UNIT 2

Force Fields

The lessons

Lesson one : Electric Forces

Lesson two : Magnetic Forces

Lesson three: Gravitational Forces

Learning Outcomes :

By the end of this unit, the student should be able to:

1. Recognize some types of fields (electric, magnetic, gravitational).
2. Conduct an experiment to prove the existence of fields between non-contact objects that exert forces on each other.
3. Differentiate between types of forces.
4. Design a model to describe how electric forces act over a certain distance.
5. Identify the factors that affect gravitational forces.
6. Provide evidence that gravitational forces are always attractive.
7. Provide evidence of the existence of a very weak gravitational force between any two objects.
8. Appreciate the role of the science and the physicists in serving humanity and the environment.
9. Acquire values of work, cooperation, and positive attitudes.
10. Acquire some cross-disciplinary skills and practices.

Lesson **One**

Electric Forces

Lesson Terminology :

- Static electricity.
- Electrostatic plating.
- Electric field.
- Electric field lines.

Lesson Objectives :

By the end of the lesson, the student should be able to :

1. Conduct activities that illustrate the concept of static electricity.
2. Explain how objects acquire static charges.
3. Provide evidence of the existence of an electric field between non-contact objects.
4. Recognize the electric field.
5. Describe the properties of electric field lines.
6. List the uses of an electroscope.
7. Design a model showing that electric forces act at a distance .

Included Skills, Values and Issues :

- **Skills** : Conclusion - Investigation - Research - Models design.
- **Values** : Appreciation of the scientists - Self-protection.
- **Issue** : Protecting installations from the lightning strikes.

Cross-Cutting Concepts :

- Cause and effect.
- The System and its models.

Lesson Preparation :

The figure in the front of you shows the attraction of lightweight paper scraps to a plastic comb.

This lesson explores ideas that help you to answer these questions :

- What happened to the comb that allowed it to attract the paper scraps ?
- How did the paper pieces get attracted to the comb without touching ?
- Can paper scraps be attracted to a comb made of iron ?
- What device can determine whether the comb is electrically charged or not ?

The Concept of Static Electricity

- You hear a slight crackling sound when removing woolen clothes in winter (Figure 1).

Figure (1)

- You feel a slight shock when you touch a metal door handle after walking barefoot on carpet (Figure 2).

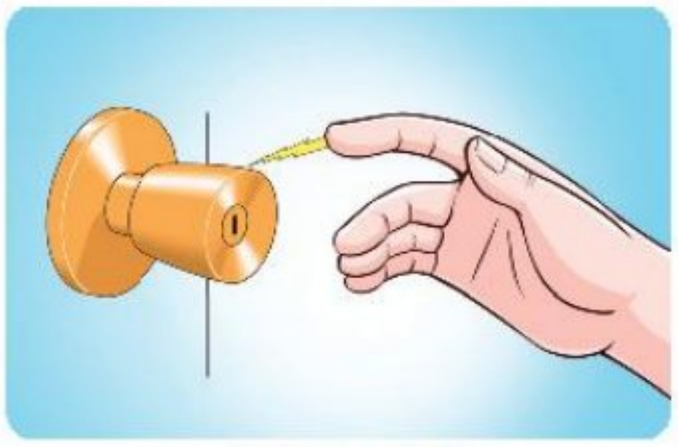


Figure (2)

What happens when two objects are rubbed together ?!

Activity 1 Practical

(1) Rub the end of an ebonite (hard rubber) rod with a piece of wool (Figure 3), then bring the rod close to light paper scraps (lightweight small pieces) (Figure 4) or small foam pieces.

What do you notice ?

.....

(2) Repeat the step (1) using a copper rod instead of the ebonite rod.

What do you observe ?

.....

Figure (3)

Figure (4)

What do you conclude?

When objects made of certain materials are rubbed with others made of suitable materials, they gain the ability to attract lightweight objects because they have been charged with static electricity (electrostatic charges). These charges settle on the surface of the rubbed part of the object and do not transfer to the rest of it.

Objects that can be charged with an electrostatic charge can be :

- Objects made of nonconducting materials, such as wood, paper, wool, silk, and glass.
- Objects made of materials that conduct electricity, but the charged part must be insulated to prevent the leakage of electric charges, such as metals and carbon.

Evaluate Your Understanding

► **Why** do fuel transport vehicles have metal chains dangling to ground ?

.....

Electric Forces

- When objects are rubbed, the electric charges are generated on it.
  Does the type of electric charge that is generated on a glass rod rubbed with silk differs from that generated on an ebonite rod rubbed with the same silk ?

Activity 2 Practical

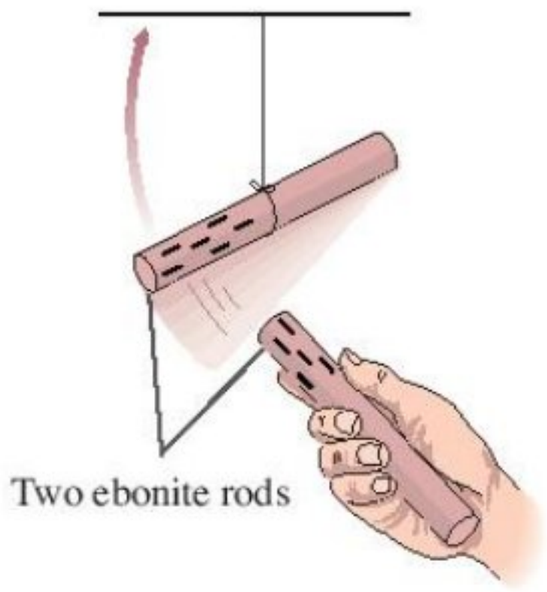


Figure (5)

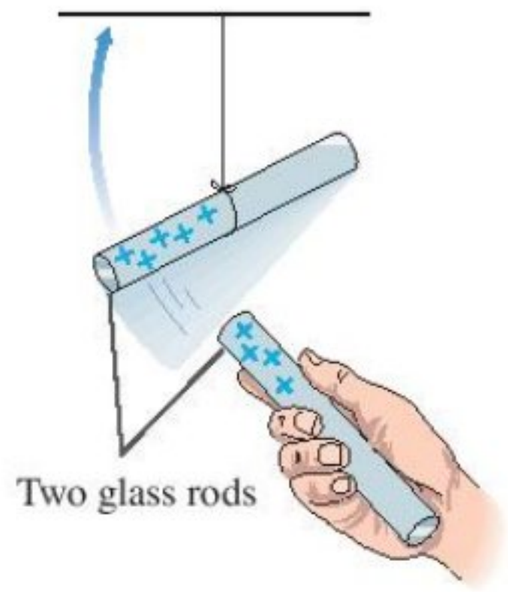


Figure (6)

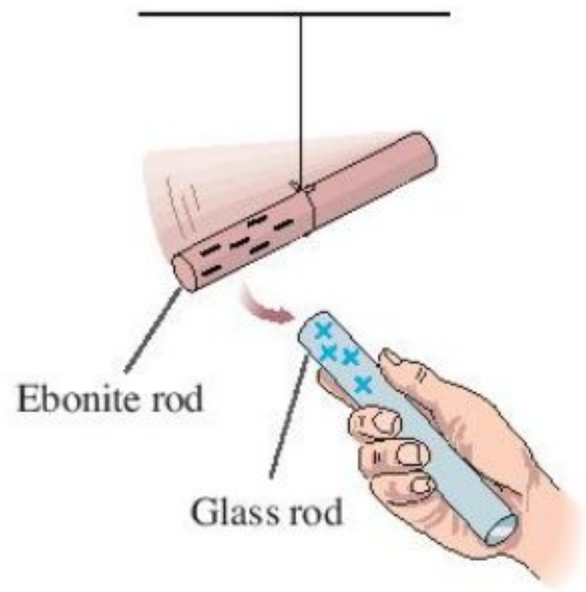


Figure (7)

(1) Rub two ebonite rods with a silk cloth, hang one freely, and then bring the other rod close to it. Figure (5) ... **What do you notice ?**

.....

(2) Repeat the step (1) with two glass rods instead of the ebonite rods, using the same cloth. Figure (6) ... **What do you notice ?**

.....

(3) Hang the ebonite rod after rubbing it with silk, and then bring a glass rod rubbed with silk close to it. Figure (7) ... **What do you notice ?**

.....

Are the electric charges formed on the ebonite rod the same as those on the glass rod ? How can this be indicated ?

.....

This can be explained as follows :

When two uncharged objects are rubbed together, electrons move from the atoms of the surface of one object to the surface of the other; charging both with equal and opposite electric charges. Figure (8).

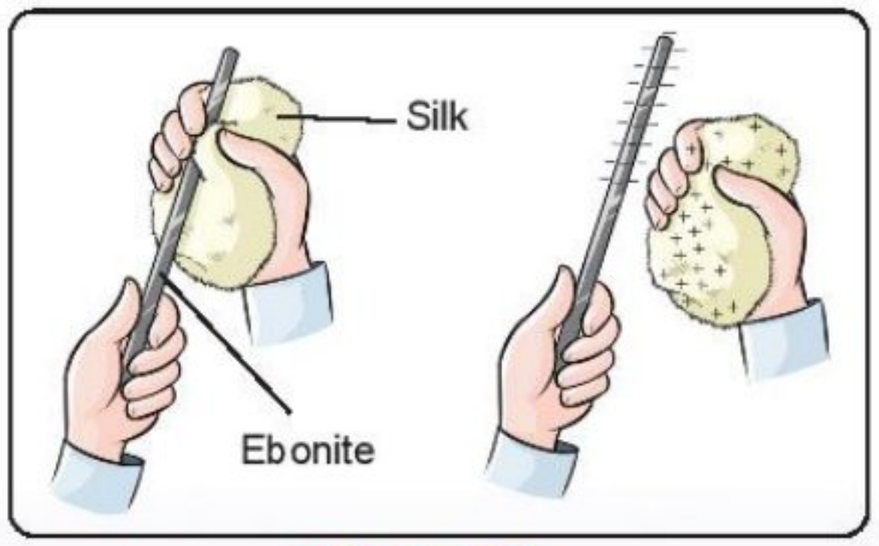


Figure (8)

What is the charge of the object that :

- Loses electrons ? .....
- Gains electrons ? .....

The accumulated charges on the surfaces of objects when they lose or gain electrons are called static electricity (electrostatic).

It is observed that the type of charge acquired by the rubbed object differs depending on the material of the rubbing object.
(Table 1) shows the order of some materials in the electrostatic series according to the easiness of losing electrons.
When a material is rubbed with another material that follows it in this series, the preceding material will be charged with a positive electric charge, and the following one will be charged with a negative electric charge. Weak electric charges are measured by a device known as a coulometer (Figure 9).
Charged objects affect each other with mutual forces, which may be attractive forces or repulsive forces.

Glass
Wood
Synthetic leather
Silk
Wool
Cotton
Paper
Ebonite

Table (1)
Electrostatic series

Figure (9)
Coulometer

Attraction may occur between an uncharged object and a charged object, such as the attraction of paper scraps to the comb after rubbing it.
When do electrically charged objects attract or repel each other ? .....

Evaluate Your Understanding

► **What is the type of charge** formed on each of a piece of synthetic leather and a wooden rod when rubbed together ? **Explain.**

.....

Cross-Cutting Concepts : Cause and effect

The type of charge acquired by the rubbed object differs depending on the material of the rubbing object.

