25 Electric Charges and Forces

25.1 Developing a Charge Model

Exercises 1–11: Your answers in Section 25.1 should make *no* mention of electrons or protons.

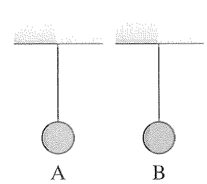
1. What is alike about charges when we say "two like charges?" Do they look, smell, or taste the same? Base your answer on experimental procedures and observations.

2. Can an insulator be charged? If so, how would you charge an insulator? If not, why not?

3. Can a conductor be charged? If so, how would you charge a conductor? If not, why not?

4. Two lightweight balls hang straight down when both are neutral. They are close enough together to interact, but not close enough to touch. Draw pictures showing how the balls hang if:

   a. Both are touched with a plastic rod that was rubbed with wool.



b. The two charged balls of part a are moved farther apart.

c. Ball A is touched by a plastic rod that was rubbed with wool and ball B is touched by a glass rod that was rubbed with silk.

d. Both are charged by a plastic rod, but ball A is charged more than ball B.

e. Ball A is charged by a plastic rod. Ball B is neutral.

f. Ball A is charged by a glass rod. Ball B is neutral.

5. Four lightweight balls A, B, C, and D are suspended by threads. Ball A has been touched by a plastic rod that was rubbed with wool. When the balls are brought close together, without touching, the following observations are made:
   - Balls B, C, and D are attracted to ball A.
   - Balls B and D have no effect on each other.
   - Ball B is attracted to ball C.

   What are the charge states (glass, plastic, or neutral) of balls A, B, C, and D? Explain.

6. Charged plastic and glass rods hang by threads.
   a. An object repels the plastic rod. Can you predict what it will do to the glass rod? If so, what? If not, why not? Explain.

   b. A different object attracts the plastic rod. Can you predict what it will do to the glass rod? If so, what? If not, why not? Explain.

7. After combing your hair briskly, the comb will pick up small pieces of paper.
   a. Is the comb charged? Explain.

   b. How can you be sure that it isn't the paper that is charged? Propose an experiment to test this.

   c. Is your hair charged after being combed? What evidence do you have for your answer?

   d. What kind of charge is the comb likely to have? Why?

   e. How could you test your answer to part d?

8. When you take clothes out of the drier right after it stops, the clothes often stick to your hands and arms. Is your body charged? If so, how did it acquire a charge? If not, why does this happen?

9. A lightweight metal ball hangs by a thread. When a charged rod is held near, the ball moves toward the rod, touches the rod, then quickly "flies away" from the rod. Explain this behavior.

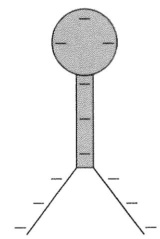
10. You've been given a piece of material. Propose an experiment or a series of experiments to determine if the material is a conductor or an insulator. State clearly what the outcome of each experiment will be if the material is a conductor and if it is an insulator.

11. Suppose there exists a third type of charge in addition to the two types we've called glass and plastic. Call this third type X charge. What experiment or series of experiments would you use to test whether an object has X charge? State clearly how each possible outcome of the experiments is to be interpreted.

25.2 Charge

25.3 Insulators and Conductors

12. A negatively charged electroscope has separated leaves.



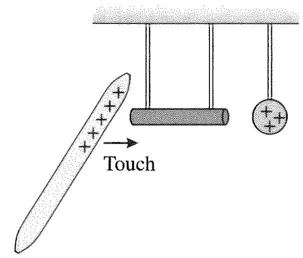
a. Suppose you bring a negatively charged rod close to the top of the electroscope, but not touching. How will the leaves respond? Use both charge diagrams and words to explain.

b. How will the leaves respond if you bring a positively charged rod close to the top of the electroscope, but not touching? Use both charge diagrams and words to explain.

13. a. A negatively charged plastic rod touches a neutral piece of metal. What is the final charge state (positive, negative, or neutral) of the metal? Use both charge diagrams and words to explain how this charge state is achieved.

b. A positively charged glass rod touches a neutral piece of metal. What is the final charge state of the metal? Use both charge diagrams and words to explain how this charge state is achieved.

