THE REPUBLIC OF UGANDA

Ministry of Education and Sports

# HOME-STUDY LEARNING

SENIOR 3

# PHYSICS

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## FOREWORD

Following the outbreak of the COVID-19 pandemic, government of Uganda closed all schools and other educational institutions to minimize the spread of the coronavirus. This has affected more than 36,314 primary schools, 3129 secondary schools, 430,778 teachers and 12,777,390 learners.

The COVID-19 outbreak and subsequent closure of all has had drastically impacted on learning especially curriculum coverage, loss of interest in education and learner readiness in case schools open. This could result in massive rates of learner dropouts due to unwanted pregnancies and lack of school fees among others.

To mitigate the impact of the pandemic on the education system in Uganda, the Ministry of Education and Sports (MoES) constituted a Sector Response Taskforce (SRT) to strengthen the sector's preparedness and response measures. The SRT and National Curriculum Development Centre developed print home-study materials, radio and television scripts for some selected subjects for all learners from Pre-Primary to Advanced Level. The materials will enhance continued learning and learning for progression during this period of the lockdown, and will still be relevant when schools resume.

The materials focused on critical competences in all subjects in the curricula to enable the learners to achieve without the teachers' guidance. Therefore effort should be made for all learners to access and use these materials during the lockdown. Similarly, teachers are advised to get these materials in order to plan appropriately for further learning when schools resume, while parents/guardians need to ensure that their children access copies of these materials and use them appropriately.
I recognise the effort of National Curriculum Development Centre in responding to this emergency through appropriate guidance and the timely development of these home study materials. I recommend them for use by all learners during the lockdown.

**Alex Kakooza**
Permanent Secretary
Ministry of Education and Sports

## ACKNOWLEDGEMENTS

National Curriculum Development Centre (NCDC) would like to express its appreciation to all those who worked tirelessly towards the production of home–study materials for Pre-Primary, Primary and Secondary Levels of Education during the COVID-19 lockdown in Uganda.

The Centre appreciates the contribution from all those who guided the development of these materials to make sure they are of quality; Development partners - SESIL, Save the Children and UNICEF; all the Panel members of the various subjects; sister institutions - UNEB and DES for their valuable contributions.

NCDC takes the responsibility for any shortcomings that might be identified in this publication and welcomes suggestions for improvement. The comments and suggestions may be communicated to NCDC through P.O. Box 7002 Kampala or email admin@ncdc.go.ug or by visiting our website at http://ncdc.go.ug/node/13.

**Grace K. Baguma**
Director,
National Curriculum Development Centre

## ABOUT THIS BOOKLET

Dear learner, you are welcome to this home-study package. This content focuses on critical competences in the syllabus.

The content is organised into lesson units. Each unit has lesson activities, summary notes and assessment activities. Some lessons have projects that you need to carry out at home during this period. You are free to use other reference materials to get more information for specific topics.

Seek guidance from people at home who are knowledgeable to clarify in case of a challenge. The knowledge you can acquire from this content can be supplemented with other learning options that may be offered on radio, television, newspaper learning programmes. More learning materials can also be accessed by visiting our website at www.ncdc.go.ug or ncdc-go-ug.digital/. You can access the website using an internet enabled computer or mobile phone.

We encourage you to present your work to your class teacher when schools resume so that your teacher is able to know what you learned during the time you have been away from school. This will form part of your assessment. Your teacher will also assess the assignments you will have done and do corrections where you might not have done it right.

The content has been developed with full awareness of the home learning environment without direct supervision of the teacher. The methods, examples and activities used in the materials have been carefully selected to facilitate continuity of learning.

You are therefore in charge of your own learning. You need to give yourself favourable time for learning. This material can as well be used beyond the home-study situation. Keep it for reference anytime.

Develop your learning timetable to ca ter for continuity of learning and other responsibilities given to you at home.

**Enjoy learning**

## PHYSICS SELF-STUDY MATERIALS FOR SENIOR THREE 2020

These self study materials have been developed to help you continue with learning despite the closure of schools that was necessitated by the Covid-19 pandemic.

They are a continuation of the first self study materials that were previously developed. They will help you understand the major concepts in different topics in Physics for your level.

A variety of activities and exercises have been provided. Please try out all the activities and exercises to improve your understanding of the topics. Where possible, consult with other learners in your area. You can also consult from other sources like textbooks and use internet to further your knowledge.

However, ensure that you are following the standard operating procedures (SOPs) so as to avoid Covid-19.

You should ensure that you regularly wash your hand with soap and water and avoid crowded places. In case you are to be in public, always put on your mask.

**All the best as you continue to study using these materials.**

# TOPIC: VECTORS AND SCALARS

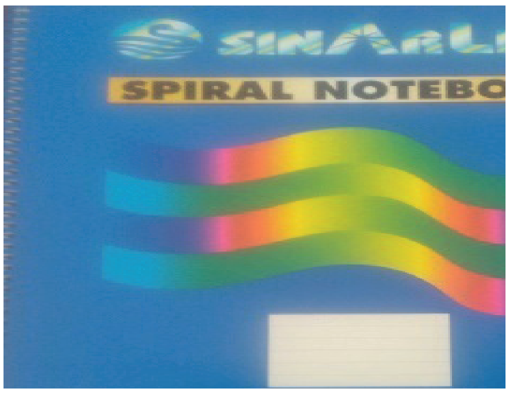
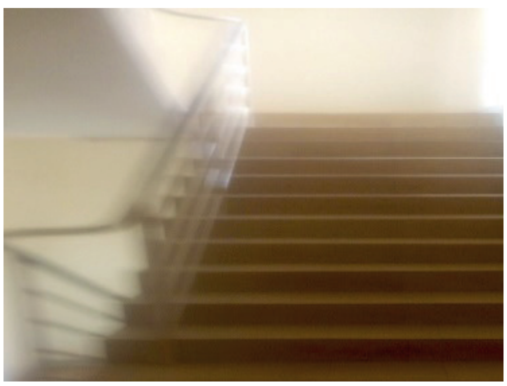
**By the end of this topic, you should be able to:**

i) understand the differences between vector and scalar quantities, and give examples of each.
ii) understand that a number of forces acting on a body can be represented by a single resultant force.
iii) find the perpendicular components of a vector.

## LESSON 1: IDENTIFYING SCALARS AND VECTORS

You should be able to understand the differences between vector and scalar quantities, and give examples of each.

**ACTIVITY 1**

| | |
|---|---|
|  | Count the number of sheets in your physics note book.<br><br>Did it matter in which direction you counted? |
|  | Count the number of steps in the picture.<br><br>Does it matter whether you counted from down –up or the other way round? |

In cases where the direction does not matter, the quantity got is called a scalar quantity. For example, in counting the number of sheets in your physics note book, whether you began from the front to the back, or back to the front, the number of sheets is the same.

Therefore, number of sheets in a book is a scalar quantity.

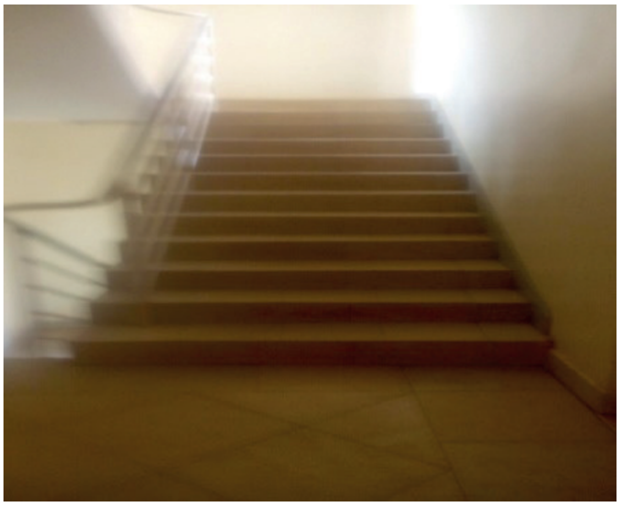
Similarly, the number of stairs will remain the same whether you count form down-up or up-down. Hence number of stairs is a scalar quantity.

Task: Identify other examples of scalar quantities.

**ACTIVITY 2**

What is the difference between these two statements?

a. How many steps make up the flight?
b. How many steps would you descend from the top to the ground?



You notice that in the first statement, it is only a quantity (how many) that is required while in the second, it is the quantity and the direction of movement (descend) as well.

Cases where direction matters are called vector quantities.

**TASK**
Indicate whether it is a vector or scalar quantity.

| | **Quantity** | **Vector/scalar?** |
|---|---|---|
| 1 | Jane moved 500 m | |
| 2 | David parked his car 500 m east of the main house | |
| 3 | Speed | |
| 4 | Velocity | |
| 5 | Force | |
| 6 | Pressure | |

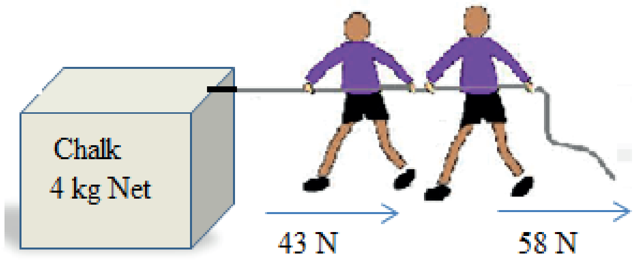
**Summary**

*A scalar quantity is one with only magnitude.*
*A vector quantity is one with both magnitude and direction.*

## LESSON 2: RESULTANT FORCE

You should be able to understand that a number of forces acting on a body can be represented by a single resultant force.

**Case 1**

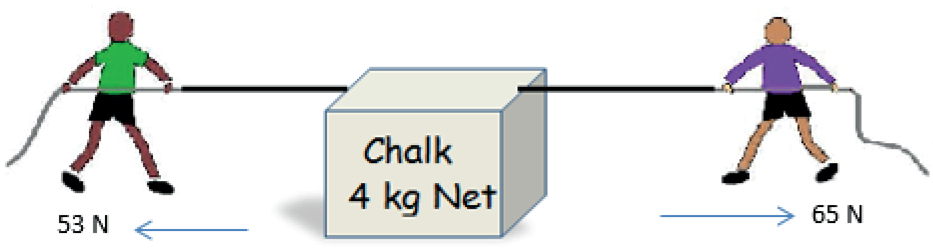



The picture above represents a box of chalk being pulled.

65 N

What is the resultant force with which the box moves? Explain your answer.

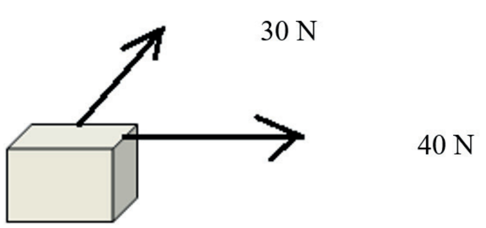
**Case 2**




The same box is being pulled in different directions.

a. In which direction will the box move? Explain your answer.
b. What is the resultant force with which the box moves?

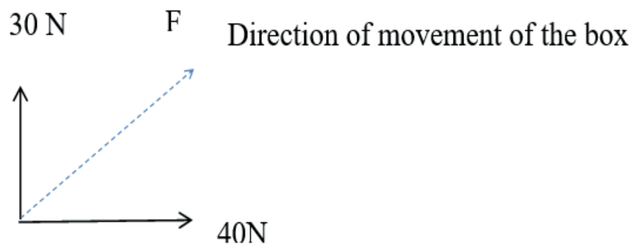
**Case 3**



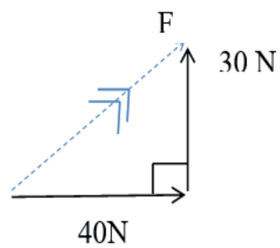

Two forces pull at a box in directions that are perpendicular to each other.

In which direction does the box move? What is the resultant force with which the box moves?

The action of forces on the box, the net (resultant) force F, and the direction of movement of the box can be represented by the diagram below;




This diagram can also be drawn as;




F can be determined using Pythagoras' theorem.

$F^2 = 30^2 \text{ x } 40^2$

$F^2 = 2500 \text{ N}$

$\therefore F = 50 \text{ N}$

Task: Find the angle the resultant force makes with either the horizontal, or vertical. This will describe the direction of the resultant force.

