

Practice Questions: Topic 1– Electrostatics

Multiple Choice

1. Which of the following are the fundamental forces in nature?

- I. Gravitational force
- II. Electromagnetic force
- III. Weak nuclear force
- IV. Strong nuclear force

- A. I and II only
- B. II and IV only
- C. I, II and IV only
- D. I, II, III and IV

2. Which of the four fundamental forces in nature is the weakest as well as long ranged force?

- A. Gravitational force
- B. Electromagnetic force
- C. Weak nuclear force
- D. Strong nuclear force

Listing them from
 Strongest to weakest
 ① Strong nuclear
 ② Electromagnetic
 ③ Weak nuclear
 ④ Gravitational

3. Which one of these systems has the most negative charge?

- A. 2 electrons → charge $2e^-$
- B. 3 electrons and 1 proton → charge $2e^-$
- C. 5 electrons and 5 protons → charge is 0
- D. N electrons and N – 3 protons → charge will always be $3e^-$

4. Which of the following is an SI unit of charge?

- A. Coulomb (C)
- B. Ampere (A) → current
- C. Joule (J) → Energy
- D. Volt (V) → voltage

5. Which of the following is correct for the charge of electrons, protons and neutrons?

	e^- Electrons	$+$ Protons	Neutrons
A.	Positive	Negative	Neutral
B.	Negative	Neutral	Positive
C.	Negative	Positive	Neutral
D.	Neutral	Positive	Negative

6. Consider two protons placed near one another with no other objects close by. They would ____.

- A. accelerate away from each other

- B. remain motionless
- C. accelerate toward each other
- D. be pulled together at constant speed

→ Because electrostatic force is present & $F=ma$



7. When a metal plate is given a positive charge, which of the following is taking place?

- A. Positive charges are transferred to the plate from another object
- B. Negative charges are transferred from the plate to another object

Negative charges are transferred from the plate to another object, and positive charges are also transferred to the plate from another object

- C. It depends on whether the object conveying the charge is a conductor or an insulator

8. Like charges ____ and unlike charges ____ each other.

- A. attract repel
- B. attract attract
- C. repel attract
- D. repel repel

9. Which of the following statements is/are true regarding electric charges?

- I. Like charges attract $\propto$ Repel
- II. Unlike charges attract
- III. If a neutral object gains electrons, it becomes positively charged $\propto$ negatively charged
- IV. If a neutral object loses electrons, it becomes positively charged

- A. I and III
- B. I and IV
- C. II and III
- D. II and IV

10. When a rubber rod is rubbed with rabbit fur, the rod becomes ____.

- A. negatively charged
- B. positively charged
- C. neutral
- D. either positively charged or negatively charged depending on the direction or is moved back and forth

11. When a glass rod is rubbed with a polyester scarf, the rod becomes ____.

- A. negatively charged
- B. positively charged
- C. neutral
- D. either positively charged or negatively charged depending on the direction or is moved back and forth

12. A metal sphere, X, has an initial net charge of $-6 \times 10^{-6} \text{ C}$ and an identical sphere, Y, has an initial net charge of $+2 \times 10^{-6} \text{ C}$. The spheres touch each other and then separate. What is the net charge on sphere X after the spheres have separated?

- A. 0 C
- B. $-2 \times 10^{-6} \text{ C}$
- C. $-4 \times 10^{-6} \text{ C}$
- D. $-6 \times 10^{-6} \text{ C}$

X Y
 -6 $+2$
 $\rightarrow$ charge will be distributed
 $-6 + 2 = -4$, then
 $-4 \div 2 = -2$
 $\rightarrow$ same charge after contact!

13. How many electrons does it take to make 1.00 C of charge?

- A. 1.60×10^{19}
- B. 6.60×10^{19}
- C. 3.20×10^{16}
- D. 6.24×10^{18}

$Q = \# e^- \times \text{unit electron}$
 $\downarrow$ Coulomb $\downarrow$ 1.6×10^{-19}
 $1 = e^- \times 1.6 \times 10^{-19}$
 $e^- \approx 6.24 \times 10^{18}$

14. A glass rod is charged by friction during which 13×10^{10} electrons are removed from the rod. What is the charge on the rod? $\rightarrow$ must be positive, b/c e^- are removed

- A. -20.8 nC
 - B. -6.40 nC
 - C. $+8.12 \text{ nC}$
 - D. $+20.8 \text{ nC}$
- Given: e^- removed: 13×10^{10}
unit electron = 1.6×10^{-19}
 $Q = \# e^- \times \text{unit electron}$
 $= (13 \times 10^{10}) \times 1.6 \times 10^{-19}$
 $= 2.08 \times 10^{-8}$
 $\rightarrow 20.8 \times 10^{-9} \text{ C}$
 20.8 nC

15. A negatively charged conductor attracts a second object. The second object could be which of the following?

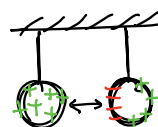
- I. A conductor with positive net charge $\rightarrow$ opposite charges
- II. A conductor with zero net charge $\rightarrow$ polarization
- III. An insulator with zero net charge $\rightarrow$ polarization

- A. I only
 - B. II only
 - C. II and III only
 - D. I, II, or III
- $\downarrow$ polarization but e^- don't move all the way!

16. Two lightweight metal spheres are suspended near each other from insulating threads. One sphere has a net charge; the other sphere has no net charge. The spheres will ____.

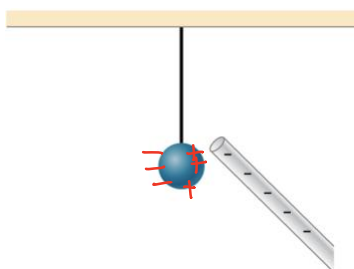
- A. attract each other
- B. exert no net electrostatic force on each other
- C. repel each other
- D. attract or repel depending on the sign of the charge on the one sphere

Ex.



attraction, even if the first one was negatively charged

17. The figure below shows a negatively charged rod brought close to, but not touching an uncharged conductor.



Which of the statements below is true regarding what happens to the conductor.

- A. The conductor is attracted to the rod due to polarization of charge
- B. The conductor is repelled away from the rod due to polarization of charge
- C. The conductor is attracted to the rod due to transfer of electrons by conduction
- D. The conductor is repelled away from the rod due to transfer of electrons by conduction

18. A neutral metal ball is suspended by a string. A positively charged insulating rod is placed near the ball, which is observed to be attracted to the rod. This is because ____.