Scientific Skills Prediction

When passing a beam of subatomic particles through an electric field composed of two plates, one is positively charged and the other is negatively charged (Figure 10), then :
- Neutrons .....
- Protons ..... toward the ..... plate.
- Electrons ..... toward the ..... plate.

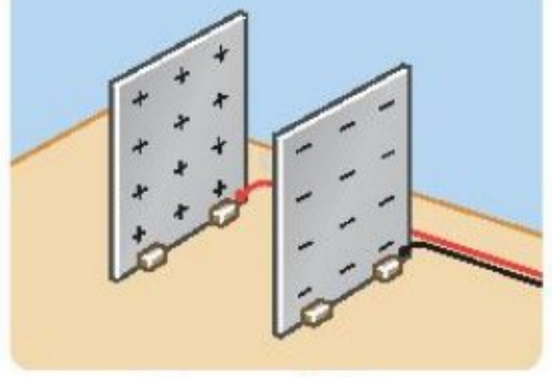


Figure (10)

Life Applications

(1) When metal is coated using the electrostatic coating method, Figure (11), the object to be coated is charged with negative electric charge, and the paint spray with positive electric charge. When the paint is sprayed, attraction occurs between the object and the paint spray due to the difference in charge; resulting in a uniform paint layer and reducing paint waste.

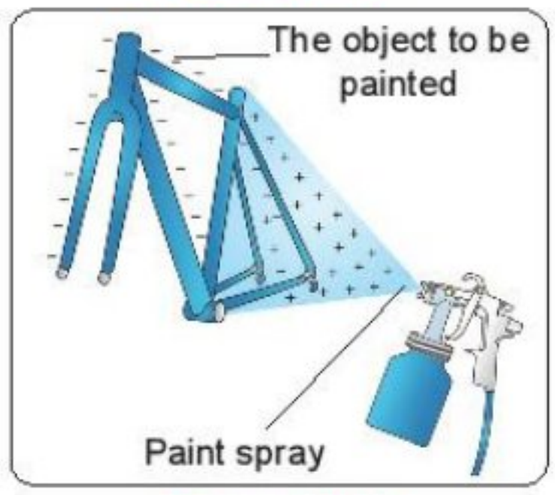


Figure (11)
Electrostatic coating

(2) Lightning Rod is a system used to protect installations and buildings from lightning strikes, Figure (12). It consists of a metal rod whose lower end is fixed in a metal plate that is buried in the ground, while its upper end is pointed, through which, the electric charges that are accumulated on nearby clouds pass to the ground without causing any damage to the building.

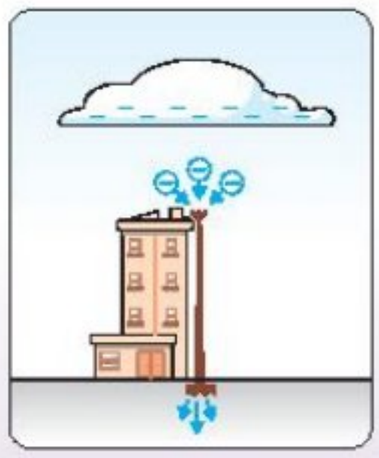


Figure (12) Lightning Rod

Electric field

- The region of space around an electric charge, in which its influence appears without contact, is called the electric field.
- The electric field of a charge can be represented by lines known as electric force lines or electric field lines, which are imaginary lines that show the path taken by a small free-moving positive charge placed in it.

Activity 3 Conclude

Study the Figures (13) : (18), then answer the following questions :

Figure (13)
Electric force lines for a positive charge

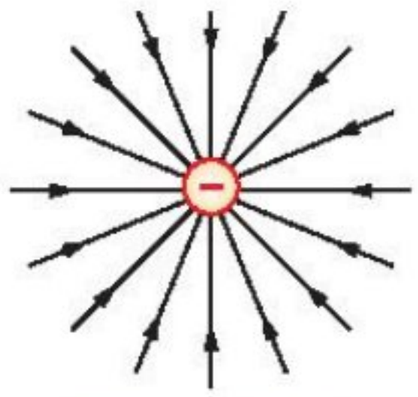


Figure (14)
Electric force lines for a negative charge

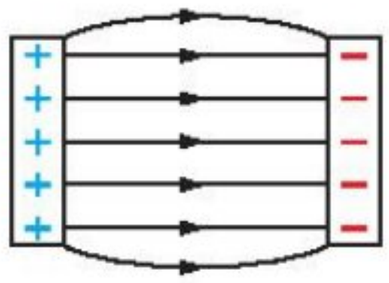


Figure (15)
Electric force lines between two metal plates charged with opposite charges

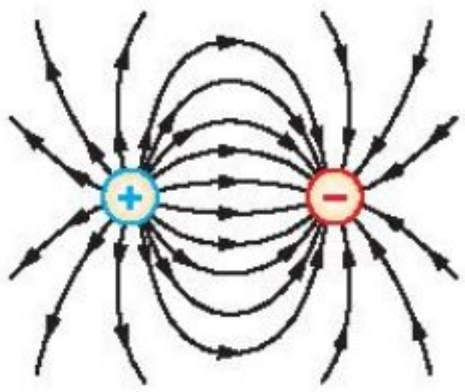


Figure (16)
Electric force lines for two opposite charges

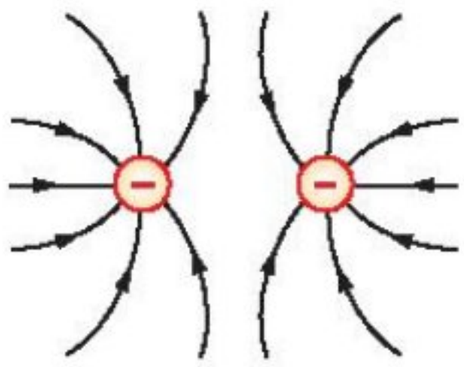


Figure (17)
Electric force lines for two similar charges

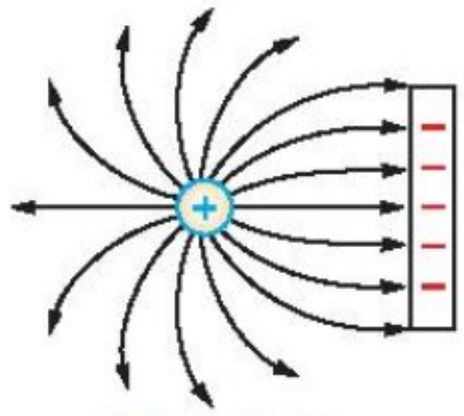


Figure (18)
Electric force lines between a charged plate and an opposite charge

1. Where do the force lines start, and where do they end ?

.....

2. Do the force lines intersect with each other ?

.....

3. Do the force lines penetrate the surfaces of charged metallic objects, or do they end there ?

.....

Cross-Cutting Concepts : System and its models

Electric force lines are imaginary lines which simplify the representation of the system (model) and are used to understand how the system works.

Conclude from the previous the properties of the electric force lines :

1. Electric force lines are imaginary lines that do not ..... .
2. They start from the ..... charge and end at the ..... charge.
3. Force lines ..... on ..... charged objects and do not ..... .

Designing a Model of an Electroscope

Use available materials to design a model of an electroscope, you can follow these steps:

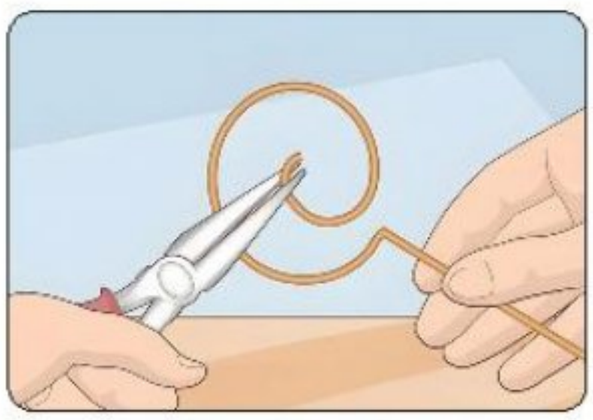


Figure (19)
(1) Wrap the end of a copper wire into a spiral

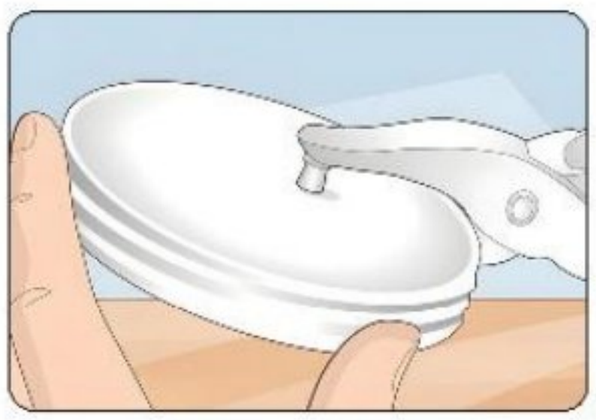


Figure (20)
(2) Pierce the cap of a glass bottle

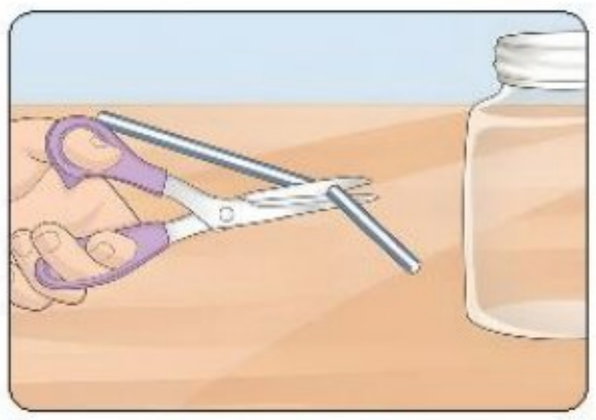


Figure (21)
(3) Cut a piece of a juice straw and pass it through the hole in the cap

