Key

Electrostatics

1. What are the elementary charged particles and what are their charges?

   Proton = $+1.602 \times 10^{-19}$ C

   electron = -1.602×10^{-19} C

2. Compare/contrast insulators and conductors.

   Insulators -- don't allow charges to move across/through them easily

   Conductors -- allow charges to move across/through them easily

3. How can an object acquire a net charge?

   By gaining or losing electrons

4. What are the ways that an object can become charged? How does each one work?

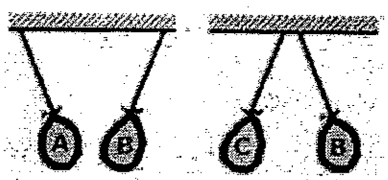
   Friction -- rub objects together; electrons go to the object with higher affinity → the 2 objects will end with opposite charges

   Conduction -- touching a charged object can allow charges to spread out onto a previously neutral object; objects end up with the same charge

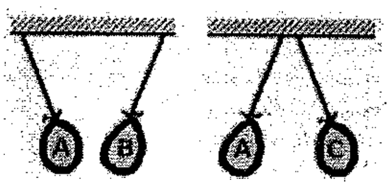
   Induction -- a charged object is brought near a neutral object; the neutral object is then grounded; the object now has the opposite charge

   Polarization -- A charged object is brought near a neutral object; charges separate and the objects attract

5.



Balloon	Conclusive evidence to conclude that the charge is +, -, neutral
A	+
B	negative
C	—



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A	+
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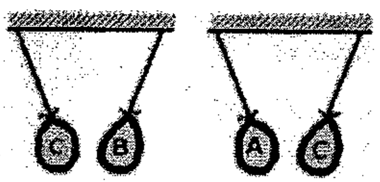


Balloon	Conclusive evidence to conclude that the charge is +, -, neutral
A	—
B	negative
C	+

6.

Triboelectric Series

Celluloid
Sulfur
Rubber
Copper, Brass
Amber
Wood
Cotton
Human Skin
Silk
Cat Fur
Wool
Glass
Rabbit Fur

When you pull a **cotton** sweater off your **skin**, electrons are transferred from the ________________ (cotton, skin) to the ________________ (cotton, skin). As a result, your body acquires a __________ (+, -) charge and the cotton sweater acquires a __________ (+ , -) charge.

When you rub a **glass** rod with a **silk** cloth, electrons are transferred from the ________________ (glass, silk) to the ________________ (glass, silk). As a result, the glass rod acquires a __________ (+, -) charge and the silk cloth acquires a __________ (+ , -) charge.

Suppose you rub a rubber rod with a silk cloth and a second rubber rod with a wool sweater. The silk cloth will acquire a _________ (+ , -) charge; the wool sweater will acquire a _________ (+, -) charge. The sweater and the cloth will then be observed to ____________________ (attract, repel, not interact with) each other.

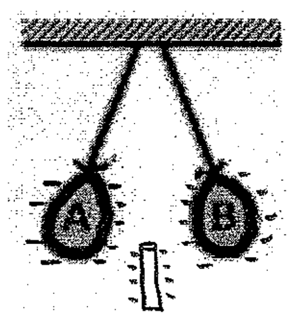
7.

T or F?		Statement
T	a.	When two objects made of different materials are rubbed together, they each acquire a charge.
F	b.	When two objects made of different materials are rubbed together, they will either be both charged positively or both charged negatively.
T	c.	When two objects made of different materials are rubbed together, they will attract each other after the charging process.
F	d.	When two objects made of different materials are rubbed together, one object gains electrons and the other objects gains protons.
T	e.	When two objects made of different materials are rubbed together, the total amount of charge among the two objects remains unchanged.

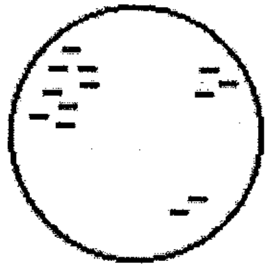
8.

Balloons A and B are suspended from the ceiling by light threads; each balloon is made of rubber. Balloon A was rubbed with animal fur. Balloon B was rubbed with animal fur. If a negatively charged plastic tube were inserted between the two balloons, then one would observe that the two balloons _____. (Refer to the triboelectric series.)

a. would deflect even more from a vertical orientation
b. would relax to a more vertical orientation
c. would not be effected at all by the presence of the plastic tube.

