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Objectives

- **Understand** the basic properties of electric charge.
- **Differentiate** between conductors and insulators.
- **Distinguish** between charging by contact, charging by induction, and charging by polarization.

End Of Slide

Properties of Electric Charge

- There are two kinds of electric charge.
  - Positive and Negative
  - like charges repel
  - unlike charges attract
- Electric charge is conserved.
  - Positively charged particles are called *protons*.
  - Uncharged particles are called *neutrons*.
  - Negatively charged particles are called *electrons*.

Electric Charge

End Of Slide

Properties of Electric Charge, *continued*

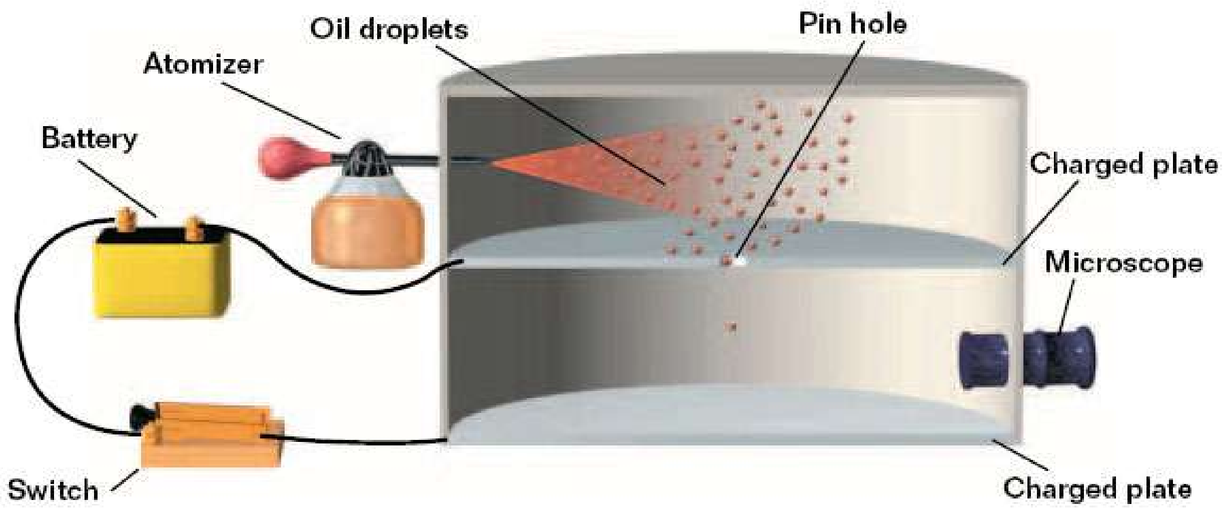
- Electric charge is *quantized.* That is, when an object is charged, its charge is always a multiple of a *fundamental unit of charge*.

- Charge is measured in coulombs (C).

- The fundamental unit of charge, *e*, is the magnitude of the charge of a single electron or proton.

$$e = 1.602\ 176 \times 10^{-19}\ \text{C}$$

The Milikan Experiment



Milikan’s Oil Drop Experiment

End Of Slide

Transfer of Electric Charge

- An **electrical conductor** is a material in which charges can move freely.
- An **electrical insulator** is a material in which charges cannot move freely.

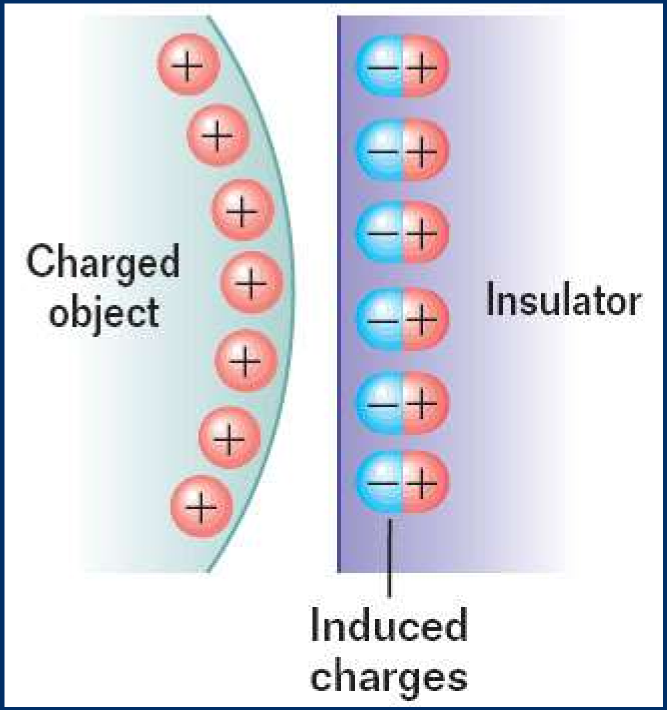
Transfer of Electric Charge, *continued*

- Insulators and conductors can be charged by contact.
- Conductors can be charged by **induction**.
- **Induction** is a process of charging a conductor by bringing it near another charged object and grounding the conductor. (charging without contact).

Charging by Induction

End Of Slide

Transfer of Electric Charge, *continued*



- A surface charge can be induced on insulators by *polarization*.
- With polarization, the charges within individual molecules are realigned such that the molecule has (making) a slight charge separation.