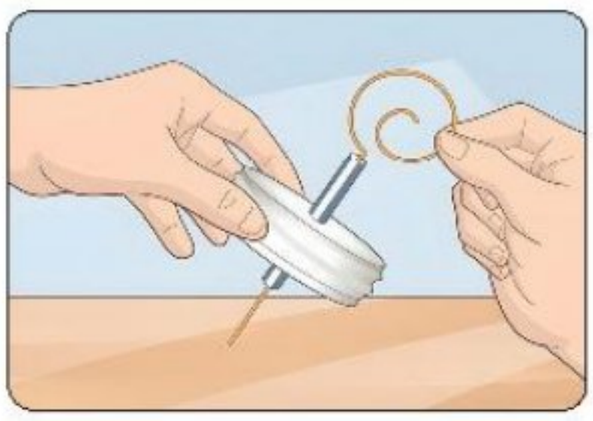


Figure (22)
(4) Insert the copper wire into the juice straw

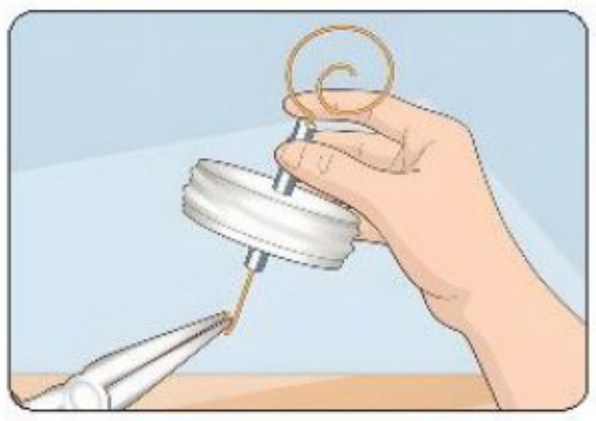


Figure (23)
(5) Bend the straight end of the copper wire into a hook

Figure (24)
(6) Fix the juice straw in the bottle cap using hot glue

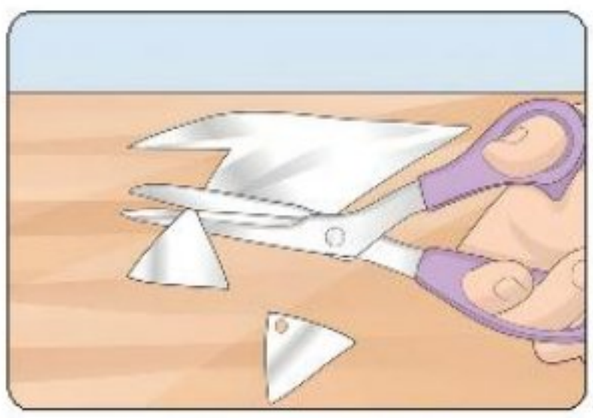


Figure (25)
(7) Cut two identical pieces of foil to make two triangles

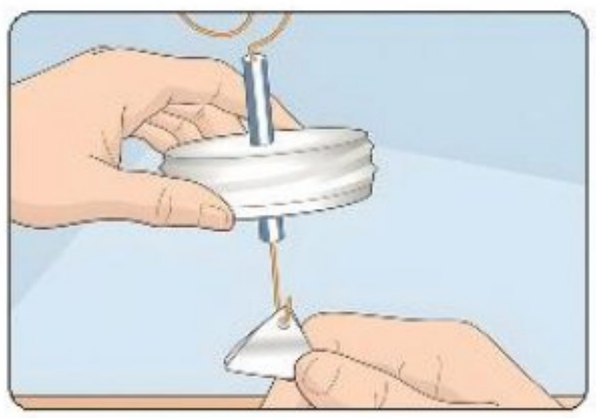


Figure (26)
(8) Hang the two foil pieces in the hook and ensure they do not touch each other

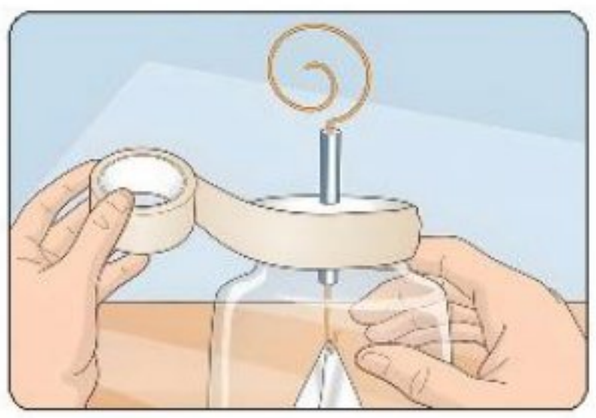


Figure (27)
(9) Fix the cap tightly on the glass bottle with duct tape

Figure (28)
(10) Place the electroscope model in a dry, non-humid place

Figure (29)
(11) Rub a piece of foam with wool

Figure (30)
(12) Bring the foam close to the copper spiral. What do you notice?

Electroscope

The electroscope is also known as the electric detector.

What is this device used for ?

Activity 4 Practical

1. Touch the metal disc of the electroscope, Figure (31), with your hand to ensure that it is free of any electric charge.
2. Bring the object which is required to be tested close to the electroscope's disc until it touches the disc. Figure (32).

What do you conclude if :

- The electroscope's leaves diverge (separate) ?

.....

- The electroscope's leaves do not diverge ?

.....

3. Bring the object whose charge type is to be tested close to a charged electroscope disc (assuming it is positively charged).

What do you conclude if :

- The electroscope's leaves diverge further?

.....

- The electroscope's leaves diverge less?

.....

From the previous it is concluded that the electroscope is used for :

(1) Determining if an object is electrically charged.

(2) Identifying the type of charge on the charged object.

It is also used to compare the magnitude of the charges on different charged objects.

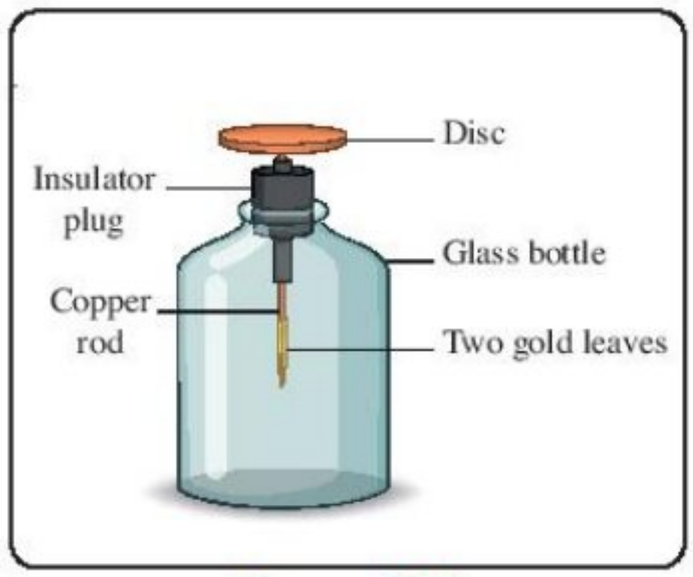


Figure (31)
The electroscope

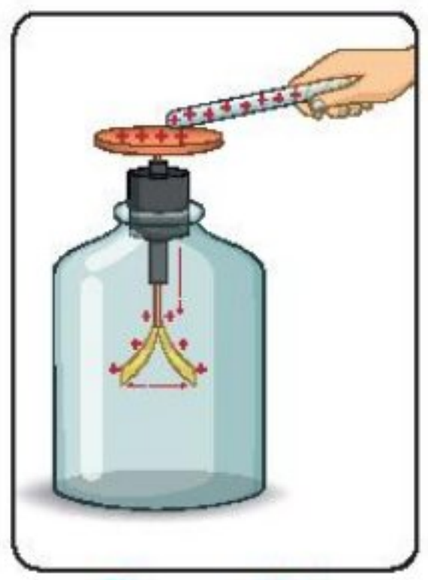


Figure (32)
Charging by touching

Analytical Thinking

Mention two methods to charge objects with electrostatic charges.

.....

Evaluate Your Understanding

► **Explain** why the divergence of the leaves of a positively charged electroscope decrease when an ebonite rod rubbed with wool touches the electroscope disc.

.....

.....

A profile of the Scientist
Charles-Augustin de Coulomb

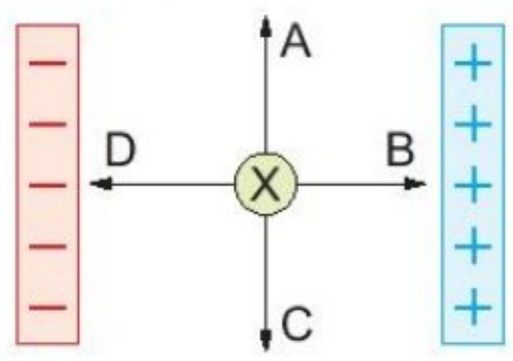
Figure (33)

A French physicist who formulated a law describing electric forces between charged particles, known as Coulomb's Law or the Inverse Square Law. His studies and discoveries in the late 18th century laid the foundation for the development of electromagnetic theory. In his honor, the unit of electric charge (Coulomb) is named after him

Evaluation Questions on Lesson One

1 Choose the correct answer to the questions (1) : (3).

(1) The following figure shows a free-moving particle (X) charged with a negative electric charge, placed between two plates of opposite charges. :

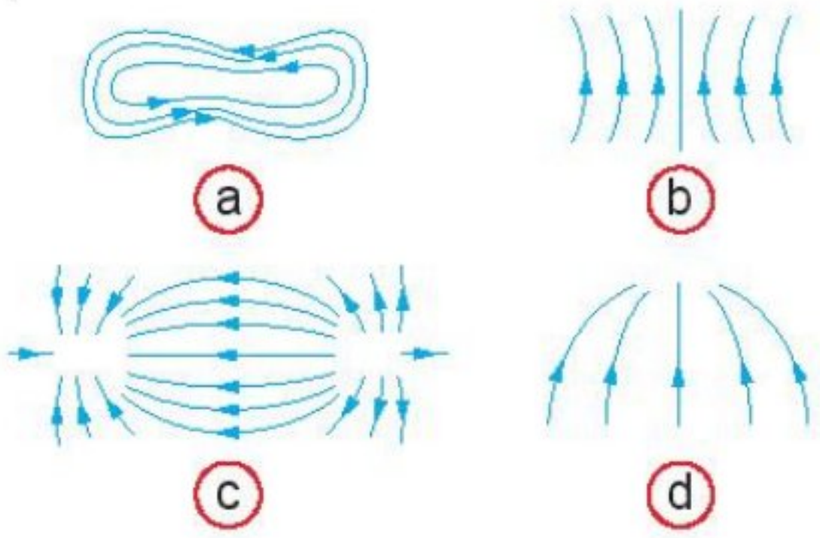


In which direction will particle (X) move ?

(a) (A). (b) (B).

(c) (C). (d) (D).

(2) Which of the following represents the electric field between two charged points ?



(3) When a wooden ruler is rubbed with a piece of cotton, an electric force is generated between them.
What is the type of charge formed on the ruler, and what type of electric force exists between them ?

(a) Positive / Repulsion.

(b) Negative / Repulsion.

(c) Positive / Attraction.

(d) Negative / Attraction.

2 Draw the electric field lines between two parallel plates charged with opposite charges.

3 A copper rod is rubbed with a piece of silk, then the rod is brought close to paper scraps.

What happens to the paper scraps ? Explain.

4 Material (X) gains a negative charge when rubbed with a piece of material (Y), while it gains a positive charge when rubbed with a piece of material (Z) :

(1) Suggest, based on what you have studied, the type of each of the materials (X) , (Y) and (Z).

(2) What is expected to happen when material (X) is brought close to material (Y) before rubbing ? Explain.

5 The following figure shows an electroscope after the body (X) has touched its metal disc :

(1) What is the charge of body (X).

(2) What happens when :

1. A positively charged object is brought close to the electroscope disc.

2. A negatively charged object is brought close to the electroscope disc.

Lesson **Two**

Magnetic Forces

Lesson Terminology :

- Lodestone.
- Permanent magnet.
- Bar magnet.
- U-Shaped magnet.
- Cylindrical magnet.
- Horse shoe magnet.
- Magnetic needle.
- Compass.
- Magnetic substances.
- Non-magnetic substances.
- Magnetic poles.
- Attraction and repulsion.
- Magnetic field.
- Magnetic field lines.

Included Skills, Values and Issues :

- **Skills** : Research - Investigation.
- **Values :** Justice.
- **Issue** : Electromagnetic pollution.

Lesson Objectives :

By the end of the lesson, the student should be able to :

1. Recognize the shapes of magnets.
2. Differentiate between magnetic and non-magnetic materials.
3. Explore the properties of magnets.
4. Conclude the law of attraction and repulsion.
5. Recognize the magnetic field.
6. Draw magnetic field lines for a magnet.
7. Draw magnetic field lines for the opposite poles of two magnets .

Lesson Preparation :

The given figure shows several magnets placed on a hand, that attract metallic paper clips. This lesson explores ideas that help you answer the following questions :

- Why do not the paper clips fall even though they are not touching the magnet ?
- What are the materials of the objects that are attracted to a magnet ?
- Why do magnets appear to attract together ?
- What happens when a single magnet is divided into several parts?