Hint: Use your knowledge of trigonometric ratios (i.e. sine, cosine and tangent)

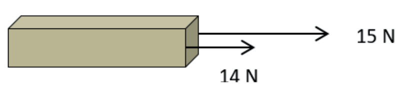
**Summary**

1. *When forces are pulling or pushing an object in the same direction, the resultant force on the object will be the sum of the forces and the object will move in the direction of two forces.*
2. *When forces are acting in opposite directions, the resultant force is obtained by getting the difference. The object will move in the direction of the bigger force.*
3. *When forces act on a body at right angles, the resultant force on the body and its direction can be determined using Pythagoras' theorem.*

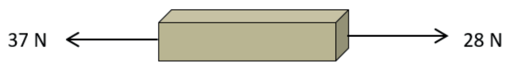
**EXERCISE**

Find the resultant force on each of the objects below. In each case, show the direction of movement of the object.

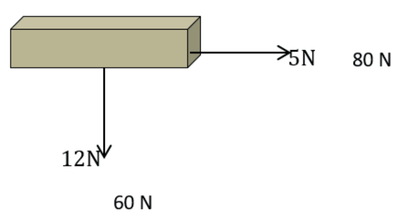
1.




2.




3.

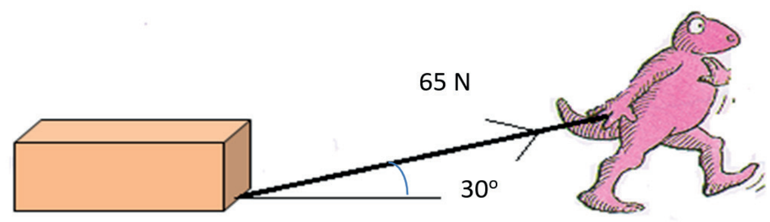


## LESSON 3: PERPENDICULAR AND HORIZONTAL COMPONENTS

You should be able to find the perpendicular components of a vector.

Activity 1

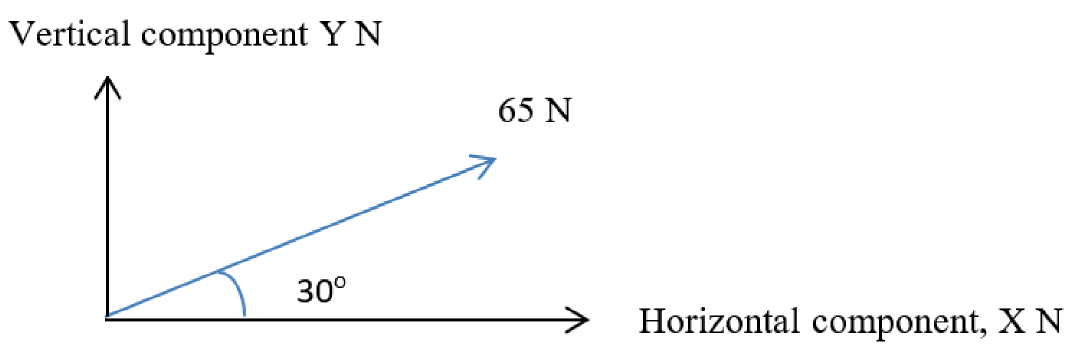
Sosea is pulling a load with a force of 65 N at an angle of 30° to the horizontal.



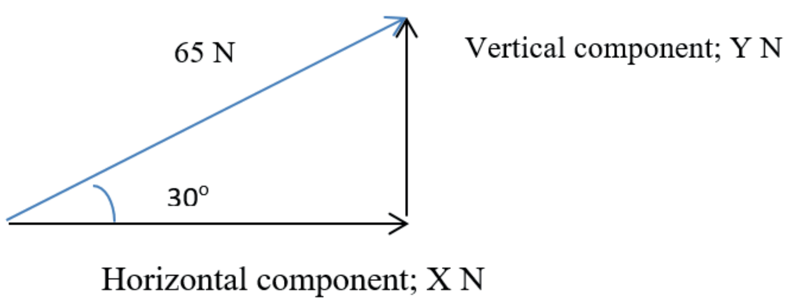

Find the;

1. horizontal component of this force
2. vertical component of this force

This can be represented by

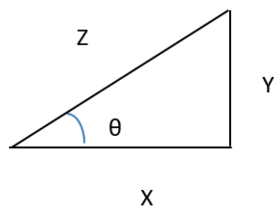



OR




Using your knowledge of trigonometry (sine, cosine and tangent), suggest how you can determine the vertical and horizontal components.

Recall




1. $sin\theta = \frac{Y}{Z}$

$\therefore Y = Zsin\theta$

2. $cos\theta = \frac{X}{Z}$

$\therefore x = Zcos\theta$

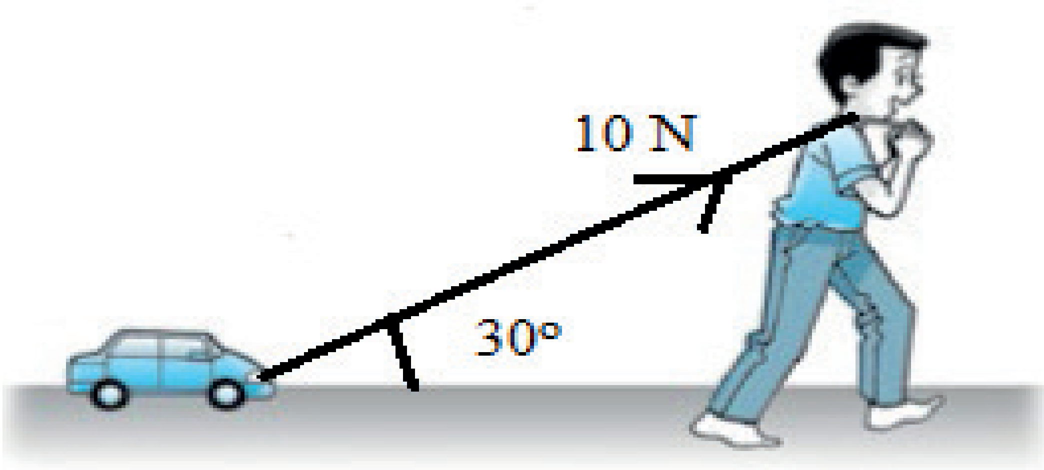
Therefore, the vertical component Y = 65 sin 30°

Y = 65 x 0.5 ∴Y =32.5 N

The horizontal component X = 65 Cos 30°

X = 65 x 0.866 ∴ X = 56.3 N

**EXERCISE**




Calculate the horizontal and vertical components of the force with which John is pulling his toy car.

**Summary**

*When a force Z is acting on an object at an angle θ to the horizontal the horizontal component of that force is given by Z cos θ while. the vertical component of that force is given by Z sin θ.*

# TOPIC: MOMENTUM

**By the end of this topic, you should be able to:**

i) understand the meaning of linear momentum.
ii) understand how momentum is conserved during a collision and solve numerical problems using the law of conservation of linear momentum.
iii) describe situations where linear momentum is applied.

## LESSON 1: MEANING OF LINEAR MOMENTUM

You should be able to understand linear momentum.

**ACTIVITY 1**

You are training as a goal keeper of your village football team. Your coach throws two balls for you to catch, one at a time.

Ball 1: Mass 0.5 kg at a velocity of 10 $ms^{-1}$

Ball 2: Mass 0.5 kg at a velocity of 30 $ms^{-1}$

If he throws the two balls with the same strength, which of the two balls would you prefer catching and why?

**ACTIVITY 2**

The following day he throws two balls with the same strength as follows;

Ball 1: Mass 0.5 kg at a velocity of 10 $ms^{-1}$

Ball 2: Mass 1.0 kg at a velocity of 10 $ms^{-1}$

Which of the two balls would you prefer catching and why?

**Summary**

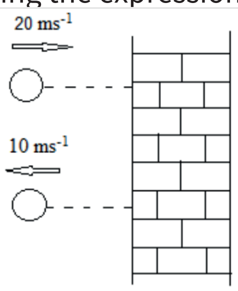
*The moving balls produce an effect on your hands which are there to stop the motion of the ball. This effect is due to the momentum of the moving ball. Momentum depends on mass and velocity of an object.*

Momentum = mass x velocity

**EXERCISE**

1. Using the expression for momentum, derive its unit.

2.

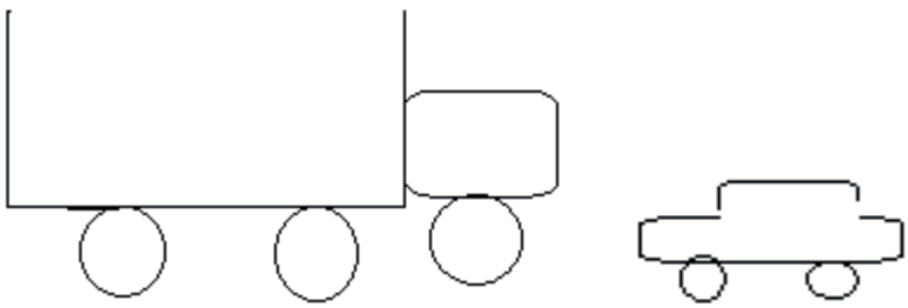


A ball of mass 1.0 kg strikes a wall with a velocity of 20 m $s^{-1}$ and rebounds at 10 m $s^{-1}$.

What is its momentum;

i) Before it strikes the wall
ii) After the rebound?

3. A lorry loaded with matooke and a saloon car are moving at the same speed. The two have to stop at a police check point. Which of the two will be easier to stop? Explain your answer.



## LESSON 2: CONSERVATION OF LINEAR MOMENTUM

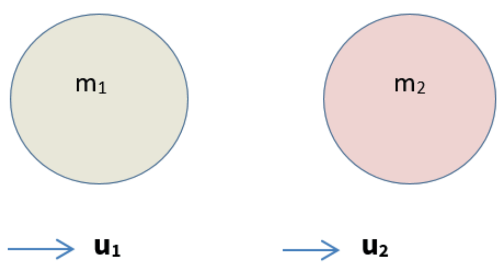
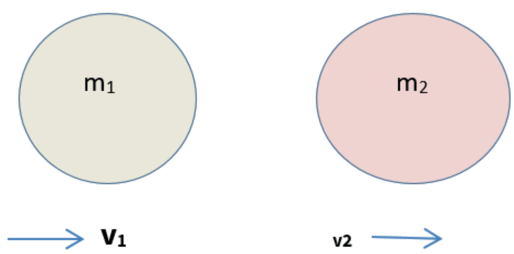
You should be able to understand how momentum is conserved during a collision and solve numerical problems using the law of conservation of linear momentum.

**ACTIVITY 1**

1. What does it mean to 'conserve'?
2. What is conservation of linear momentum?

Conservation of linear momentum occurs when total momentum of the objects before a collision equals that after the collision. Some collisions are elastic while others are inelastic.

In elastic collisions, the bodies collide and move separately after the collision.

<table>
<tr><td>Before collision<br><br>Momentum = $m_1u_1 + m_2u_2$</td><td>After collision<br><br>Momentum = $m_1v_1 + m_2v_2$</td></tr>
<tr><td colspan="2">In elastic collisions, momentum is conserved since $\mathbf{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$<br><br>In elastic collisions, Kinetic energy is also conserved and<br>$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$</td></tr>
</table>

**EXAMPLE**

A toy car of mass 3 kg moving at a velocity of 2 $ms^{-1}$ collides with another toy car of mass 0.5 kg which is moving at a velocity of 1 $ms^{-1}$ in the same direction. If the 0.5 kg toy car moves at a velocity of 2.5 m $s^{-1}$ in the same direction after the collision, what is the velocity of the 3 kg toy car?