Objectives

- **Calculate** electric force using Coulomb's law.
- **Compare** electric force with gravitational force.
- **Apply** the superposition principle to find the resultant force on a charge and to find the position at which the net force on a charge is zero.

Coulomb's Law

- Two charges near one another exert a force on one another called the *electric force.*

- Coulomb's law *states that the electric force is propor-tional to the magnitude of each charge and inversely proportional to the square of the distance between them.*

$$k_C = 8.99 \times 10^9 \frac{N \bullet m^2}{C^2}$$

$$F_{electric} = k_C \left(\frac{q_1 q_2}{r^2} \right)$$

$$\text{electric force} = \text{Coulomb constant} \times \frac{(\text{charge 1})(\text{charge 2})}{(\text{distance})^2}$$

End Of Slide

Coulomb's Law, *continued*

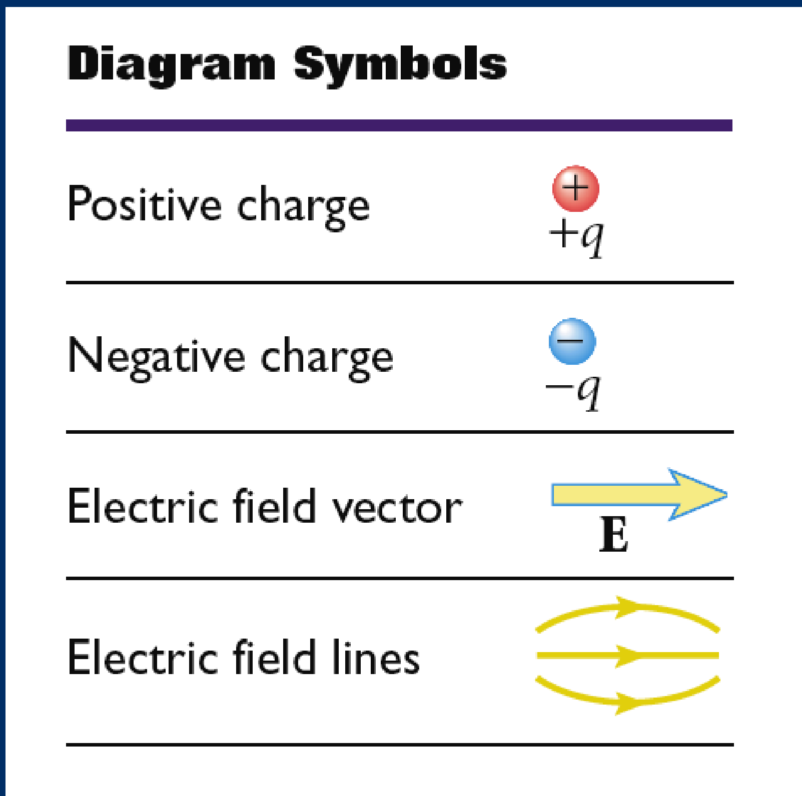
- The Coulomb force is a *field force*.
- A field force is a force that is exerted by one object on another even though there is (with) no physical contact between the two objects.

Objectives

- **Calculate** electric field strength.
- **Draw** and **interpret** electric field lines.
- **Identify** the four properties associated with a conductor in electrostatic equilibrium.

End Of Slide

Electric Field Lines



- The number of electric field lines is proportional to the electric field strength.
- Electric field lines are tangent to the electric field vector at any point.

Rules for Drawing Electric Field Lines

End Of Slide

Rules for Sketching Fields Created by Several Charges

Conductors in Electrostatic Equilibrium

- The electric field is zero everywhere inside the conductor.
- Any excess charge on an isolated conductor resides entirely on the conductor's outer surface.
- The electric field just outside a charged conductor is perpendicular to the conductor's surface.
- On an irregularly shaped conductor, charge tends to accumulate where the radius of curvature of the surface is smallest, that is, at sharp points.

Multiple Choice

1. In which way is the electric force similar to the gravitational force?

A. Electric force is proportional to the mass of the object.

B. Electric force is similar in strength to gravitational force.

C. Electric force is both attractive and repulsive.

D. Electric force decreases in strength as the distance between the charges increases.

Multiple Choice, *continued*

1. In which way is the electric force similar to the gravitational force?

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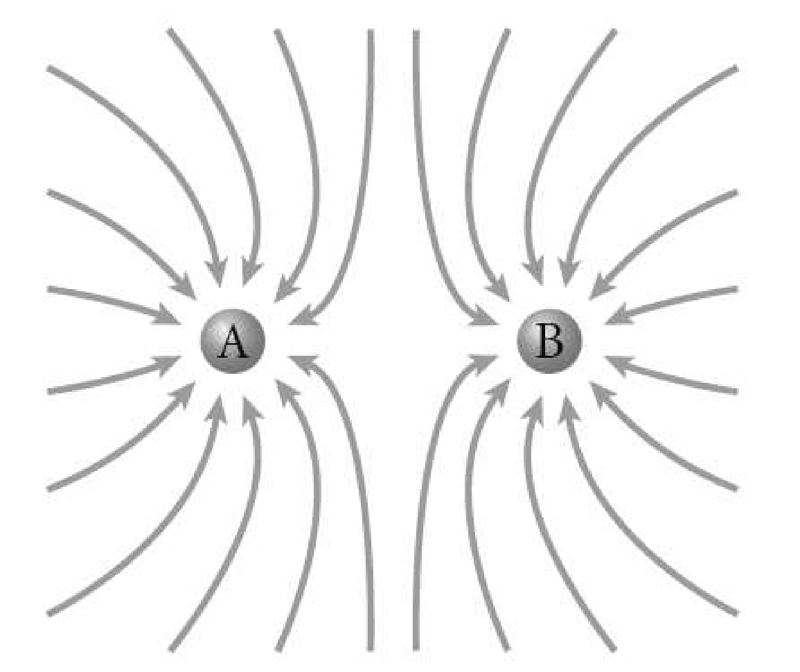
Multiple Choice, *continued*