Shapes of Magnets

Lodestone, (Figure1), is a natural magnet rock that was first found in Magnesia (a regional unit) of ancient Greece, and its distinguishing characteristic is the ability to attract certain metallic objects. The production of the industrial magnets began in the 19th century. There are different shapes of magnets, some of which are shown in (Figure 2).

Figure (1) Natural magnet (Lodestone)

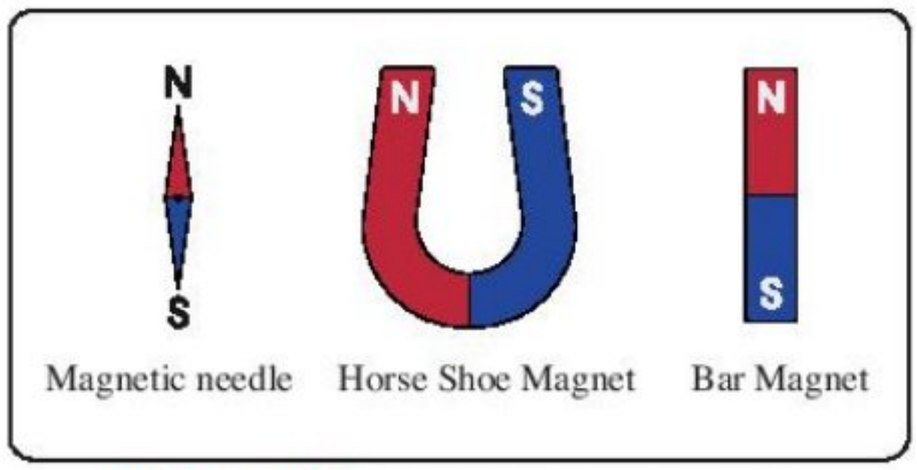


Figure (2) Industrial magnets

Activity 1 Experiment

- **What is the effect** of bringing a magnet close to a mixture of copper filings, iron filings and sand (Figure 3) ?

.....

- **Can** the magnet attract all metals ?

  It is evident from this activity that there are materials that are attracted to the magnet, known as **magnetic materials** (Figure 4), and others that are not attracted to it, known as **non-magnetic materials** (Figure 5).

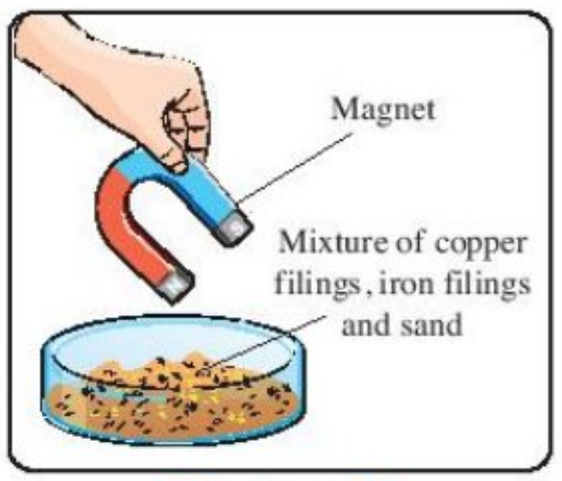


Figure (3)

Magnetic materials

- Materials that are attracted to a magnet.

Figure (4) Magnetic materials

Non-magnetic materials

- Materials that are not attracted to a magnet.

Figure (5) Non-magnetic materials

Life Application

The compass is an old tool used to determine the Earth's four main geographical directions.
It consists of a free-moving magnetic needle fixed at its pivot (Figure 6). It is placed inside a box made of copper or plastic... **Why** ?
Can you make a compass using materials available in your environment ?

Figure (6) Compass

Properties of Magnets

Activity 2 Practical

① Insert a magnet into iron filings (Figure 7).
What do you observe ?

.....

Do the iron filings attract to all parts of the rod with the same density ?

.....

② Hang a bar magnet from its middle using a silk thread, allowing it to move freely (Figure 8) until it settles.
What do you observe ?

.....

Figure (7)

Figure (8)

It is evident from this activity that :

- The attraction force of the magnet is the strongest at its ends, (that are known as the poles of the magnet), and it decreases as it gets closer to the middle of the magnet.
- When a magnet is suspended freely, its north pole (N) almost points towards the Earth's geographical North Pole, while its south pole (S) points towards the Earth's geographical South Pole (Figure 9).

The Earth acts as a giant magnet, which affects the freely suspended magnet and always causing it to take a certain direction.

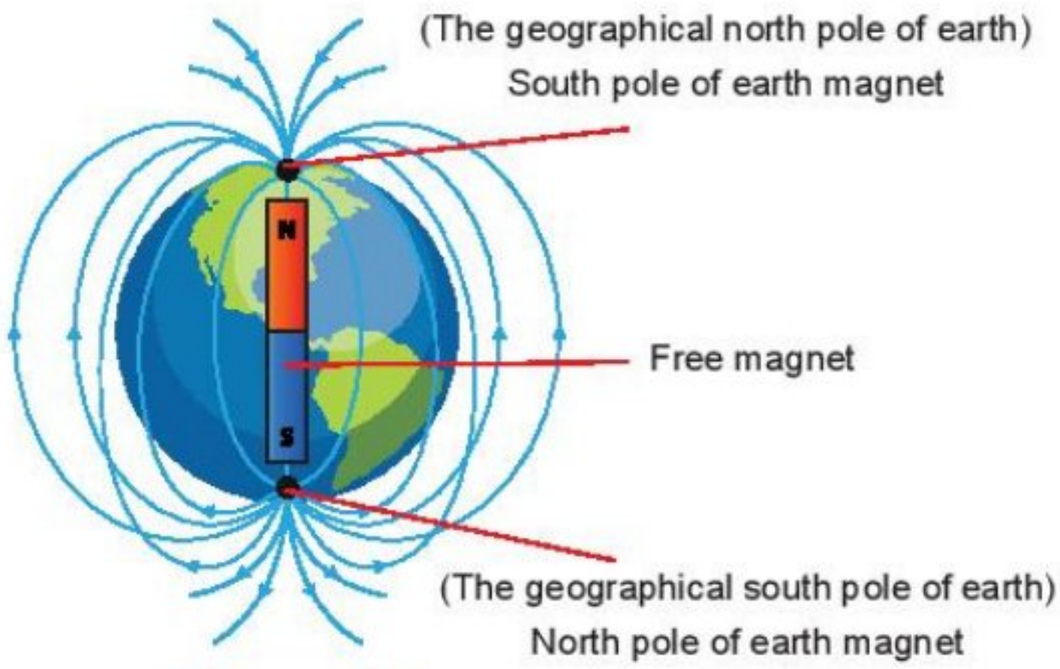


Figure (9)

It is also observed that when a single magnet is divided into several parts, each part forms a new magnet with two poles, one is the north (N) and the other is the south (S) (Figure 10).

It is impossible to obtain an isolated (only one) magnetic pole.

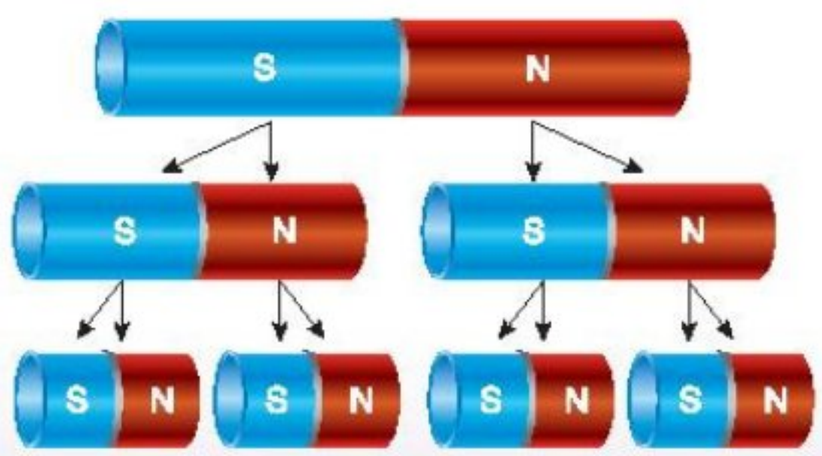


Figure (10)

Law of Attraction and Repulsion

Activity 3 Conclude

Suspend two magnets freely as shown in (Figures 11 : 13):

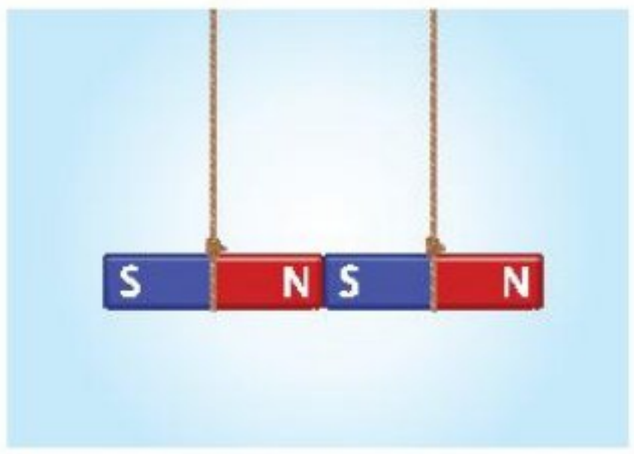


Figure (11)

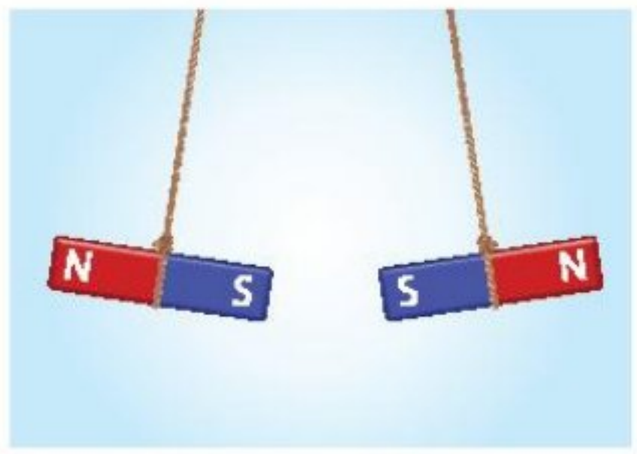


Figure (12)

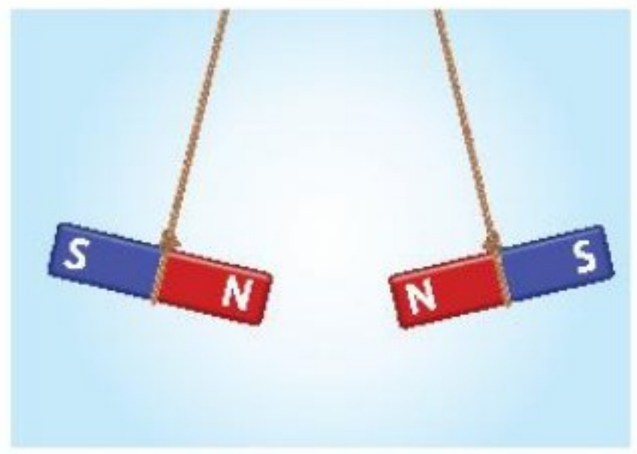


Figure (13)

What happens when :

- You bring together two different poles of two magnets (Figure 11) ? .....
- You bring together the south poles of two magnets (Figure 12) ? .....
- You bring together the north poles of two magnets (Figure 13) ? .....