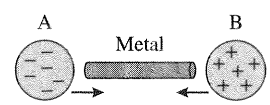
14. A lightweight, positively charged ball and a neutral rod hang by threads. They are close but not touching. A positively charged glass rod touches the hanging rod on the end opposite the ball, then the rod is removed.



a. Draw a picture of the final positions of the hanging rod and the ball if the rod is made of glass.

b. Draw a picture of the final positions of the hanging rod and the ball if the rod is metal.

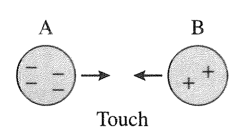
15. Two oppositely charged metal spheres have equal quantities of charge. They are brought into contact with a neutral metal rod.



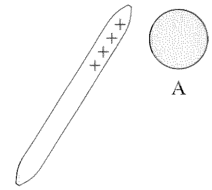
a. What is the final charge state of each sphere and of the rod?

b. Give a microscopic explanation, in terms of fundamental charges, of how these final states are reached. Use both charge diagrams and words.

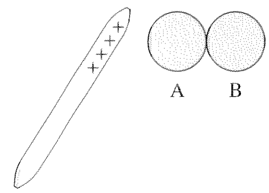
16. Metal sphere A has 4 units of negative charge and metal sphere B has 2 units of positive charge. The two spheres are brought into contact. What is the final charge state of each sphere? Explain.



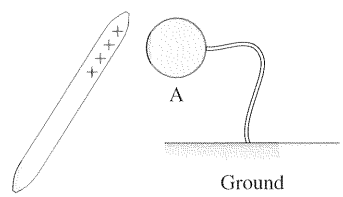
17. a. Metal sphere A is initially neutral. A positively charged rod is brought near, but not touching. Is A now positive, negative, or neutral? Explain.



b. Metal spheres A and B are initially neutral and are touching. A positively charged rod is brought near A, but not touching. Is A now positive, negative, or neutral? Explain.

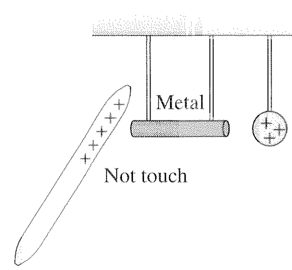


c. Metal sphere A is initially neutral. It is connected by a metal wire to the ground. A positively charged rod is brought near, but not touching. Is A now positive, negative, or neutral? Explain.



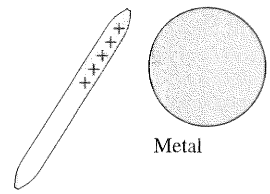
18. A lightweight, positively charged ball and a neutral metal rod hang by threads. They are close but not touching. A positively charged rod is held close to, but not touching, the hanging rod on the end opposite the ball.

a. Draw a picture of the final positions of the hanging rod and the ball. Explain your reasoning.

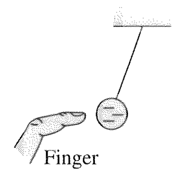


b. Suppose the positively charged rod is replaced with a negatively charged rod. Draw a picture of the final positions of the hanging rod and the ball. Explain your reasoning.

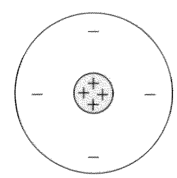
19. A positively charged rod is held near, but not touching, a neutral metal sphere.
    a. Add plusses and minuses to the figure to show the charge distribution on the sphere.
    b. Does the sphere experience a net force? If so, in which direction? Explain.



20. If you bring your finger near a lightweight, negatively charged hanging ball, the ball swings over toward your finger. Use charge diagrams and words to explain this observation.



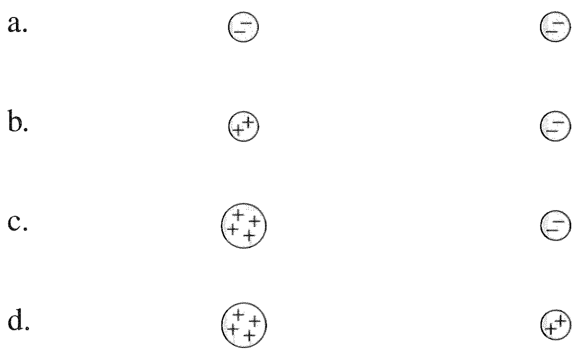
21. The figure shows an atom with four protons in the nucleus and four electrons in the electron cloud.
    a. Draw a picture showing how this atom will look if a positive charge is held just *above* the atom.