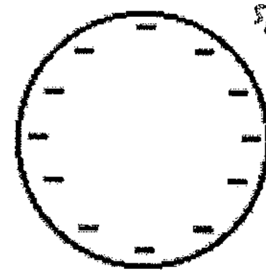


9. Insulator



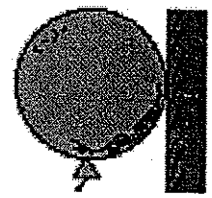
Consider these two spheres. They have both been charged. In one case the charge is isolated in three distinct locations; in the other case, the excess charge is even distributed about the surface of the sphere. Which one of these spheres is made of an insulating material and which is made of a conducting material? Label which is which and support your answer with an explanation.

Conductor -- charges spread



10.

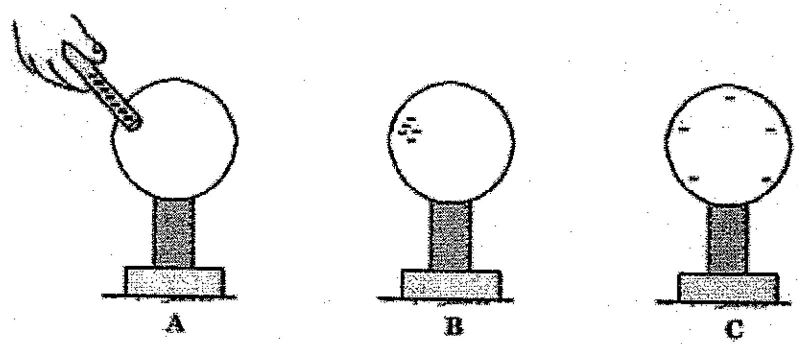
A balloon is charged by rubbing it with animal fur. It is then pressed against a wooden cabinet. The balloon and cabinet attract, seeming to defy the force of gravity. This attraction is best explained by ____.



a. induction charging of the wood
b. frictional charging of the wood
(c.) polarization of wood molecules
d. polarization of balloon molecules

11.

Consider the conduction charging process described below:



A: A teacher holds a negatively charged metal bar by its insulating handle and touches it to a metal sphere (attached to an insulating stand).
B: The teacher pulls the metal bar away and the metal sphere acquires a charge.
C: The excess negative charge spreads uniformly about the surface of the metal sphere.

Diagram A is the charging step. How does the sphere become charged?
a. Electrons move from the insulating stand into the sphere.
(b.) Electrons move from the charged metal bar into the sphere.
c. Protons move from the sphere into the negatively charged bar.

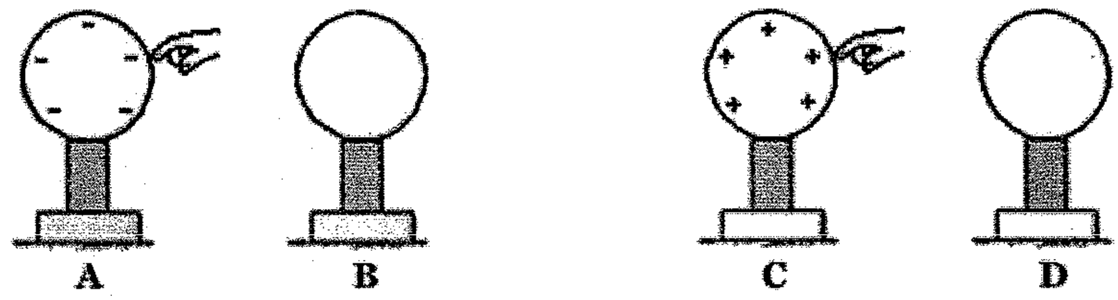
When the metal bar is pulled away in Diagram B, <u>the metal bar</u> is _____.
a. positively charged
b. electrically neutral
(c.) still negatively charged, but has fewer excess electrons than it previously did.

Diagram C shows the excess negative charge distributed differently than it is in Diagram B. Explain why the excess negative charge would distribute itself as it does in Diagram C.

(-) charges repel each other

12.

Two different processes are shown in the diagrams below:



A: A negatively charged metal sphere is touched.
B: The hand is pulled away and the sphere is then electrically neutral.

