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Synergy Education

Preliminary Physics

Module 4: Electricity and Magnetism

Lesson 1: Electrostatic Charges

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Summary of Key Words

Account
Account for: state reasons for, report on. Give an account of: narrate a series of events or transactions

Analyse
Identify components and the relationship between them; draw out and relate implications

Apply
Use, utilise, employ in a particular situation

Assess
Make a judgement of value, quality, outcomes, results or size

Calculate
Ascertain/determine from given facts, figures or information

Clarify
Make clear or plain

Classify
Arrange or include in classes/categories

Compare
Show how things are similar or different

Construct
Make; build; put together items or arguments

Contrast
Show how things are different or opposite

Deduce
Draw conclusions

Define
State meaning and identify essential qualities

Demonstrate
Show by example

Describe
Provide characteristics and features

Discuss
Identify issues and provide points for and/or against

Distinguish
Recognise or note/indicate as being distinct or different from; to note differences between

Evaluate
Make a judgement based on criteria; determine the value of

Examine
Inquire into

Explain
Relate cause and effect; make the relationships between things evident; provide why and/or how

Extract
Choose relevant and/or appropriate details

Extrapolate
Infer from what is known

Identify
Recognise and name

Interpret
Draw meaning from

Investigate
Plan, inquire into and draw conclusions about

Justify
Support an argument or conclusion

Outline
Sketch in general terms; indicate the main features of

Predict
Suggest what may happen based on available information

Propose
Put forward (for example a point of view, idea, argument, suggestion) for consideration or action

Recall
Present remembered ideas, facts or experiences

Recommend
Provide reasons in favour

Lesson Dotpoints

Inquiry question: How do charged objects interact with other charged objects and with neutral objects?

Electrostatic Charges

- Conduct investigations to describe and analyse qualitatively and quantitatively:

  - Processes by which objects become electrically charged (ACSPH002)
  - Variables that affect electrostatic forces between those objects (ACSPH103)

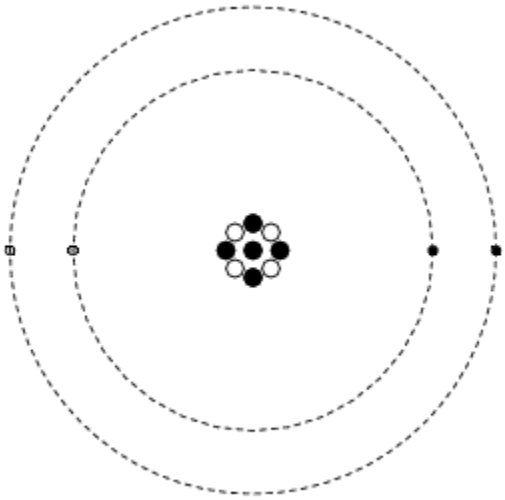
1. Electrostatic Charges

CHECKPOINT:

- Conduct investigations to describe and analyse qualitatively and quantitatively:
  - Processes by which objects become electrically charged (ACSPH002)
  - The forces produced by other objects as a result of their interactions with charged objects (ACSPH103)
  - Variables that affect electrostatic forces between those objects (ACSPH103)

Electric Charges

- Electric charges are due to the subatomic particles
- Below is a diagram of an atom:



  - Atoms consist of **subatomic particles** which include:

    Dense positive nucleus containing protons and neutrons surrounded by electrons in a shell.

- Protons have a positive charge
- Electrons have a negative charge
- If there are **equal number of protons and electrons** then the atom is known to be electrically neutral

Electric charges are properties of electrons and protons

- If there are **more electrons then protons** then the atom is known to be negatively charged
- If there are **less electrons then protons** then the atom is known to be positively charged

⚙ Static vs Current Electricity

- Before proceeding it is important to understand that there are two types of electricity:

1. Static Electricity

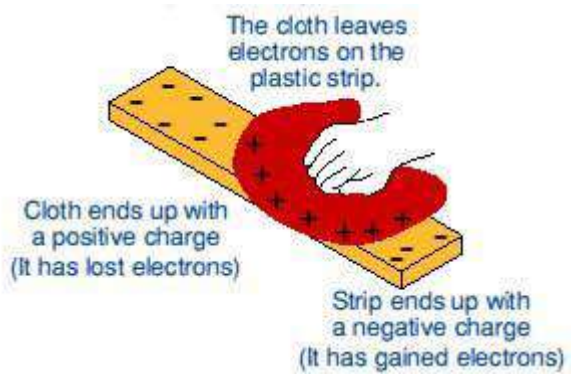
- This is created when there is an imbalance of positively and negatively charged atoms
- Electricity occurs when:

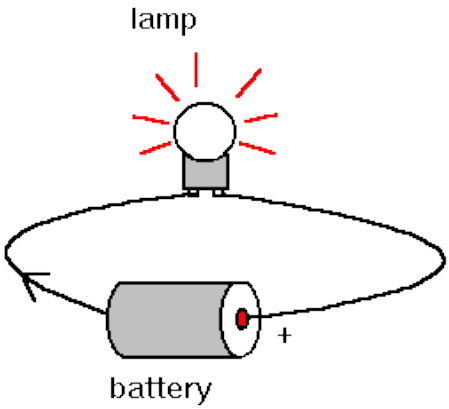
  Electrons jump from atom to atom, releasing energy.

2. Current Electricity

- This is created when there is a flow of electrons
- Current electricity is then divided into **Alternating Current (A**C) and **Direct Current (AC)**

- **Label** whether the following diagrams show static or current electricity.





Static

Current

NOTE: In this booklet we will first learn about static electricity AKA ELECTROSTATICS

⚙ Static Electricity

- You know an object is charged when it is able to attract nearby items without ever touching them
- For example,
  - If you rub a balloon against your hair the balloon will become charged
  - If you place some pieces of paper on a table and move the balloon their the balloon will attract the paper bits
  - This type of influence is known as **electric force**
- There are two types of charge:
  1. **Positive Charge**
  2. **Negative Charge**
  - What do you think occurs when an object is charge neutral and is near a charged object?

    It will either attract or repel the positive or negatively charged object.

- In the following table there are objects A and B which are placed near each other. Determine what the results will be using the following words:

  - Attract
  - Repel

Object A	Object B	Results
Positively charged	Positively charged	Repel
Negatively charged	Negatively charged	Repel
Positively charged	Negatively charged	Attract
Neutral	Positively charged	Attract or repel
Negatively Charged	Neutral	Attract or repel

- Therefore, there are three conclusions that can be reached:

Like charges REPEL

Opposite charges ATTRACT

Charge Neutral will ATTRACT OR REPEL charged objects

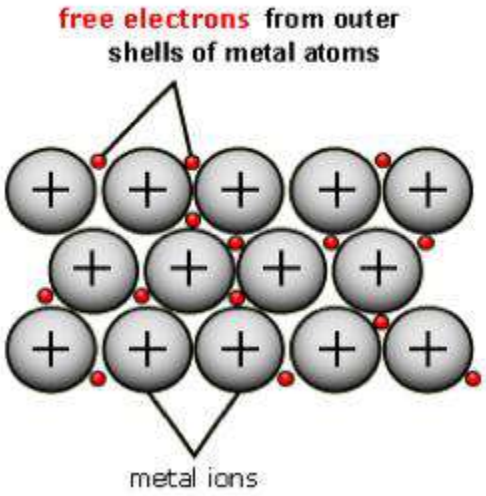
Conductors and Insulators

- The way that an object behaves when charged depends on whether the material is:
  - Conductive

    OR
  - Non – conductive

Conductors

- Conductors are materials that allow electrons to freely flow from particle to particle
- A conducting materials allows charge to transfer across the entire surface of the object
- The movement of charge is dependent on electron movement
- For example, metals are good conductors
  - Metals have a sea of free electrons as shown below:



Insulators

- Insulators are materials that impede the free flow electrons
- For example, if there is a build-up of charge in an insulator, the charge will remain at the initial location
- Charge cannot be distributed evenly for insulators
- Examples of insulators include:
  - Glass
  - Plastics
  - Rubber

Applications 3.1

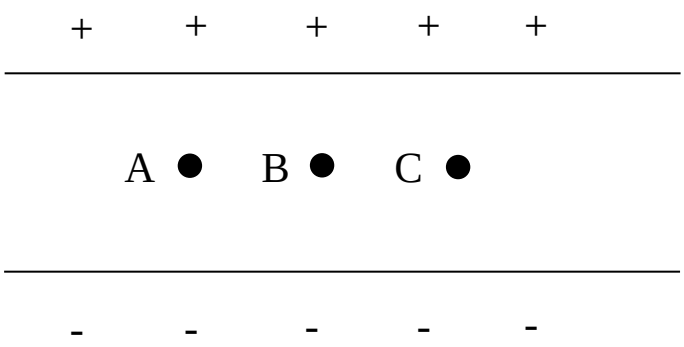
Question 1

Explain the difference between conductors and insulators. (2 marks)