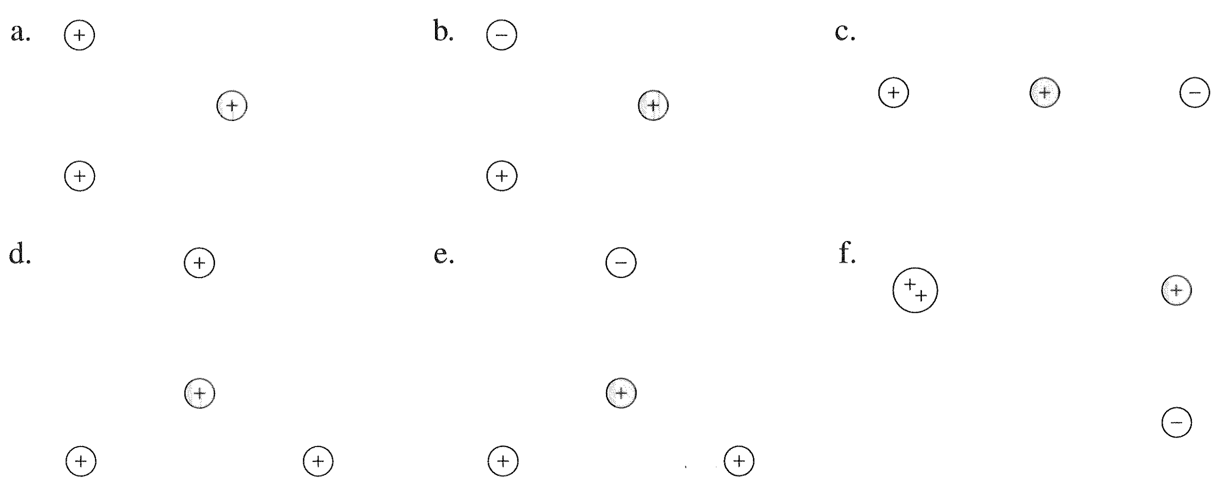
    b. Is there a net force on the atom? If so, in which direction? Explain.

25.4 Coulomb's Law

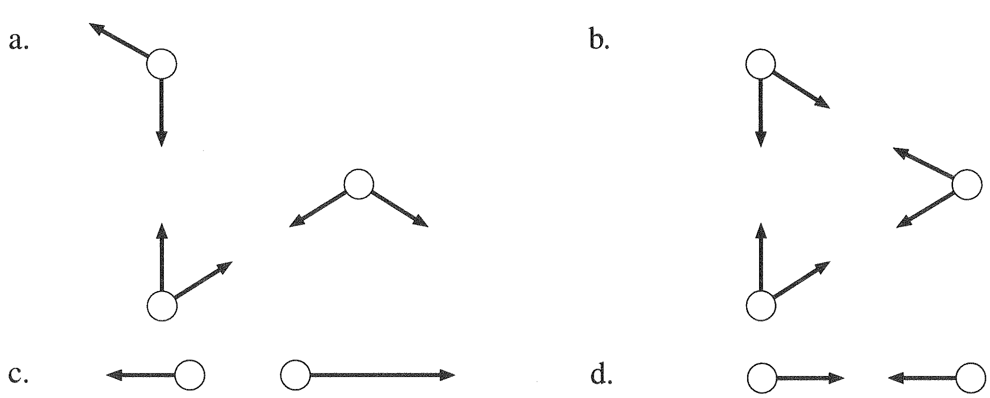
22. For each pair of charges, draw a force vector *on each charge* to show the electric force acting on that charge. The length of each vector should be proportional to the magnitude of the force. Each + and – symbol represents the same quantity of charge.



23. For each group of charges, use a **black** pen or pencil to draw the forces acting on the gray positive charge. Then use a **red** pen or pencil to show the net force on the gray charge. Label $\vec{F}_{net}$.