C: A positively charged metal sphere is touched.
D: The hand is pulled away and the sphere is then electrically neutral.

The process of neutralizing the charged spheres as depicted above is known as _____.
a. charging b. polarization c. induction d. grounding

When the negatively charged sphere is touched, ______ move from the _______ to the _______.
a. electrons, sphere, hand b. electrons, hand, sphere
c. protons, sphere, hand d. protons, hand, sphere

When the positively charged sphere is touched, ______ move from the _______ to the _______.
a. electrons, sphere, hand b. electrons, hand, sphere
c. protons, sphere, hand d. protons, hand, sphere

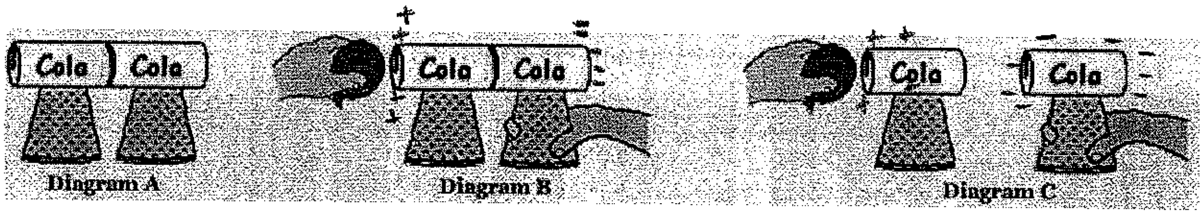
13. Missing Picture
When the pop can is touched by the hand, ______ move from the ______ to the _______.
a. protons, hand, can b. protons, can, hand
c. electrons, hand, can d. electrons, can, hand

This process causes the can to acquire a _____ charge.
a. negative b. positive c. neutral

When the induction charging process is complete, the balloon is _____.
a. positively charged b. electrically neutral
c. still negatively charged, only having fewer excess electrons as before the process began
d. still negatively charged, having the same amount of negative charge as it previously had

In general, the use of a negatively charged object to charge another object by induction causes the other object to acquire a _____ charge.
a. positive b. negative

14.



In terms of electron movement, explain what is happening in Diagrams B and C above. Finally, state the charge acquired by the left and the right can as a result of this process.

Left Can	Right Can
+	−

15.

Two charged objects have a repulsive force of .080 N. If the charge of one of the objects is doubled, then what is the new force? 0.16 N

Two charged objects have a repulsive force of .080 N. If the charge of both of the objects is doubled, then what is the new force?

0.32 N

16.

Two charged objects have a repulsive force of .080 N. If the distance separating the objects is doubled, then what is the new force? 0.02 N

Two charged objects have a repulsive force of .080 N. If the distance separating the objects is tripled, then what is the new force? 0.0089 N

Two charged objects have an attractive force of .080 N. If the distance separating the objects is quadrupled, then what is the new force? 0.005 N

Two charged objects have a repulsive force of .080 N. If the distance separating the objects is halved, then what is the new force? 0.32 N

Two charged objects have a repulsive force of .080 N. If the charge of one of the objects is doubled, and the distance separating the objects is doubled, then what is the new force? $\frac{2}{(2)^2} = \frac{1}{4}$ 0.04 N

Two charged objects have a repulsive force of .080 N. If the charge of both of the objects is doubled and the distance separating the objects is doubled, then what is the new force? $\frac{(2)(2)}{(2)^2} = 1$ 0.08 N

Two charged objects have an attractive force of .080 N. If the charge of one of the objects is increased by a factor of four, and the distance separating the objects is doubled, then what is the new force? $\frac{(4)}{(2)^2} = 1$ 0.08 N

Two charged objects have an attractive force of .080 N. If the charge of one of the objects is tripled and the distance separating the objects is tripled, then what is the new force?