Before collision

$m_1$ = 3 kg, $u_1$ = 2$ms^{-1}$

$m_2$ = 0.5 kg, $u_2$ = 1$ms^{-1}$

After collision

$v_1$=?$v_2$ = 2.5$ms^{-1}$

If momentum is conserved, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

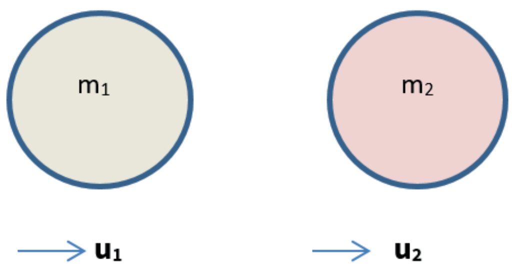
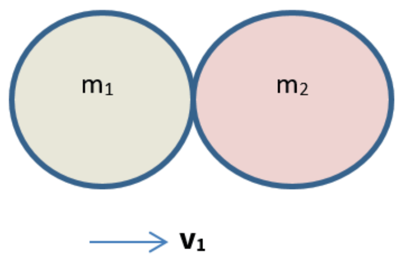
$\Rightarrow (3 \times 2) + (0.5 \times 1) = (3 \times v_1) + (0.5 \times 2.5)$

$6.5 = 3v_1 + 1.25$

$3v_1 = 5.25$

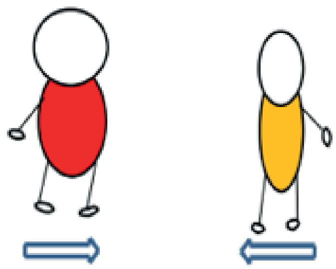
$\therefore v_1 = 1.75\ ms^{-1}$

In inelastic collisions, objects combine and stop or move together with a common velocity after collision.

| **Before collision** | **After collision** |
|---|---|
|   |   |
| **Momentum = $m_1u_1 + m_2u_2$** | **Momentum = $(m_1 + m_2)\ v_1$** |
| In inelastic collisions, momentum is conserved; **$m_1u_1 + m_2u_2 = (m_1 + m_2)\ v_1$** | |
| But kinetic energy is not conserved i.e. there is always loss of kinetic energy. | |

**EXAMPLE**

You meet a friend you have not seen in a long time. The two of you run towards each other with open arms. When you meet, you hug each other for two minutes as you exchange greetings and slowly fall on the side of your friend because he is lighter than you. If your mass is 60 kg and velocity is 5$ms^{-1}$, while your friend's mass is 45 kg and velocity is 7$ms^{-1}$, find the velocity with which the two of you will gradually fall to the ground.

| | |
|---|---|
| <br>$V = 5ms^{-1}$ $V = 7\ ms^{-1}$ | Your momentum before collision = 60 x 5<br>= $300ms^{-1}$<br>Your friend's momentum before collision = 45 x -7<br>= -315 $kgms^{-1}$........ (1)<br><br>What does the negative sign mean?<br><br>Total momentum before collision = 300 - 315<br>= -15 $kgms^{-1}$<br>Total momentum after collision = (60 + 45)v<br>=105v.....(2)<br><br>If momentum is conserved, (1) = (2)<br>-15 = 105v<br>v = -0.14 $ms^{-1}$; where v is your common velocity (i.e. the velocity with which the two of you fell to the ground).<br><br>**Question:** Why is your common velocity negative? |

**Summary**

1. *Conservation of linear momentum occurs when total momentum of the objects before a collision equals that after the collision provided no external forces act on the colliding objects.*
2. *There are two types of collision; elastic and inelastic collision.*
3. *In elastic collisions, momentum and kinetic energy are conserved. So,*
4. $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ *and* $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$
5. *In inelastic collisions, momentum is conserved if m1u1 + m2u2 = (m1 + m2) v1; where v1 is the common velocity of the two objects, but kinetic energy is not conserved.*

## EXERCISE

1. A butterfly rests on a leaf floating on the surface of a pond. The butterfly then starts moving to the tip of the leaf at a speed of 5 cm $s^{-1}$ while the leaf moves at 3 cm $s^{-1}$ in the opposite direction. If the mass of the leaf is 8 g, determine the mass of the butterfly.
2. In the Bible, 1Kings 17: 49, David, a small boy, was able to kill Goliath, a giant using a small stone! Discuss with a friend, how possible this could have been.

# TOPIC: NEWTON'S LAWS OF MOTION

**By the end of this topic, you should be able to:**

i) understand and apply Newton's first law of motion.
ii) understand and apply Newton's second law of motion.
iii) understand and apply Newton's third law of motion.

## LESSON 1: NEWTON'S FIRST LAW OF MOTION

You should be able tounderstand and apply Newton's first law of motion.

**ACTIVITY 1: DEMONSTRATING NEWTON'S 1ST LAW OF MOTION**
**What you need:**

- a coin
- a beaker
- a smooth cardboard (you can also fold a piece of paper)

**What to do:**

1. Push the card slowly and observe what happens to the coin.
2. Repeat the activity but this time push the card a way suddenly. Observe what happens to the coin.

3. Why does the coin behave differently in these steps?

**EXERCISE**

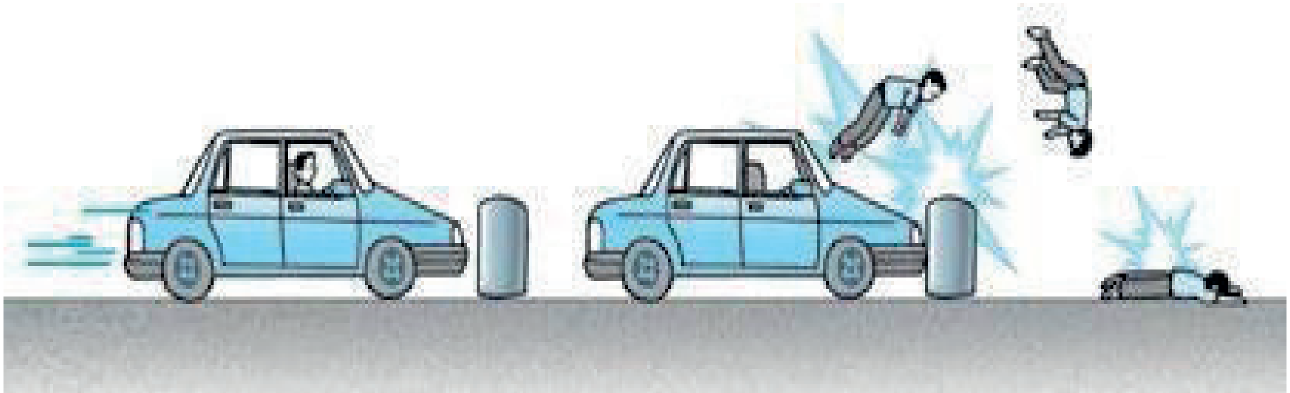
Explain each of the following:

1. A passenger sways backwards when a car initially at rest suddenly starts moving forward.
2. When a bus is moving very fast and suddenly negotiates a corner in one direction, the

passengers sway to the opposite direction.

3. If the brakes of the fast moving car are applied suddenly, the passengers jerk forward.

This can result into a fatal accident as shown below.



Look at the illustration above. When the car abruptly stops by hitting the obstacle, the driver or passenger in front continues to move with uniform velocity. Therefore, the driver can knock their head on the front screen. For this reason, the driver is advised to put on a seat belt to avoid hitting their head in front.

**Summary**

*Newton's first law of motion (The law of inertia) states that a body continues in its state of rest or continuous motion in a straight line unless compelled by some external force to act otherwise.*

## LESSON 2: NEWTON'S SECOND LAW OF MOTION

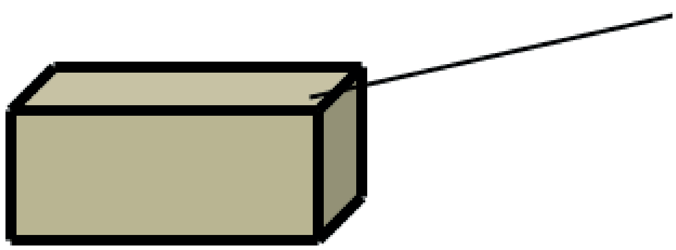
You should be able to understand and apply Newton's second law of motion

**ACTIVITY 1**
**What you need:**

- an empty box
- a few masses (e.g. books)
- a string

**What to do:**

Tie the string to the box and put some masses in the box.



i) Hold the string and drag the box with a big effort in 1 minute. Note the distance the box covered.
ii) Using a less effort drag the box in 1 minute and note the distance the box covered.

Try to move in a straight line in both cases.

Did the box cover the same distance in the two cases? Explain your answer.

In this activity, you realize that the mass (of the box) is the same, the time for which the box is dragged is the same but the effort with which the box is dragged is different.

Hence, the distance the box moved depends on the effort (force) that you used to drag it.

**ACTIVITY 2**

Two cars, A and B are labeled at their rear as follows:

Car A: 1500 cc

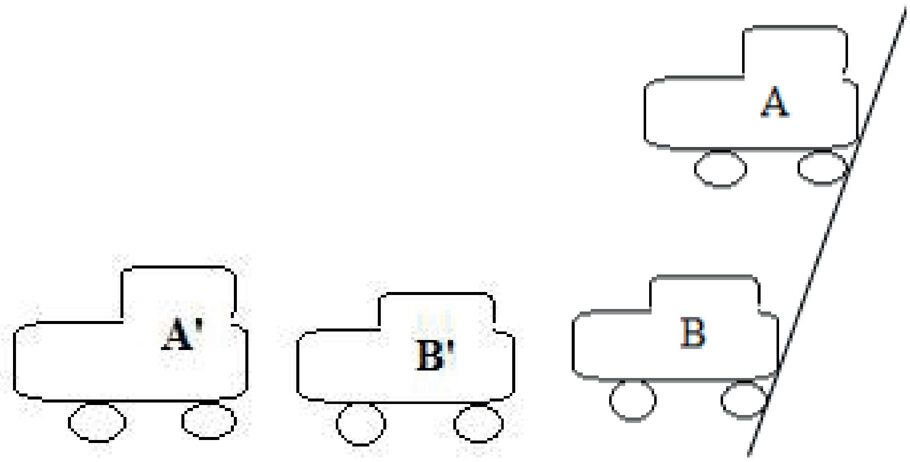
Car B: 3000 cc

What do these labels mean? You can ask someone at home or in the neighborhood that is knowledgeable about cars.

Use this knowledge to study the figure below and answer the questions that follow.

Cars A and B, of the same mass are at the same starting line. The engine capacity of car A is much bigger than car B.

A' and B' shows their new positions after 3 seconds. Explain why this is possible?

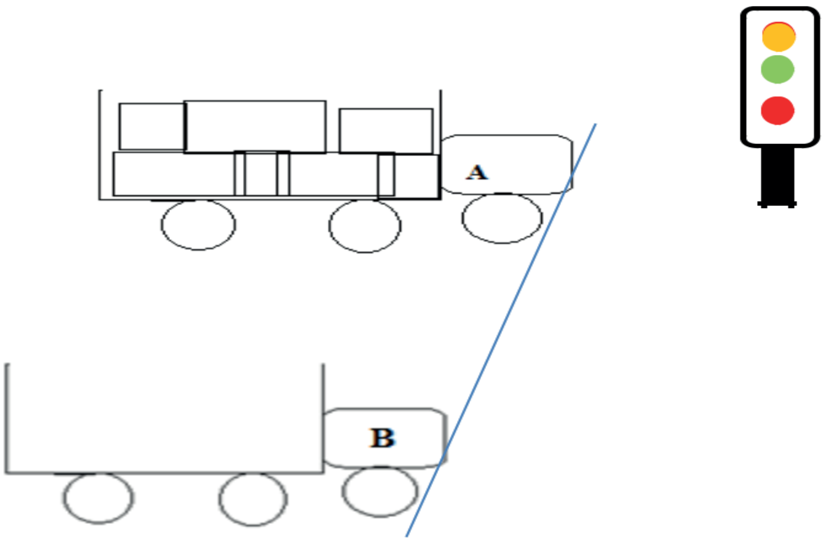



Using Activity 1 and 2, draw a conclusion on the relationship between the force applied to the mass and its acceleration.

In Activity 1 and 2, the mass of the objects is the same but the force with which they move is different. They move different distances because the force causes different accelerations on them. A bigger force causes a bigger acceleration causing it to move a bigger distance. Therefore, acceleration is directly proportional to the force applied.

**ACTIVITY 3**

The figure below shows two similar lorries, A (loaded) and B (not loaded) in front of a traffic light. When the light turns green, both drivers step on the accelerator at the same time with the same effort. Three seconds later, the lorry B is ahead of A.




Explain why this is possible.

Using Activity 3, draw a conclusion on the relationship between the mass and the acceleration on the mass.

**Summary**

*The acceleration of an object is directly proportional to the force applied if the mass is constant (aα F).*
*The acceleration of an object is inversely proportional to its mass when the force acting on it is constant (a α 1/F).*

Hence Newton's second law of motion can be stated in words that: The rate of change of momentum of a body is directly proportional to the force applied to it and the change takes place in the direction of force.

Task: Using the two relationships above, establish a relationship between force, mass and acceleration.