- A. the ball becomes positively charged by induction
- B. the ball becomes negatively charged by induction
- C. the number of electrons in the ball is more than the number in the rod
- D. there is a rearrangement of the electrons in the ball

19. Which of the following is an example of a semiconductor?

- A. Copper
- B. Silicon
- C. Wood
- D. Glass

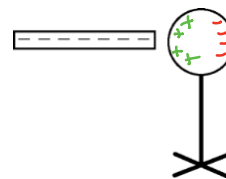
conductor

insulators

20. Materials that have zero resistance to the conduction of electricity are called as ____.

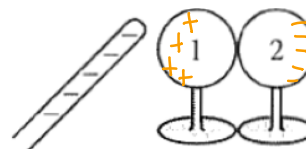
- A. Conductors
- B. Insulators
- C. Superconductors
- D. Semiconductors

21. A spherical conductor is on an insulating stand, as shown in the figure below. A negatively charged rod is brought close to the sphere but does not touch the sphere. Which of the following describes the resulting charge on the sphere?



- A. Positive
- B. Negative
- C. No net charge, but the sphere is polarized with positive charge on the left side
- D. No net charge, but the sphere is polarized with negative charge on the left side

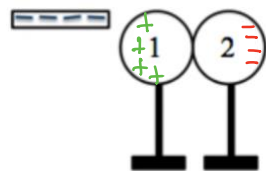
22. Two initially uncharged conductors, 1 and 2, are mounted on insulating stands and are in contact, as shown below. A negatively charged rod is brought near but does not touch them. With the rod held in place, conductor 2 is moved to the right by pushing its stand, so that the conductors are separated. Which of the following is now true of the conductor 2?



- A. Uncharged
- B. Positively charged
- C. Negatively charged
- D. Charged, but its sign can't be predicated

23. The figure below shows a negatively charged rod held close to, but not touching, a pair of conducting spheres 1 & 2, which are in contact with each other. While the rod is still held in place, sphere 2 is moved away from sphere 1. Which of the following statements is true about the charges on the two spheres?

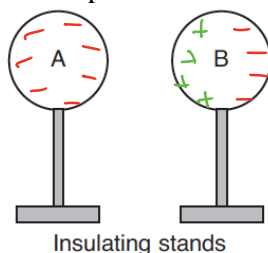
* Always make sure to separate them first then move the rod



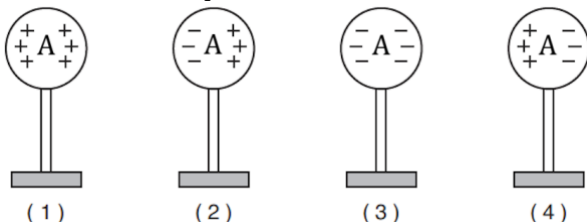
- | | Sphere 1 | Sphere 2 |
|----|----------|----------|
| A. | Positive | Positive |
| B. | Positive | Negative |
| C. | Negative | Negative |
| D. | Negative | Positive |

Questions 24 and 25

Two identically-sized metal spheres, A and B, are on insulating stands, as shown in the diagram below. Sphere A possesses an excess of 6.3×10^{10} electrons and sphere B is neutral.

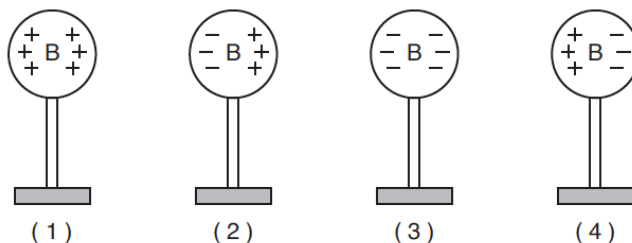


24. Which diagram best represents the charge distribution on sphere A?



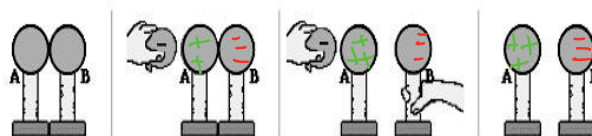
- A. 1
B. 2
C. 3
D. 4

25. Which diagram best represents the charge distribution on sphere B?



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

26. The diagrams below show two conducting spheres A and B in contact with each other. With a negatively charged object close to them, the spheres are separated.



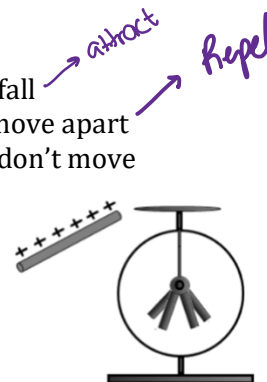
Identify the charges on A and B after separation.

- | | Charge on A | Charge on B |
|----|-------------|-------------|
| A. | Positive | Negative |
| B. | Positive | Positive |
| C. | Negative | Positive |
| D. | Negative | Negative |

27. A positively charged rod is brought close to a charged electroscope. What is the charge on the electroscope?

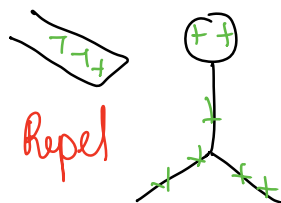
- I. Negative if the leaves fall
II. Positive if the leaves move apart
III. Negative if the leaves don't move

- A. I only
B. II only
C. I and II only
D. II and III only

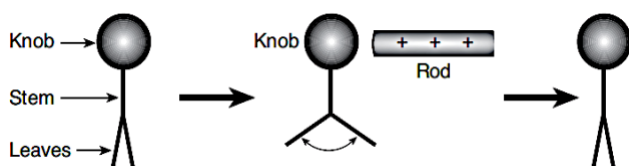


28. When a rod is brought near a positively charged electroscope, the leaves separate further. What charge, if any, does the rod carry?

- A. Zero
- B. Positive
- C. Negative
- D. Unknown



29. The electroscope shown in the diagram below is made completely of metal and consists of a knob, a stem, and leaves. A positively charged rod is brought near the knob of the electroscope and then removed.



The motion of the leaves results from electrons moving from the ____.

- A. leaves to the knob, only
- B. knob to the leaves, only
- C. leaves to the knob and then back to the leaves
- D. knob to the leaves and then back to the knob

30. The diagram below shows the steps followed by a student to charge a neutral conducting sphere with a positively charged object. The sphere is charged by the process of ____.



- A. friction
- B. induction
- C. conduction
- D. grounding

31. The figure below shows an electroscope. The hinged conductor moves away from the fixed conductor if a charge is applied to the electroscope, because ____.



