
  - The Molar volume of ANY gas at STP is given the symbol V_m
    ($V_{m\,=\,22,4\,dm^{-3}}$.mol^{-1})

    NOTE: STP stands for standard Temperature (0°C) and pressure (100kPa).
  - For any gas at STP **n** = $\frac{V}{V_m}$
  - 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)

WORKED EXAMPLES

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

Solutions

1. $n = \frac{V}{Vm}$
   $V = 2X22.4$= 44.8 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 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}*

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.

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

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.

STEPS TO DETERMINE MOLECULAR FORMULAR

- ✓ Determine the empirical formula (if not given).
- ✓ Determine the molar mass of the empirical formula.
- ✓ Determine the ratio between molecular formula and empirical 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 $CH_2 \times 4 = C_4H_8$

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

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.

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 = $\frac{\textbf{Mass of pure substance}}{\textbf{Mass of impure substance}} \times \mathbf{100}\ \%$

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 = $\frac{\textbf{Actual yield}}{\textbf{Theoritical yield}} \times \mathbf{100}\%$

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

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)
$$Percentage\ yield = \frac{actual\ yield\ mass}{theoretical\ yeild\ mass}X100$$
$$Percentage\ yield = \frac{0.583}{1.04}X100$$

$$Percentage\ yield = 56.1\%$$

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)
	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? **A** 0,5 **B** 2 **C** 1 **D** 1,47	(2)
	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)
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)

6.3 37 g C react with an excess of oxygen and produce 65 dm3 CO2 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·dm^{-3} is mixed thoroughly with 50 ml of an NaOH solution with a concentration of 0,3 mol·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·dm^{-3} and thoroughly mixed. Assume that the volume of the solution does not change. Calculate the concentration of the final solution.	(7)
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) → $MgCl_2$ (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) → $Ca(NO_3)_2$ (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)
9.2		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)
9.3	A 10 g sample of a compound contains 2,66 g of potassium, 3,54 g of chromium and 3,81 g of oxygen.		

	9.3.1	Define the term empirical formula	(2)
	9.3.2	Determine the empirical formula of this compound.	(7)

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)	$\times10^{-2}$
milli− (mC)	$\times10^{-3}$
micro− (μC)	$\times10^{-6}$
nano− (nC)	$\times10^{-9}$
pico− (pC)	$\times10^{-12}$

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·m^2·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?

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

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

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

$F_{new} = 24F$

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?