**Summary**

*The net force Fnet = ma is the mathematical expression of Newton's second law of motion*

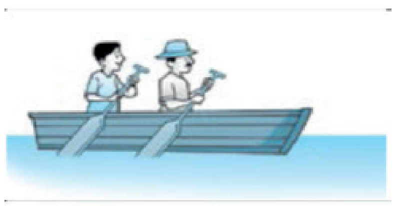
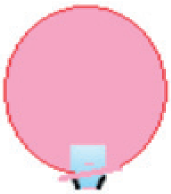
**EXERCISE**

| | |
|---|---|
|  | Okello pushes a 15kg box with a force of 60N.<br>If the floor is frictionless, find the<br>acceleration with which the box moves. |
|  thrust | A car of mass 1200 kg is moving at an acceleration of 2 m $s^{-2}$. If the frictional force<br>acting on the car is 750 N, find its enginew |

## LESSON 3: NEWTON'S THIRD LAW OF MOTION

You should be able to understand and apply Newton's third law of motion.

Newton's third Law of Motion

| | |
|---|---|
|  | Explain how boat is able to move forward (or back-wards)on water |
|  | The picture shows a squid. Do some research and find out how it is able to propel itself in water |
|  | Explain how your chair, at school or at home, is able to sustain your weight without breaking or collapsing |
|  | Explain what happens when air in an inflated balloon is released |

The answers to the above scenarios lies in action and reaction on bodies.

Summary

When a body exerts a force on another body, the other body exerts an equal but opposite force on the first body.

This is stated as: To every action there is an equal and opposite reaction. This is Newton's third law.

**EXERCISE**

Discuss and make short notes on other real life situations where action and reaction apply.

## TOPIC: FRICTION

**By the end of this topic, you should be able to:**

i) understand the concept of friction and its effects
ii) describe advantages and disadvantages of friction
iii) describe methods of reducing or increasing friction

### LESSON 1: YOU SHOULD BE ABLE TO UNDERSTAND THE CONCEPT OF FRICTION AND ITS EFFECTS.

**ACTIVITY 1**
Push a heavy load across a rough floor.

Now push the same load across a smooth floor.

In which of these two situations was it easy to push the load?

Explain your answer.

**ACTIVITY 2**

The table below shows new items and how they look after years of use. What causes such new items to look like this after years of use?

| New | After a long period of use |
|---|---|
|  |  |
|  |  |

**ACTIVITY 3**
Rub your palms together. Begin slowly and increase the speed at which you are doing it. What do you feel? What causes this feeling?

**SO, WHAT IS FRICTION?**
It is the force that tries to stop materials sliding or rubbing against each other.

That is why in activity 1, you probably found it easier to push the load on smooth floor than rough floor.

Since friction opposes relative sliding motion, it has effects on surfaces that slide against each other for some time.

For example, in the course of digging, the surface of the hoe and soil are rubbing against each other. This causes the hoe to wear away. The same happens to the soles of shoes.

Friction also causes heat. That is why when you rubbed your palms against each other, they felt warm.

**TASK: IDENTIFY OTHER CASES WHERE EFFECTS OF FRICTION ARE OBSERVED.**

## LESSON 2: YOU SHOULD BE ABLE TO DESCRIBE ADVANTAGES AND DISADVANTAGES OF FRICTION.

**ACTIVITY 1**

1. Open a clean page in your physics note book.
2. Write your name on this page.
3. Smear some little vaseline in one corner of this page and write your name over the patch of vaseline.

Were you able to write your name over the patch of vaseline?
Explain your answer.
When you smear vaseline on the paper, you make it smooth and the pen cannot write over it.
This activity shows that friction is necessary in writing.

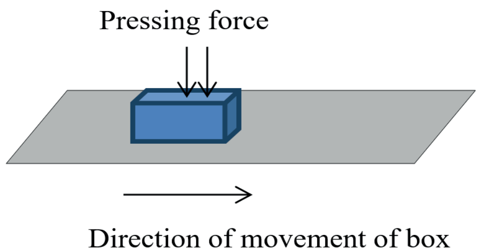
The match stick and box also use friction to make fire! Imagine if the match box was smooth.
Would you be able to light a fire?
This concept is applied in brakes. For example, in applying brakes of a car, or bicycle or motor cycle (bodaboda), friction between the brake pad and wheel causes the wheel to stop moving.

**TASK: IDENTIFY OTHER CASES WHERE FRICTION IS NECESSARY IN LIFE.**
**ACTIVITY 2**

When you rubbed your palms, they felt warm. If you continue rubbing, and rubbing faster, they will feel hot and some skin might peel off.
Using this example, imagine two moving parts of a vehicle or bicycle that rub against each other, for example, the wheel and wheel axle. What would happen if they continue rubbing against each other?
Friction causes wearing away of surfaces and undesirable heat.
Question: How can you reduce the undesirable effects of friction?
This can be done by lubrication and use of ball bearings.
Visit a garage, bicycle/bodaboda mechanic and ask to see ball bearings and lubricating oils.
Ask him/her how ball bearings are used to reduce friction.

**Question: How would you increase friction?**

1. Increasing friction necessitates making surfaces rubbing against each other rough.
2. It can also be done by increasing the force that presses the two surfaces together.



# TOPIC: FLOATING AND SINKING

**By the end of this topic, learners should be able to:**

a. explain why some objects sink while others float.
b. explain the concept of floatation.
c. understand Archimedes Principle.
d. understand the relationship between floatation and Archimedes principle.
e. demonstrate applications of Archimedes principle in everyday life.
f. solve numerical problems involving Archimedes principle.

## LESSON 1: YOU SHOULD EXPLAIN WHY SOME OBJECTS SINK WHILE OTHERS FLOAT.

**Question: Have you ever wondered why some objects sink in water while others float?**

**ACTIVITY 1**
**What you need:**

- a stone
- a piece of dry wood
- bucket/basin
- water

**What to do:**

1. Fill the bucket with water.
2. Drop the stone and piece of wood in the water.
3. What do you observe?

Explain your observation.

From your study of density, you remember that a stone is denser than wood.

An object will sink in water if its density is greater than the density of water. On the other hand, an object will float if its density is less than the density of water.

Task: List items that are denser than water and those that are less dense than water.

Some objects, however, are made of dense material but do not sink.

For example; have you ever wondered why a small steel ball will sink in water but a mighty ship made of steel will float?

This is possible because the ship is partly made of steel. Most of its underside contains a lot of air. Therefore, its overall density is less than that of water. So, it is able to float.

**Summary**

*An object sinks in a liquid because it is denser than that liquid. It will float if it is less dense than the liquid.*

## LESSON 2: UPTHRUST

Have you ever wondered: If you try to lift a heavy object under water, you find it surprisingly light and much easier to lift than when it is out of the water? Why?

**ACTIVITY 1**

**What you need:**

- bucket
- 3-litre jerry can
- water

**What to do:**

1. Fill the bucket with water.
2. Insert the 3-litre jerry can in the bucket and let it fill with water.
3. Slowly pull it out of the bucket.

Does it feel the same lifting the jerry can in water and out of the water?

Explain your answer.
As you lift the object out of the water, the water pushes upwards on the jerry can. It exerts an upward force on the jerry can. This upward force of water on the jerry can is upthrust. So, the up thrust causes the object to feel lighter while in the water.

You can confirm the existence of up thrust by conducting activity 4

**ACTIVITY 3**

**What you need:**

- bucket
- water
- an empty mineral water bottle

**What to do:**

1. Fill the bucket with water.
2. Tightly cover the water bottle and hold it under the water.
3. Let the bottle go.
4. What do you observe?

**Summary**

*When on object is placed in a fluid (liquid or gas), the fluid exerts an upthrust on the object. This force opposes the weight of the object and tends to push the object upwards. This causes an imaginary or apparent loss in weight for the object.*

**MEASURING UPTHRUST**

**ACTIVITY 4**

**What you need:**

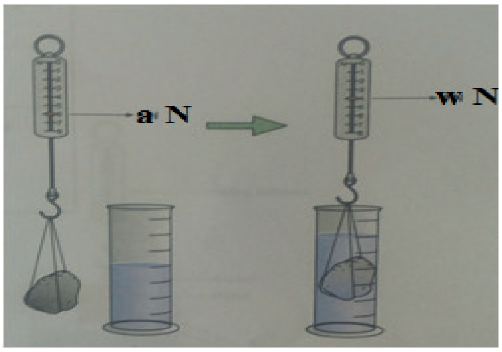
- a stone
- piece of thread
- spring balance
- measuring cylinder/bucket
- water

**What to do:**

1. Put some water in the measuring cylinder.
2. Suspend the stone to the hook of a spring balance using the piece of thread.
3. Record the balance reading when the stone is in air (a N).
4. Gradually lower the stone into the water.
5. Record the balance readings when the stone is totally under water (w N).
6. Calculate the up thrust of the water on the stone.

Up thrust is given by: Weight of stone in air – weight of stone in water.

Up thrust = a N – w N




Explaining up thrust

Where does this up thrust come from?

Recall:

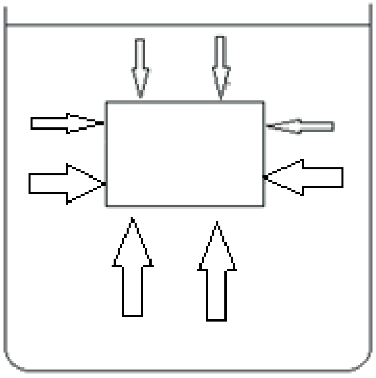
From your knowledge of pressure:

i) pressure increases with depth.
ii) acts in all directions.

From pressure increases with depth, the pressure on the lower surface is greater than the pressure on the top.

Pressure acting on the sides cancels out since it will be equal and acting in opposite directions.

Therefore, the result is an upward force on the block because of the greater pressure on its lower surface.



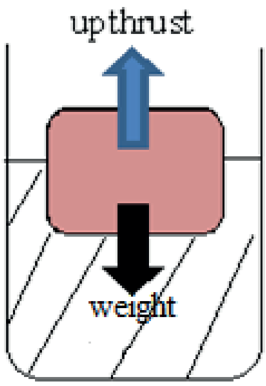
You should be able to explaining floating and sinking.

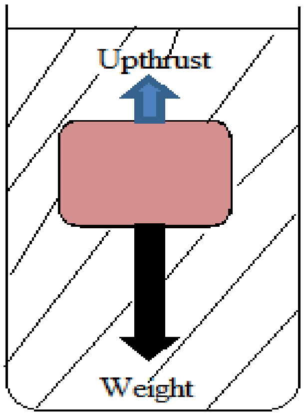
Since up thrust is a force, we shall use an arrow to represent it.

In (a): weight = up thrust. The object floats

In (b): weight > up thrust. The object sinks

Question: What do you think would happen if up thrust > weight?




(a) (b)

**Summary**

*When:*
*weight = up thrust.,the object floats.*
*weight> up thrust,the object sinks.*
*weight < up thrust the object rises.*

## LESSON 3: YOU SHOULD BE ABLE TO UNDERSTAND AND APPLY ARCHIMEDES' PRINCIPLE TO FLOATING

Archimedes observed that when an object is placed in water, it displaces some of the water.

So, Archimedes principle gives the relationship between weight of the water that the object displaces and the up thrust on the object.

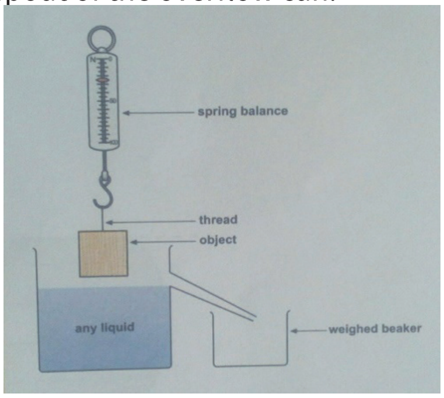
**ACTIVITY 1**
**What you need:**

- object (e.g. stone or block of wood)
- piece of thread
- spring balance
- overflow can
- beaker

**What to do:**

1. Suspend the stone to the hook of a spring balance using the piece of thread
2. Record the balance reading when the stone is in air (a N)
3. Weigh the beaker (b N)

4. Place the overflow can on a flat surface and fill it with water until no more water drips from the spout.
5. Place the beaker under the spout of the overflow can.




6. Lower the stone carefully into the water until it is partially immersed.
7. Note the reading on the spring balance. It is the apparent weight of the stone.
8. Weigh the beaker with the displaced water.

   Up thrust on the object = weight of object in air – weight of object in water
   Weight of displaced water = weight of beaker with water – weight of empty beaker

Compare the up thrust on the stone and the weight of the water displaced.

Archimedes found out that these two were equal.

Task: Lower the stone into the can until it is completely immersed but not touching the bottom of the can. Find the apparent weight of the stone. Is it different from when the stone is partially immersed in the water?