Conductor -> object that allows the flow of electrons
Insulator -> object that inhibits the free flow of electrons

Question 2

Three small spheres, A, B and C were placed between oppositely charged plates, as shown in the diagram below. The top plate was positively charged; the bottom plate was negatively charged.



All the spheres are charged; they all have the same mass. A gravitational force acts on each sphere.

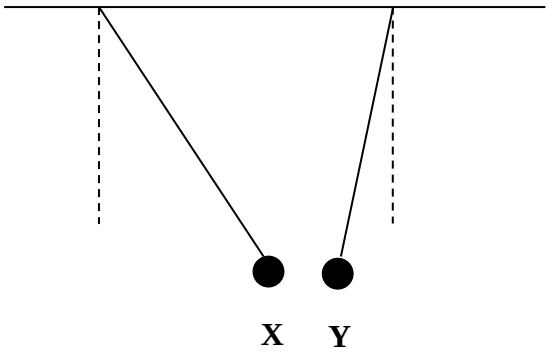
Sphere A moves up, sphere B remains stationary, and sphere C moves down. What can you conclude about the charge on each sphere? Explain your answer. (3 marks)

As A moves up it must be negatively charged. B remained at rest so it also must be negatively charged but it has a smaller negative charge than A. (The electrostatic force upwards balances the gravitational force downwards).

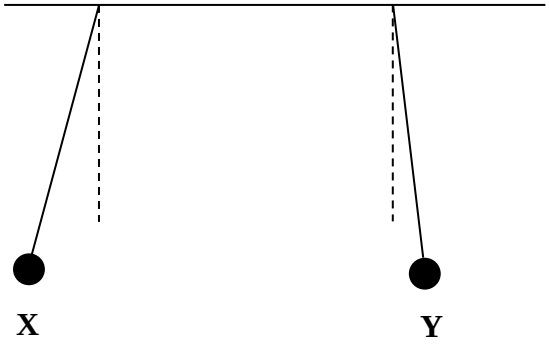
C may have a smaller negative charge than B or it may be positively charged. (There is a net force acting downward on C, so if C is negatively charged, the force of gravity downward must be greater than the electrostatic force upward).

Question 3

Two metal coated sphere X and Y are suspended from light insulating threads of equal length. The spheres are of equal radii, and each carries an electric charge. The diagram below shows the positions of the charged spheres at equilibrium.



The two spheres are touched together and then separated. The new equilibrium positions are shown below.



The student makes the following correct deductions:

i. The sign of the charges on the two spheres was not the same
ii. The magnitude of the charges on the two spheres was unequal
iii. The mass of sphere X is less than the mass of sphere Y

In the spaces provided in your answer book use the information contained in the diagrams above to justify each deduction. (4 marks)

i. Before contact the spheres attract and must therefore have had opposite charges
ii. After contact, the net charge (if any) will be disitributed evenly between the two spheres. As the spheres repel after contact there was a net charge, i.e. the magnitude of the charges was not the same.
iii. Equal electrostatic forces must act on the two charges. As X is deflected from the vertical more than Y, X must have a smaller mass than Y.

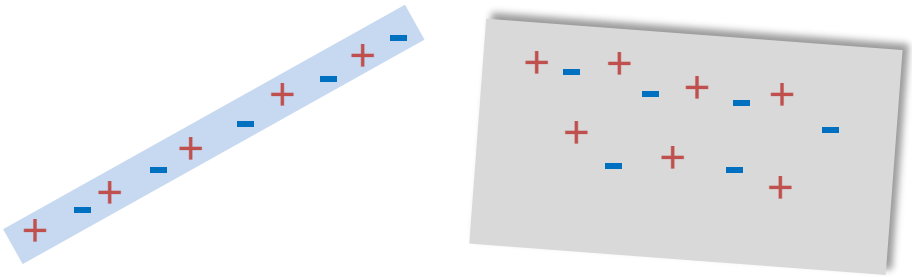
How can we Charge Objects?

