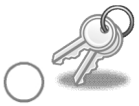
21 Electric Charges and Electric Forces

21.1 Electric charges

Learning objectives

- Understand the concept of electric charge and explain daily-life phenomena related to electrostatics.
- Examine the evidence of two kinds of charges and realize the forces between them.
- Understand what electric charges are from the microscopic view.



Key ideas

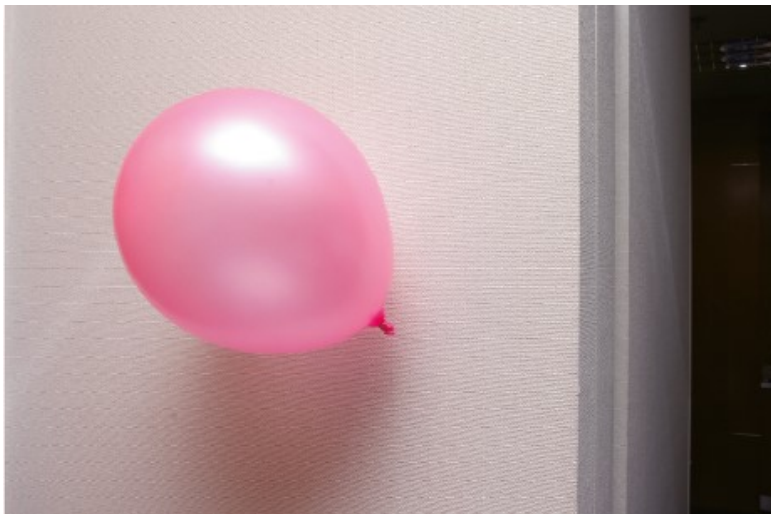
- There are two kinds of charges, namely _____ and _____ charges.
- Like charges _____ each other, unlike charges _____ each other.
- A _____ atom has equal numbers of protons and electrons.
- When a neutral object loses electrons, it becomes _____ charged. When it gains electrons, it becomes _____ charged.
- The amount of charge in an isolated system is _____.
- Electric charges are measured in _____ (C).
- Charges can flow easily in _____.
- Charges cannot move in _____ but stay at where they are placed.
- _____ objects can attract both neutral and oppositely charged objects.

Follow-up

Checkpoint (p.8)
Checkpoint (p.10)
Checkpoint (p.11)
Checkpoint (p.14)
Exercise (p.15)

Example 21.1A Attracted to a board (p.13)

A student rubs a balloon with a dry cloth. Then the balloon can be attracted to a board. Explain the phenomenon briefly.

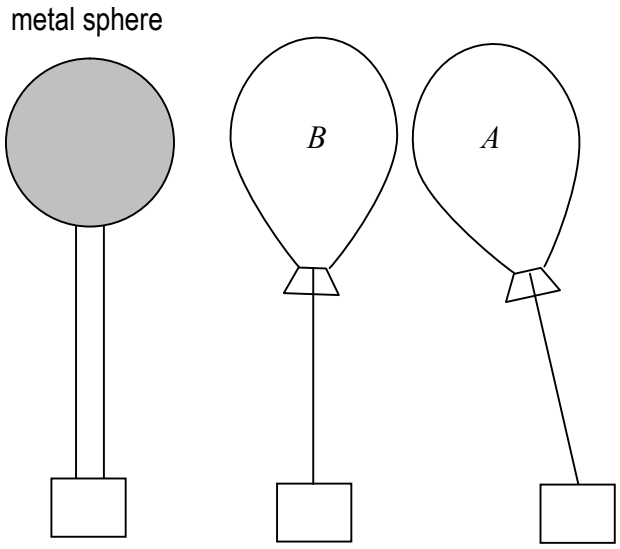


Solution

(What happens when a balloon is rubbed?)
(How does the balloon affect the charge distribution of the board when the balloon is put close to the board?)
(What electric forces will be caused?)

Example 21.2A Electric charges on balloons (p.14)

In the figure below, balloon *A* carries a negative charge and the metal sphere carries a positive one. The amount of charges on a metal sphere and balloon *A* are the same. When a student puts balloon *B* in the middle of balloon *A* and the metal sphere, balloon *A* tilts as shown above. What is the charge on balloon *B*? Explain your answer briefly.



Solution

(What is the electric force acting on balloon *B* due to balloon *A*? What is the electric force acting on balloon *B* due to the metal sphere?)

21.2 Charging and discharging methods

Learning objectives

- Understand charging in terms of electron transfer.

Key ideas

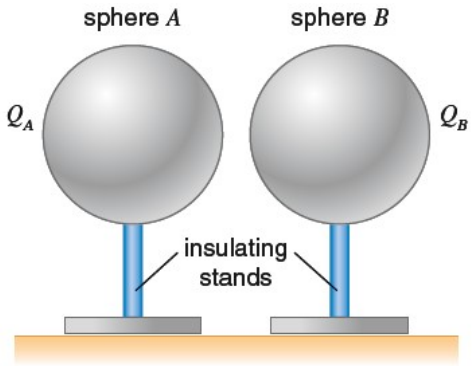
- Conductors and insulators can be charged by _____.
- Conductors can also be charged by _____ or by _____.
- Instruments like EHT supply and Van de Graaff generator can be used to charge objects.

Follow-up

Checkpoint (p.24)
Exercise (p.25)

Example 21.3A Sharing charges between objects (p.18)

A and *B* are two identical, insulated metal spheres. After rubbed by a cloth, *A* carries a charge of $Q_A = +4 \times 10^{-10}$ C. *B* is then brought in contact with the cloth. Assume that *B* shares half of the charge on the cloth.



(a) What is the charge on *B*?

(b) *A* is then brought in contact with *B*.