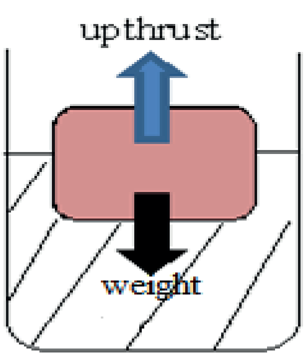
**Summary**

*Archimedes' Principle states that 'when an object is partially or fully immersed in a fluid it experiences an upthrust equal to the weight of the fluid displaced'.*

Archimedes' Principle and Floating Objects

Recall:

a.




b. Archimedes' principle tells us that the upthrust is also equal to the weight of the water displaced.

When we relate these two, we notice that: a floating object displaces its own weight of water (or fluid) in which it floats. This is known as the law of floatation.

**Summary**

*The law of floatation states: "A floating object displaces its own weight of fluid in which it floats". It is a special case of Archimedes' principle.*

## LESSON 4: YOU SHOULD BE ABLE TO DEMONSTRATE APPLICATIONS OF ARCHIMEDES PRINCIPLE IN EVERYDAY LIFE.

Example 1: Ship
A ship, though very heavy, floats in the sea. This is because the volume of sea water displaced by the ship is sufficiently large to have a weight equal to the weight of the ship.
Although a ship is constructed of metal, which has a greater density than water, its shape is hollow so that the overall density of the ship is less than the density of sea water. As a result, the upthrust acting on the ship is large enough to support its weight.

This can be confirmed by the activity below:

**What you need:**
- Plasticine or clay
- Basin/sauce pan/container
- Water

**What to do:**
1. Roll a small piece of plasticine or clay into a ball and place it on water.
2. Observe what happens
3. Remove the ball from the water and make it into a shape of a bowel.
4. Place the bowel on water.
5. What do you observe?

A ship may travel from sea water, which is salty, into river water, which is fresh. However, it will submerge deeper in fresh water because the density of fresh water is less than seawater.

Activity

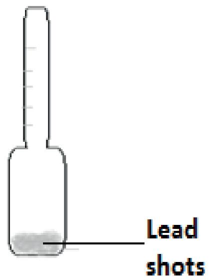
| What you need: | What to do: |
|---|---|
| • a glass<br>• water<br>• salt<br>• an egg | 1. Place a fresh egg in water. What do you observe?<br>2. Now dissolve salt in the water while stirring until the egg floats.<br>3. Why does the egg float in the salt water? |

Therefore in sea water, a ship must displace more water to obtain sufficient upthrust to support its weight.

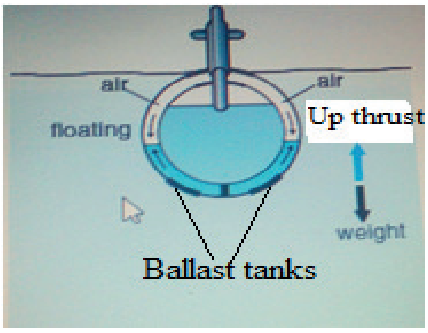
To ensure that a ship is loaded to within safety limits, the Plimsoll line marked on the body of the ship acts as a guide.

In countries that experience very cold weather, a ship can also float higher in cold seasons because of the higher density of cold water.

Example 2: Hydrometer

| | |
|---|---|
|   | A hydrometer is an instrument used to measure the **relative density of liquids** such as milk or acid in batteries. It consists of a tube with a bulb at one end. Lead shots are placed in the bulb to weigh it down and enable the hydrometer to float vertically in a liquid. In a liquid of lower density, a greater volume of liquid must be displaced for the up thrust to equal the weight of the hydrometer and so it sinks lower. However, the hydrometer floats higher in a liquid of higher density. |

Example 3: The submarine

| | |
|---|---|
|   | When water enters the ballast tank of a submarine, the weight of the submarine becomes greater than the up thrust. Thus, the submarine dives into the sea. When compressed air forces water out of the ballast tank, the weight of the submarine becomes less than the up thrust. A submarine floats in the sea because the up thrust acting on the submarine is the same as the weight of the displaced water |

Now let us solve numerical problems involving Archimedes' principle

**Example 1**

A steel bar weighs 300N when weighed in air, and 260 N when weighed in water.

a. What is the up thrust of the water on the bar?
b. What weight of water does the bar displace?

**Solution**

a. Up thrust = weight of object in air – weight of object in water

Up thrust of the water on the steel bar = 300 N – 260 N

= 40 N

b. Archimedes' principle states that when an object is partially or fully immersed in a fluid, it experiences an up thrust equal to the weight of the fluid displaced.
Hence, the weight of the water the bar displaces = 40 N

**Example 2**

An object weighs 30 N in air and 20 N when immersed in water of density 1000 $kgm^{-3}$.

Determine:

a. up thrust on the object
b. volume of the object

**Solution**

a. Up thrust = weight of object in air – weight of object in water
Up thrust of the water on the steel bar = 30 N – 20 N
= 10 N

b. Up thrust = weight of the fluid displaced =10 N
Weight = mg
Weight of liquid displaced = mg = 10
Assuming g = 10 $ms^{-2}$, mass of liquid displaced = 1 kg
But an object displaces its own volume of the liquid in which it is immersed.
From density = mass/volume ⇒ Volume = mass/density
∴volume of liquid displaced = 1/1000 = $10^{-3}$ $m^3$

Volume of object = $10^{-3}$ $m^{-3}$

Exercise

1. Explain why a coke stopper held below the surface of the water rises when released.
2. A wooden sphere of mass 6 kg and volume 0.02 $m^{-3}$ floats on water.
   a. Find the volume of the sphere below the water surface.
   b. Density of the wood.
3. A block of metal of volume 0.08$m^3$ has a density of 5$gcm^{-3}$. Determine:
   a) The weight of the block in air.
   b) The upthrust on the object and the apparent weight of the object when fully submerged in a liquid of density 1.2$gcm^{-3}$.

# TOPIC: FLUID FLOW

**By the end of this topic, you should be able to:**

i) understand streamline flow and turbulence.
ii) understand the relationship between pressure, velocity.
iii) explain practical applications of the relationship between pressure and velocity.
iv) explain the concept of terminal velocity.

**INTRODUCTION**

Fluid means something that flows. Fluids include gases and liquids. In this topic, you will learn what affects fluid flow and the practical applications of fluid flow.

**You should be able to:**

- streamline flow and turbulence of objects.
- understand the relationship between pressure, velocity.

When water is flowing smoothly, it behaves in a streamlined way. When it is flowing quickly, it becomes turbulent.

Fluid flow is represented with streamlines. Therefore, a streamline is a line showing how a small part of a fluid is moving. It also shows the direction of flow using an arrow.

Turbulent flow creates unpredictable currents in the flow and energy is wasted as a result. If you have cycled, you must have experienced air resistance. To attain speed, you need to keep your head down in order to reduce air resistance.

Boats are designed to travel through water. The water drags on the boat's body which slows it down. So, their bodies are made in a streamlined shape so that it can cut through the water with as little hindrance as possible.

Cars too experience air resistance as they move, because air is a fluid. Therefore, cars that are designed to be very fast, for example sport cars, have streamlined bodies to reduce the effect of air resistance.

B

ig trucks have a wind deflector on the top of the cab to force air to flow over the top of the trailer rather than allow it to flow down between the back of the cab and underneath the trailer. This reduces the drag due to air. It also saves a lot of fuel on a long journey.

**Wind deflector**

**ACTIVITY 1**

**What you need:**

2 strips of paper

What to do:

| | |
|---|---|
| 1. Predict the direction of movement of the strip paper if you blew above it.<br>2. Blow above the strip of paper.<br>3. What do you observe? |  |

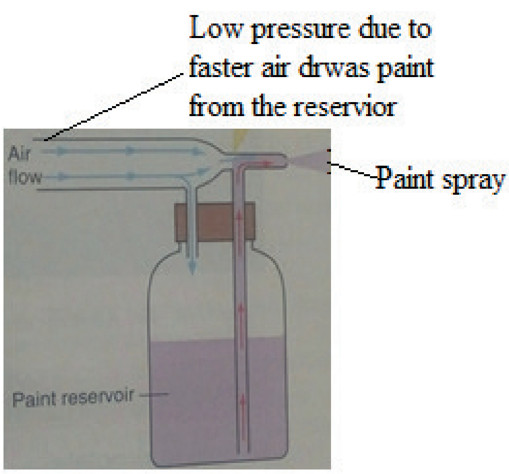
When you blow above the strip of paper, the velocity of the air above the strip increases but the pressure reduces. The pressure below the strip becomes greater than the pressure above it and it rises.

Task:

1. Try the experiment above but this time, blow between two strips of paper.
2. What do you observe?
3. Explain your observation.
   The relationship illustrated above between pressure and velocity is known as Bernoulli's principle and states,"When the speed of a fluid increases, the pressure in the fluid decreases."

**Practical Applications of the Relationship Between Pressure and Velocity**

One of the applications of this relationship is the lift force on an aircraft. The aircraft first accelerates to a high velocity and due to the shape of its wings, the velocity of the air above the aircraft increases as the pressure reduces. The pressure below the aircraft becomes greater than the one above causing the aircraft to lift. This is demonstrated below.




Other applications of Bernoulli's principle include among others; the carburettor found in engines, the filter pump, flow meters such as venture-meter and pitot tubes, Bunsen burner etc.

**The Concept of Terminal Velocity**

When an object moves through water or air (fluid) it experiences a drag (or hindrance) as discussed above. When it is moving slowly, there is little drag. The drag increases rapidly as the object moves faster.

An example is a stone dropped into water. At first, the stone is only acted up on by its weight and therefore falls with acceleration due to gravity. When it is fully immersed in water, an upthrust and a viscous drag oppose its downward motion and as its speed increases, the viscous drag also increases. A point is reached when the total force opposing its downward motion becomes equal to its weight. The stone then moves with a constant maximum velocity called terminal velocity.

Can you sketch a graph for this?

**EXERCISE**

1. Explain why it is not advisable for one to stand near a railway line as a fast moving train passes by.
2. Explain why the roof of a hut may be blown off the hut during a thunderstorm.

# TOPIC: REFRACTION OF LIGHT AT PLANE SURFACES

**By the end of this topic, you should be able to:**

i) understand that light may be refracted as it passes from one medium to another and explain the consequences of refraction.
ii) verify laws of refraction using glass block and a triangular prism.
iii) solve numerical problems involving refractive index.
iv) understand total internal reflection.
v) describe applications and effects of total internal reflection.

**Introduction**

When light travels from one medium to another of different optical density, it changes direction. This is called refraction. For example, when you place a spoon in a glass of water, it appears bent. Swimming pools appear shallower than they actually are.In this chapter you will learn how refraction occurs. You will also learn its consequences and uses.

## LESSON 1

You should be able to understand that light may change direction as it passes from one medium to another and explain the consequences of refraction.

Demonstrating Refraction

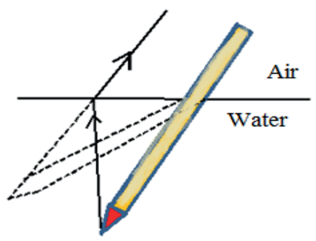
**ACTIVITY 1**

**What you need:**

- a glass
- water
- a spoon/pencil/stick

**What to do:**

1. Place a pencil in an empty glass at a slant position.
2. Pour water in the glass.
3. Look at the pencil through the water sidewise along its length and note what you see.
4. Explain your observation.




The ‘bent pencil’ illusion occurs because light is bent by the glass.

**ACTIVITY2**

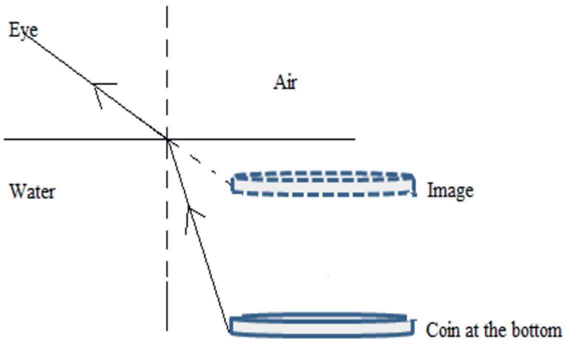
**What you need:**

- a dish or mug
- water
- a coin

**What to do:**

1. Put a coin in the dish.
2. Hold the dish up to almost the level of your eye, until you just cannot see the coin at the bottom of the dish.
3. Gently pour water in the dish to cover the coin completely.
4. What do you observe?
5. Explain your observation.