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

$F_{new} = k\frac{2q_12q_2}{(\frac{1}{2}r)^2}$

$F_{new} = 16k\frac{q_1q_2}{r^2}$

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$\frac{q_1 q_2}{r^2}$

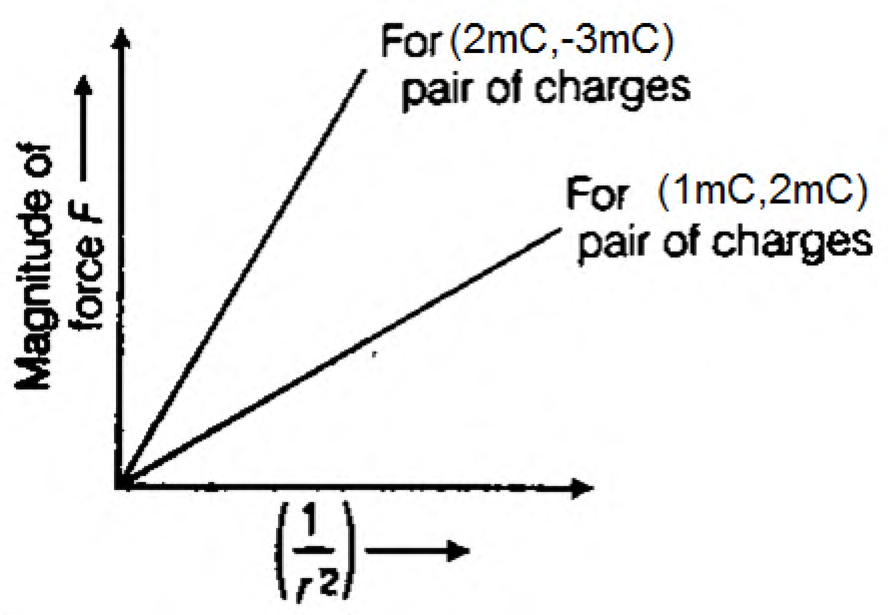
F_{new} = k$\frac{1/2 q_1 q_2}{(2r)^2}$

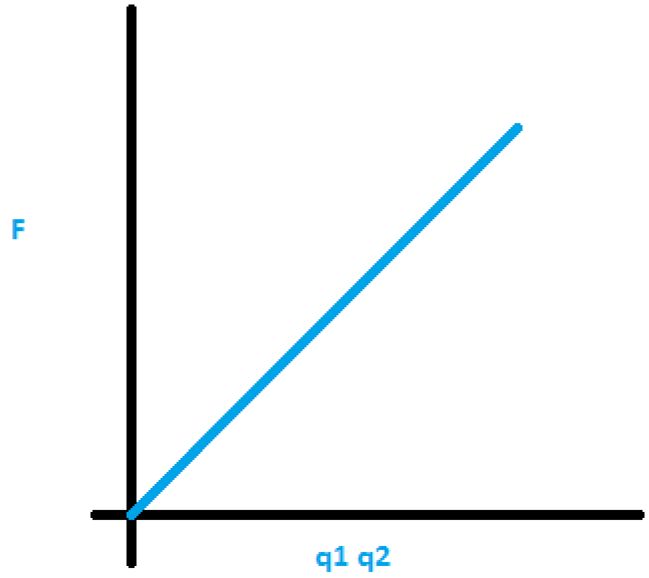
F_{new} = 1/4k$\frac{q_1 q_2}{r^2}$

F_{new} = 1/4F

Graphical representation of Coulombs law:

Electrostatic force and 1/d2





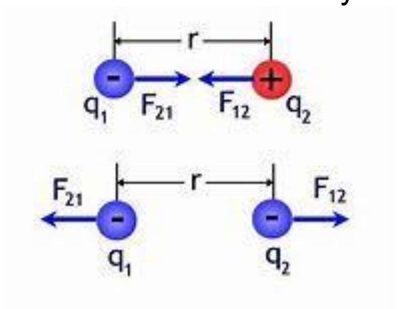
Electrostatic force vs product of charges

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).

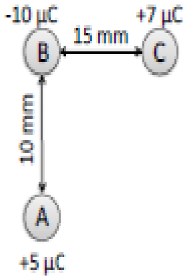


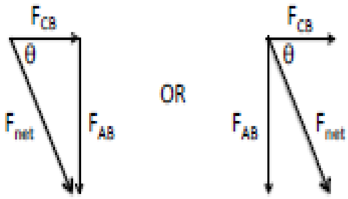
• Both objects experience the EQUAL but opposite forces (Newton's Third Law of Motion).

1-Dimensional
Determine the resultant electrostatic force on Q_B.

2-Dimensional

Determine the resultant electrostatic force on Q_B.





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

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

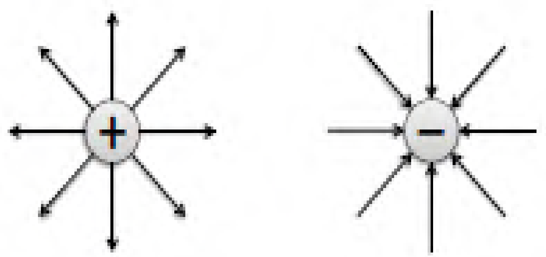
PYTHAGORAS:
$$F_{net}^2 = F_{AB}^2 + F_{BC}^2$$
$$F_{net} = \sqrt{4\ 500^2 + 2\ 800^2}$$
$$F_{net} = 5\ 300 \text{ N}$$

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

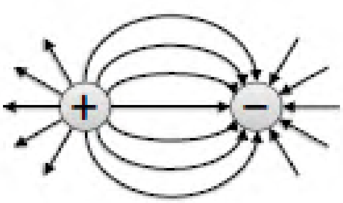
ELECTRIC FIELDS
An electric field is a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge (+1C) would move if placed at that point.