Conclude the law of attraction and repulsion

Like magnetic poles ..... each other, and unlike magnetic poles ..... each other.

Evaluate Your Understanding

Figure (14) shows four ring magnets placed in such a way that they pass through a vertical rod. Knowing that the lower magnetic pole of magnet (A) is the north pole.

Conclude the type of the poles (1) and (2) according to your understanding of the law of attraction and repulsion.

.....

.....

.....

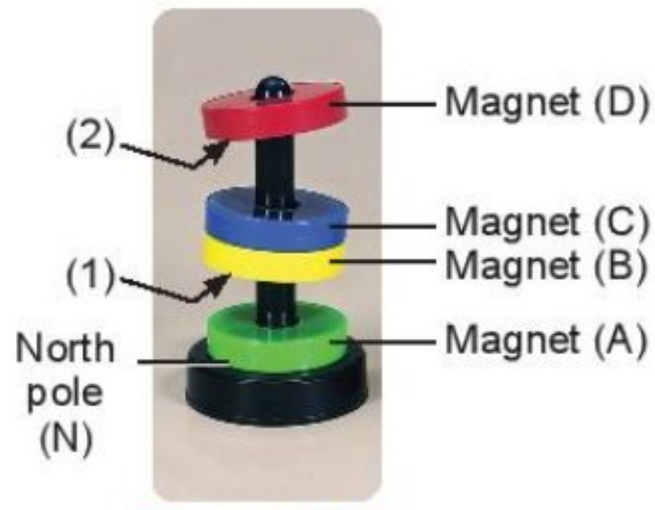


Figure (14)

Life Application

Forensic and criminal investigation experts use a magnetic brush and iron filings in criminal investigations to reveal the unclear fingerprints (Figures 15 , 16) where the brush is passed over surfaces with the unclear fingerprints, causing some iron filings to stick to the traces left by the fingerprints, which makes them visible.

Figure (15)

Figure (16)

Magnetic Field

What is the similarity between an electric field and a magnetic field ?

An electric charge has an electric field that extends through the space around it, and exerts a certain force on the charged objects found inside it at a distance. The electric forces are represented by imaginary lines called electric field lines. Similarly, a magnet has a magnetic field that extends through the space around it and affects magnetic materials placed in it at a distance by a magnetic force.

The magnetic field is represented by imaginary lines called magnetic field lines, as shown in (Figures 17 : 19).

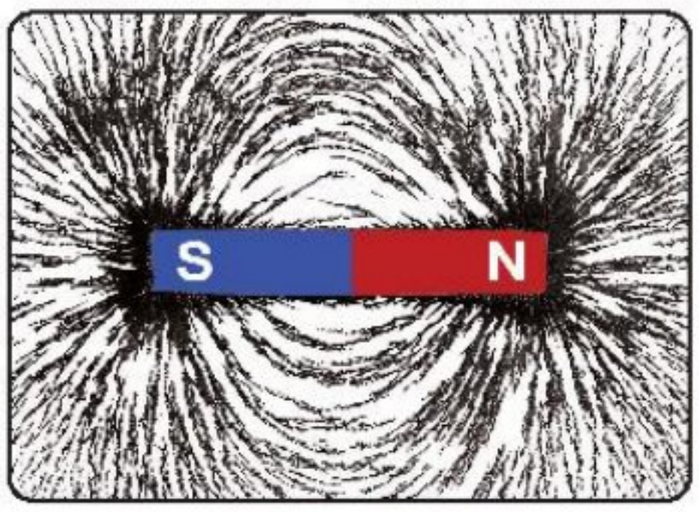


Figure (17)
Magnetic field lines of a magnet

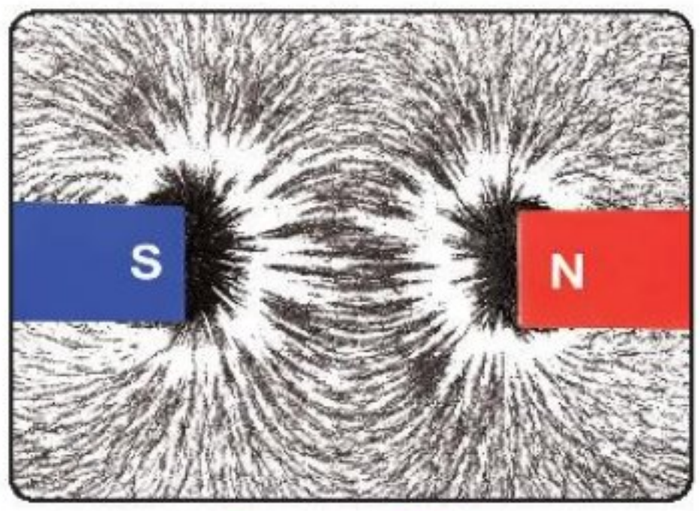


Figure (18)
Magnetic field lines between two opposite poles of two magnets

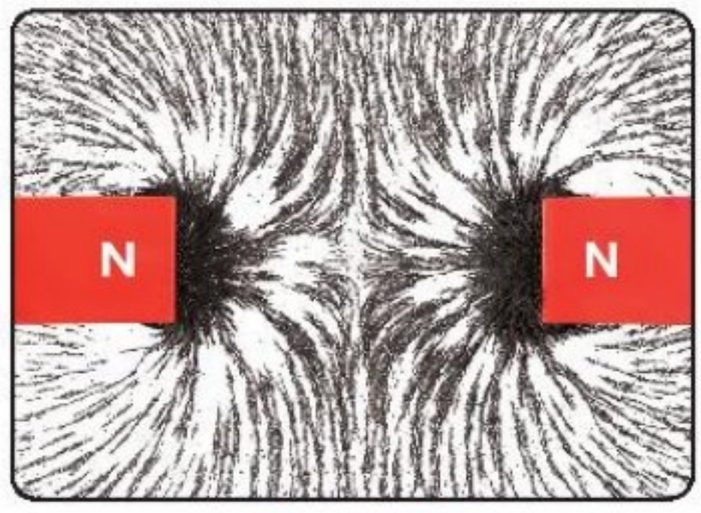


Figure (19)
Magnetic field lines between two similar poles of two magnets

Conclude the properties of magnetic field lines from (Figure 20).

(1) Imaginary lines that do not ..... each other.

(2) They start from the ..... pole of the magnet and end at the .....

(3) They are denser near ..... and far separated ..... from them.

According to the above, conclude the definition of the magnetic field.

- The magnetic field is the region of space ..... the magnet, where the effect of the magnetic ..... appears in it.

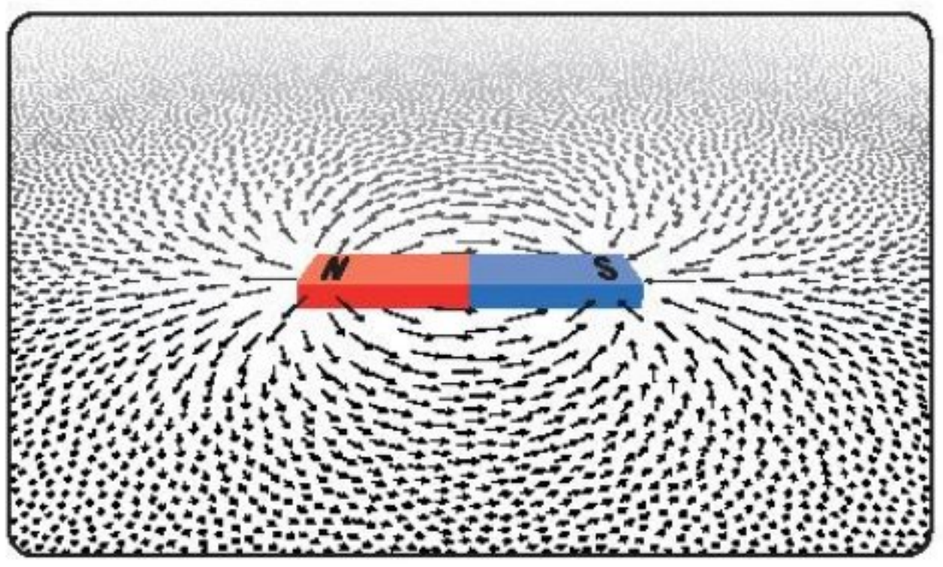


Figure (20)

◂ **Does the mutual forces** among a magnet and the magnetic substances that are found within its field considered a force of repulsion **or** attraction **or** both ?

.....

Research Activity

Search in the different knowledge sources, including the internet or the Egyptian Knowledge Bank, about the advantages of each of the electric monorail and the maglev (magnetic levitation) train.

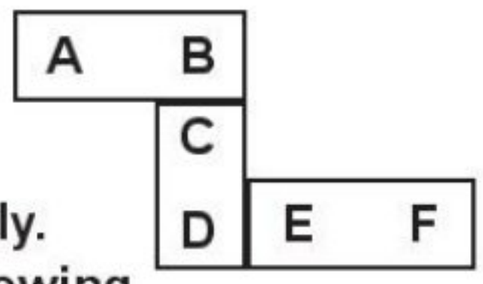
Evaluation Questions on Lesson Two

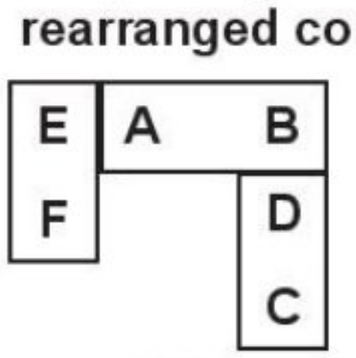
1 Choose the correct answer to the questions (1) : (3).

(1) One end of a rod is attracted to a bar magnet. Which of the following describes the nature of the rod?

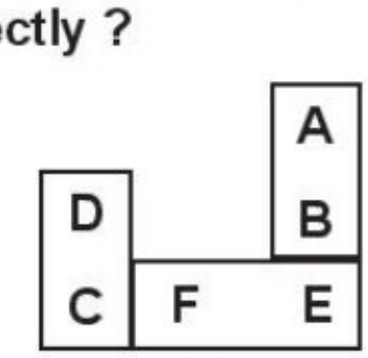
(a) A rod of nickel only.
(b) A rod of nickel or a magnet.
(c) A magnet only.
(d) A rod of nickel or copper.

(2) The opposite figure shows three magnets arranged correctly. Which of the following shapes represents them when rearranged correctly ?