$\frac{3}{(3)^2} = \frac{1}{3}$ 0.027 N

17. A balloon with a charge of 4.0×10^{-5} C is held a distance of 0.10 m from a second balloon with the same charge. Calculate the electrostatic force between them.

$$F_e = \frac{(8.99\times10^{9})(4.0\times10^{-5})(4.0\times10^{-5})}{(0.1)^2} = 1438.4\ N$$

18. Calculate the electrical force (in Newtons) exerted between a 22-gram balloon with a charge of -2.6 μC and a wool sweater with a charge of +3.8 μC; the separation distance is 0.75 m. (NOTE: a μC or microCoulomb is a unit of charge; 10^6 μC = 1 C)

$$F_e = \frac{(8.99\times10^{9})(2.6\times10^{-6})(3.8\times10^{-6})}{(.75)^2} = 0.158\ N$$

19. Suppose that two equally charged spheres attract each other with a force of -0.492 N when placed a distance of 29.1 cm from each other. Determine the charge of the spheres.

$$0.492 = \frac{(8.99\times10^{9})\,q^2}{(.291)^2}$$

$q_1 = 2.153\times10^{-6}$ C

$q_2 = -2.153\times10^{-6}$ C

20. How far apart are two electrons if they exert a force of repulsion of 1.0 N on each other?

$$1.0 = \frac{(8.99\times10^{9})(1.602\times10^{-19})(1.602\times10^{-19})}{r^2}$$

$r = 1.52\times10^{-14}$ m

21. A conducting sphere with a charge of -5 μC is brought in contact with an identical conducting sphere with a charge of 3 μC.

a. What is the charge of each sphere after touching? -1 μC

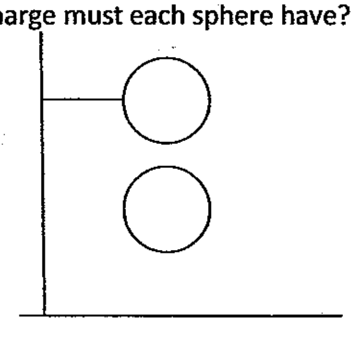
b. How many electrons are transferred during the touch, and where do they move?

$$\frac{4\mu C}{1} \times \frac{1e^-}{1.602\times10^{-19}C} = 2.5\times10^{19}$$ electrons move from the (-) sphere to the (+) sphere

22. Two identical conducting spheres with charges 2 μC and -6 μC are brought together and touched, then moved 4cm apart. What is the electrostatic force between them?

$$F_e = \frac{(8.99\times10^{9})(-2\times10^{-6})(-2\times10^{-6})}{(.04)^2} = 22.5\ N$$ repulsive

23. The spheres are both 2.0 g and have the same magnitude of charge. They are separated by a distance of 3.0 cm. In order for the bottom sphere to hover and not touch the ground, what charge must each sphere have?



$$F_g = F_e$$

$$mg = \frac{Kqq}{r^2}$$

$$(.002)(9.8) = \frac{(8.99\times10^{9})q^2}{(.03)^2}$$

4.4×10^{-8} C = q

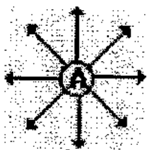
One is 4.4×10^{-8} C
the other is -4.4×10^{-8} C

Electric Fields

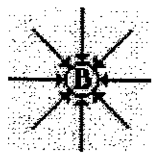
24.

Electric field lines begin on ______ (+, -) charges or at infinity and terminate on ______ (-, +) charges or infinity. The number of lines that emanate from a charge or approach a charge depends upon ___relative charge___. At locations where a line meets the surface of a charge, the lines are drawn in a __________ (tangent, radial) direction. The strength of the electric field is ______________ (smallest, greatest) wherever the lines are closest together.

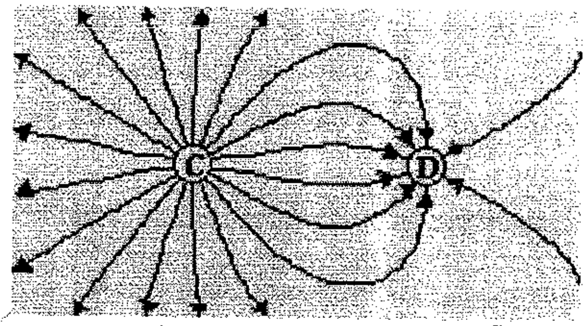
25.