- There are three main ways in which objects can be charged:

1. Friction
2. Contact
3. Induction

Charging by Friction

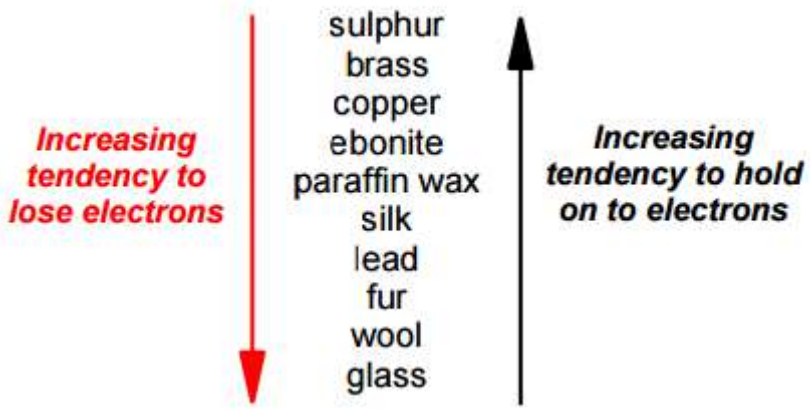
- When you rub two materials against each other, they are charged by friction
- For example, the diagram below shows a glass rod and some fur:



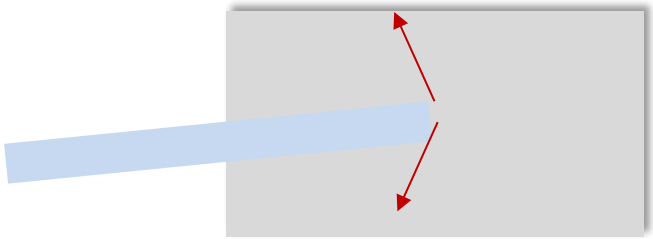
- Determine the charge for each of the materials.

  Charge neutral

- The following diagram is called the "Electrostatic Series". It is used to determine which objects are more likely to hold on to electrons.



- If the objects are allowed to rub against each other draw a diagram showing the charges for each material:



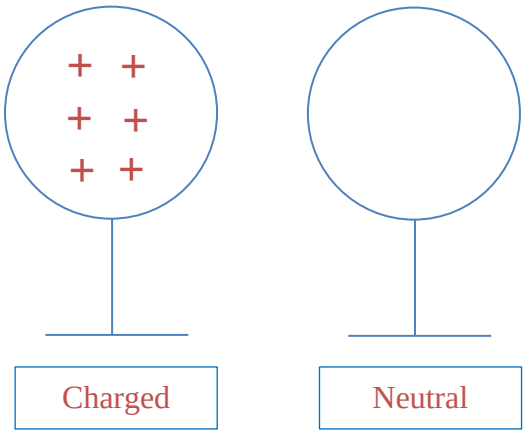
- Determine the charges for each material after rubbing against each other. Explain your answer.

  Electrons are transferred from the rod to the fur. Therefore, the fur has an excess in electrons. It becomes negatively charged.

Charging by Contact

- Charging by contact occurs when one conductor is already **charged** while the other is still **uncharged**

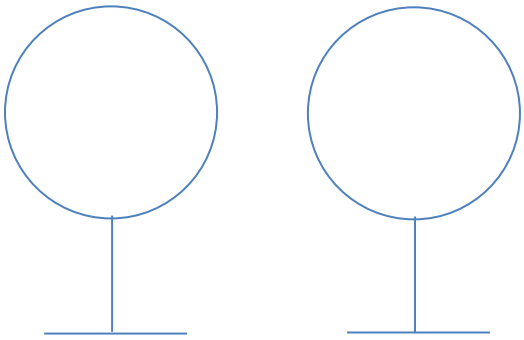
- For example, one conductor is already positively charged while the other is charge neutral:



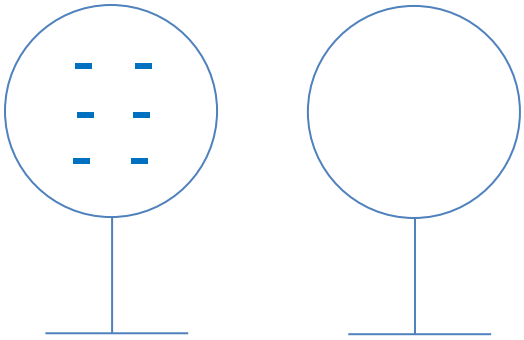
- If the two conductors are now in contact as shown below, how do you think charge by contact works?