ELECTRIC FIELD LINE PATTERNS

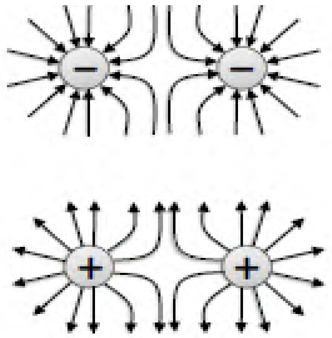
Field lines around the single point charge



Field lines between two unlike charges



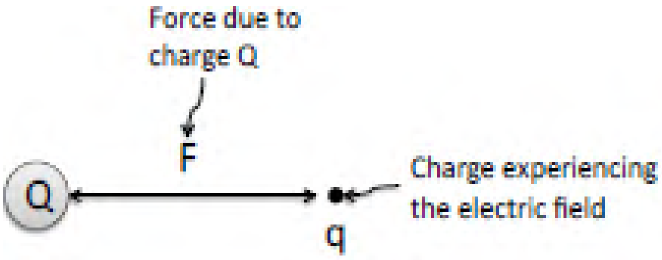
Electric Field Lines between the two like charges



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.



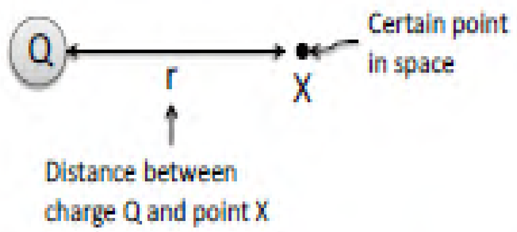
EXAMPLE:
Charge B experiences a force of 2 N due to charge A.
Determine the electric field strength at point B.

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

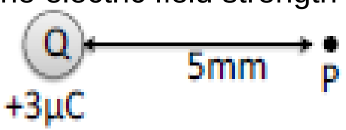
$$\boldsymbol{E = k\frac{Q}{r^2}}$$

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

Q is the charge that creates the electric field.



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



$$E = \frac{kQ}{r^2}$$

$$= \frac{9\times 10^{9}(3\times 10^{-6})}{(5\times 10^{-3})^{2}}$$

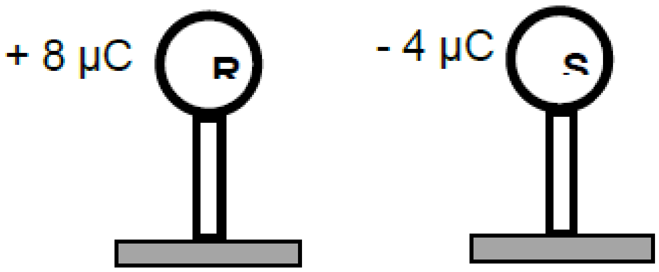
$$= 1{,}08\times 10^{9}\ \text{N}\cdot\text{C}^{-1} \text{ to the right}$$

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.)

ACTIVITIES

SQUESTION 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.



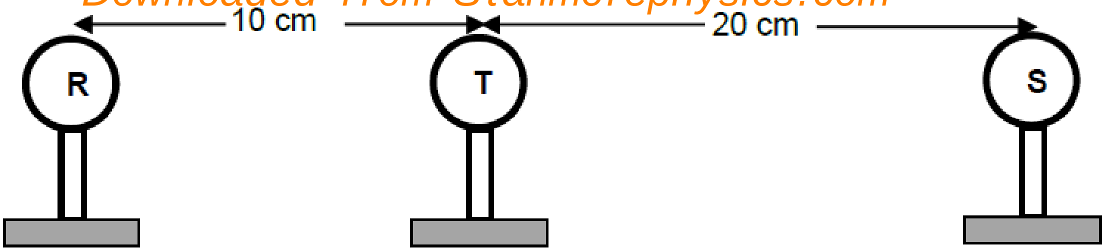
1.1 Explain why the spheres were placed on wooden stands. (1)

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.



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)

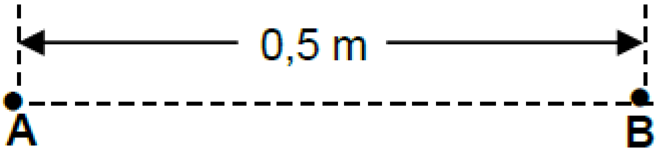
1.6 Define the *electric field at a point*. (2)

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\



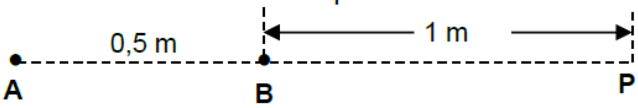
2.1 State Coulomb's law in words. (2)

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**.