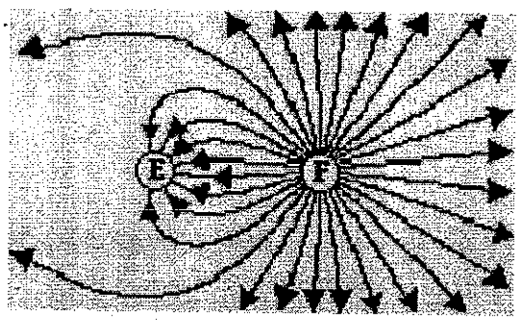
A: + or -



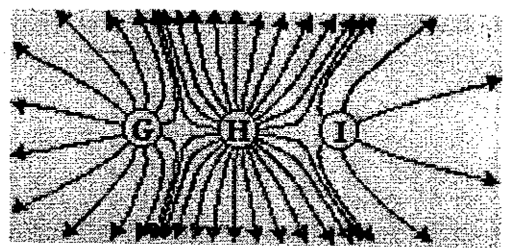
B: + or -



C: + or - D: + or -

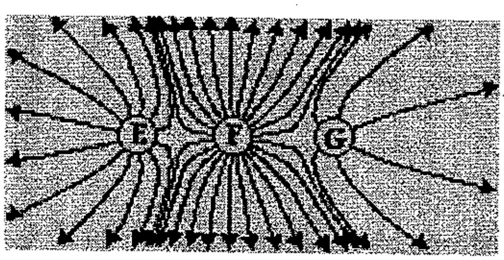


E: + or - F: + or -

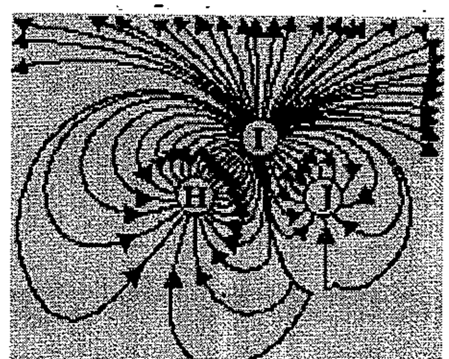


G: + or - H: + or - I: + or -

26.



Ranking: __G__ < __E__ < __F__

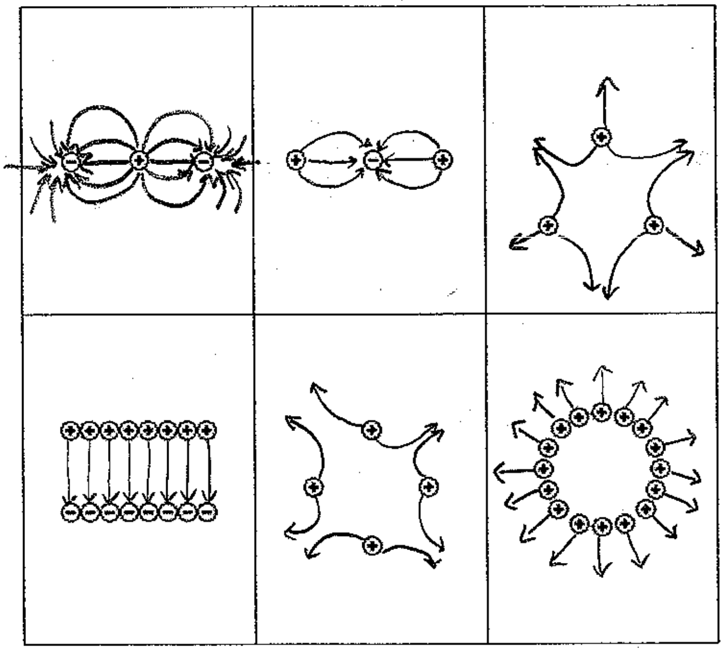


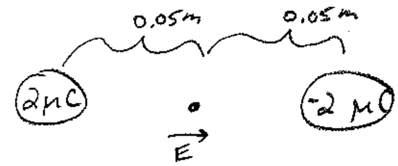
Ranking: __J__ < __H__ < __I__

→ |charge|

27.

Draw the electric field lines for the following configurations of charges. Place arrows upon your electric field lines.





28. Two point charges are 10.0 cm apart and have charges of 2.0 μC and –2.0 μC, respectively. What is the magnitude of the electric field at the midpoint between the two charges?