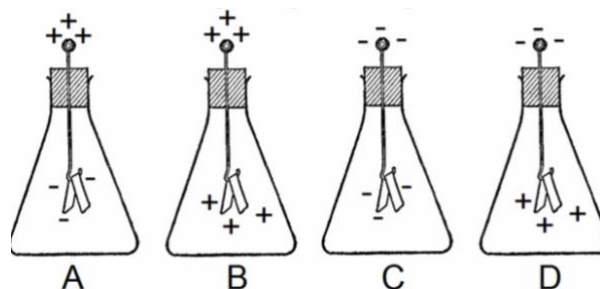
- A. like charges repel each other
- B. like charges attract each other
- C. unlike charges attract each other
- D. unlike charges repel each other

32. The leaves of a positively charged electroscope diverge more when an object is brought near the knob of the electroscope. The object must be ____.

- A. a conductor
- B. an insulator
- C. positively charged
- D. negatively charged

So it can repel

33. Which of the following figures show an electroscope that is charged by conduction using a positively charged rod?



- A. A
- B. B
- C. C
- D. D

Conduction ends up with the same charge on the object!

34. You place two charges a distance r apart. Then you double each charge and double the distance between the charges. How does the force between the two charges change?

- A. The new force is twice as large
- B. The new force is half as large
- C. The new force is four times larger
- D. The new force is the same

$$F \propto q_1 q_2$$

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

$$\frac{2 \times 2 \times F}{4} = F$$

35. The magnitude of the electrostatic force between two point charges is F . If the distance between the charges is doubled, the electrostatic force between the charges will become ____.

- A. $F/4$
- B. $F/2$
- C. $2F$
- D. $4F$

$$\frac{F}{2^2} = \frac{F}{4}$$

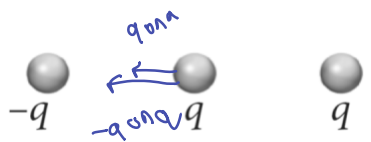
36. The force between a charge of $25 \mu\text{C}$ and a charge of $-10 \mu\text{C}$ is 8.0 N . What is the separation between the two charges?

- A. 0.15 m
- B. 0.28 m
- C. 0.45 m
- D. 0.53 m

$F = 8 \text{ N}$
 $Q_1 = 25 \times 10^{-6}$
 $Q_2 = 10 \times 10^{-6}$
 $* k = 8.99 \times 10^9$
 $F = \frac{k Q_1 Q_2}{r^2} \rightarrow r = \sqrt{\frac{k Q_1 Q_2}{F}} = 0.53 \text{ m}$

37. Three charges are arranged on a straight line as shown in the figure. What is the direction of the electrostatic force on the middle charge?

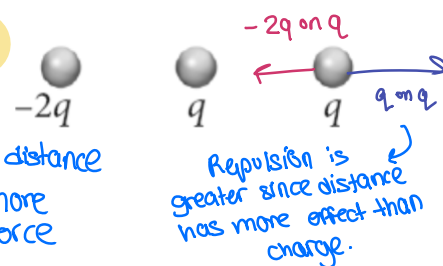
- A. $\rightarrow$
- B. $\leftarrow$
- C. $\downarrow$
- D. $\uparrow$



analyze the question carefully!

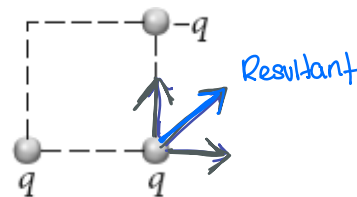
38. Three charges are arranged on a straight line as shown in the figure. What is the direction of the electrostatic force on the right charge?

- A. $\rightarrow$
- B. $\leftarrow$
- C. $\downarrow$
- D. $\uparrow$



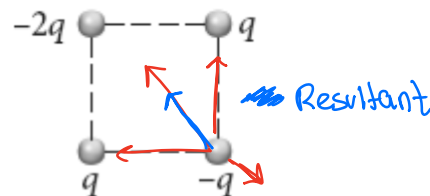
39. Three charges are arranged at the corners of a square as shown in the figure. What is the direction of the electrostatic force on the lower-right charge?

- A. $\swarrow$
- B. $\nwarrow$
- C. $\nearrow$
- D. $\searrow$



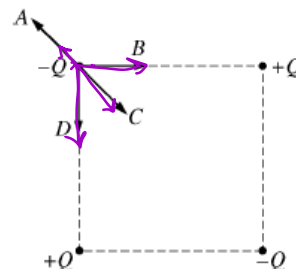
40. Four charges are arranged at the corners of a square as shown in the figure. What is the direction of the electrostatic force on the lower-right charge?

- A. $\swarrow$
- B. $\nwarrow$
- C. $\nearrow$
- D. $\searrow$

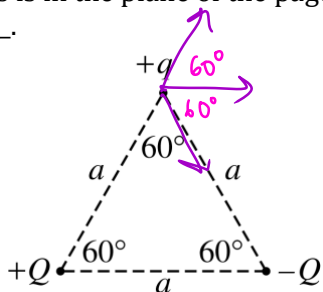


41. Four point charges of equal magnitude but different signs are arranged on the corners of a square as shown below. Which of the vectors shown represents the direction of the net force acting on the charge at the upper left-hand corner of the square due to the other charges?

- A. A
- B. B
- C. C
- D. D



42. Three particles having charges of $+q$, $+Q$, and $-Q$ are placed at the corners of an equilateral triangle of side a , as shown below. The net force on the particle with charge $+q$ due to the other two charges is in the plane of the page and directed ____.



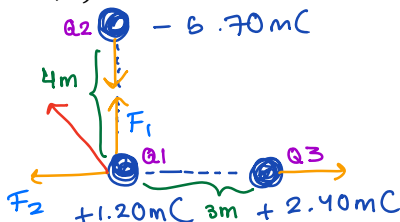
- A. vertically upward
- B. vertically downward
- C. horizontally to the right
- D. horizontally to the left

43. Which of the following produces the largest net force on the charge Q ?

$$F = \frac{kQ_1Q_2}{r^2}$$

- A. Charge $Q = 1 \text{ C}$ is 1 m from a charge of -2 C
- B. Charge $Q = 1 \text{ C}$ is 0.5 m from a charge of -1 C
- C. Charge $Q = 1 \text{ C}$ is halfway between 2 charges of -2 C , that are 2 m apart
- D. Charge $Q = 1 \text{ C}$ is a distance of 2 m from a charge of -4 C

44. Find the magnitude of the net force on a $+1.20 \text{ mC}$ charge at the origin if there is a $+2.40 \text{ mC}$ charge at $(3.0 \text{ m}, 0)$ and a -5.70 mC charge at $(0, 4.0 \text{ m})$.