2. What must the charges be for A and B in the figure so that they produce the electric field lines shown?

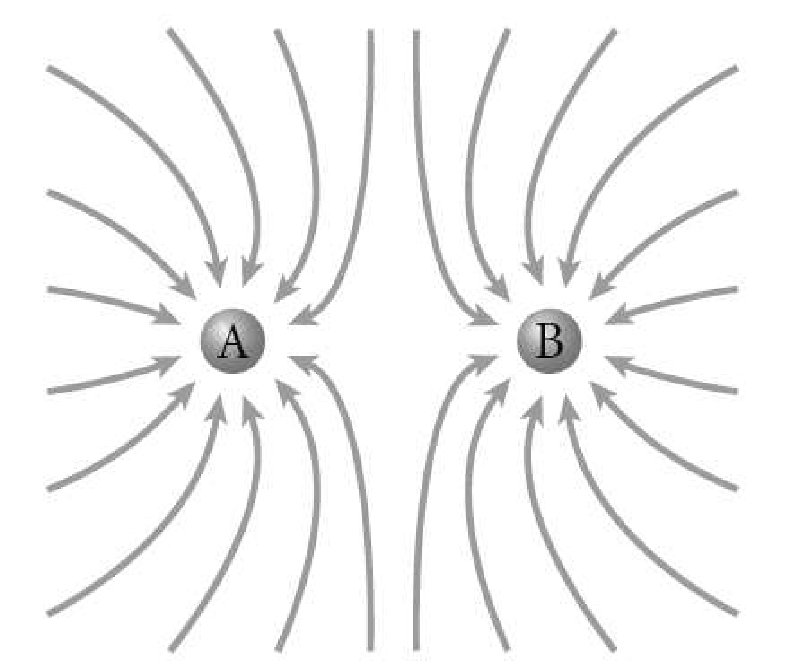
F. A and B must both be positive.

G. A and B must both be negative.

H. A must be negative, and B must be positive.

J. A must be positive, and B must be negative.

Multiple Choice, *continued*



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F. A and B must both be positive.

G. A and B must both be negative.

H. A must be negative, and B must be positive.

J. A must be positive, and B must be negative.

Multiple Choice, *continued*

3. Which activity does not produce the same results as the other three?

A. sliding over a plastic-covered automobile seat

B. walking across a woolen carpet

C. scraping food from a metal bowl with a metal spoon

D. brushing dry hair with a plastic comb

Multiple Choice, *continued*

3. Which activity does not produce the same results as the other three?

A. sliding over a plastic-covered automobile seat

B. walking across a woolen carpet

C. scraping food from a metal bowl with a metal spoon

D. brushing dry hair with a plastic comb

Multiple Choice, *continued*

4. By how much does the electric force between two charges change when the distance between them is doubled?

F. 4

G. 2

H. $\frac{1}{2}$

J. $\frac{1}{4}$

Multiple Choice, *continued*

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F. 4

G. 2

H. $\frac{1}{2}$

J. $\frac{1}{4}$

Multiple Choice, *continued*

Use the passage below to answer questions 5–6.

A negatively charged object is brought close to the surface of a conductor, whose opposite side is then grounded.

5. What is this process of charging called?

A. charging by contact

B. charging by induction

C. charging by conduction

D. charging by polarization

Multiple Choice, *continued*

Use the passage below to answer questions 5–6.

A negatively charged object is brought close to the surface of a conductor, whose opposite side is then grounded.

5. What is this process of charging called?

A. charging by contact

B. charging by induction

C. charging by conduction

D. charging by polarization

Multiple Choice, *continued*

Use the passage below to answer questions 5–6.

A negatively charged object is brought close to the surface of a conductor, whose opposite side is then grounded.

6. What kind of charge is left on the conductor's surface?

F. neutral

G. negative

H. positive

J. both positive and negative

Multiple Choice, *continued*

Use the passage below to answer questions 5–6.

A negatively charged object is brought close to the surface of a conductor, whose opposite side is then grounded.