$E = \frac{kq_1}{r^2} + \frac{kq_2}{r^2}$ $\quad E = \frac{2kq}{r^2} = \frac{2(8.99\times10^9)(2\times10^{-6})}{(.05)^2} = 14384000\ \frac{N}{C}$

* Same q and r

29. Two point charges are 4.0 cm apart and have values of 30.0 μC and –30.0 μC, respectively. What is the electric field at the midpoint between the two charges? ($k_C = 8.99 \times 10^9\ N{\bullet}m^2/C^2$)

$E = \frac{kq_1}{r^2} + \frac{kq_2}{r^2}$ * Same q and r $\quad E = \frac{(2)(8.99\times10^9)(30\times10^{-6})}{(.02)^2} = 1.35\times10^9\ \frac{N}{C}$

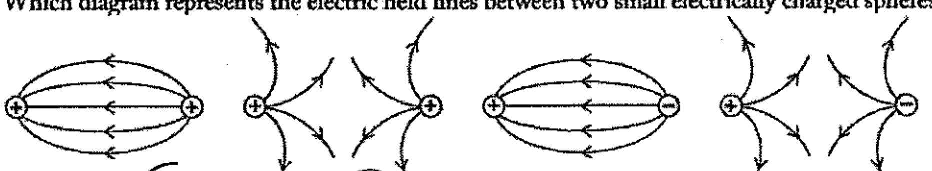
30. An electric field of 3279 N/C is produced by a charge of 5.72×10^{-11} C. For this field strength, what is the distance to the charge? ($k_C = 8.99 \times 10^9 Nm^2/C^2$)

$E = \frac{kq}{r^2} \quad 3279 = \frac{(8.99\times10^9)(5.72\times10^{-11})}{r^2}$

$r = 0.0125m$

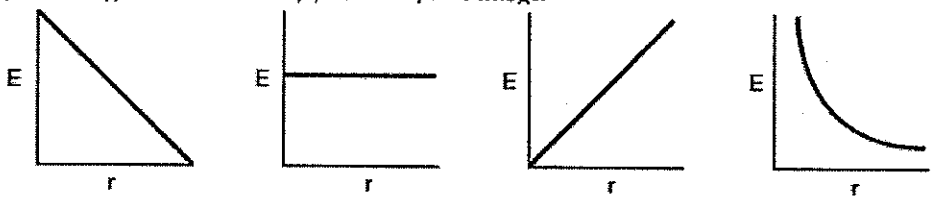
31.

Which diagram represents the electric field lines between two small electrically charged spheres?



(1) (2) (3) (4)

32.
Which graph best represents the relationship between the magnitude of the electric field strength, E, around a point charge and the distance, r, from the point charge?

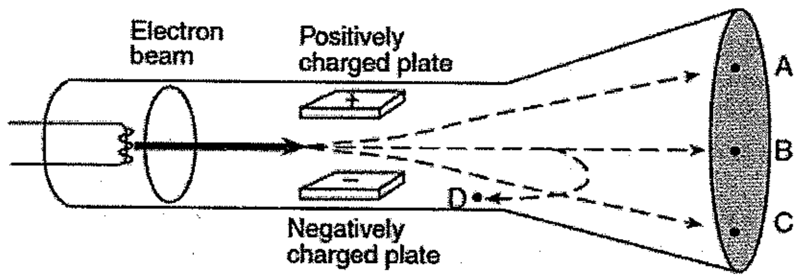


(1) (2) (3) (4)

$E = \frac{kq}{r^2}$

$E \propto \frac{1}{r^2}$

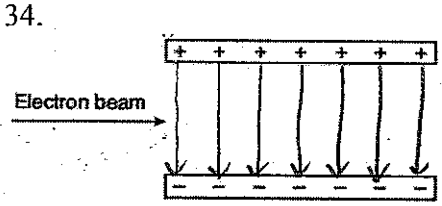
33.



After passing between the charged plates, the electrons will most likely travel path

1. A   Attracted to (+) plate
2. B
3. C
4. D

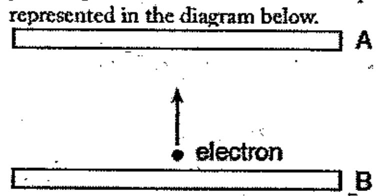
34.



The electrostatic force exerted on the electrons by the electric field is directed

1. into the page
2. out of the page
3. toward the bottom of the page
4. toward the top of the page

An electron placed between oppositely charged parallel plates A and B moves toward plate A, as represented in the diagram below.