(i) What is the amount of charge on *A* and *B* after they touch each other? Explain briefly.

(ii) What charged particle(s) move(s) between *A* and *B*? What is the amount of charge transferred?

(c) What would happen if the spheres are not insulated?

Solution

(a) _____

(b) (i) _____

_____

_____

_____

(ii) _____

_____

(c) _____

_____

Example 21.4A Gold-leaf electroscope (p.23)

A student turns on a Van de Graaff generator which produces a negative charge on its dome. The student holds a small, insulated conducting ball to touch the dome of the generator and then the cap of a neutral electroscope.

(a) What happens to the electroscope when the conducting ball touches the cap? Explain briefly.

(b) What is the charge of a charged object if the leaf of the electroscope in (a) falls when the object is put close to the cap? Explain briefly.

Solution

(a)

(b)

21.3 Hazards and applications of electrostatics

Learning objectives

- Realize the hazards and applications of electrostatics.

Key ideas

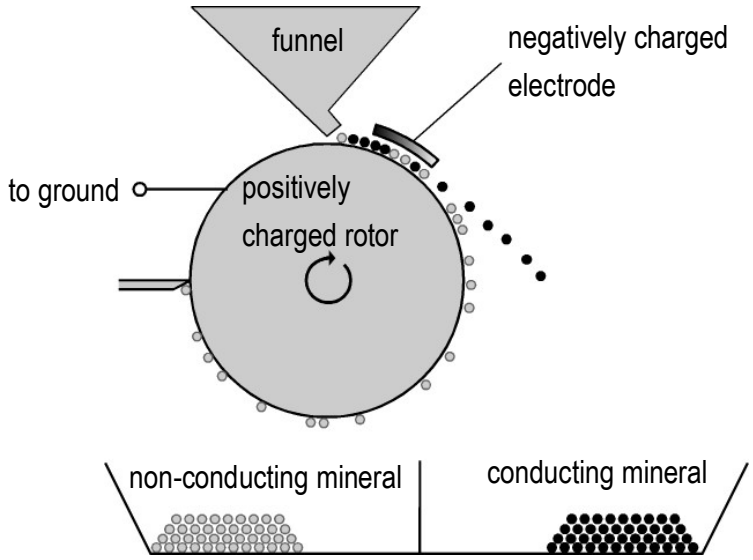
- _____ may be produced when a huge amount of charge are built up on an object.
- Sparks can be dangerous in places where _____ substances are present.
- Attractive electric force can be a help or a nuisance in everyday life.
- _____ materials are used to prevent the build-up of charges on objects.
- Applications of _____ include photocopying, laser printing, electrostatic precipitators and electrostatic spraying.

Follow-up

Checkpoint (p.31)

Example 21.5A Electrostatic separator (p.30)

Electrostatic charges can be applied to separate minerals. The following diagram shows a simple machine that can separate conducting and non-conducting minerals. Minerals first fall from a funnel onto a positively charged rotor. The minerals then pass beneath a negatively charged electrode.



(a) What happens when non-conducting minerals fall on the rotor? Why are they attracted to the rotor?

(b) What happens when conducting minerals fall on the rotor? Why do conducting minerals fall off from the rotor?

Solution

(a) _____

_____

_____

_____

_____

_____

_____

(b) _____

_____

_____

_____

_____

_____

_____

21.4 Coulomb's law

Learning objectives

- Understand the law which governs the forces between point charges.

Key ideas

- Electric forces between point charges are governed by _____.
- The magnitude of the electric force F exerted on a point charge Q_1 by another point charge Q_2 is _____ to the product of the magnitudes of their charges and inversely proportional to the square of their separation r.

  Mathematically,

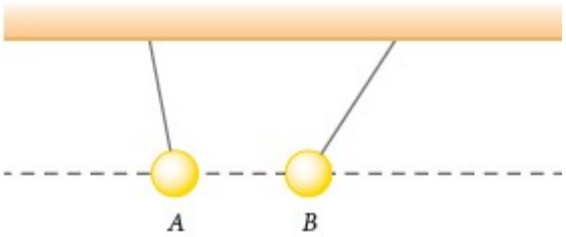
- Electric forces acting on a point charge by other charges add as vectors.

Follow-up

Checkpoint (p.35)
Exercise (p.36)

Example 21.6A Electric force (p.33)

Two small spheres are hung by two nylon threads. The separation between them is 10 cm. The amount of charge carried by A and B are +1 μC and −2 μC respectively.



(a) Find the electric force acting on A by B.

(b) Hence, find the electric force acting on B by A.

(c) Which sphere is heavier?

Solution

(a) _____

_____

_____

(b) _____

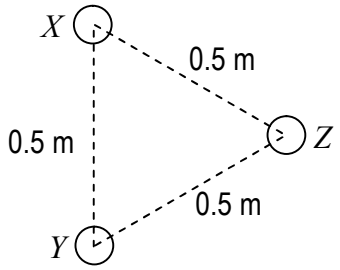
_____

_____

(c) _____

Example 21.7A Resultant electric force (p.34)

Three point charges X, Y and Z have the same amount of charge, 10^{-12} C. The distance between each pair of the charges is 0.5 m.

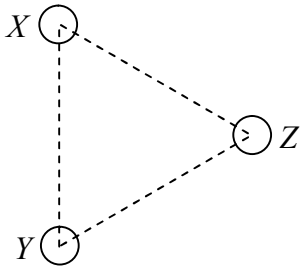


(a) Draw the electric force acting on Z due to X and Y.

(b) Find the resultant electric force acting on charge Z.

Solution

(a) (Do charges repel or attract each other?)
(What is the direction of the electric force acting on Z due to X and Y respectively?)



(b) _____