What you have observed can be explained by the ray diagram below;

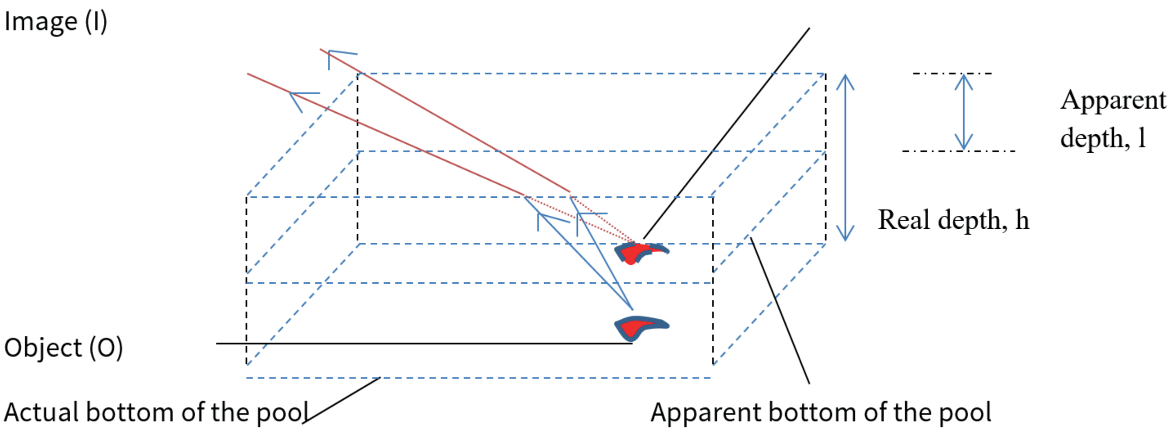



We can only see the coin because the light rays coming from it are bent at the water surface away from the normal of the water surface.

6. Now lower the dish and look at the water vertically from above.
7. Where does the coin appear now?
8. Explain the observation.

When viewed vertically from above, the coin appears to be at the bottom of the dish.

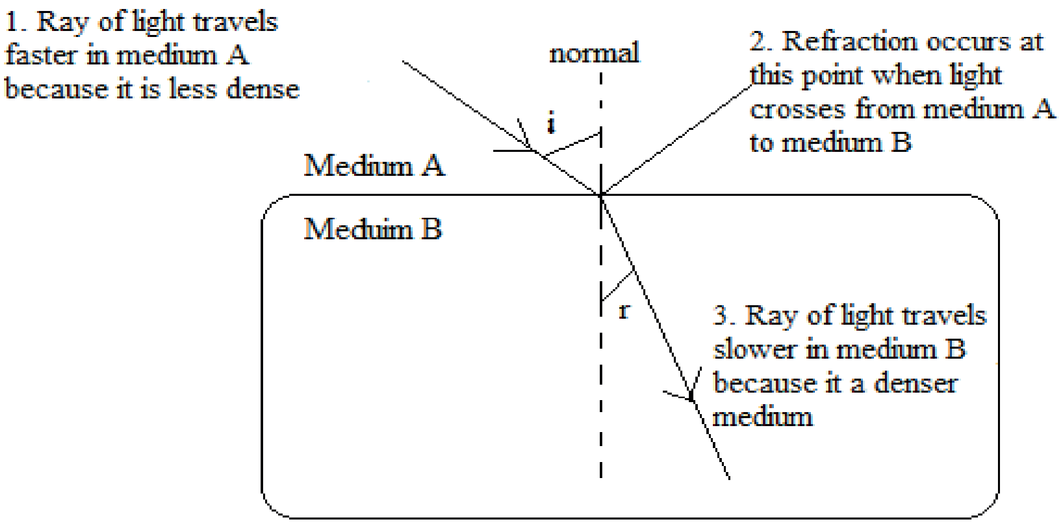
However, the bottom seems to have risen. This explains why swimming pools appear shallow.



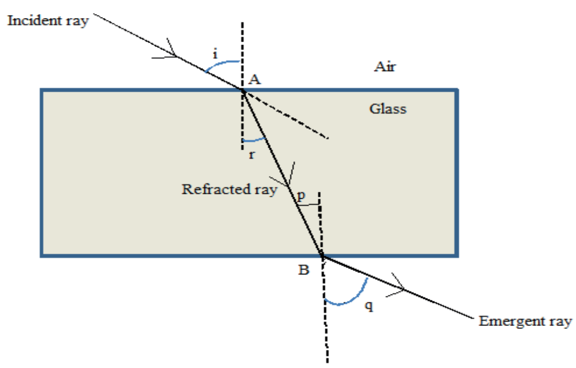

Have you ever seen someone standing in a swimming pool and he/she appeared shorter? This phenomenon can be explained by refraction.

**Summary**

*This bending effect is called refraction of light. Refraction of light is the change in direction or bending of the light as it moves from one medium to another. It is caused by the change in the velocity of light as it propagates from one medium to another of different optical densities.*




A medium in which the velocity of light is lower is an optically dense medium. For example, glass is optically denser than water.




At point A, as a ray of light passes from air to glass, the ray is bent towards the normal and the velocity of light decreases. At point B, as the ray emerges from the glass, it bends away from the normal because it is moving from an optically denser medium to a less dense medium.

Test your mathematical skill: What is the relationship between;

1. <r and <p?
2. <i and <q?

**EXERCISE**

Sketch diagrams showing refraction of a ray that is passing from:

a) air to water
b) air to glass
c) glass to water
d) glass to air

Understanding refractive index

In our discussion of refraction earlier, you saw that a ray of light bends as it moves from one optical medium to another. How much the ray of light bends when it enters the surface of a medium from air is called the refractive index of that medium. A material with a higher refractive index has a greater bending effect on light because it slows down the light more and it bends the ray of light more towards the normal. It causes a larger angle of deviation of the ray of light.

## LESSON 2: LAWS OF REFRACTION

**You should be able to verify laws of refraction using glass block.**

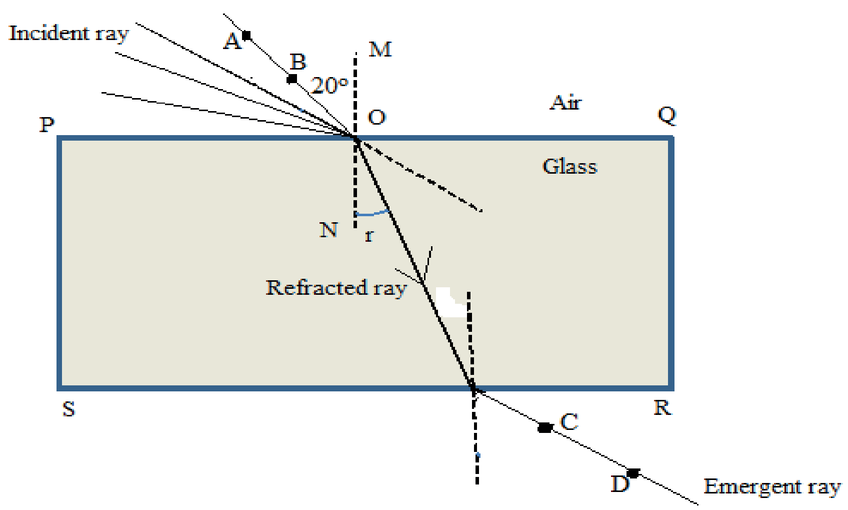
**ACTIVITY 3**
**What you need;**

- glass block,
- white paper,
- protractor
- optical pins
- pencil

**What to do:**

Caution: make sure that you have a sharp and hard pencil

1. Trace the outline of the glass bock onto a sheet of white paper and label it as PQRS.
2. Remove the glass block and mark a point O on the side PQ such that PO = OQ.
3. Use a protractor to draw and mark the normal, MN, through point O.
4. Draw lines forming angles of incidence of 20°, 30°, 40°, 50° and 60° with the normal.
5. Place two optical pins A and B along the line making the angle of 20° to the normal so that they are a distance from each other.
6. Replace the glass block on its outline.
7. Looking through side RS of the glass block, place two optical pins C and D such that they appear to be in straight line with the images of pins A and B.
8. Remove the glass bock.
9. Remove pins C and D. Join the points C and D to face RS of the outline of the glass block with a straight line. Using your prior knowledge, name this ray.
10. Join the point of incidence to the corresponding points of emergence of the rays of light.
11. Repeat procedure 5 to 10 with the rest of the angles of incidence.




12. Draw the refracted rays and measure the respective angles of refraction.
13. Tabulate your results including values of sin i, sin r and sini/sinr
14. What is your observation about the column of sin i/sin r?
15. Plot a graph of sin i against sin r and determine its gradient.

16. What does the value of the gradient represent?
17. Compare the value of the gradient with the value obtained in xv?

## LAWS OF REFRACTION

Choose any ray of incidence and its corresponding refracted ray. You will observe that;

The incident ray and the refracted ray are on opposite sides of the normal at the point of incidence, and all the three lie on the same plane. This is the first law of refraction.

From activity 3, you should also have observed that;

i) values in the sin i/sin r column are approximately the same.

ii) the gradient of the graph gives you a value of sin i /sin r that is approximate to the values in the sin i/sin r column.

Therefore, when a ray of light travels from one medium to another, the value of sin i/sin r is a constant, where i is the angle of incidence and r is the angle of refraction. This is the second law of refraction also known as Snell's law.

**Summary**

***Laws of Refraction***

*The incident ray and the refracted ray are on opposite sides of the normal at the point of incidence, and all the three lie on the same plane.*

*When a ray of light travels from one medium to another, the value of sin i/sin r is a constant. This is called Snell's law.*

*When a ray of light travels from air at an angle of incidence, i and is refracted into another medium at an angle of refraction, r, the refractive index, η of the medium is given by*

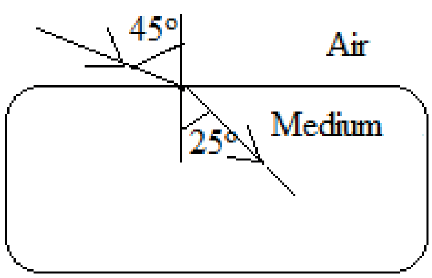
$$\eta = \frac{sini\ (in\ air)}{sinr\ (in\ medium)} \text{ or } \eta = \frac{speed\ of\ light\ in\ a\ vacuum\ or\ air}{speed\ of\ light\ in\ a\ medium}$$

This means that the refractive index of water, $\eta_w = \frac{sini\ (in\ air)}{sinr\ (in\ water)}$ or $\eta_w = \frac{speed\ of\ light\ in\ air\ or\ vacuum}{speed\ of\ light\ in\ water}$

This is true only when light travels from air (or vacuum) to the medium concerned.

**EXERCISE**

1. From the expressions of refractive index, work out the SI unit of refractive index.
2. Figure below shows a ray of light passing from air to a medium whose refractive index is η.

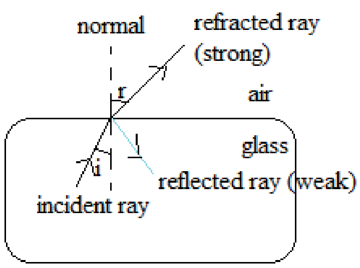
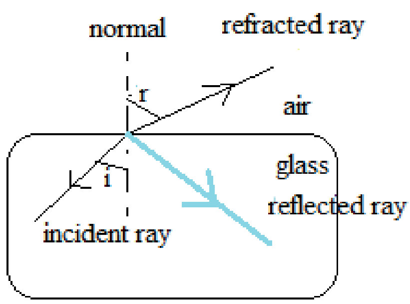
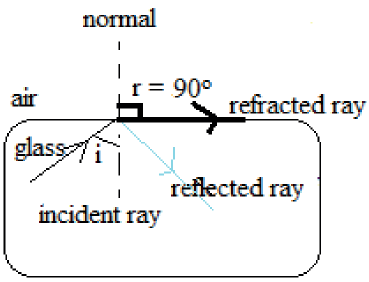
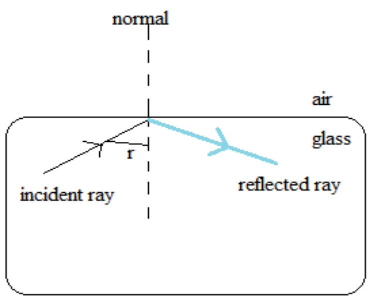


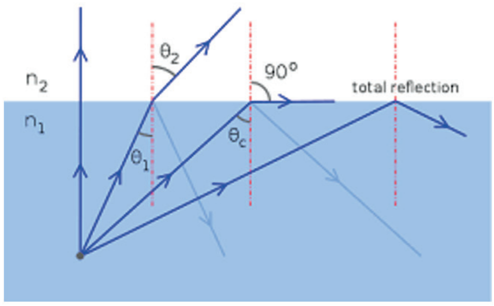
Calculate η

3. Light travelling from air is incident on an air-water boundary at an angle of 60°. If the refractive index of water is1.33, calculate;
   i) the angle of refraction r.
   ii) the speed of light in water given that the speed of light in air is.
   iii) sketch the ray diagram.