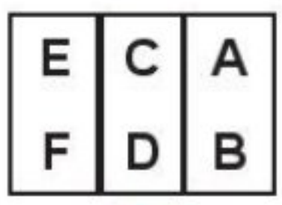




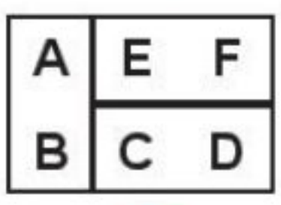
(a)



(b)

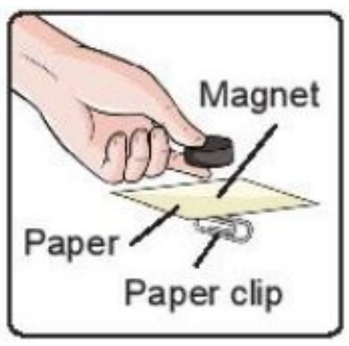


(c)



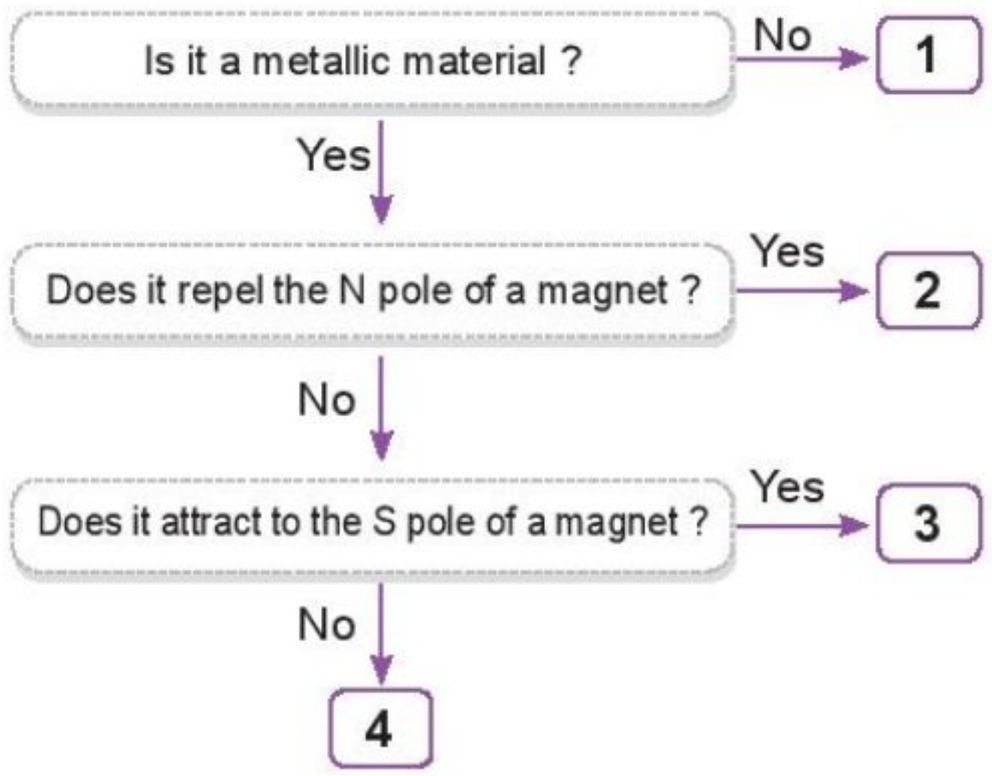
(d)

(3) The opposite figure shows a paper clip attracted to a magnet despite the presence of a paper between them. What can be concluded ?

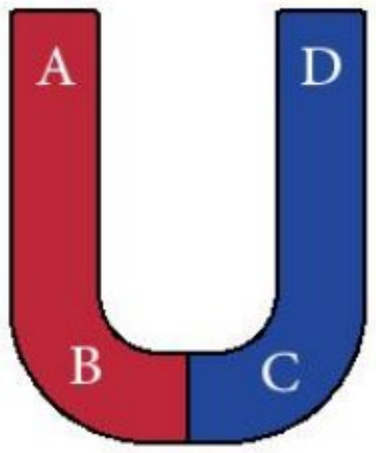


(a) Opposite poles attract each other.
(b) The magnetic force is an attractive force.
(c) The paper clip is attracted to the north pole of the magnet.
(d) The magnetic force acts at a distance.

2 Which of the numbers shown in the following diagram represents a rod of silver? With explanation.



3 When the magnet (shown in the opposite figure) is placed in iron filings, the density of the filings was high at certain positions. Identify these positions



4 The following table shows the number of pins attracted to four magnets placed at the same height from a container containing a load of pins

Magnet	(A)	(B)	(C)	(D)
Number of pins attracted to it	4	6	2	8

Arrange these magnets ascendingly according to the strength of their magnetic fields.

Lesson **Three**

Gravitational Forces

Lesson Terminology :

- Force.
- Gravitational force.
- Gravitational field intensity.
- Gravitational field lines.
- Orbital motion.
- Mass.
- Weight.

Included Skills, Values and Issues :

- **Skills** : Comparison - Observation - Discovery - Engineering design.
- **Values** : Appreciation of the scientists.
- **Issue** : Health awareness.

Cross-Cutting Concepts :

- Patterns.

Lesson Objectives :

By the end of the lesson, the student should be able to :

1. Recognize the gravitational field.
2. Provide evidence of the existence of gravity between non-contacting objects.
3. Distinguish between contact forces and field forces.
4. Identify the factors that affect the gravitational forces.
5. Provide evidence that gravitational forces are always attractive.
6. Provide evidence that gravitational forces are very weak between any two objects whose masses are small.

Lesson Preparation :

The figure shows a hand holding a device with an apple attached to it.

This lesson explores the ideas that help you to answer the following questions :

- What force acts on the apple downwards ?
- Does the device measure the mass of the apple or its weight ?
- Do the mass and weight of the apple differ from one planet to another ?
- What is the relation between mass and weight ?

Classification of The Forces

The governorate of your country, Egypt have many beautiful tourist attractions. You can enjoy safari trips in Wadi El-Rayan in Fayoum Governorate and practice sand skiing on its soft dunes. **What force** affects the skier person in (Figure 1) and causes him to descend from the top of the sand dunes towards the ground?

Figure (1)
Sand skiing in Wadi El-Rayan

Activity 1 Compare

What is the similarity between electrostatic forces (Figure 2), magnetic forces (Figure 3), and gravitational force (Figure 4)?

Figure (2)
Electrostatic forces

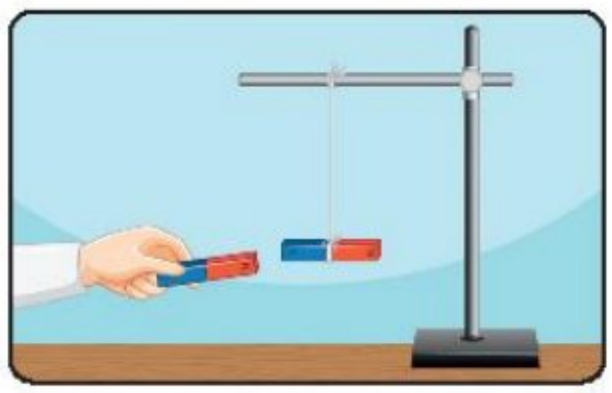


Figure (3)
Magnetic forces

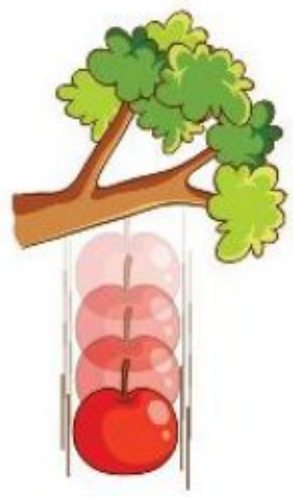


Figure (4)
Gravitational force

What is the difference between gravitational force (Figure 4) **and** both collision forces (Figure 5) **and** elasticity forces (Figure 6)?

Figure (5) Collision forces

Figure (6) Elasticity forces

It is clear from the above that the force that pulls (attracting) all objects downward towards the center of the Earth (Figure 4) is called the gravitational force.
In general, forces are either contact forces that act on objects when they touch each other, such as collision forces, elasticity forces and friction forces or field forces that act over a certain distance, such as gravitational forces, electrostatic forces and magnetic forces.

Evaluate Your Understanding

► **Why** do gravitational, electric and magnetic forces have **fields,** while frictional forces do not have a field ?

Earth's Gravitational Field

Earth's gravitational force causes all objects to fall downwards in the direction of Earth's center (Figure 7).

The space in which Earth's gravitational force affects material objects with an attraction towards Earth's center is known as **Earth's gravitational field**.

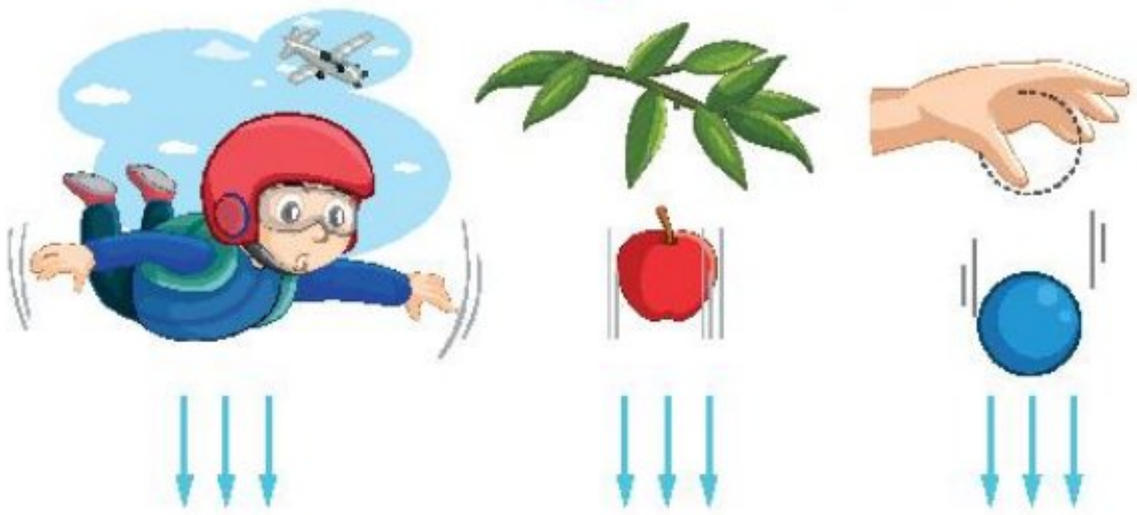


Figure (7)

Earth's gravitational force is represented by lines called **Earth's gravitational field lines** (Figure 9), and the direction of the arrow indicates the direction of the gravitational force acting on an object placed in its field.

A profile of the scientist

Isaac Newton

Figure (8)

The scientist Newton discovered that all material objects in the universe attract each other, and in recognition of his scientific contributions, the unit of force (Newton) was named after him

Figure (9)

Earth's gravitational field lines

The Mutual Attraction Forces between Two Objects

Gravitational force is not only between the Earth and objects within its gravitational field but also between any two objects.

Activity 2 Observe

Figure (10) shows the mutual attraction forces between two spherical objects made of the same material, and the arrows indicate the direction of the mutual attraction forces F

- Do the attraction forces work in one direction only or in two directions ?

.....

- Why are the attraction forces represented in Figure (11) greater than the attraction forces represented in Figure (10) ?

.....

.....

- Why are the attraction forces represented in Figure (11) greater than the attraction forces represented in Figure (12) ?

.....

.....

Figure (10)

Figure (11)

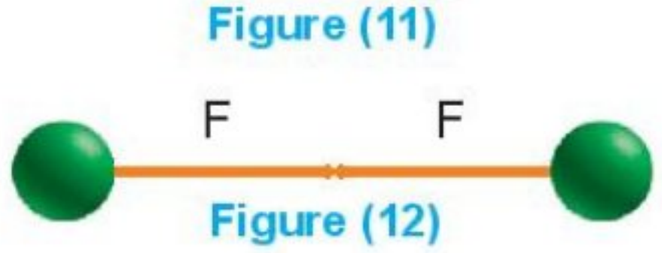


Figure (12)

Information and Communication Technology

Watch videos from reliable digital sources that show evidence of the small gravitational force between small masses.

According to activity (2), it is clear that gravitational forces are mutual forces between two objects, it acts on each of the two objects by equal magnitude but in opposite directions, it increases as the masses of the two objects increase and it decreases as the distance between the centers of the two objects increases.