24. Can you assign charges (positive or negative) so that these forces are correct? If so, show the charges on the figure. (There may be more than one correct response.) If not, why not?

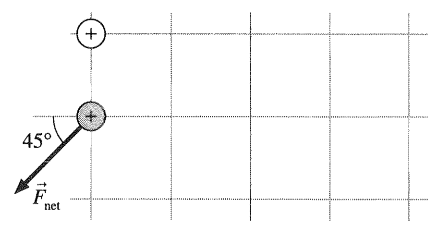


25. a. Draw a + on the figure below to show the position or positions where a proton would experience no net force.

b. Would the force on an electron at this position (or positions) be to the left, to the right, or zero?

26. Draw a – on the figure below to show the position or positions where an electron would experience no net force.

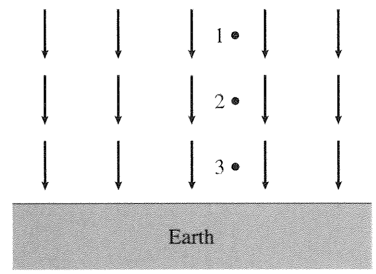
27. The gray positive charge experiences a net force due to two other charges: the +1 charge that is seen and a +4 charge that is not seen. Add the +4 charge to the figure at the correct position.



28. In your own words, describe what is meant by a "point charge."

25.5 The Concept of a Field

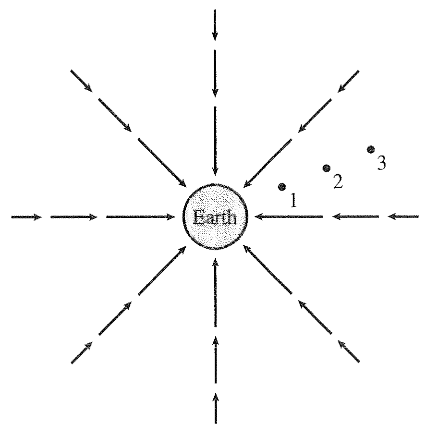
29. This is a uniform gravitational field near the earth's surface. Rank in order, from largest to smallest, the accelerations a_1 to a_3 of a small mass at points 1, 2, and 3.



Order:

Explanation:

30. This is the gravitational field of the earth. Rank in order, from largest to smallest, the accelerations a_1 to a_3 of a small mass at points 1, 2, and 3.

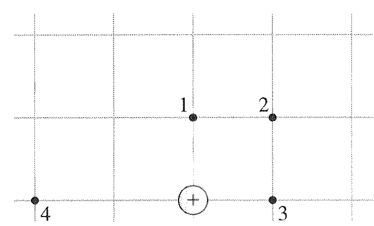


Order:

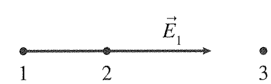
Explanation:

25.6 The Field Model

31. At points 1 to 4, draw an electric field vector with the proper direction and whose length is proportional to the electric field strength at that point.



32. The dots are three points in space. The electric field $\vec{E}_1$ at point 1 is shown.



a. Can you determine the direction of the electric field at point 2? If so, what is it? If not, why not?

b. Can you determine the direction of the electric field at point 3? If so, what is it? If not, why not?

33. a. The electric field of a point charge is shown at *one* point in space.

Can you tell if the charge is + or –? If not, why not?

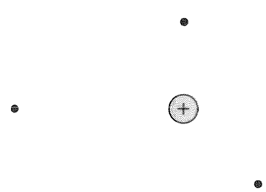
b. Here the electric field of a point charge is shown at two positions in space.

Now can you tell if the charge is + or –? Explain.

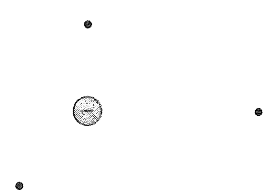
c. Can you determine the location of the charge? If so, draw it on the figure. If not, why not?

34. At the three points in space indicated with dots, draw the unit vector $\hat{r}$ that you would use to determine the electric field of the point charge.

a.



b.



35. a. This is the unit vector $\hat{r}$ associated with a positive point charge. Draw the electric field vector at this point in space.

b. This is the unit vector $\hat{r}$ associated with a negative point charge. Draw the electric field vector at this point in space.