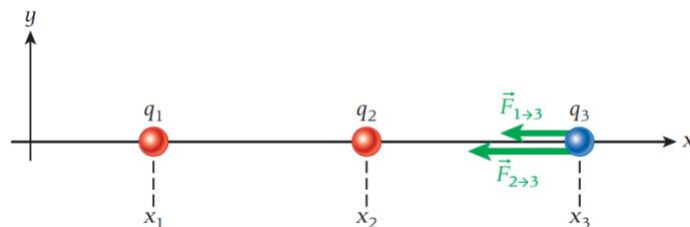
- A. 1.8 kN
- B. 2.9 kN
- C. 3.8 kN
- D. 4.8 kN

$$F_1 = \frac{kq_1q_3}{r^2} = \frac{(8.99 \times 10^9)(1.2 \times 10^{-3})(5.7 \times 10^{-3})}{4^2} = 3843.225 \text{ N}$$

$$F_2 = \frac{kq_1q_2}{r^2} = \frac{(8.99 \times 10^9)(1.2 \times 10^{-3})(2.4 \times 10^{-3})}{3^2} = 2876.8 \text{ N}$$

$$F_{\text{total}} = \sqrt{F_1^2 + F_2^2} = \sqrt{(3843.225)^2 + (2876.8)^2} = 4.8 \text{ kN}$$

Questions 45 and 46



45. What do the forces acting on the charge q_3 in the figure below indicate about the signs of the three charges?

- A. All three charges must be positive
- B. All three charges must be negative
- C. Charge q_3 must be zero
- D. Charges q_1 and q_2 must have the same sign, and q_3 must have the opposite sign

46. Assuming that the lengths of the vectors in the figure are proportional to the magnitudes of the forces they represent, what do they indicate about the magnitudes of the charges q_1 and q_2 ? (The distance between x_1 and x_2 is the same as the distance between x_2 and x_3).

- A. $|q_1| < |q_2|$
- B. $|q_1| = |q_2|$
- C. $|q_1| > |q_2|$
- D. The answer cannot be determined from the information given in the figure

47. Object A and object B are separated by distance d . Object A has charge $+q$, and object B has charge $-2q$. Object A has a force of magnitude F exerted on it by object B. What are the magnitude and direction of the force exerted on object B?

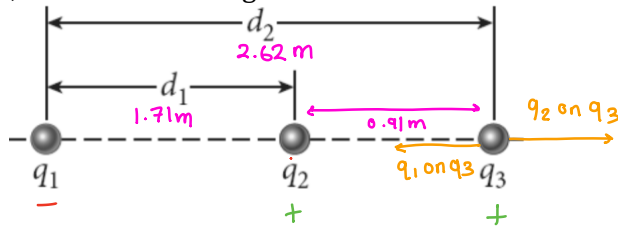
- | | Magnitude | Direction |
|----|-----------|--------------------|
| A. | $F/2$ | Away from object A |
| B. | F | Away from object A |
| C. | $2F$ | Away from object A |
| D. | F | Toward object A |

Forces between 2 charges are equal in magnitude but opposite in direction.

$$\textcircled{1} F_1(q_1 \text{ on } q_3) = \frac{(8.99 \times 10^9)(8.10 \times 10^{-6})(2.16 \times 10^{-12})}{2.62^2}$$

$$= 2.29 \times 10^{-8} \text{ N (negative)}$$

48. Consider three charges placed along the x-axis, as shown in the figure.



The values of the charges are:

$$q_1 = -8.10 \mu\text{C}, \quad \textcircled{2} F_2(q_2 \text{ on } q_3) = \frac{(8.99 \times 10^9)(2.16 \times 10^{-6})(2.16 \times 10^{-12})}{0.91^2}$$

$$q_2 = 2.16 \mu\text{C}, \quad = 5.06 \times 10^{-8} \text{ N (positive)}$$

$$q_3 = 2.16 \mu\text{C}.$$

$$\textcircled{3} F_{\text{Total}} = (5.06 \times 10^{-8}) - (2.29 \times 10^{-8}) = 2.77 \times 10^{-8}$$

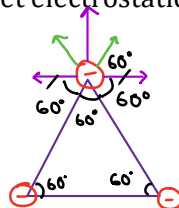
The distance between q_1 and q_2 is $d_1 = 1.71 \text{ m}$.

The distance between q_1 and q_3 is $d_2 = 2.62 \text{ m}$.

What is the magnitude of the total electrostatic force exerted on q_3 by q_1 and q_2 ?

- A. $2.77 \times 10^{-8} \text{ N}$
- B. $7.92 \times 10^{-6} \text{ N}$
- C. $1.44 \times 10^{-5} \text{ N}$
- D. $2.22 \times 10^{-4} \text{ N}$

49. Three electrons are located at the vertices of an equilateral triangle, one at each vertex. The length of one side of the triangle is 1.00 nm. What is the magnitude of the net electrostatic force on each electron?

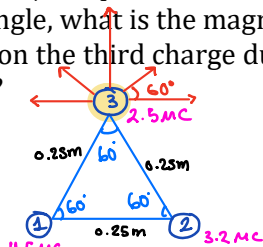


- A. $2.30 \times 10^{-10} \text{ N}$
- B. $3.25 \times 10^{-10} \text{ N}$
- C. $3.39 \times 10^{-10} \text{ N}$
- D. $4.60 \times 10^{-10} \text{ N}$

$$F = \frac{(8.99 \times 10^9)(1.6 \times 10^{-19})(1.6 \times 10^{-19})}{(1 \times 10^{-9})^2}$$

$$= 2.3 \times 10^{-10} \times \sin 60^\circ \times 2 = 3.98 \times 10^{-10}$$

50. Two charges are placed at the corners of an equilateral triangle that is 0.25 m on each side. The first charge is $4.5 \mu\text{C}$ and the second is $3.2 \mu\text{C}$. If a charge of $2.5 \mu\text{C}$ is placed at the third corner of the triangle, what is the magnitude of the electric force on the third charge due to the first two charges?