6. What kind of charge is left on the conductor's surface?

F. neutral

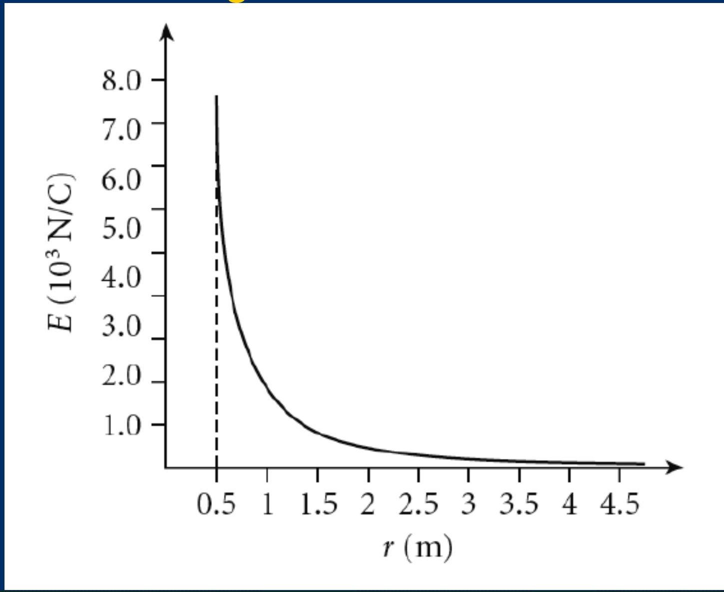
G. negative

H. positive

J. both positive and negative

Multiple Choice, *continued*

Use the graph below to answer questions 7–10. The graph shows the electric field strength at different distances from the center of the charged conducting sphere of a Van de Graaff generator.



7. What is the electric field strength 2.0 m from the center of the conducting sphere?

A. 0 N/C

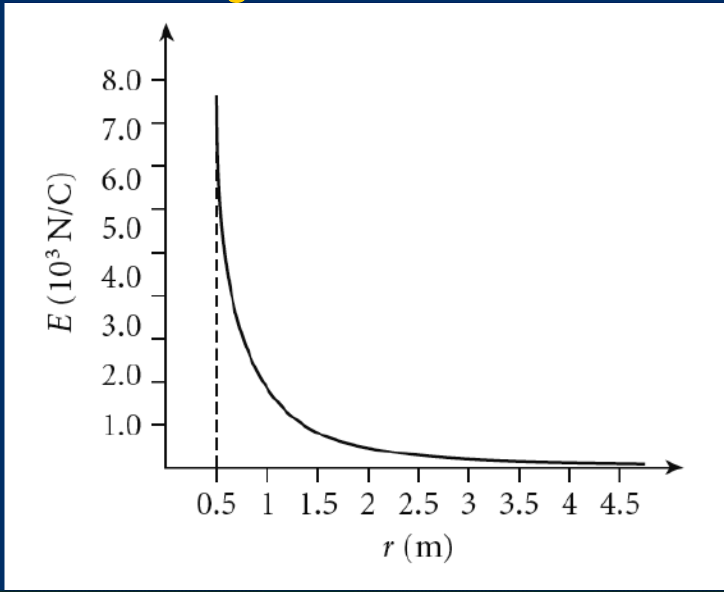
B. 5.0×10^2 N/C

C. 5.0×10^3 N/C

D. 7.2×10^3 N/C

Multiple Choice, *continued*

Use the graph below to answer questions 7–10. The graph shows the electric field strength at different distances from the center of the charged conducting sphere of a Van de Graaff generator.



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Multiple Choice, *continued*

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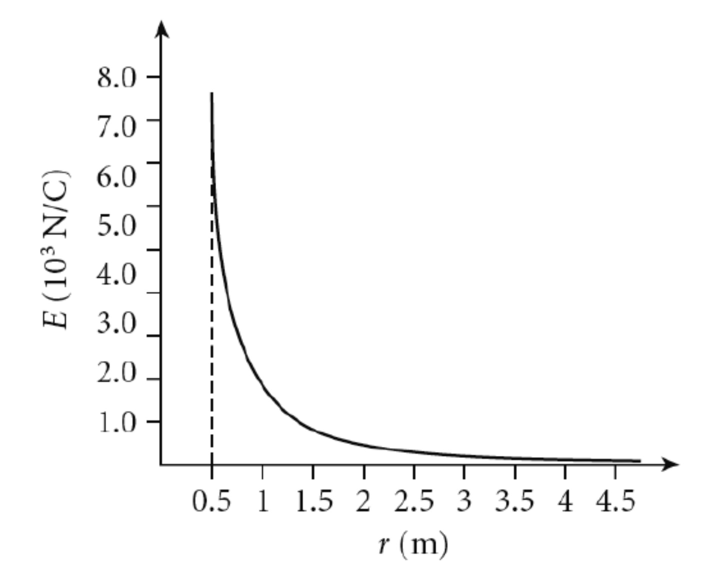

8. What is the strength of the electric field at the surface of the conducting sphere?

F. 0 N/C

G. 1.5×10^2 N/C

H. 2.0×10^2 N/C

J. 7.2×10^3 N/C

Multiple Choice, *continued*

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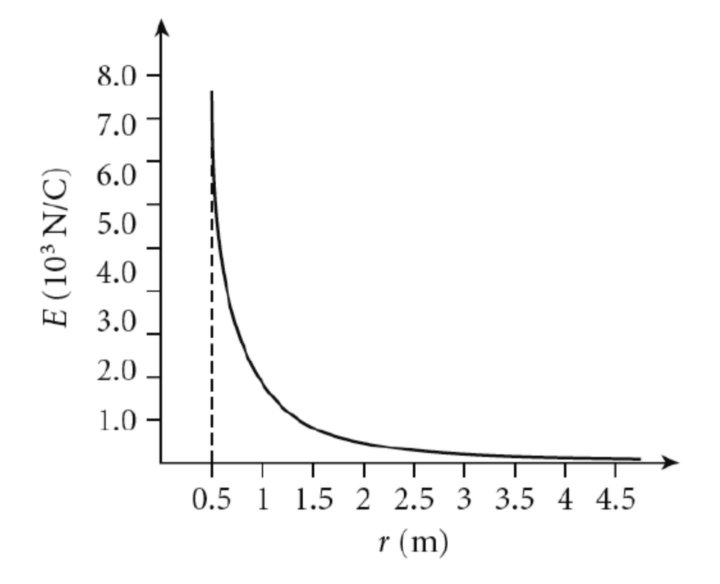