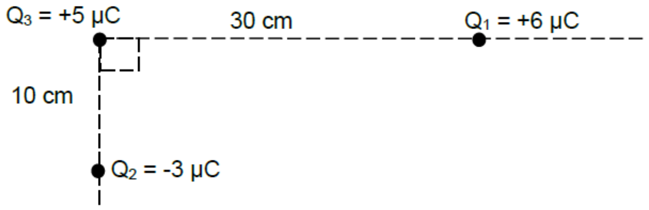
2.3.1 What is the direction of the net electric field at point **P**? (1)

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]

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.

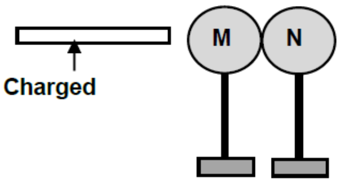


3.1 State Coulomb's law in words. (2)

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**.

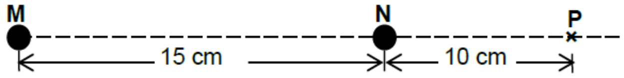


When the spheres are separated it is found that 5 x 10^6 electrons were transferred from sphere **M** to sphere **N**.

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)

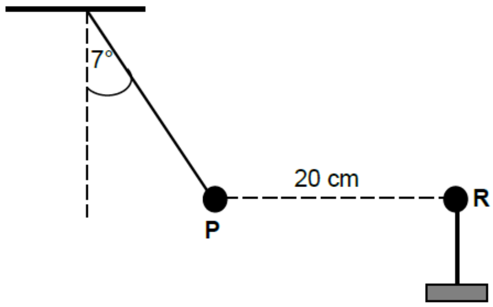
4.4 Calculate the net electric field at point **P** due to **M** and **N**. (6)
[13]

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°.

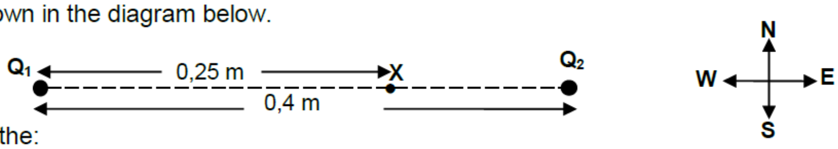
5.2 Draw a labelled free-body diagram showing ALL the forces acting on sphere **P**. (3)

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:

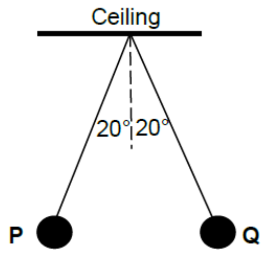
6.1 Net electric field at point **X** due to the two charges (6)

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]

QUESTION 7

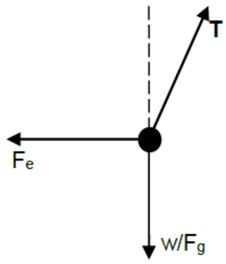


Two identical spherical balls, **P** and **Q**, each of mass 100 g, are suspended at the same point from a ceiling by means of identical light, inextensible insulating strings. Each ball carries a charge of +250 nC. The balls come to rest in the positions shown in the diagram.

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:

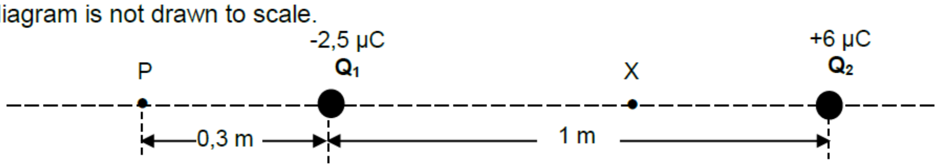


7.3.1 Magnitude of the tension (T) in the string (3)

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.