- A. 0.602 N
- B. 1.96 N
- C. 2.41 N
- D. 3.19 N

$$F_{1 \text{ on } 3} = \frac{(8.99 \times 10^9)(4.5 \times 10^{-6})(2.5 \times 10^{-6})}{0.25^2} = 1.6182 \text{ N}$$

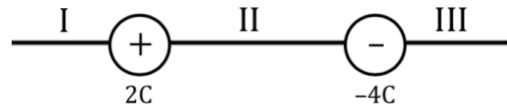
$$F_{2 \text{ on } 3} = \frac{(8.99 \times 10^9)(3.2 \times 10^{-6})(2.5 \times 10^{-6})}{0.25^2} = 1.15072 \text{ N}$$

$$\Sigma F_y = (1.6182 \times \sin 60^\circ) + (1.15072 \times \sin 60^\circ) = 2.40 \text{ N}$$

$$\Sigma F_x = (1.6182 \times \cos 60^\circ) - (1.15072 \times \cos 60^\circ) = 0.23374 \text{ N}$$

$$F = \sqrt{2.4^2 + 0.23374^2} \approx 2.41 \text{ N}$$

51. Two point charges are arranged as shown. In which region could a third charge $+1 \text{ C}$ be placed so that the net electrostatic force on it is zero?

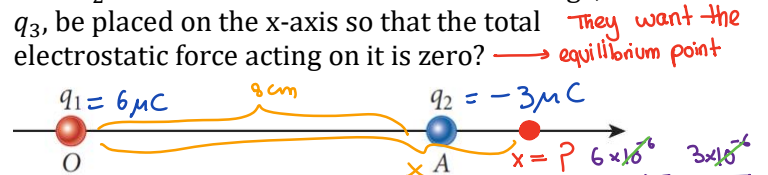


- A. I only
- B. II only
- C. III only
- D. I and II only

→ different charges & closer to smaller charge

52. Two point charges are fixed on the x-axis:

$q_1 = 6.0 \mu\text{C}$ is located at the origin, O, with $x_1 = 0.0 \text{ cm}$, and $q_2 = -3.0 \mu\text{C}$ is located at point A, with $x_2 = 8.0 \text{ cm}$. Where should a third charge, q_3 , be placed on the x-axis so that the total electrostatic force acting on it is zero?



- A. 0.0 cm
- B. 8.0 cm
- C. 19 cm
- D. 27 cm

At point $\Sigma F = 0$

$$F_1 = F_2$$

$$\frac{k|q_1||q_3|}{r^2} = \frac{k|q_2||q_3|}{r^2}$$

$$\frac{|q_1|}{r^2} = \frac{|q_2|}{r^2}$$

$$\frac{6}{x^2} = \frac{3}{(x-8)^2}$$

$$\sqrt{\frac{6}{x^2}} = \sqrt{\frac{3}{(x-8)^2}}$$

$$\frac{\sqrt{6}}{x} = \frac{\sqrt{3}}{x-8}$$

$$\sqrt{6}(x-8) = \sqrt{3}x$$

$$\sqrt{6}x - 8\sqrt{6} = \sqrt{3}x$$

$$(\sqrt{6} - \sqrt{3})x = 8\sqrt{6}$$

$$x = 27 \text{ cm}$$

53. A charge $Q_1 = Q$ is positioned on the x-axis at $x = a$. Where should a charge $Q_2 = 9Q$ be placed to produce a net electric force of zero on a charge placed at the origin?

- A. At $x = -3a$
- B. At $x = -2a$
- C. At $x = 2a$
- D. At $x = 3a$

$$\frac{Q_1}{r^2} = \frac{Q_2}{r^2}$$

$$\frac{Q}{a^2} = \frac{9Q}{x^2}$$

$$9Qa^2 = Qx^2 \rightarrow \sqrt{x^2} = \sqrt{9a^2} \rightarrow x = 3a$$

54. A fixed $+2.0 \text{ mC}$ charge is located at the origin, and a fixed -5.0 mC charge is located at $x = 1.0 \text{ m}$. Where could a $+7.0 \text{ mC}$ charge be placed so that the net force on it is zero?

- A. -1.7 m
- B. -0.67 m
- C. -0.39 m
- D. $+0.39 \text{ m}$

$$\frac{Q_1}{r^2} = \frac{Q_2}{r^2}$$

$$\sqrt{\frac{2}{x^2}} = \sqrt{\frac{5}{(x-1)^2}}$$

$$\frac{\sqrt{2}}{x} = \frac{\sqrt{5}}{x-1}$$

$$\sqrt{2}(x-1) = \sqrt{5}x$$

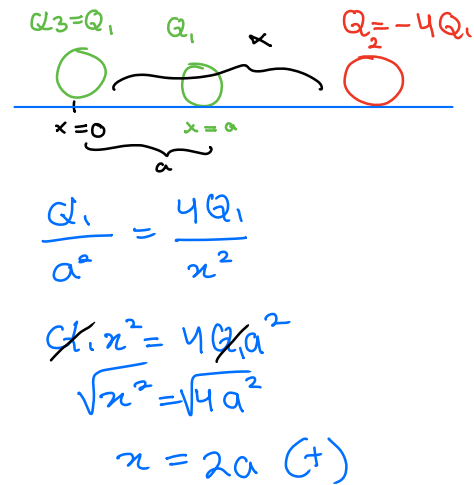
$$\sqrt{2}x - \sqrt{2} = \sqrt{5}x$$

$$(\sqrt{2} - \sqrt{5})x = \sqrt{2}$$

$$x = -1.7 \text{ m}$$

55. A charge Q_1 is positioned on the x -axis at $x = a$. Where should a charge $Q_2 = -4Q_1$ be placed to produce a net electrostatic force of zero on a third charge, $Q_3 = Q_1$, located at the origin?

- A. At the origin
- B. At $x = -2a$
- C. At $x = -a$
- D. At $x = 2a$



Free Response:

1. Give the charge of the following elementary particles or atoms in terms of the elementary charge, $e = 1.602 \times 10^{-19} \text{ C}$.

- a. Proton $+e$
- b. Electron $-e$
- c. Neutron 0
- d. Helium atom (2 protons, 2 neutrons and 2 electrons) 0
- e. Hydrogen atom (one proton and one electron) 0
- f. Alpha particle (2 protons, 2 neutrons) $+2e$

2. An atomic nucleus contains positively charged protons and uncharged neutrons. Since nuclei do stay together, what must we conclude about the forces between these nuclear particles?

The force holding them together must be extremely large & strong, and we are correct in that assumption, as the strongest fundamental force in nature is known as the strong nuclear force and it is the same one that's holding the nucleus together. $\rightarrow$ actual answer: the force holding the nucleus together must be greater than the electrostatic repulsive force on the protons.