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Multiple Choice, *continued*

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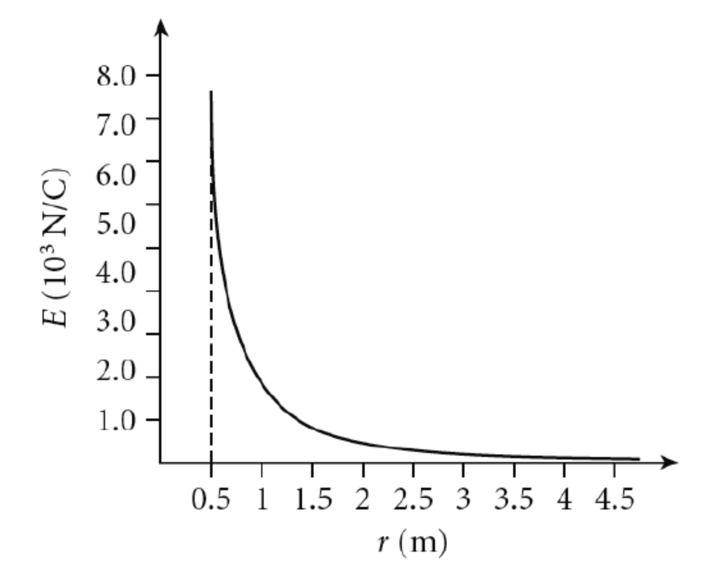


9. What is the strength of the electric field inside the conducting sphere?

A. 0 N/C

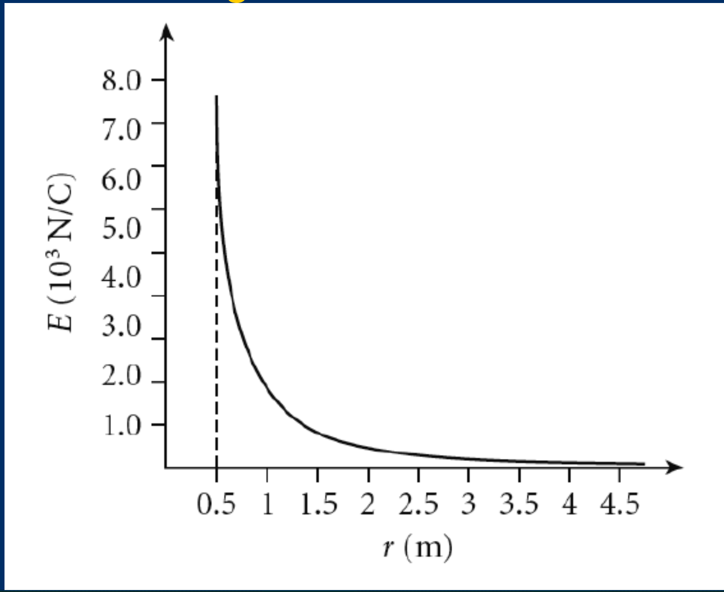
B. 1.5×10^2 N/C

C. 2.0×10^2 N/C

D. 7.2×10^3 N/C

Multiple Choice, *continued*

Use the graph below to answer questions 7–10. The graph shows the electric field strength at different distances from the center of the charged conducting sphere of a Van de Graaff generator.



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Multiple Choice, *continued*

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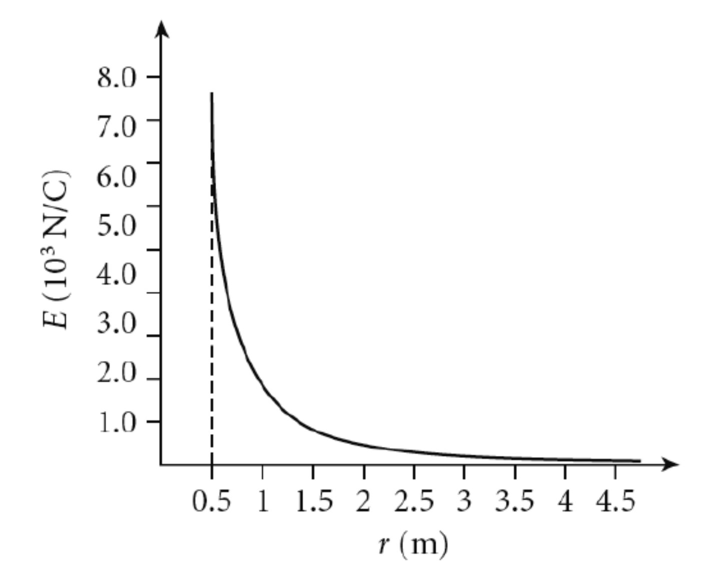