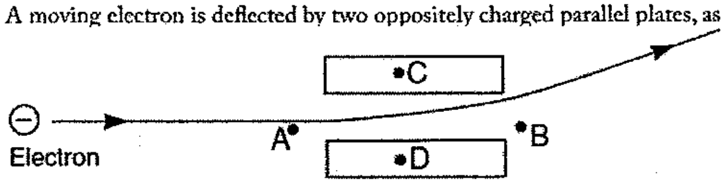


What is the direction of the electric field between the plates?

1. toward plate A
2. toward plate B
3. into the page
4. out of the page

35.

A moving electron is deflected by two oppositely charged parallel plates, as shown in the diagram below.



The electric field between the plates is directed from

1. A to B
2. B to A
3. C to D
4. D to C

36.

A 3.00×10^{-9}-coulomb test charge is placed near a negatively charged metal sphere. The sphere exerts an electrostatic force of magnitude 6.00×10^{-5} newton on the test charge. What is the magnitude and direction of the electric field strength at this location?

1. 2.00×10^{4} N/C directed away from the sphere
2. 2.00×10^{4} N/C directed toward the sphere
3. 5.00×10^{-5} N/C directed away from the sphere
4. 5.00×10^{-5} N/C directed toward the sphere

$E = \frac{F_{on\ q}}{q}$

$E = \frac{(6 \times 10^{-5})}{(3 \times 10^{-9})} = 2 \times 10^{4} \frac{N}{C}$

37.

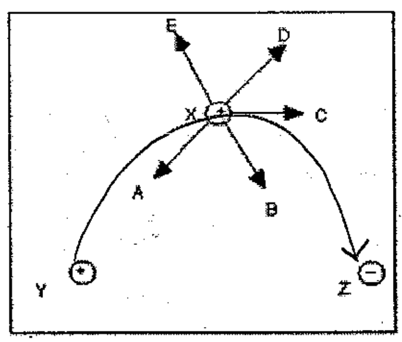
The figure on the right shows *strongly* charged **source charges Y and Z that are fixed in place. Test charge X** is free to move and has a *small* positive charge. Initially sphere X is equidistant from spheres Y and Z.

a. Which path will test charge X initially follow?

C

b. Explain why you chose that path.

tangent to field lines

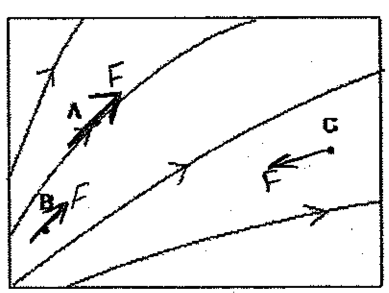


c. Draw an electric field line due to source charges Y and Z that passes through charge X.

see diagram

38.

Three charged particles are placed in an electric field as shown in the diagram.



a. Assuming that A has a positive charge, draw a vector for the electric force on point A. How do you know the direction of the force?

tangent to field; towards (−)

b. Assuming that B has a positive charge, draw a vector for the electric force on point B. How do you know the direction of the force?

tangent to field; towards (−)

c. Assuming that C has a negative charge, draw a vector for the electric force on point C. How do you know the direction of the force?

tangent to field

d. Which of the three points will have the strongest force per charge ratio? Explain how you know.

B; lines are closest together

39. Suppose you are given an electric field, but the charges that produce the field are hidden. If a positive test charge brought into the region shows that all the field lines point into the hidden region, what can you say about the sign of the charge in that region? How do you know?

(−) ; field lines point to (−)

40. Find the electric force on a charge of +4.0 x 10-3C when it is in an electric field at a point where the electric field strength is 20.0 N/C.

$20 = \frac{F}{4\times10^{-3}}$ $F = 0.08\ N$

41. A negative charge of 2.0 x 10-8 C experiences a force of 0.060 N when in an electric field. How strong is the electric field at the point where the charge is located?

$E = \frac{F}{q} = \frac{0.06}{2\times10^{-8}} = 3\times10^{6}\ \frac{N}{C}$

42. How much charge does a particle have that experiences a force of 1.0 x 10-8 N at a point where the electric field intensity is 0.00020 N/C?

