Student #: ______________________ Student Name: ____________________________

TOPIC 11: ELECTROSTATICS

1. Two electric objects experience a repulsive force. What happens to that force if the distance between the objects is doubled?

   (A) It decreases to one-fourth its value.
   (B) It decreases to one-half its value.
   (C) It stays the same.
   (D) It doubles.
   (E) It quadruples.

2. A pith ball is a tiny piece of Styrofoam that is covered with a conductive paint. One pith ball initially has a charge of 6.4×10^{-8} C, and it touches an identical, neutral pith ball. After the pith balls are separated, what is the charge on the pith ball that had the initial charge?

   (A) 6.4×10^{-8} C
   (B) 3.2×10^{-8} C
   (C) 0 C
   (D) -3.2×10^{-8} C
   (E) -6.4×10^{-8} C

3. Glass becomes positively charged when it is rubbed with silk. Which of the following is the best description of what's happening?

   (A) Electrons are rubbed off the glass onto the silk.
   (B) Electrons are rubbed off the silk onto the glass.
   (C) Protons are rubbed off the glass onto the silk.
   (D) Protons are rubbed off the silk onto the glass.
   (E) Neutrons in the glass have an affinity for positive charge.

4. Consider an isolated, neutral system consisting of wool fabric and a rubber rod. If the rubber rod is rubbed with wool to become negatively charged, what can be said about the wool fabric?

   (A) It becomes equally negatively charged.
   (B) It becomes equally positively charged.
   (C) It becomes negatively charged but not equally.
   (D) It becomes positively charged but not equally.
   (E) In a neutral system, neither object can become charged.

5. An electron and a proton are separated by 1.50×10^{-10} m. If they are released, which one will accelerate at a greater rate, and what is the magnitude of that acceleration?

   (A) The electron; 1.12×10^{22} m/s^2
   (B) The proton; 1.12×10^{22} m/s^2
   (C) The electron; 6.13×10^{18} m/s^2
   (D) The proton; 6.13×10^{18} m/s^2
   (E) They both accelerate at the same rate; 1.02×10^{-8} m/s^2

6. A negatively charged object is placed near, but not touching, a neutral conductor. As a result, the two objects are attracted to each other. Which of the following is true?

   (A) The neutral object gains positive charges to become positively charged.
   (B) The neutral object loses negative charges to become positively charged.
   (C) The neutral object loses positive charges to become negatively charged.
   (D) The neutral object gains negative charges to become negatively charged.
   (E) Negative charges of the neutral object move to the side opposite the negatively charged object.

7. A rubber comb is rubbed on hair and then attracts paper bits off the table. Which of the following best compares the forces on the paper bits?

   (A) The gravitational force is stronger than the electric force.
   (B) The electric force is stronger than the gravitational force.
   (C) The strong nuclear force dominates all other forces.
   (D) The normal force is stronger than the electric force.
   (E) The magnetic force is stronger than the electric force

8. Which of the following may be said about an object that is a good electrical conductor?

   (A) The protons are free to move within the object.
   (B) The electrons are free to move within the object.
   (C) The electrons are bound to their individual atom.
   (D) The object cannot maintain its electric charge.
   (E) It may be made of materials such as rubber and plastic

9. Paper is considered an insulator. How does a positively charged piece of tape pick up a neutral paper bit?

   (A) The tape makes the protons flow to the opposite end of the paper, causing an attraction between the electrons left behind and the tape.
   (B) The tape polarizes the paper atoms, attracting the electrons to the side of the atoms closest to the tape.
   (C) The tape forces electrons at the opposite end of the paper to flow through the paper toward the tape.
   (D) The tape polarizes the paper atoms, moving the protons within the atoms to the side of the atom farthest from the tape.
   (E) It is not possible for a charged object to attract a neutral object.

10. Three particles are located on a coordinate system. An electron is located at the origin, a proton is located at $(0, 1)$, and an electron is located at $(1, 0)$. What is the direction of the net electrostatic force on the electron located at the origin?

    (A) To the right on the coordinate plane
    (B) At an angle of 45° (up and to the right on the coordinate plane)
    (C) Up on the coordinate plane
    (D) At an angle of 135° (up and to the left on the coordinate plane)
    (E) To the left on the coordinate plane

11. A carbon nucleus has 6 protons. What can be said about the electrostatic force between an orbital electron and the carbon nucleus?