3. Two bodies attract each other electrically.

- a. Do they both have to be charged?

No (It could be through polarization which requires only one of them to be charged)

- b. Do they both have to be charged if the bodies repel one another

yes.

9



4. Suppose you place a charge q near a large metal plate.

a. If q is attracted to the plate, is the plate necessarily charged?

NO (b/c of polarization)

b. If q is repelled by the plate, is the plate necessarily charged?

yes, since polarization charge would produce only an attractive force.

or by using another rod.

5. How would you determine whether the charge on a particular rod is positive, negative or neutral?

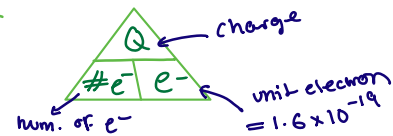
you can bring it near a charged electroscope. If the leaves diverge, then the rod has the same charge as the electroscope. If the leaves come closer together, the rod has an opposite charge to that of the electroscope. If nothing happens then the rod is neutral.

6. Common static electricity involves charges.

a. How many electrons are needed to form a charge of -2.00 nC ?

$$Q = 2 \times 10^{-9} \text{ C} \quad Q = \#e^- \times e^- \quad \#e^- = \frac{2 \times 10^{-9}}{1.6 \times 10^{-19}} = 1.25 \times 10^{10} \text{ electrons}$$

Remember the triangle!



b. How many electrons must be removed from a neutral object to leave a net charge of $0.500 \mu\text{C}$?

$$Q = 0.5 \times 10^{-6} \text{ C} \quad Q = \#e^- \times e^- \quad \#e^- = \frac{0.5 \times 10^{-6}}{1.6 \times 10^{-19}} = 3.125 \times 10^{12} e^- \text{ must be removed.}$$

7. To start a car engine, the car battery moves 3.75×10^{21} electrons through the starter motor. How many coulombs of charge were moved?

$$\#e^- = 3.75 \times 10^{21} \quad Q = \#e^- \times e^- = (3.75 \times 10^{21})(1.6 \times 10^{-19}) = -600 \text{ C}$$

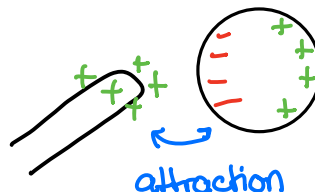
why (-)?
Because we have an excess of electrons.

8. When a positively charged rod is brought near to an isolated neutral conductor without touching it, will the rod experience an attractive force, a repulsive force, or no force at all?

A. an attractive force

B. a repulsive force

C. no force at all



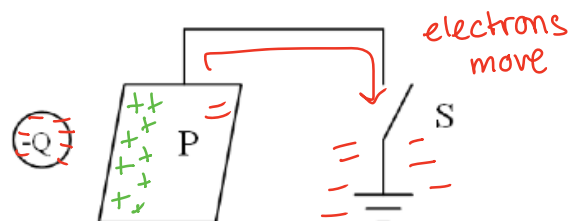
connected to ground

9. An uncharged metal plate (P) is connected by a conductor to ground through a switch (S). The switch (S) is initially closed. A negative charge $-Q$ is brought close to P without touching it and then the switch (S) is opened. After the switch (S) is open, the negative charge $-Q$ is removed. After the negative charge $-Q$ is removed, what is the charge on the plate (P)?

A. It is now positively charged

B. It is now negatively charged

C. It is still uncharged

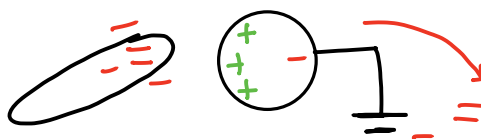


10. You bring a negatively charged rubber rod close to a grounded conductor without touching it. Then you disconnect the ground. What is the sign of the charge on the conductor after you remove the charged rod?

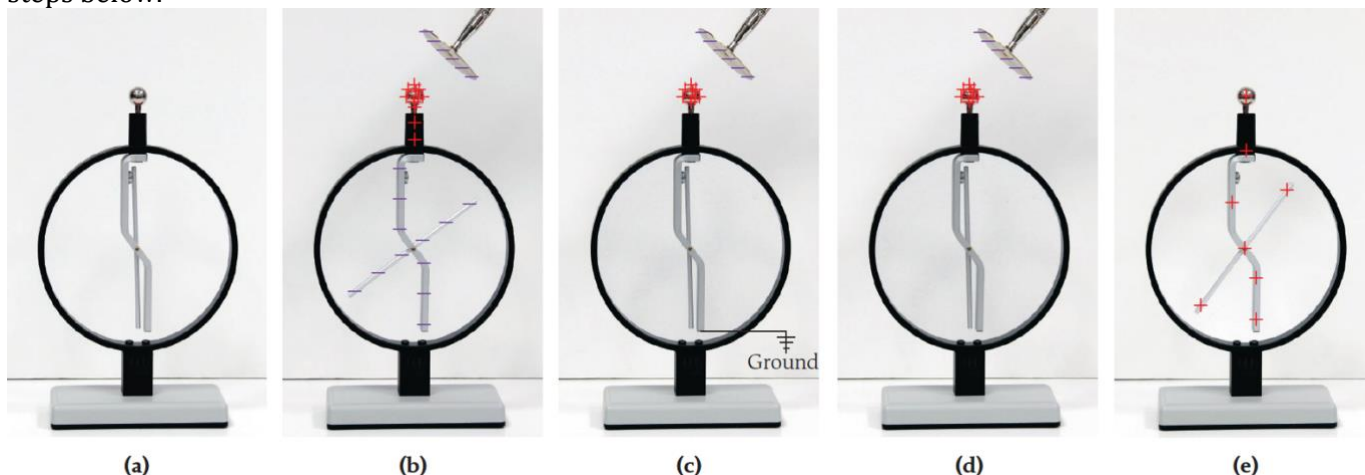
A. Negative

B. Positive

C. No charge



11. The figure below shows the process of charging an electroscope by induction. Describe each of the steps below.



Electroscope is neutral.

Negatively charged rod polarizes the electroscope making the leaves diverge as electrons there repel.

The electroscope is grounded making the electrons move from the leaves of the electroscope to the ground.

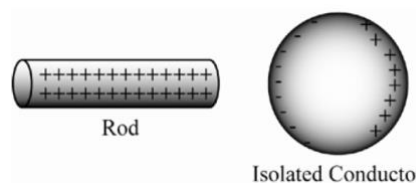
The electroscope becomes positively charged, & connection to ground is removed.