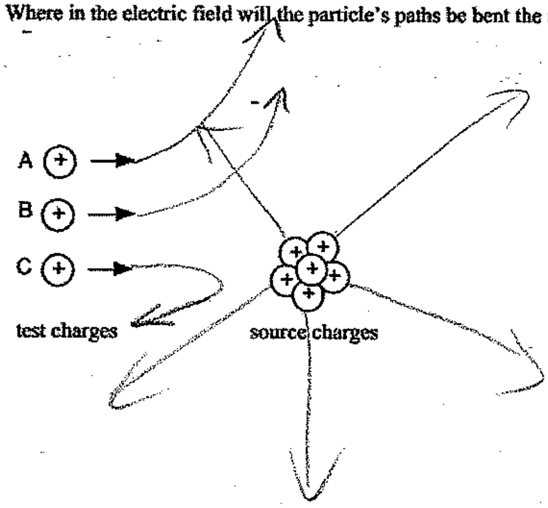
$E = \frac{F}{q} =$ $0.0002 = \frac{1\times10^{-8}}{q}$ $q = 0.00005\ C$

43.

a. Sketch the electric field created by the group of positive source charges shown below (ignore test charges A, B, and C for the moment.) Use arrows on field lines to show the direction of the field.

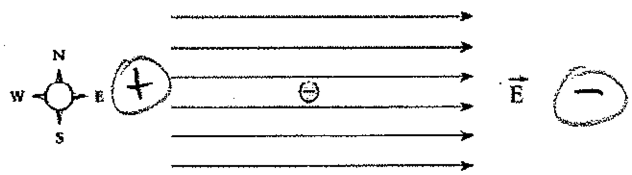
b. Test charge particles A, B, and C are shot to the right. Predict and draw the path each particle will take.

c. Where in the electric field will the particle's paths be bent the most? C



44.

An electron in the electric field has an electric force acting on it in what direction?

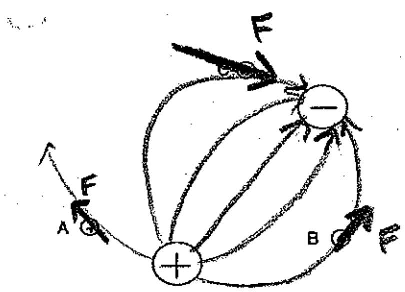


A. North
B. South
C. East
D. West

45.

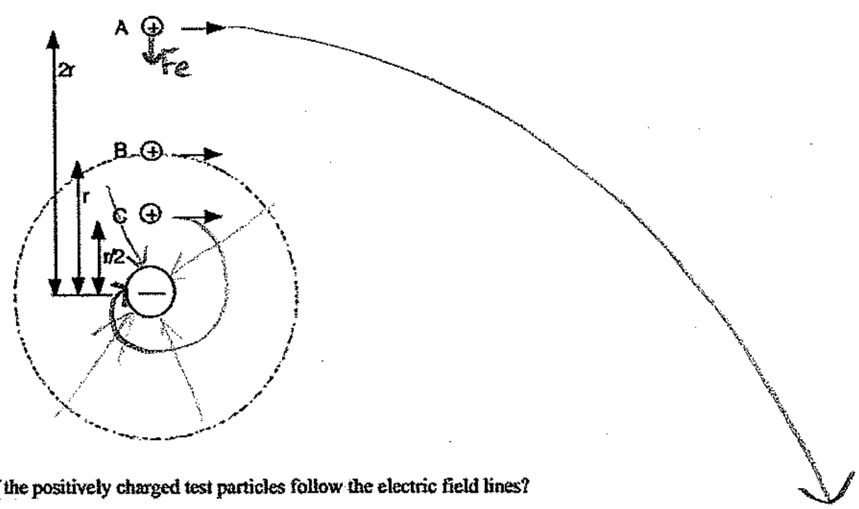
a. Sketch the electric field created by the large positive and negative source charges shown below. Use arrows on field lines to show the direction of the field.
b. Indicate the direction and size of the electric force on test charges A, B, and C with vectors.
c. How does the direction of the force on test charges A, B, and C relate to the field lines?

↳ tangent



46.

The three particles shown have equal velocities to the right. B's velocity allows the particle to travel in a circle around the negatively charged particle.
a. Draw the electric field lines due to the negative charge. Use arrows on field lines to show the direction of the field.
b. Draw and label a force diagram for test charge A.
c. Use your knowledge of Coulomb's law and circular motion to predict and draw the paths of test charges A and C.



d. Do the paths of the positively charged test particles follow the electric field lines?

Yes