10. What is the radius of the conducting sphere?

F. 0.5 m

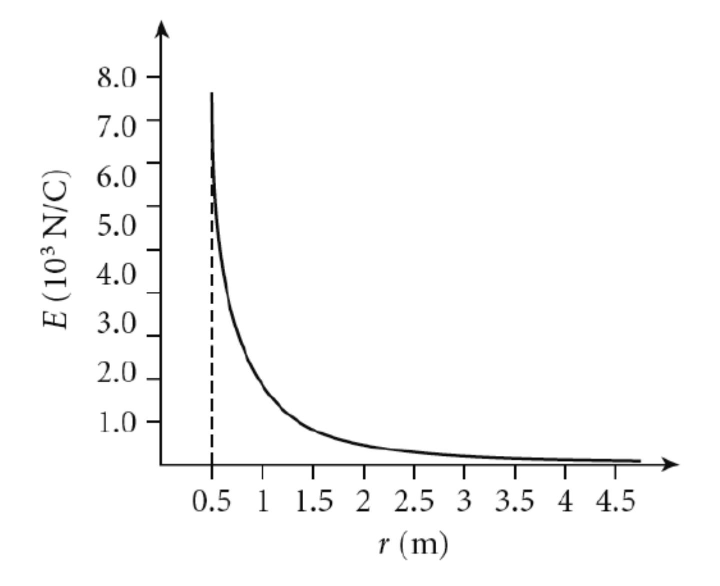
G. 1.0 m

H. 1.5 m

J. 2.0 m

Multiple Choice, *continued*

Use the graph below to answer questions 7–10. The graph shows the electric field strength at different distances from the center of the charged conducting sphere of a Van de Graaff generator.



10. What is the radius of the conducting sphere?

F. 0.5 m

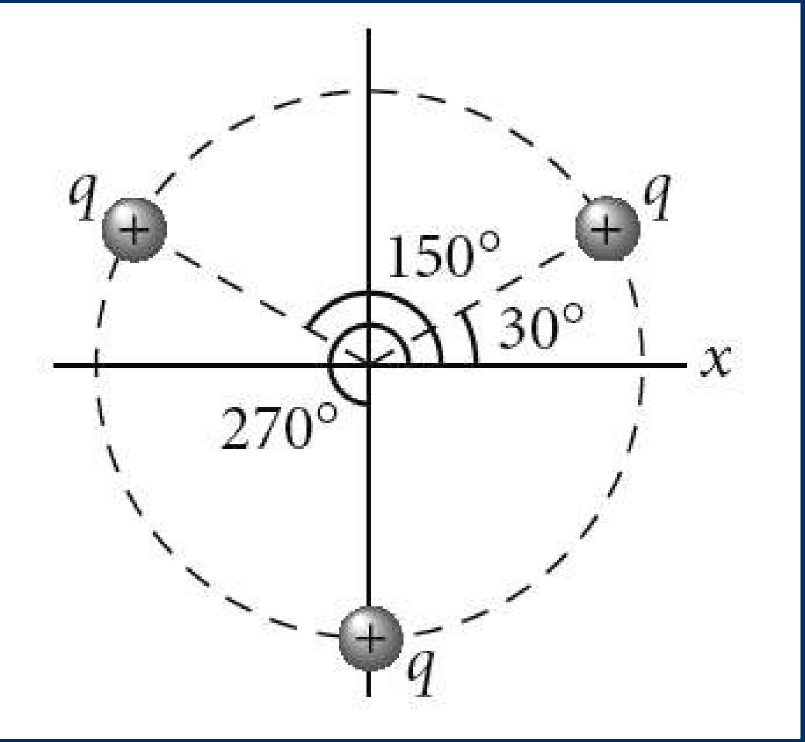
G. 1.0 m

H. 1.5 m

J. 2.0 m

Short Response

11. Three identical charges (q = +5.0 mC) are along a circle with a radius of 2.0 m at angles of 30°, 150°, and 270°, as shown in the figure. What is the resultant electric field at the center?



Short Response, *continued*

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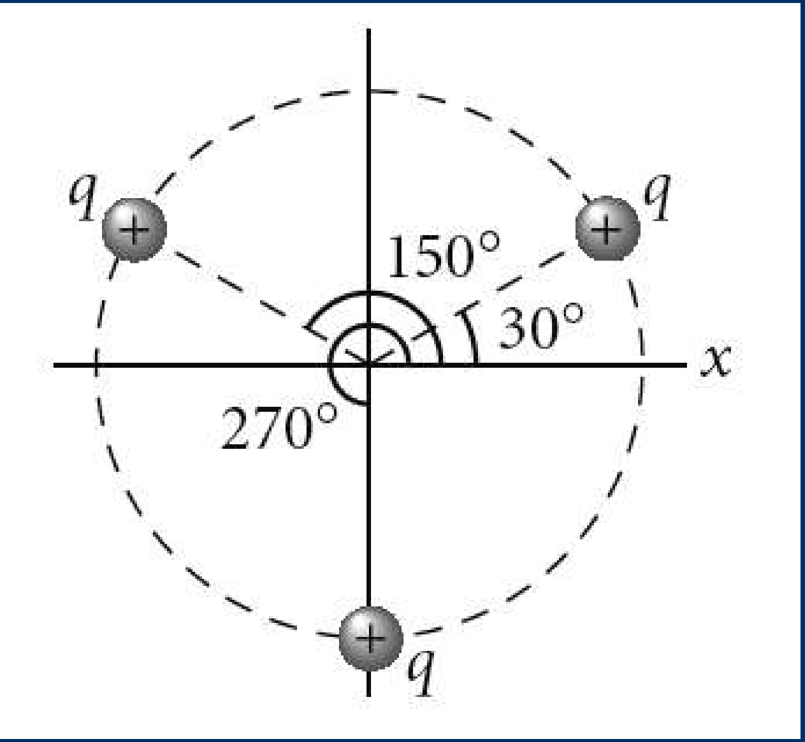


Answer: 0.0 N/C

Short Response, *continued*

12. If a suspended object is attracted to another object that is charged, can you conclude that the suspended object is charged? Briefly explain your answer.