  Electrons are transferred to the positively charged conductor.

- Show the distribution of charge after they contact.



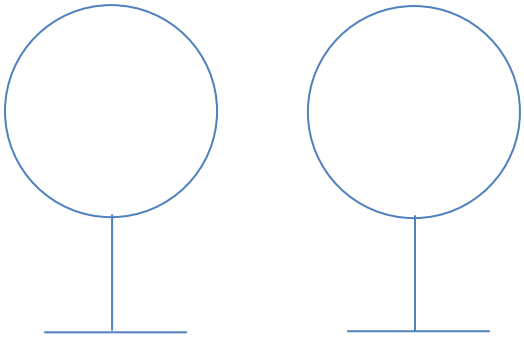
- Another example is one conductor is negatively charged while the other is charge neutral:



- If the two conductors are now in contact as shown below, how do you think charge by contact works?

  Electrons are transferred to the charge neutral conductor.

- Show the distribution of charge after they contact.



Charging by Induction

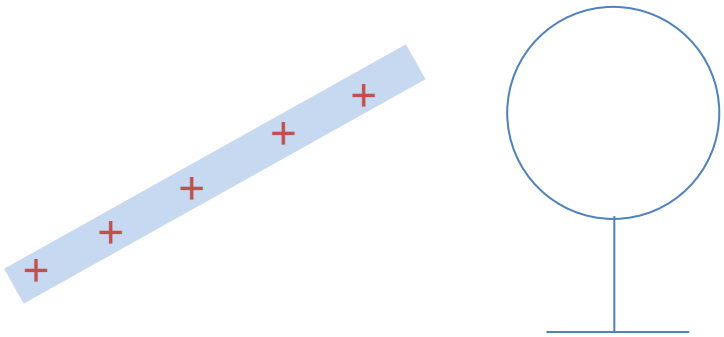
- Inducting charging is when an object is charged **without** actually making contact with another charged object

- Charging by induction allows the original objects charge to remain **UNAFFECTED**

  - Therefore, the charged object is able to continually induce charges in other objects without losing its own charge

Case Study A – Temporary Induced Charging

- A charged rod is placed near a charge neutral metal sphere:



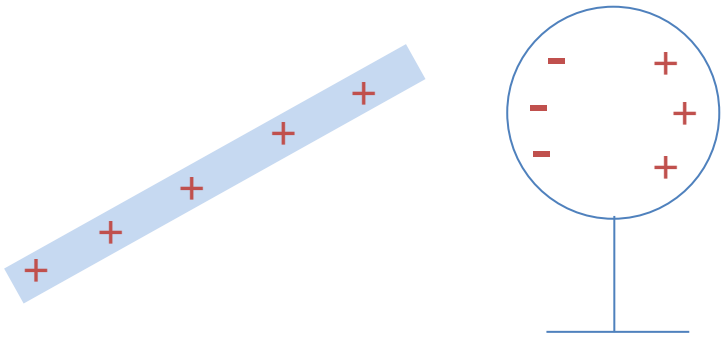
- What occurs next is what we call **polarisation**. Explain what is polarisation.

  Polarisation means to separate into opposites. In the case of induction it is the process of separating opposite charges within an object.

- Explain why polarisation occurred.

  Like charges in the sphere repel while unlike charges attract.

- **Show** the occurrence of polarisation in the diagram below.



- The sphere is now said to have an:

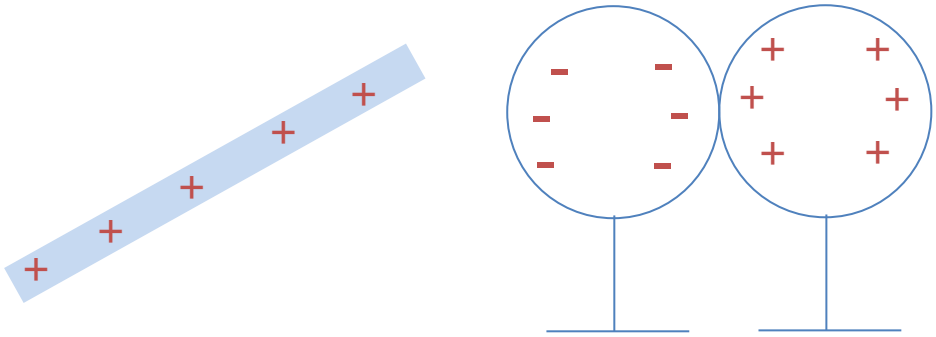
INDUCED CHARGE but overall charge is NEUTRAL