The charges redistribute around the electroscope, making the leaves diverge again.

12. When a positively charged rod is brought close to a neutral conductor without touching it, will the rod experience an attractive force, a repulsive force, or no force at all? Explain.

Actual answer :

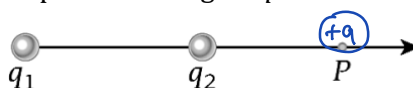
When a positively charged rod is brought near to an isolated neutral conductor without touching it the rod will experience an attractive force. The electric charge on the rod induces a redistribution of charge in the conductor. The net effect of this distribution is that electrons move to the side of the conductor nearest to the rod as shown below. The positively charged rod is attracted to this region.



my answer :

Attractive force because the rod will cause polarization to occur in the neutral conductor. This will have the side close to the rod concentrated with electrons & so they'll attract because opposite charges attract.

13. A positive point charge $+q$ is placed at point P , to the right of two charges q_1 and q_2 , as shown in the figure below. The net electrostatic force on the positive charge $+q$ is found to be zero. Identify each of the following statements as true or false.



a. Charge q_2 must have the opposite sign from q_1 and be smaller in magnitude.

b. The magnitude of charge q_1 must be smaller than the magnitude of charge q_2 .

c. Charges q_1 and q_2 must have the same sign.

d. If q_1 is negative, then q_2 must be positive.

e. Either q_1 or q_2 must be positive.

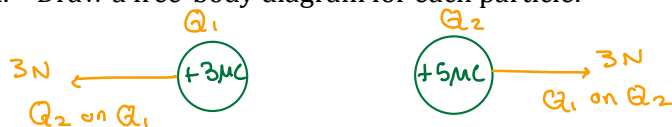
→ since it's placed on the side, q_1 & q_2 must have opposite signs

→ since it's placed near q_2 , then q_2 must have the smaller charge.



14. Two point particles with charges $+3 \mu\text{C}$ and $+5 \mu\text{C}$ are held in place by 3.0 N forces on each charge in appropriate directions.

a. Draw a free-body diagram for each particle.

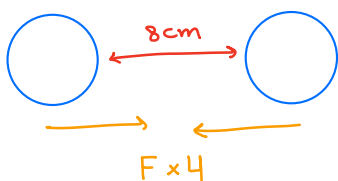


b. Find the distance between the charges.

$$F = \frac{kQ_1Q_2}{r^2}$$

$$r = \sqrt{\frac{kQ_1Q_2}{F}} \rightarrow r = \sqrt{\frac{(8.99 \times 10^9)(3 \times 10^{-6})(5 \times 10^{-6})}{3}} \approx 0.21 \text{ m}$$

15. Two charged spheres are 8.00 cm apart. They are moved closer to each other by enough that the force on each of them increases four times. How far apart are they now?



Final answer:

$$\frac{1}{2} \times 8 = 4 \text{ cm}$$

They are 4 cm apart now.

$$F_1 \propto \frac{1}{r_1^2} \text{ \& } F_2 \propto \frac{1}{r_2^2}$$

We will take the ratio of F_1/F_2

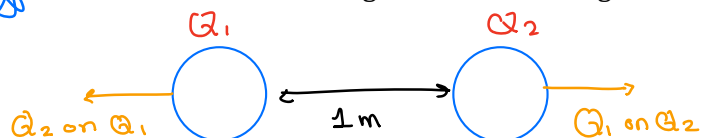
$$\frac{F_1}{4F_1} = \frac{r_2^2}{r_1^2} \rightarrow \frac{1}{4} = \frac{r_2^2}{r_1^2}$$

$$r_2 = \sqrt{\frac{r_1^2}{4}} = \frac{r_1}{2} = \frac{8}{2} = 4 \text{ cm}$$

They're flipped because

$$F_1 = \frac{1}{r_1^2} \text{ \& } \frac{1}{4F_1} = \frac{r_2^2}{1}$$

16. Two identically charged particles separated by a distance of 1.00 m repel each other with a force of 1.00 N . What is the magnitude of the charges?



$$* Q_1 = Q_2$$

$$F = \frac{kQ_1Q_2}{r^2}$$

Since the charges are equal

$$F = \frac{k \cdot Q^2}{r^2}$$

$$Q_1 = \sqrt{\frac{Fr^2}{k}}$$

$$= \sqrt{\frac{1 \times 1^2}{8.99 \times 10^9}} = 1.05 \times 10^{-5} \text{ C}$$

& the charges repel

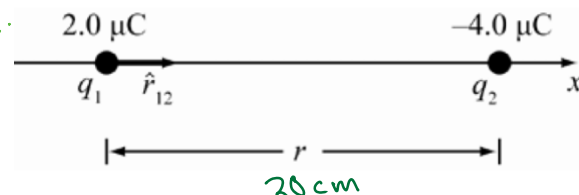


17. A $-4.00 \mu\text{C}$ charge lies 20.0 cm to the right of a $2.00 \mu\text{C}$ charge on the x -axis as shown below. What is the force on the $2.00 \mu\text{C}$ charge? $L_2 = 0.2 \text{ m}$

The force between the two charges is equal but opposite.

$$F = \frac{kQ_1Q_2}{r^2}$$

$$F = \frac{(8.99 \times 10^9)(2 \times 10^{-6})(4 \times 10^{-6})}{(0.2)^2}$$

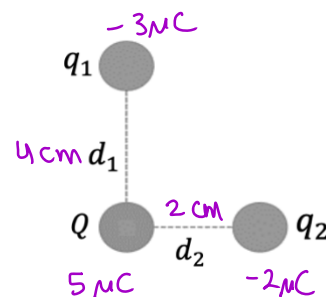


$F = 1.798 \text{ N}$ to the right as it is attracted by the $-4 \mu\text{C}$ charge.

* Convert cm to m using $\times 10^{-2}$



18. Three charges are located in the xy -plane as shown below. Charge $Q = 5.0 \mu C$ is located at the origin, charge $q_1 = -3.0 \mu C$ is located on the $+y$ -axis, a distance $d_1 = 4.0 \text{ cm}$ from Q and charge $q_2 = -2.0 \mu C$ is located on the $+x$ -axis, a distance $d_2 = 2.0 \text{ cm}$ from Q .



a. Determine the magnitude of the force that charge q_1 exerts on Q .