Short Response, *continued*

12. If a suspended object is attracted to another object that is charged, can you conclude that the suspended object is charged? Briefly explain your answer.

Answer: not necessarily; The suspended object might have a charge induced on it, but its overall charge could be neutral.

Short Response, *continued*

13. One gram of hydrogen contains 6.02×10^{23} atoms, each with one electron and one proton. Suppose that 1.00 g of hydrogen is separated into protons and electrons, that the protons are placed at Earth's north pole, and that the electrons are placed at Earth's south pole. Assuming the radius of Earth to be 6.38×10^6 m, what is the magnitude of the resulting compressional force on Earth?

Short Response, *continued*

13. One gram of hydrogen contains 6.02×10^{23} atoms, each with one electron and one proton. Suppose that 1.00 g of hydrogen is separated into protons and electrons, that the protons are placed at Earth's north pole, and that the electrons are placed at Earth's south pole. Assuming the radius of Earth to be 6.38×10^{6} m, what is the magnitude of the resulting compressional force on Earth?

Answer: 5.12×10^{5} N

Short Response, *continued*

14. Air becomes a conductor when the electric field strength exceeds 3.0×10^6 N/C. Determine the maximum amount of charge that can be carried by a metal sphere 2.0 m in radius.

Short Response, *continued*

14. Air becomes a conductor when the electric field strength exceeds 3.0×10^6 N/C. Determine the maximum amount of charge that can be carried by a metal sphere 2.0 m in radius.

Answer: 1.3×10^{-3} C

Extended Response

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^{6} m/s.

15. What is the magnitude of the acceleration of the proton?

Extended Response, *continued*

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^6 m/s.

15. What is the magnitude of the acceleration of the proton?

Answer: 6.1×10^{10} m/s^2

Extended Response, *continued*

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^{6} m/s.

16. How long does it take the proton to reach this speed?

Extended Response, *continued*

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^{6} m/s.

16. How long does it take the proton to reach this speed?

Answer: 2.0×10^{-5} s

Extended Response, *continued*

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^{6} m/s.

17. How far has it moved in this time interval?

Extended Response, *continued*

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^6 m/s.

17. How far has it moved in this time interval?

Answer: 12 m

Extended Response, *continued*

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^{6} m/s.

18. What is its kinetic energy at the later time?

Extended Response, *continued*

Use the information below to answer questions 15–18.

A proton, which has a mass of 1.673×10^{-27} kg, accelerates from rest in a uniform electric field of 640 N/C. At some time later, its speed is 1.2×10^{6} m/s.