## LESSON 3

**You should be able to understand total internal reflection.**
When a beam of light moves from an optically dense medium to a less optically dense medium, part of it is refracted and the rest is totally reflected at the boundary of two media. The table below illustrates what happens as the angle of incidence increases.

| | |
|---|---|
|  | When the angle of incidence, i is small the refracted ray is strong but the reflected ray is weak. |
|  | When the angle of incidence, i increases, the angle of refraction also increases and the refracted ray gets closer to the glass-air boundary. The refracted ray gets weaker while the reflected ray gets stronger. |
|  | As the angle of incidence increases further, it reaches a certain value called the critical angle, c. At this value of i = c, the refracted ray travels along the glass-air boundary. The angle of refraction becomes 90° |
|  | When the angle of incidence increases beyond c, no refraction occurs. All the incident light is reflected back into the glass. At this point, total internal reflection occurs.<br><br>i > c |




This diagram summarizes how total internal reflection occurs.

**Exercise**

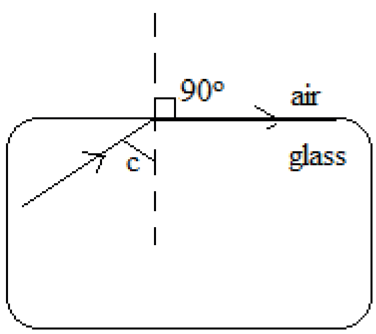
1. Would total internal reflection occur if light traveled from an optically less dense medium to optically denser medium? Use ray diagrams to illustrate your answer.
2. State the conditions necessary for total internal reflection.

Applying Snell's Law to Critical Angle

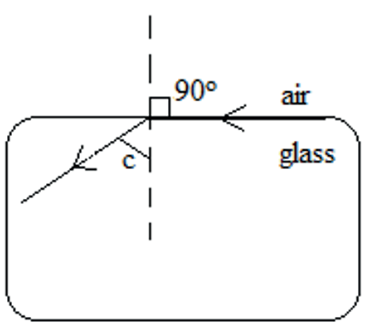
Recall Snell's law: refractive index of a medium, $\eta_m = \frac{\sin i \text{ (in air)}}{\sin r \text{ (in medium)}}$

and is only true when light travels from air (or vacuum) to the medium concerned.

However, for total internal reflection to occur, light must travel from an optically dense medium to an optically less dense medium, i.e. the critical angle should be in the optically denser medium; not air.




Therefore, you have to apply the principle of reversibility of light




From $\eta = \frac{sini}{sinr}$ It implies that

$$\eta = \frac{sin90}{sinc}$$

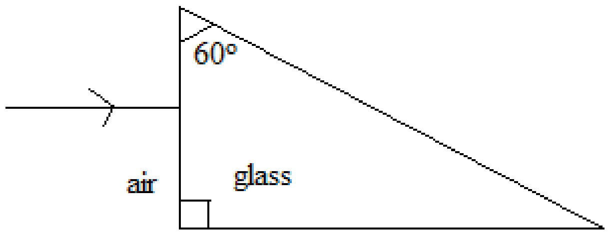
$$\eta = \frac{1}{sinr\ c}$$

**Summary**

1. *The angle of refraction in the air increases when the angle of incidence in the glass is increased.*
2. *The critical angle of glass, c is obtained when the angle of refraction in the air is 90°.*
3. *Total internal reflection occurs when the angle of incidence exceeds the critical angle.*
4. *The refractive index of glass can be calculated using the formula, n = 1/sin c.*

**EXERCISE**

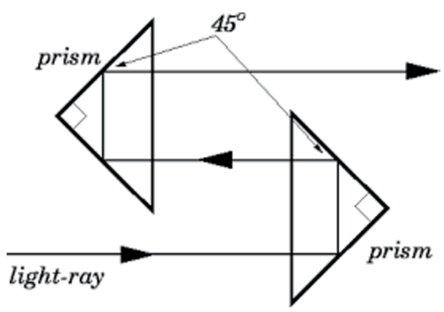
Complete the ray diagram below given that the critical angle, c of glass is 42°




## LESSON 4

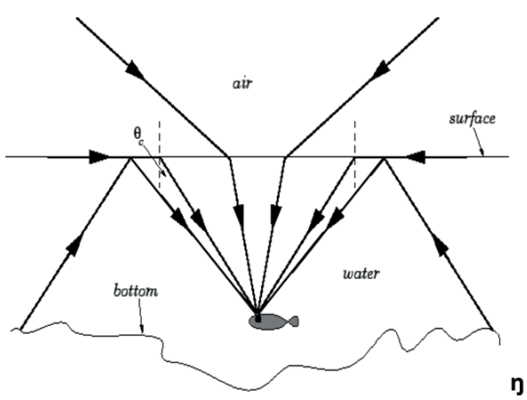
You should be able to describe applications and effects of total internal reflection.

1. Binoculars




When total internal reflection occurs at an interface, the interface in question acts as a perfect reflector. This allows 45⁰ crown glass prisms to be used, in place of mirrors, to reflect light in binoculars. The angles of incidence on the sides of the prism are all45⁰, which is greater than the critical angle 41⁰ for crown glass (at an air-glass interface).

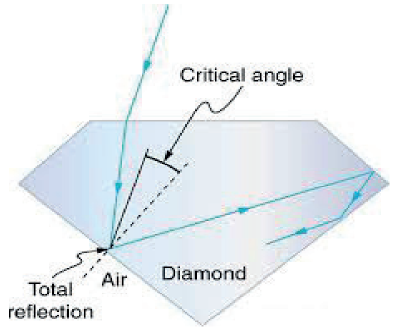
2. Fish' view



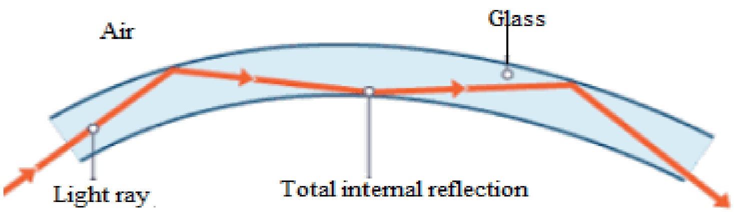

Consider a fish (or a diver) swimming in a clear pond. If the fish looks upwards it sees the sky, but if it looks at too large an angle to the vertical it sees the bottom of the pond reflected on the surface of the water. The critical angle to the vertical at which the fish first sees the reflection of the bottom of the pond is equal to the critical angle for total internal reflection at an air-water interface.

3. Diamonds: Diamond sparkles because of the total internal reflection that takes place in it.

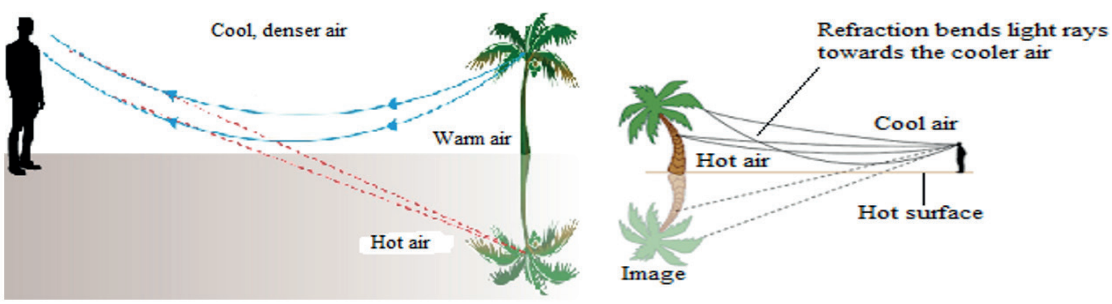
Diamonds for which the refractive index, η = 2.42, have a critical angle $\theta_c$ which is only $24^0$. The faces on a diamond are cut in such a manner that much of the incident light on the diamond is reflected many times by successive total internal reflections before it escapes. This effect gives rise to the characteristic sparkling of cut diamonds.




4. Glass fibers: Total internal reflection enables light to be transmitted inside thin glass fibers. The light is internally reflected off the sides of the fiber, and, therefore, follows the path of the fiber. Light can actually be transmitted around corners using a glass fiber, provided that the bends in the fiber are not too sharp, so that the light always strikes the sides of the fiber at angles greater than the critical angle. Fiber optics, and its applications is also based on this effect.




5. The mirage




The mirage is caused by the total internal reflection of light at layers of air of different densities. In a desert, or tarmac road, the surface is very hot during day time and as a result, the layer of air in contact with it gets heated up and becomes lighter. The lighter air rises up and the denser air from above comes down. A mirage is formed when light bends as it passes through air with different temperatures, and therefore densities, and forms a virtual image.

# TOPIC: ELECTROSTATICS

**By the end of this topic, you should be able to:**

i) prove the existence of two types of charges experimentally and verify the law of charges.
ii) describe the use of a gold leaf electroscope to detect charge and determine the sign of a charge.
iii) use movement of electrons to explain charging by friction and induction.
iv) describe charge distribution on a conductor and inside a hollow metal conductor.
v) investigate and explain the distribution of charge in a flame and in the atmosphere
vi) explain the occurrence of lightning and thunder.
vii) explain the action of a lightening conductor.
viii) define electric field and electric field lines.
ix) draw electric field patterns for different charge distributions.

**INTRODUCTION**

Have you ever wondered why pens and combs made of certain plastics attract small pieces of paper after being rubbed in hair? A piece of polythene rubbed with fur will attract small pieces of paper. The pen, comb fur and polythene acquire charge by rubbing. These charges are static (they do not move). Therefore, in this topic, you will study the behavior of static electricity or electrostatics.

## LESSON 1

You should be able to prove the existence of two types of charges experimentally and verify the law of charges.

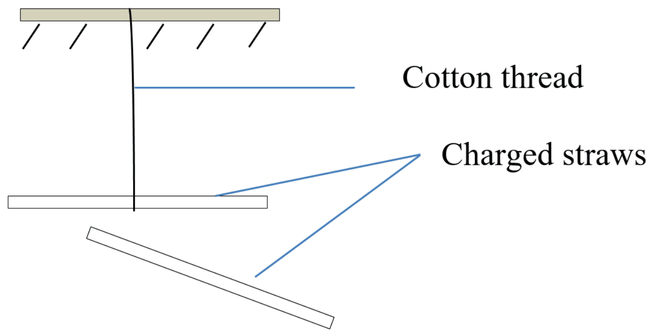
**What you need:**

- 2plastic straws
- 2glass rods
- aglass rod
- apiece of cotton wool
- apiece of cotton thread

**What to do:**

1. Suspend one of the straws using a piece of cotton thread.
2. Rub the suspended straw with cotton wool making sure that you do not touch the straw with your bare hands.
3. Rub the second straw with cotton and bring it close to the suspended straw. Ensure that you do not touch it with your hands.

Question: Why shouldn't you touch the straws with your bare hands?



**What do you observe?**

4. Repeat this procedure with two glass rods.
   What do you observe?
5. Rub a glass rod with cotton wool and bring it close to the suspended straw.

**What do you observe?**
When you bring two charged straws close to each other, there is repulsion. The two straws were rubbed with the same item (cotton wool) so they acquired the same charge. When the same charge is brought close to each other, there is repulsion.

When a charged glass rod is brought close to another charged glass rod, there is repulsion. This also suggests that when they were rubbed with the same material (cotton wool), they acquired the same charge.

When a charged glass rod is brought near a charged straw, the straw moves towards the glass rod. This means there is attraction.