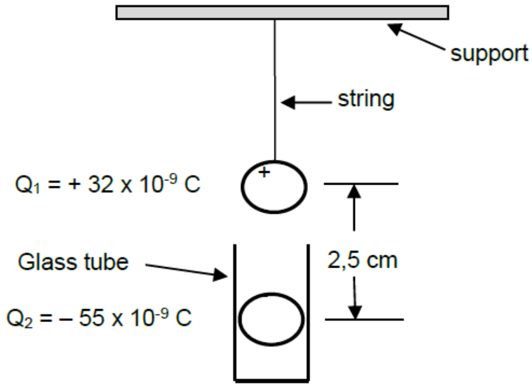


8.1 Show, with the aid of a VECTOR DIAGRAM, why the net electric field at point **X** *cannot be zero.* (4)

8.2 Calculate the net electric field at point **P**, due to the two charged spheres **Q_1** and **Q_2**. (6)
[10]

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)

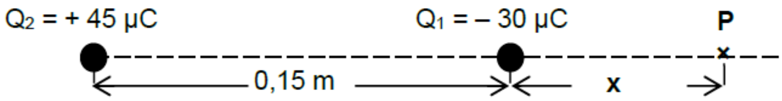
[11]

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.

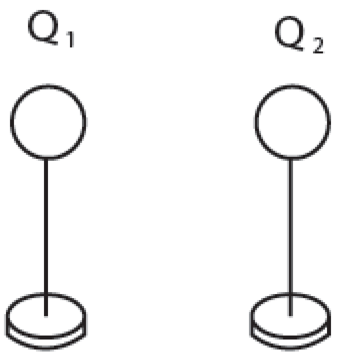


Calculate **x**, the distance of point **P** from charge Q_1. (5)

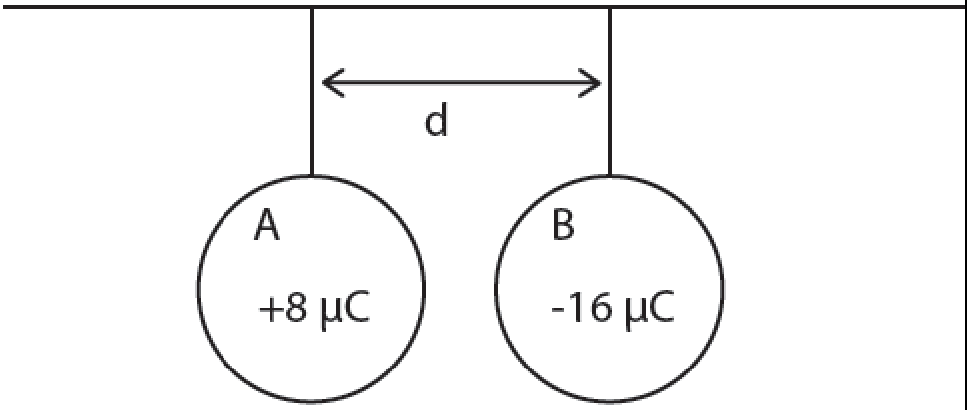
[10]

WORKSHEET 1 (20 Min)

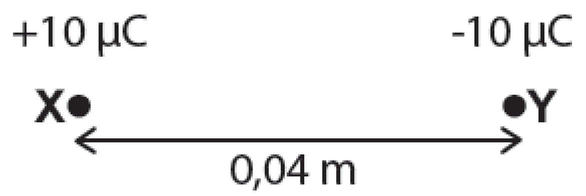
1.1	Two identical small metal spheres on insulated stands carry equal charges and are a distance *d* apart. Each sphere experiences an electrostatic force of magnitude F. The spheres are now placed a distance *d* apart. The magnitude of the electrostatic force each sphere now experiences is: **A.** 1/2F **B.** F **C.** 2F **D.** 4F	**(2)**
1.2	Two charged objects on insulated stands have charges of **3Q** and **5Q** respectively. The 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)**
2	Calculate the new charge on each of the spheres in the following diagram after they have touched.  ____	**(3)**