- When the charged rod is taken away the separated charges in the metal sphere returns to its original position

- Therefore, the charging of the sphere is temporary

Case Study B – Permanent Induced Charging

- A charged rod is placed near two metal sphere that are charging as shown below:
-



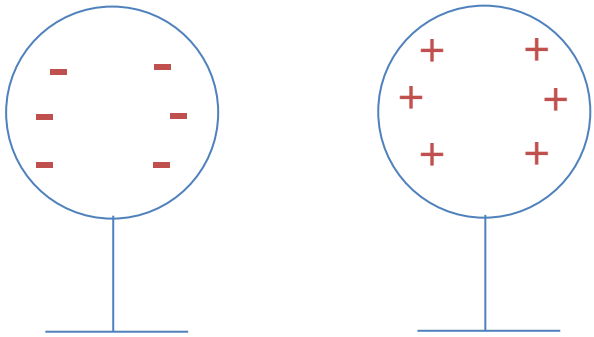
- The charges in the metal spheres will separate in which:

  Positive charge will move towards the right as like charges repel.
  Negative charges will move towards the left as it attracts towards to the positively charged rod.

- **Show** the separation of charges on the diagram above.

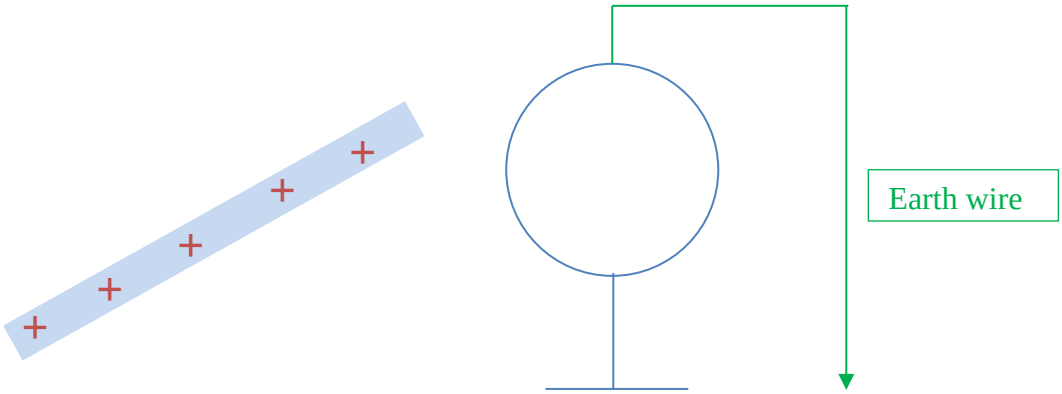
- If the charged rod is removed and the two spheres are separated they will maintain a permanent charge via induction

  - **Show** this on the diagram below.

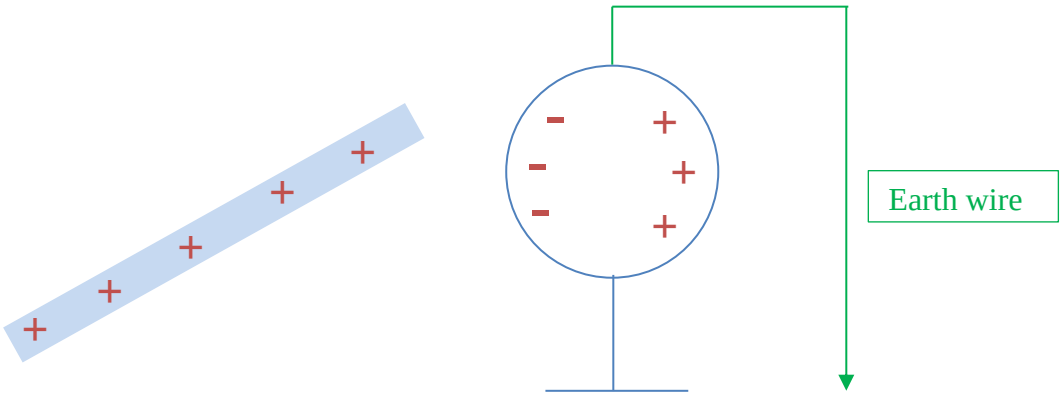


Case Study C – Permanent Induced Charging

- A charged rod is placed near a charge neutral metal sphere that is connected by a earth wire:



  - There will be a charge separation as shown below:



- What is the purpose of the Earth wire?