- Despite the weakness of the gravitational force compared to other forces in the universe, its effects are extremely important as it is responsible for the stability of the objects, rainfall, and all the objects falling towards Earth.

The phenomenon of **tides** is one of the results of the gravitational force between the moon and Earth. This phenomenon is most noticeable in **the Bay of Fundy in Canada**, where the difference between the elevation and the recession of water reaches 19 meters (Figure 13). The tides occur twice daily, "once every 12 hours," and are at their peak when the moon is either new moon or full moon. The phenomenon of tides can be used to generate electricity as a source of renewable energy and is naturally used to cleanse water bodies from impurities.

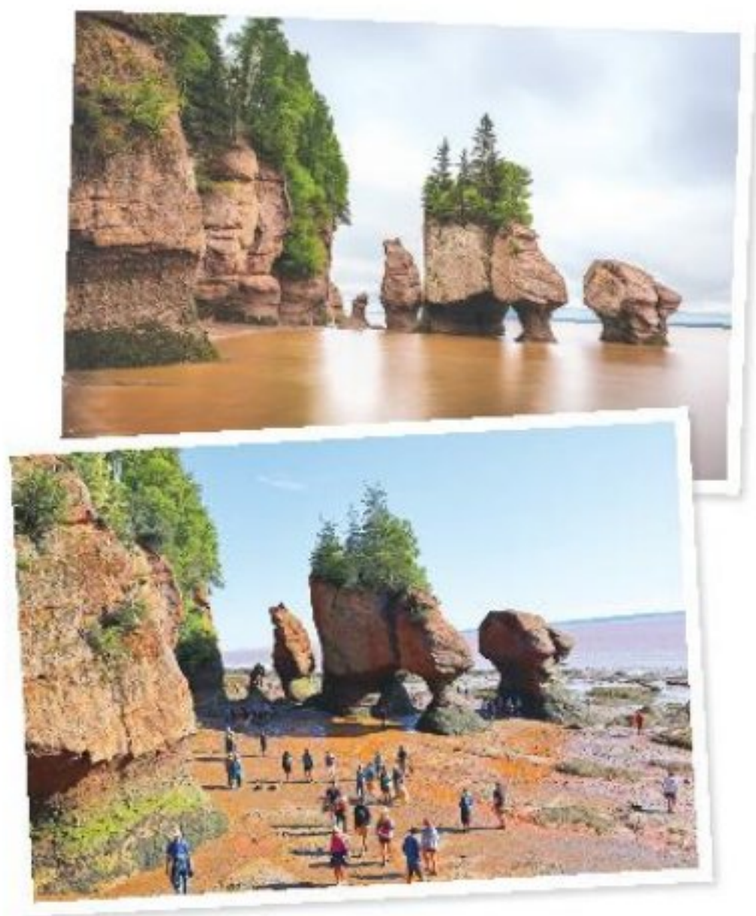


Figure (13)
Tides in the Bay of Fundy

Combination with Space Science

Scientists in the early 20th century discovered regions in the space known as **black holes** (Figure 14), which are formed when a massive star collapses at the end of its life. Black holes are characterized by **immense gravity**, so that even light cannot escape from them.

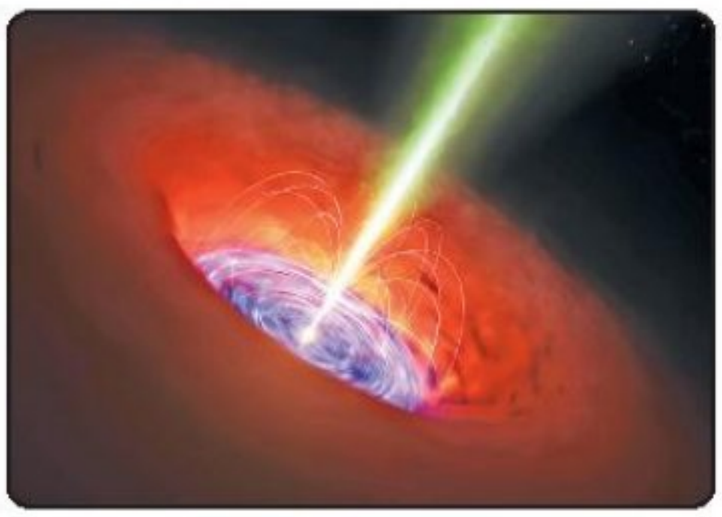


Figure (14) **Black hole**

Issue for Discussion

Discuss the effects of the absence of gravity in space on bone fragility, lung capacity, the circulatory system and blood pressure on astronauts.

Information and Communication Technology

Watch educational videos from reliable digital sources that show the effect of the mutual gravitational forces between the moon and Earth on the occurrence of the tide phenomenon.

Cross-Cutting Concepts : Patterns

Electric, magnetic and gravitational forces are similar in that they all act at a distance.
In case of electric forces, an electric charge affects another electric charge, while in case of magnetic forces, one magnetic pole affects another magnetic pole.
In case of gravitational forces, the mass of one object affects the mass of another object.

Role of Gravity in Orbital Motion

There is a gravitational attraction between any object moving in a curved path in space around another central object (orbiting this central object). This motion is known as orbital motion, such as the motion of the moon around Earth, Earth's motion around the sun (Figure 15), and the motion of satellites around Earth (Figure 16).

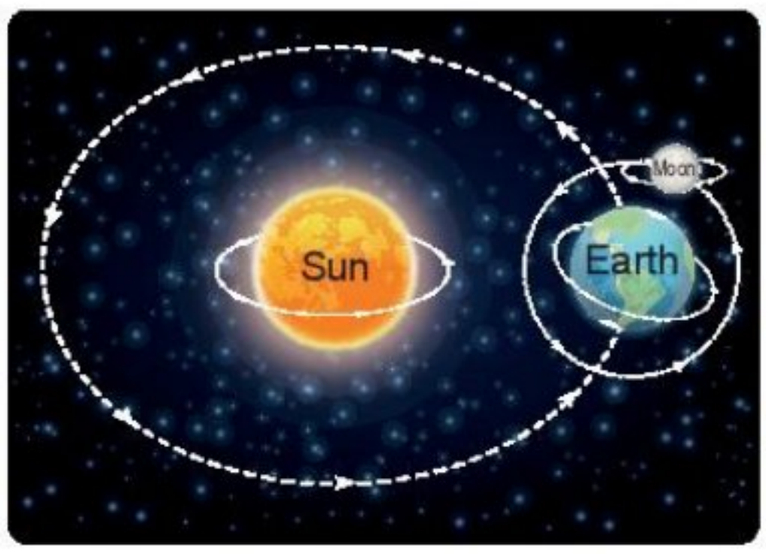


Figure (15)

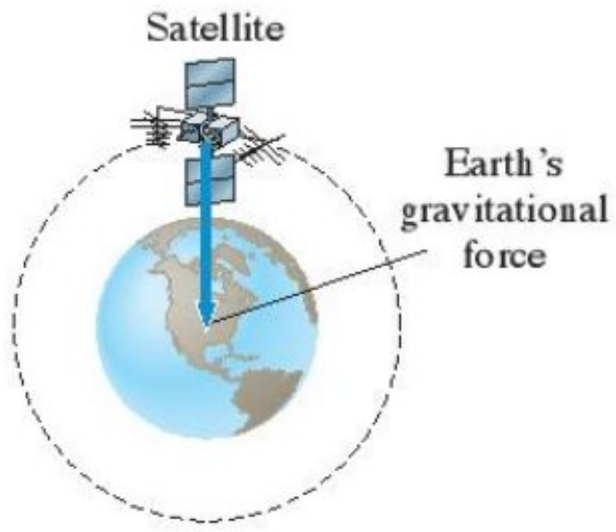


Figure (16)
Orbital motion of satellites depends on Earth's gravitational force

Evaluate Your Understanding

According to what you have studied, **explain** the types of field forces in a helium atom $_2He$ (Figure 17), and **identify** the weakest force among them.

.....

.....

.....

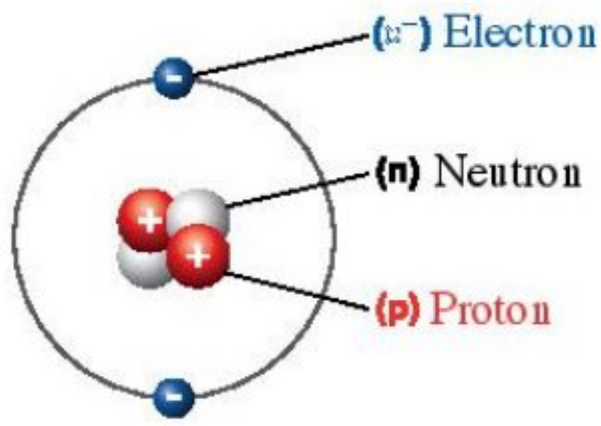


Figure (17)
Helium atom

The Relation Between Weight and Gravity

Why is the mass of an ostrich egg greater than the mass of a chicken egg as in Figure (18) ?

Does the weight of the egg equal to its mass ?

The mass of an object (m) is the amount of matter it contains, while the weight of an object (w) is the gravitational force that Earth exerts on it.

Figure (18)

Activity 3 Practical

(1) Hang a mass of 1 kg on the hook of a spring balance (Newton meter) (Figure 19) and record the weight in Newtons (N) in Table (1):

Mass (kg)	1	2	3	4	5
Weight (N)	.....	.....	.....	.....	.....

Table (1)

Figure (19)

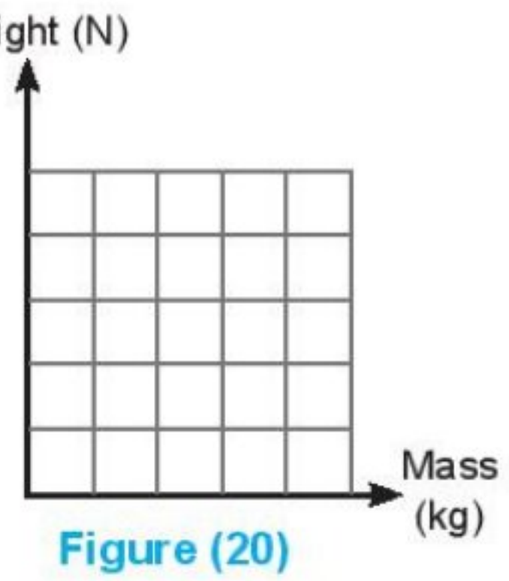


Figure (20)

(2) Repeat step (1) with different masses.

(3) Represent the results with a graph in which weight in Newtons is represented on the vertical axis and mass in kilograms is represented on the horizontal axis (Figure 20).

It is evident from practical activity (3) that the weight of an object is calculated using the mathematical relation :

Weight (w) = Mass (m) × Gravitational field intensity (g)

Knowing that Earth's gravitational field intensity is approximately 10 N/kg, i.e. any mass of 1 kg at Earth's surface is attracted towards Earth's center by a force that equals approximately 10 N

Activity 4 Discover

What is the relation between the weight of an object **and** the gravitational field intensity acting on it ?

Figures (21) : (23) show the masses and weights of an object in three different locations.