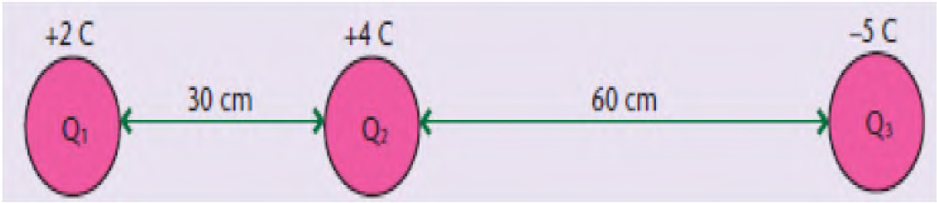
3.	Two metal spheres Q1 and Q2 on insulated stands, carry charges of +4nC and −12nC respectively.  3. 1 Using free body diagrams, show the electrostatic force on each sphere. 3.2 State the Principle of conservation of charge.	(2) (2)
4	4.1 A neutral object obtains a charge by gaining 1 800 electrons. What is the charge that the object obtains? 4.2 Two metal spheres Q1 and Q2 on insulated stands, carry charges of +8nC and −10n respectively. The two spheres are now brought together to touch each other. They are then placed back in their original positions. 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) (3) (2)

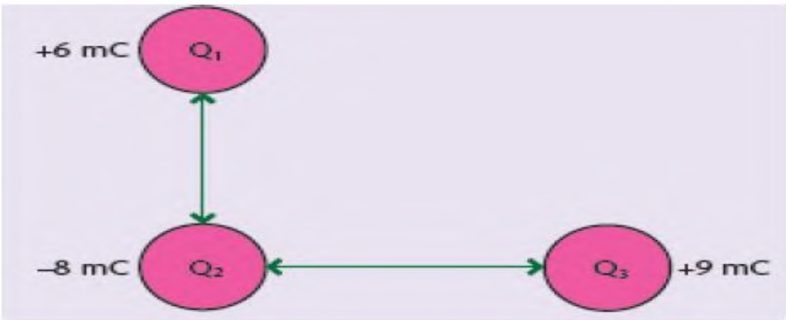
WORKSHEET 2 - COULOMB'S LAW (30min)

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. 2.2.1 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*.	(2) (3)
3.		(3

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)

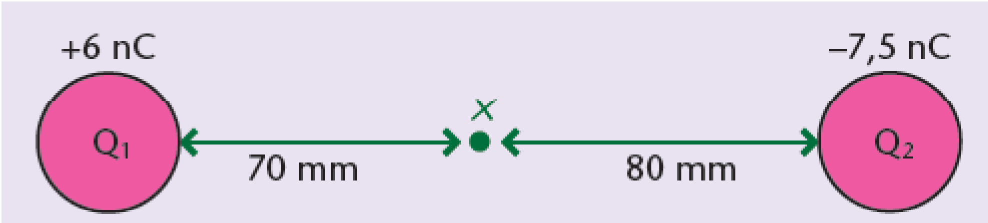
5.	Two charged spheres X and Y are placed 0,04m apart, as shown in the diagram below. .  5.1 Calculate the electrostatic force that **Y** experiences due to charge **X** 5.2 Thus state the force that X experiences due to Y
6	Three point charges are in a straight line. The charges and distances between them are shown.

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

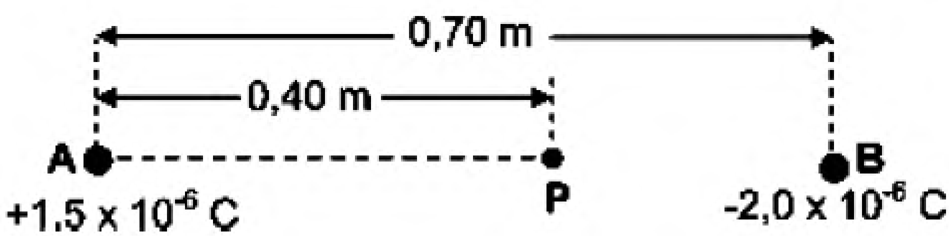
7.	Three point charges are placed in close proximity to one another. The charges and distances between them are shown. What is the resultant electrostatic force on Q_2 as result of the other two charges? 

	WORKSHEET 3 - **THE ELECTRIC FIELD (25min)**
1.	Define an electric field at a point.
2.	2.1 Draw the electric field pattern for a single positive point charge. 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.	(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. (4)

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. (3)