→ we must find F between q_1 & Q

$$F = \frac{kQq_1}{r^2} = \frac{(8.99 \times 10^9)(5 \times 10^{-6})(3 \times 10^{-6})}{0.04^2} \approx 84.3 \text{ N (y-axis)}$$

b. Determine the magnitude of the force that charge q_2 exerts on Q .

→ we must find F between q_2 & Q

$$F = \frac{kQq_2}{r^2} = \frac{(8.99 \times 10^9)(5 \times 10^{-6})(2 \times 10^{-6})}{0.02^2} \approx 224.75 \text{ N (x-axis)}$$

c. Determine the magnitude of the net force on the charge Q .

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(84.3)^2 + (224.75)^2} \approx 240 \text{ N}$$

d. Determine the direction (angle from the $+x$ -axis) of the net force.

$$\theta = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{84.3}{224.75}\right) \approx 20.56^\circ$$



19. The charges $q_1 = 2.00 \times 10^{-7} \text{ C}$, $q_2 = -4.00 \times 10^{-7} \text{ C}$, and $q_3 = -1.00 \times 10^{-7} \text{ C}$, are placed at the corners of the triangle shown below. What is the force on q_1 ?

Breaking the question down

* They want the total force on q_1

① Find the force between q_1 & q_2 , then between q_1 & q_3

② Break each force into F_x & F_y

③ Find ΣF_x & ΣF_y

④ Use the formula $F = \sqrt{F_x^2 + F_y^2}$

Extra: we can find the direction using $\tan^{-1}\left(\frac{y}{x}\right)$

$$\begin{aligned} 1) F_1 &= \frac{kq_1q_2}{r^2} \\ &= \frac{(8.99 \times 10^9)(2 \times 10^{-7})(4 \times 10^{-7})}{5^2} \\ &= 2.87 \times 10^{-5} \text{ N} \end{aligned}$$

$$\begin{aligned} F_{1x} &= (2.87 \times 10^{-5}) \times \sin 53.13 \\ F_{1y} &= (2.87 \times 10^{-5}) \times \cos 53.13 \\ F_{1x} &\approx 2.3 \times 10^{-5} \text{ N right} \\ F_{1y} &= 1.72 \times 10^{-5} \text{ N down} \end{aligned}$$

$$\begin{aligned} 2) F_2 &= \frac{kq_1q_3}{r^2} = \frac{(8.99 \times 10^9)(2 \times 10^{-7})(1 \times 10^{-7})}{3^2} \\ &\approx 1.99 \times 10^{-5} \text{ N down} \end{aligned}$$

* It's only on the y -axis, so no need to break it down

$$3) \Sigma F_x = 2.3 \times 10^{-5} (+)$$

$$\Sigma F_y = (-1.72 \times 10^{-5}) + (-1.99 \times 10^{-5}) = -3.71 \times 10^{-5}$$

$$4) F = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$$

$$= \sqrt{(2.3 \times 10^{-5})^2 + (-3.71 \times 10^{-5})^2}$$

$$= 4.36 \times 10^{-5} \text{ N}$$

$$\text{direction: } \theta = \tan^{-1}\left(\frac{y}{x}\right) = \left(\frac{-3.71 \times 10^{-5}}{2.3 \times 10^{-5}}\right) = -58.2^\circ \text{ below the +ve x-axis so, } 360 - 58.2$$

$= 301.8^\circ$ from the +ve x -axis.



20. Two charged objects experience a mutual repulsive force of 0.100 N. If the charge of one of the objects is reduced by half and the distance separating the objects is doubled, what is the new force?

info we can get from question:

- Two charged objects Q_1, Q_2 for example
- mutual repulsive force of 0.1 N
- charge of one object is reduced by $\frac{1}{2}$
- Distance, r , is doubled

Before

$$F = \frac{Q_1 Q_2}{r^2}$$

After

$$F = \frac{\frac{1}{2} Q_1 Q_2}{(2r)^2}$$

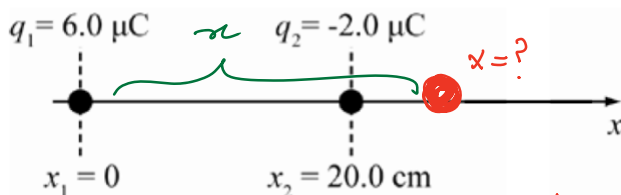
$$F = \frac{\frac{1}{2} Q_1 Q_2}{4r^2}$$

$$F = \frac{1}{8} \left(\frac{Q_1 Q_2}{r^2} \right)$$

* we can ignore it

$$F_{\text{new}} = \frac{1}{8} (F_{\text{old}}) = \frac{1}{8} (0.1 \text{ N}) = 0.0125 \text{ N}$$

21. Two point charges lie on the x-axis. If one point charge is $6.00 \mu\text{C}$ and lies at the origin and the other is $-2.00 \mu\text{C}$ and lies at 20.0 cm, at what position must a third charge be placed to be in equilibrium?



* you can convert to meter or keep it as cm your choice!

Think

- Since the charges have different signs, the third must be placed at one of the sides
- It also must be placed beside the smaller charge
- So the red dot shows where we predict it to be placed.

more explanation:

A third point charge needs to be placed on the x-axis such that it is in equilibrium. This means that the net force on the third charge due to the other charges is zero. Since $q_1 > q_2$, the third charge must be closer to q_2 than to q_1 . Also, since q_1 and q_2 are oppositely charged, the forces on a particle in between them will be in the same direction and hence cannot cancel. The third charge must be in the region $x > 20.0 \text{ cm}$.

At point $\Sigma F = 0$

$$F_1 = F_2$$

$$\frac{q_1 q_3}{r^2} = \frac{q_2 q_3}{r^2}$$

$$\frac{q_1}{r^2} = \frac{q_2}{r^2}$$

Distance from q_1 to point of equilibrium

Distance from q_2 to point of equilibrium

$$\frac{6 \times 10^{-6}}{x^2} = \frac{2 \times 10^{-6}}{(x-20)^2}$$

$$\sqrt{\frac{6}{x^2}} = \sqrt{\frac{2}{(x-20)^2}}$$

$$\frac{\sqrt{6}}{x} = \frac{\sqrt{2}}{x-20}$$

$$\sqrt{6}(x-20) = \sqrt{2}x$$

$$\sqrt{6}x - 20\sqrt{6} = \sqrt{2}x$$

$$\sqrt{6}x - \sqrt{2}x = 20\sqrt{6}$$

$$x(\sqrt{6} - \sqrt{2}) = 20\sqrt{6}$$

$$x \approx 47.32 \text{ cm}$$

which is right according to our prediction.