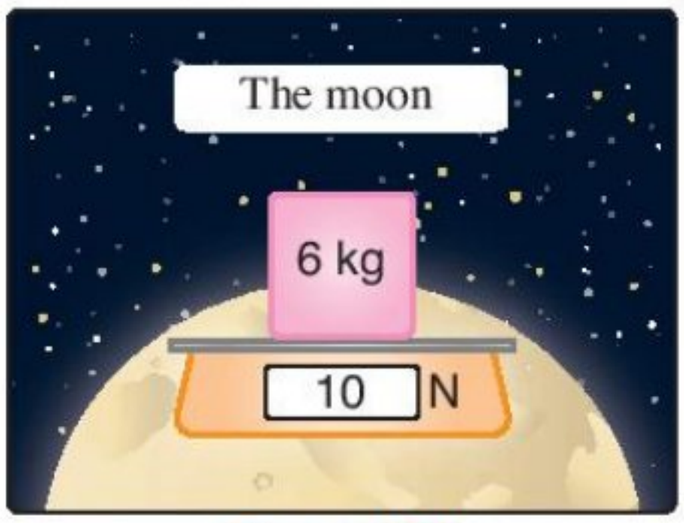


Figure (21)

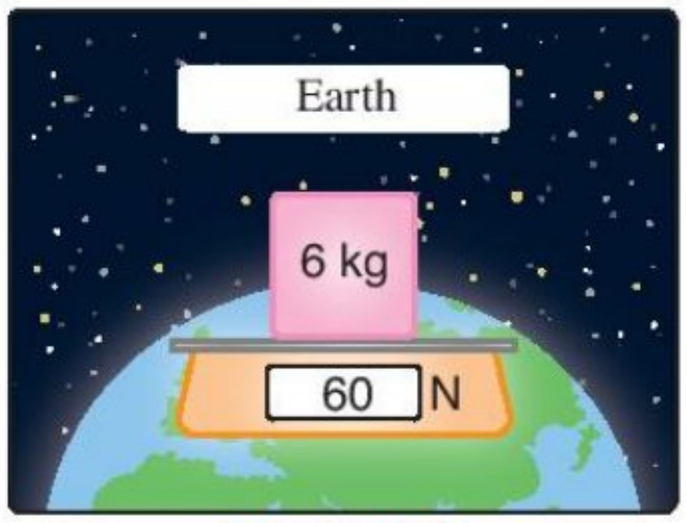


Figure (22)

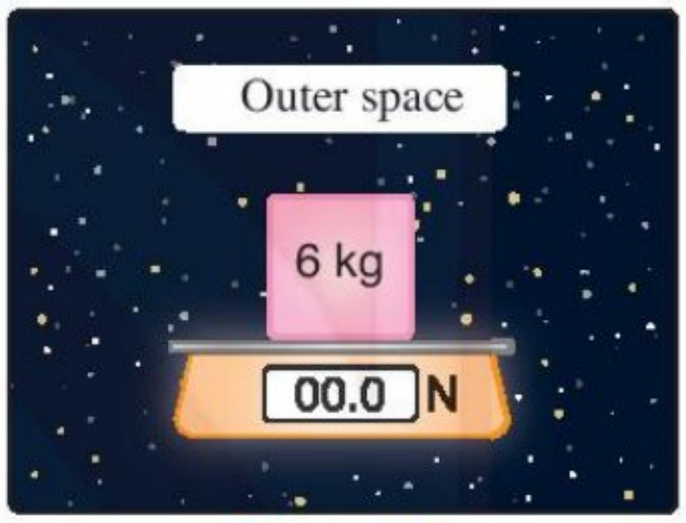


Figure (23)

(1) Does the mass of an object change depending on its location ?

.....

(2) Does the weight of an object change depending on its location ?

.....

(3) Which is greater: Earth's gravitational pull on the objects or the moon's gravitational pull on them ?

.....

(4) Why does the weight of an object become zero in outer space ?

.....

It is evident from the previous that :

The moon's gravitational field intensity at its surface is $\frac{1}{6}$ of Earth's gravitational field intensity at its surface.

It is noted that :

- Earth's gravitational field intensity decreases as we move away from Earth's center (upwards).
- The weight of an object changes from one planet to another due to the change of the gravitational field intensity.

Engineering design

Designing bridges requires a precise understanding of physics and mathematics to prevent them from collapsing due to Earth's gravitational pull on the large combined masses of the heavy vehicles that travel on them. This requires choosing suitable strong materials during designing the bridges and distributing loads appropriately on the bridge foundations.

Design a bridge from materials available in the environment, as shown in Figure (24), and test the maximum load your design can hold.

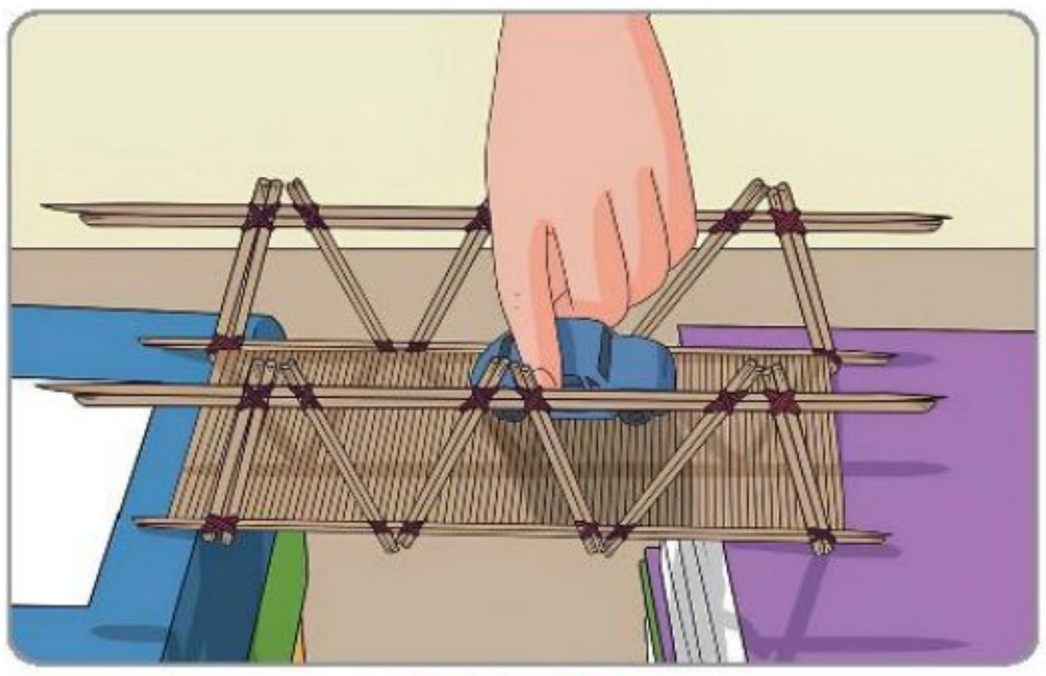


Figure (24)

Scientific Skills Comparison

Compare between mass **and** weight in three points :

Comparison point	Mass (m)	Weight (w)
Definition	.....	.....
Measuring unit	.....	.....
Change in magnitude with changing object's position	.....	.....

Table (2)

Evaluation Questions on Lesson Three

1 **Mark (✓) or (✗) next to each of the following statements that describe Earth's gravity :**

(1) A force that acts at a distance. ( )

(2) It affects the masses of objects. ( )

(3) It causes objects to fall towards Earth's center. ( )

(4) Its intensity decreases with increasing the distance from Earth's center. ( )

2 **Choose the correct answer for the questions (1) to (3):**

(1) You have two objects, the mass of the first is 5 kg and the mass of the second is 20 kg. Which of the following describes the attraction forces between the two objects?

(a) The force of attraction of the first object to the second is greater.

(b) The force of attraction of the second object to the first is greater.

(c) Both objects attract each other with the same force.

(d) There is no attraction force between the two objects.

(2) What is the force that causes a ball to fall from a high position to Earth's surface?

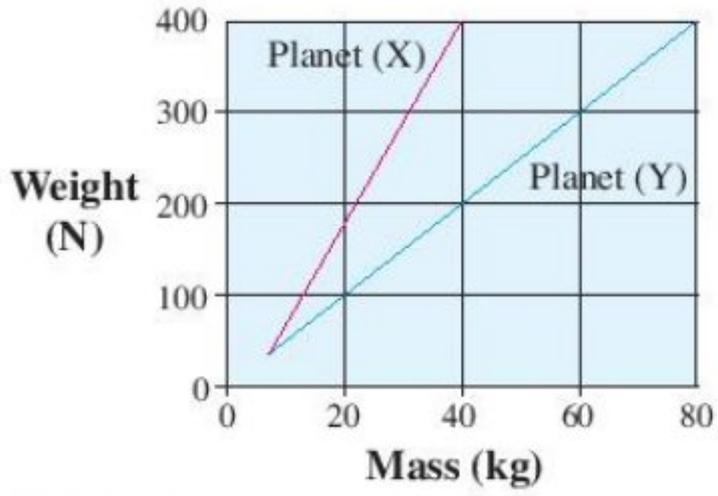
(a) Gravity. (b) Magnetism.

(c) Friction. (d) Collision.

(3) An object weight is 600 N at the base of a high mountain. Which of the following could describe its mass and weight at the top of this mountain?

Choices	Mass	Weight
(a)	60 kg	600 N
(b)	6 kg	600 N
(c)	60 kg	598 N
(d)	6 kg	598 N

3 **The graph below shows the relation between weight and mass for several different objects on the surfaces of two different planets:**

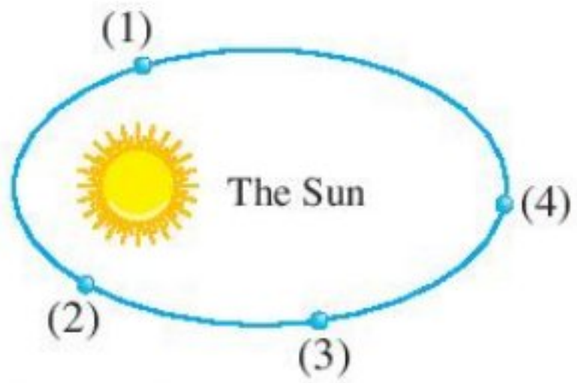


Which planet has lower gravitational field ? Explain.

4 **Identify** the similarity and the difference between gravitational force and magnetic force.

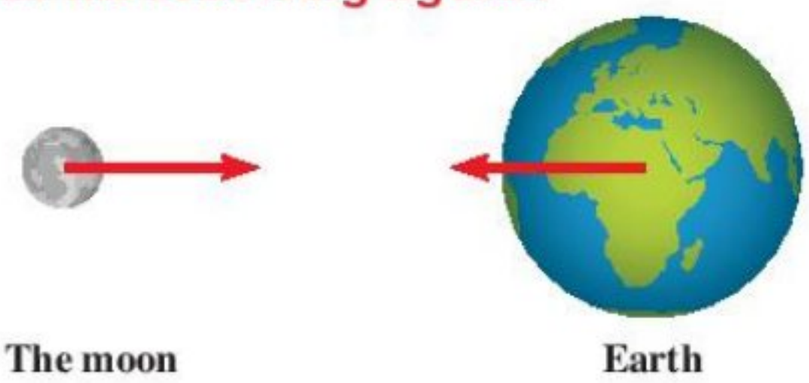
5 **Mention one difference between** elasticity forces and gravitational forces.

6 **The following figure shows the orbit of a planet around the sun :**



At which point is the gravitational force between the sun and the planet is the weakest ? **Explain** the affecting factor.

7 **From the following figure :**



Explain the relation between Earth's gravitational pull on the moon **and** the moon's gravitational pull on Earth.