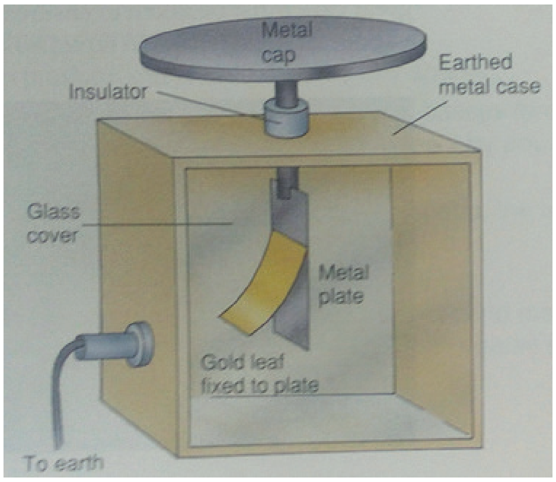
This suggests that when glass and straw were rubbed with the same material, they acquired different charge.

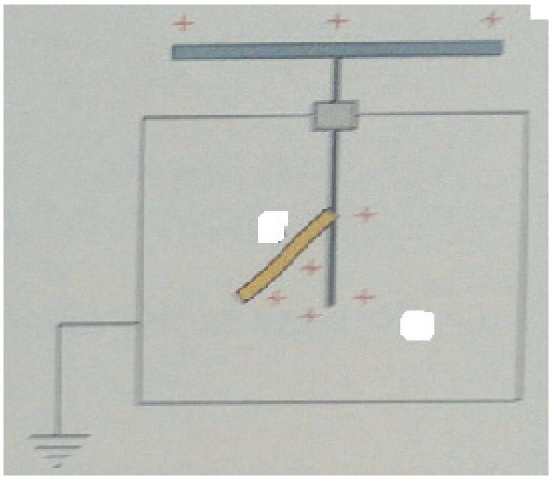
This simple experiment demonstrates the existence of two different charges. It also demonstrates that like charges repel while unlike charges attract.

## LESSON 2

You should be able to describe the use of a gold leaf electroscope to detect charge and determine the sign of a charge

Structure of a gold leaf electroscope (GLE)



A metal cap is connected to a rod(stem) whose lower part is flattened out into a plate. The plate and leaf are enclosed in a metal casing which is connected to the ground (earthed). The point where the rod enters the casing is insulated. One side of the casing is made of transparent glass so that the gold leaf can be seen.

Use of a gold leaf electroscope to detect charge

The GLE should first be charged. It can be charged by contact or induction. It can be charged by contact by placing a charged object on the cap of the GLE. This transfers the charge on the electroscope. If the object was positively charged, the GLE will acquire a positive charge. The same will be true for a negatively charged body.

The body whose charge is not known is brought near the cap of the GLE. Increase in the divergence of the leaf means that the body and the GLE carry the same charge.

If the leaf of the GLE collapses, then the body that was brought near the cap carries opposite charge or no charge at all.

**Example**
If a negatively charged body is brought near a positively charged GLE, electrons will be repelled from the cap to neutralize the positive charge on the leaf and plate of the GLE. This will cause the leaf to collapse.

If a positively charged object is brought near a positively charged GLE, electrons will be attracted from the leaf and plate to the cap leaving behind positive charge. This increases presence of positive charge on leaf and plate causing a divergence of the leaf.

Summary

| Charge on GLE | Charge brought near the GLE | Effect on Divergence of the Gold Leaf |
|---|---|---|
| Negative | positive | decrease in divergence |
| Positive | positive | increase |
| Negative | negative | increase |
| Positive | negative | decrease |

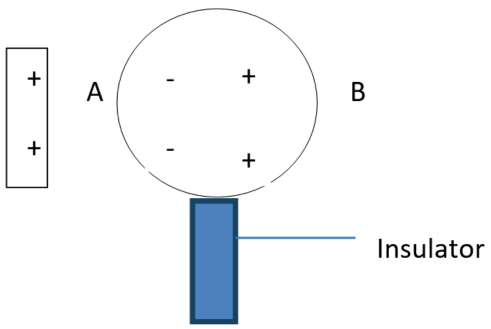
## LESSON 3
**You should be able to explain charging by friction and induction.**

**Charging by friction**

When a substance is rubbed against another, e.g. cotton material rubbed against plastic straw. The friction results into transfer of some of the loosely bound electrons from the surface atoms of the cotton to the surface atoms of the plastic (straw). Hence the straw acquires negative charge and cotton is left with an excess positive charge and therefore becomes positively charged.

Charging by induction

A positively charged rod is brought near an insulated conductor. Side A of the conductor near the charged rod, acquires negative charge by attraction while the further end B, acquires positive charge.



End B is now earthed by touching it. Electrons will drift from the earth to end B to neutralize the positive charge.

With the charging rod still in place, the earthing is disconnected. The charging rod is then removed.

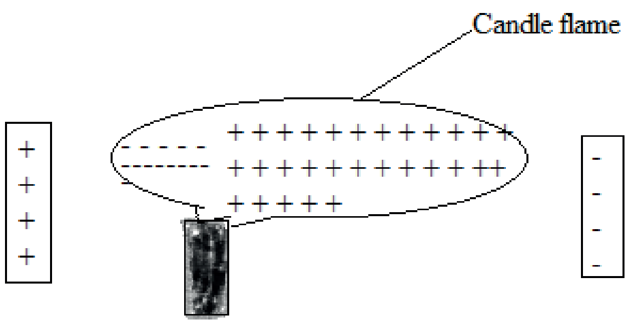
The negative charge will now redistribute themselves throughout the conductor which then becomes negatively charged.

Task: Explain how you would charge a body positively by induction.

**LESSON 4**
You should be able to
investigate and explain the distribution of charge in a flame and in the atmosphere.

Procedure:

1. A lighted candle is placed between two metal plates which are connected to the terminals of a high voltage supply.
2. The voltage supply is switched on and the movement of the candle flame is observed.
3. The candle flame flattens and spreads out in both directions.




**Explanation**

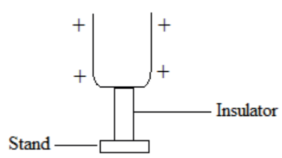
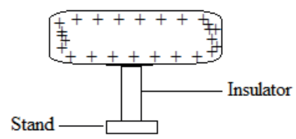
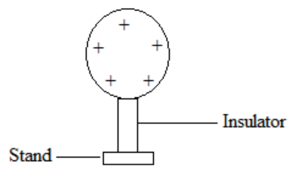
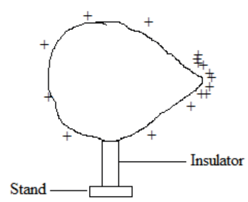
a. The heat of the burning gases allows air to ionize easily in the flame to produce positive and negative ions.
b. The positive ions are pulled towards the negative plate while the negative ions are pulled towards the positive plate.
c. The heavier positive ions occupy a larger proportion of the flame.
d. The negative ions (electrons), which are lighter, occupy a smaller proportion of the flame.
e. Hence, the flame is seen to spread out more to the negative plate than to the positive plate.

To describe charge distribution on a conductor and inside a hollow metal conductor

This is investigated by using a proof plane and a gold leaf electroscope. A proof plane is used to obtain charge from various points on the surface of a charged conductor and then transferred to the electroscope. The degree of divergence of the gold leaf gives a rough measure of the amount of charge transferred.

a. On a hollow conductor: An insulated hollow conductor is charged and the inside and outside surfaces are tested for charge using a proof plane. It is found that there is no charge on the inside of the conductor but the outside surface possesses charge. This shows that for a hollow conductor, charge resides only on the outer surface.

b. On a cylindrical conductor: Where the surface is flat, there is very little charge and where the surface is curved, there is more charge.
c. A circular conductor: The surface is equally curved so the distribution of charge is uniform.
d. Pear-shaped conductor: Where the surface is strongly curved (pointed), there is the greatest concentration of charge.
e.

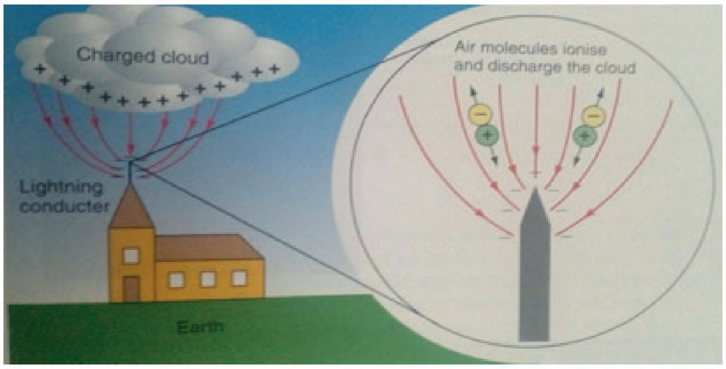
| Type of conductor | Charge distribution |
|---|---|
| Hollow |  |
| Cylindrical |  |
| Circular |  |
| Pear-shaped |  |

In general, charge is distributed depending on the shape of the surface of a conductor.

The quantity of charge per unit area of surface of a conductor is called charge density.

## LESSON 5: THE LIGHTNING CONDUCTOR

You should be able to explain the action of a lightening conductor.



A ightning conductor is composed of a sharp pointed metal rod fixed at the highest point of the building and connected with a thick copper strip to a copper plate buried in the ground.

When clouds move in the air, they become charged due to friction between them and air. As negatively charged clouds pass over the building, it induces a positive charge on the point at the top of the lightning conductor. The high concentration of charge at the sharp point causes air to ionize. Point discharge takes place and the positive ions are repelled to the cloud to neutralize it so that it is less likely to produce a lightning flash. The negative charges that are attracted to the conductor are attracted harmlessly to the earth through the copper strip.

**EXERCISE**

1. Why are lightning conductors;
   i) fixed to the ground?
   ii) fixed at the highest point on a building?
   iii) pointed at the end?
   iv) made of metal?
2. Why is it dangerous to stand under a tree during a thunderstorm?

**LESSON 6**

You should be able to sketch electric field patterns.
Recall: When you were carrying out the activity involving straws, there was a distance beyond which there was no attraction or repulsion. This means the straw in your hands was outside the electric field of the suspended straw.

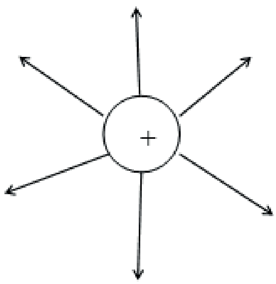
If you bring a magnet close to another, there will be repulsion or attraction. If you move one of the magnets slowly away, there will be a point at which, and beyond which there won't be any attraction or repulsion. This means that the magnet in your hands is outside the magnetic field of the stationary one and vice versa.

Therefore, the region surrounding an electric charge in which the influence (force) of the charge is felt is called an electric field. Electric fields are represented by electric field lines

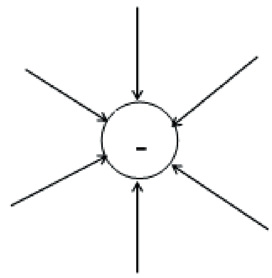
The direction of the field is such that it moves from a positive charge towards the negative charge. It is defined as the direction of the force that would act on a positive charge placed in a field. The closeness of the field lines is the measure of the strength (force) of the field. The field lines should never cross or touch each other because they repel each other sideways.

You should be able to raw electric field patterns for different charge distributions.

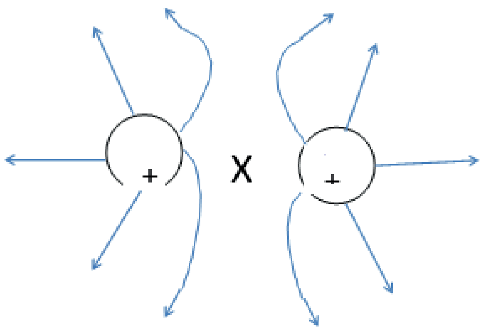
Positive charge




Negative charge

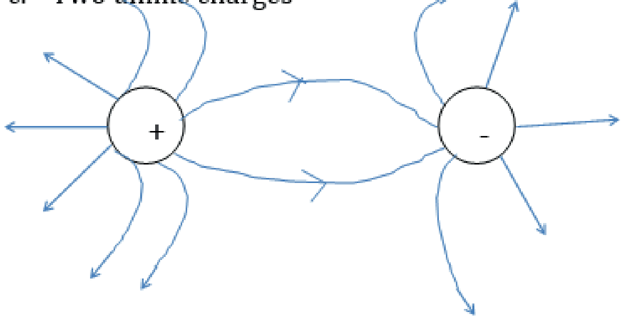



b. Two like charges




**Task:** Draw an electric field pattern for two negative charges close to each other.

c. Two unlike charges




**Task:** Draw an electric field pattern for a negative point charge and a positively charged plate.

**END**

**Please stay safe. Covid-19 is real.**

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