18. What is its kinetic energy at the later time?

Answer: 1.2×10^{-15} J

Extended Response, *continued*

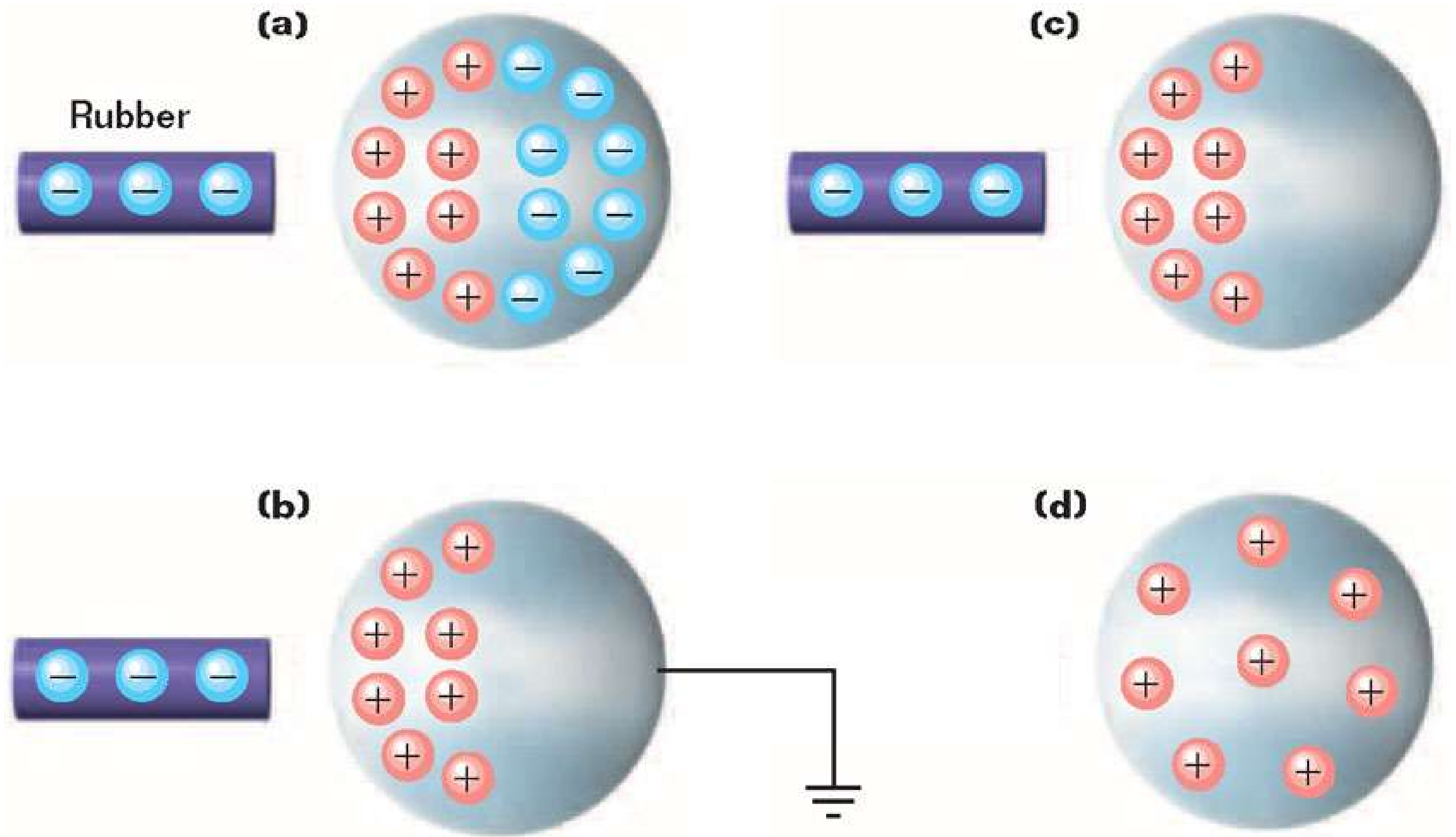
19. A student standing on a piece of insulating material places her hand on a Van de Graaff generator. She then turns on the generator. Shortly thereafter, her hairs stand on end. Explain how charge is or is not transferred in this situation, why the student is not shocked, and what causes her hairs to stand up after the generator is started.

Extended Response, *continued*

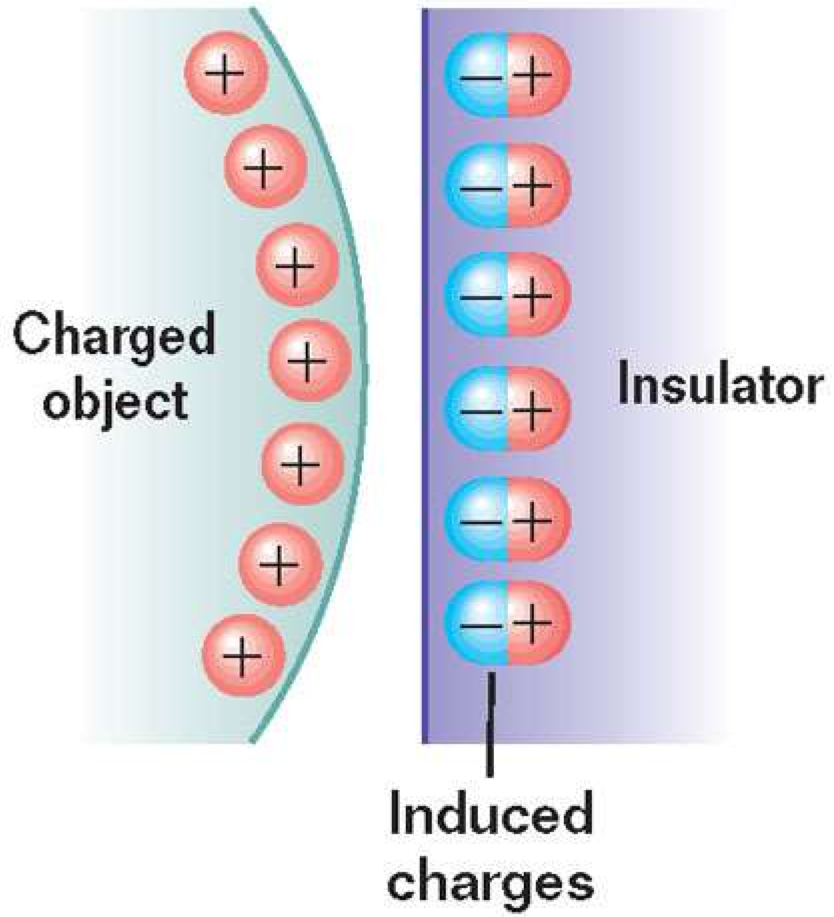
19. (See previous slide for question.)

Answer: The charge on the sphere of the Van de Graaff generator is transferred to the student by means of conduction. This charge remains on the student because she is insulated from the ground. As there is no path between the student and the generator and the student and the ground by which charge can escape, the student is not shocked. The accumulation of charges of the same sign on the strands of the student's hair causes the strands to repel each other and so stand on end.

Charging By Induction



Transfer of Electric Charge



Electric Field Lines

Diagram Symbols

Positive charge	$+q$
Negative charge	$-q$
Electric field vector	**E**
Electric field lines