

Summary of Terms

Electrostatics The study of electric charge at relative rest, as opposed to electric currents.

Coulomb's law The relationship among electric force, charge, and distance:

$$F \sim \frac{qq'}{d^2}$$

If the charges are alike in sign, the force is repelling; if the charges are unlike, the force is attractive.

Conductor Any material through which charge easily flows when subject to an impressed electrical force.

Insulator Any material through which charge resists flow when subject to an impressed electrical force.

Semiconductor A normally insulating material such as crystalline silicon or germanium that becomes conducting when made with certain impurities or when energy is added.

Charging by friction The transfer of charge between bodies by virtue of rubbing.

Charging by contact The transfer of charge from one body to another by physical contact between the bodies.

Charging by induction The redistribution of charge in an object, caused by the electrical influence of a charged body close by, but not in contact.

Electric field The energetic region of space surrounding a charged body; about a charged point, the field decreases with distance according to the inverse-square law, like the gravitational field. Between oppositely charged parallel plates, the electric field is uniform. A charged object placed in the region of an electric field experiences a force.

Electric potential The electric potential energy per quantity of charge, measured in volts, and often called *voltage*:

$$\text{Voltage} = \frac{\text{electrical energy}}{\text{charge}}$$

Review Questions

- The strength of the gravitational force between a pair of electrons is incredibly tiny compared to the electric force, yet gravitation is the predominant force between celestial bodies. Why is this so?
- What is the fundamental force that underlies all "chemical" forces?
- How is Coulomb's law similar to Newton's law of gravitation? How is it different?
- By how much does the electric force between a pair of charged bodies diminish when their separation is doubled? Tripled?
- Cite three major differences between gravitational and electric forces.
- Distinguish between a *conductor* and an *insulator* and between a *conductor* and a *semiconductor*.
- Distinguish between a *positively* and *negatively* charged object.
- If you rub a glass rod with silk and make the glass positive, what is the sign of charge on the silk?
- What does it mean to say that in all interactions electrical charge is conserved?
- Distinguish between *charging by contact* and *charging by induction*.
- What is charge polarization?
- Explain how an electrically neutral object can be attracted to a charged body.
- What is an electric field? How is it similar to a gravitational field?
- What is the difference between *electric potential* and *electric potential energy*?
- What is a volt?

Home Projects

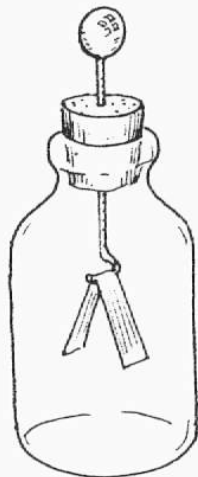
- Demonstrate charging by friction and discharging from points with a friend who stands at the far end of a carpeted room. With leather shoes, scuff your way across the rug until your noses are close together. This can be a delightfully tingling experience, depending on how dry the air is and how pointed your noses are.
- Bring a comb that has been briskly rubbed on your hair or a woolen garment near a small but smooth stream of running water. Is the stream of water charged?

Exercises

- We do not feel the gravitational forces between ourselves and the objects around us because these forces are extremely small. Electrical forces, in comparison, are extremely huge. Since we and the objects around us are composed of charged particles, why don't we feel electrical forces?
- Why do clothes often cling together after tumbling in a clothes dryer?
- When combing your hair, you scuff electrons from your hair onto the comb. Is your hair then positively or negatively charged? How about the comb?
- At automobile toll-collecting stations a thin metal wire sticks up from the road and makes contact with cars before they reach the toll collector. What is the purpose of this wire?

5. Why are the tires for trucks carrying gasoline and other flammable fluids manufactured to conduct electricity?

6. An electroscope is a simple device consisting of a metal ball that is attached by a conductor to two fine gold leaves that are protected from air disturbances in a jar as shown. When the ball is touched by a charged body, the leaves that normally hang straight down suddenly spring apart. Why? (Electroscopes are useful not only as charge detectors, but also for measuring the quantity of charge: the more charge transferred to the ball, the more the leaves diverge.)



7. The leaves of a charged electroscope collapse in time. At higher altitudes they collapse more readily. Why is this true? (*Hint:* The existence of cosmic rays was first indicated by this observation.)

8. Would it be necessary for a charged body to actually touch the ball of the electroscope for the leaves to diverge? Defend your answer.

9. Strictly speaking, when an object acquires a positive charge, what happens to its mass? When it acquires a negative charge? (Think small!)

10. How can you charge an object negatively with only the help of a positively charged object?

11. It is relatively easy to strip the outer electrons from a heavy atomic nucleus like that of uranium (which is then a uranium ion) but very difficult to strip the inner electrons. Why do you suppose this is so?

12. If a large enough electric field is applied, even an insulator will conduct an electric current, as is evident in lightning discharges through the air. Explain how this happens, taking into account the opposite charges in an atom and how ionization occurs.

13. If you are caught outdoors in a thunderstorm, why should you not stand under a tree? Can you think of a reason why you should not stand with your legs far apart? Or why lying down can be dangerous? (*Hint:* Consider electric potential *difference*.)

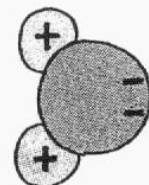
14. Which of the two would be safer—a house with no lightning rod or a house with a lightning rod *not* connected to the ground? Explain.

15. Why is a good conductor of electricity also a good conductor of heat?

16. If you rub an inflated balloon against your hair and place it against a door, by what mechanism does it stick? Explain.

17. How are electrically neutral atoms and molecules able to electrically attract each other?

18. An H_2O molecule is called a “polar” molecule. How does this relate to the fact that charging demonstrations are more difficult to do on a humid day? (*Hint:* How does the presence of polar molecules in the air affect its conductivity?)



19. A gravitational field vector points toward the earth; an electric field vector points toward an electron. Why do electric field vectors point *away* from protons?

20. By what specific means do the bits of fine threads line up in the electric fields shown in Figure 20.15?

21. Suppose a “free” electron and a “free” proton were placed in an electric field. Compare their accelerations and their directions of travel.

22. If you put in 10 joules of work to push a unit charge into an electric field, what will be its voltage with respect to its starting position? When released, what will be its kinetic energy as it flies past its starting position?

23. Can we say that a body with twice the electric potential energy of another has twice the electric potential? Why or why not? (*Hint:* Consider the analogy with thermal energy and temperature.)

24. Can we say that a body with twice the electric potential of another has twice the electric potential energy? Why or why not? (*Hint:* Consider the analogy with temperature and thermal energy.)

25. What safety is offered by staying inside an automobile during a thunderstorm? Defend your answer.

26. Would you feel any electrical effects if you were inside the charged sphere of a Van de Graaff generator? Why or why not?