  It allows the electrons flow to the Earth. The positive charge remains as they are fixed.

Law of Conservation of Charge

- The law of conservation of charge simply states:

> **Charges in a CLOSED SYSTEM, will remain constant**

- An example of this law functioning is when objects are charged by friction

  - Explain how rubbing two objects follows the law of conservation of charge.

    No charge is actually created. Rubbing two objects only redistributes charge already present.

Applications 3.2

Question 1

A person walks across carpet and then touches a metal doorknob. Explain how the person may get 'shocked'.

As a person rubs her/his shoes across a carpet, the person becomes charged because electrons move into or out of the person. When the charged person touches a neutral doorknob, electrons move to make the person more neutral and this movement of electrons is the spark.

Question 2

a) You touch a charged metal rod and it becomes neutral. Explain what happened. (1 mark)

The charge has been removed by electrons moving into or out of the object to the hand.

b) Two identical glass rods are rubbed against each other. Explain whether a static charge can be created. (1 mark)

No because they both have an equal attraction for their electrons.

Question 3

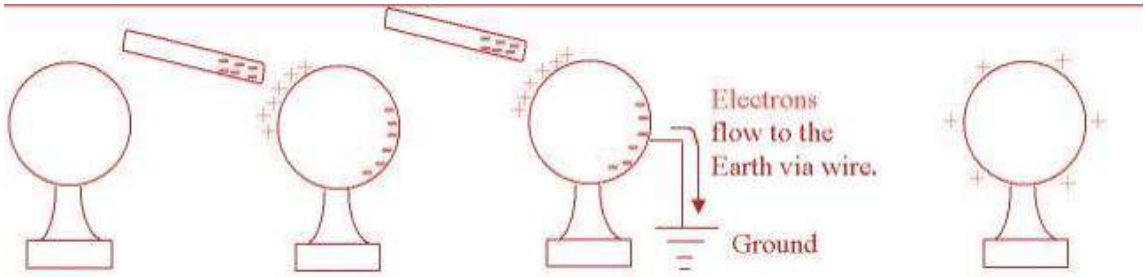
If a neutral metal sphere (X) is placed in contact with a positively charged metal sphere (Y), sphere X will become positively charged as well. Explain why. (2 marks)

The positively charged sphere (deficient of electrons) will take some electrons from the initially neutral sphere. This will make the initially neutral sphere also deficient in electrons and therefore positively charged.

Question 4

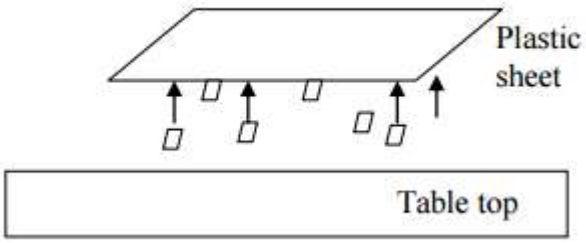
In charging by induction, a charged body (X) is placed near to a neutral body (Y) that is to be charged. If X is negatively charged and Y is connected to the ground, what will happen to Y? Explain your answer and provide a diagram with your answer. (3 marks)

Y will become positively charged. Body X will cause electrons in body Y to move away to the side far from body X. With the grounding, electrons will flow out from body Y.



Question 5

You conducted a "magic show" with the kids in an orphanage you visited. You showed them the demonstration where tissue bits flew up to the plastic sheet. How would you best explain to the kids why the tissue bits moved up, defying gravity? Assume the plastic sheet to be negatively charged. (3 marks)



The negatively charged plastic sheet repels the electrons in the tissue bits, pushing them lower.

This polarizes the tissue bits, with the upper side positively charged, and the lower side negatively charged.

The tissue bits however are still electrically neutral. (Left figure below) With the tissue bits now polarized, the upper side gets attracted to the plastic sheet. The attraction overcomes the repulsion that the lower side experiences.