    (A) The attractive force of the nucleus on the electron is greater than the force of the electron on the nucleus.
    (B) The attractive force of the nucleus on the electron is less than the force of the electron on the nucleus.
    (C) The attractive force of the nucleus on the electron is equal to the force of the electron on the nucleus.
    (D) The repulsive force of the nucleus on the electron is equal to the force of the electron on the nucleus.
    (E) The repulsive force of the nucleus on the electron is greater than the force of the electron on the nucleus.

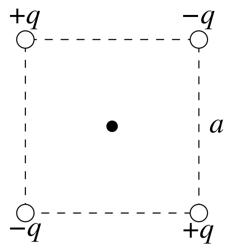
12. A hydrogen nucleus (charge $+e$) and a beryllium nucleus (charge $+4e$) experience a force, F. Which of the following expressions may be used to solve for the distance between the nuclei?

    (A) $e\sqrt{\frac{5k}{F}}$ (B) $2e\sqrt{\frac{k}{F}}$ (C) $\frac{4ke^2}{F}$ (D) $6Fe^2$ (E) $3Fe^2$

13. Two electrons exert an electrostatic repulsive force on each other. Is it possible to arrange the two electrons so the gravitational attraction between them is large enough to cancel out the electric repulsive force?

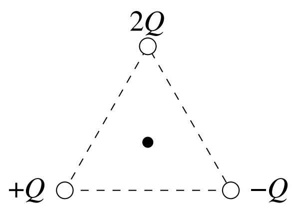
    (A) No, the charge of the electrons squared is much larger than the mass of the electrons squared.
    (B) No, there is no gravitational force between subatomic particles.
    (C) Yes, reducing the radius between the electrons will increase the gravitational force as it is proportional to the inverse of the radius squared.
    (D) Yes, increasing the distance between the electrons will reduce the electrostatic repulsion until it is equal to the gravitational force.

14. Four charges are arranged at the corners of a square of side a as shown. Which of the following is true of the electric field and the electric potential at the center of the square?



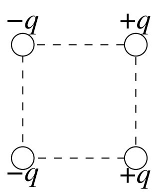
	Electric Field	Electric Potential
(A)	zero	zero
(B)	$\frac{kQ}{a\sqrt{2}}$	zero
(C)	$\frac{kQ^2}{2a^2}$	$\frac{kQ}{2a}$
(D)	zero	$\frac{kQ}{\sqrt{2}a}$
(E)	$\frac{kQ^2}{2a}$	$\frac{kQ}{a\sqrt{2}}$

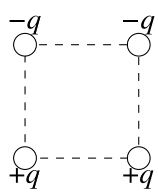
15. Three charges, $+Q$, $-Q$, and $+2Q$, are arranged in an equilateral triangle as shown. Which of the arrows below best represents the direction of the electric field at the center of the triangle?

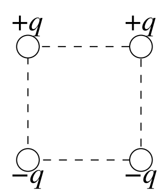


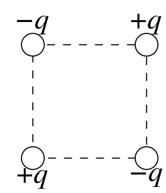
(A) $\downarrow$ (B) $\uparrow$ (C) $\searrow$ (D) $\swarrow$ (E) $\nearrow$

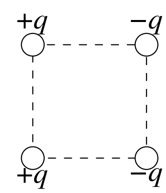
16. Which of the following diagrams best represents how you might rearrange the charges so that the electric field at the center would point directly toward the top of the page?

(A) 

(B) 

(C) 

(D) 

(E) 

17. The electric potential at the surface of the sphere from the last question is

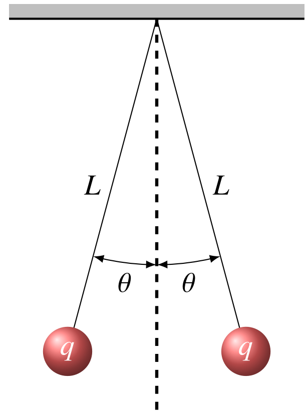
(A) $\frac{\beta R^3}{12\epsilon_0}$ (B) $\frac{\beta R}{2\epsilon_0}$ (C) $\frac{\beta R^3}{3\epsilon_0}$ (D) $\frac{\beta R^2}{2\epsilon_0}$ (E) $\frac{\beta R^2}{4\epsilon_0}$

18. Electric potential

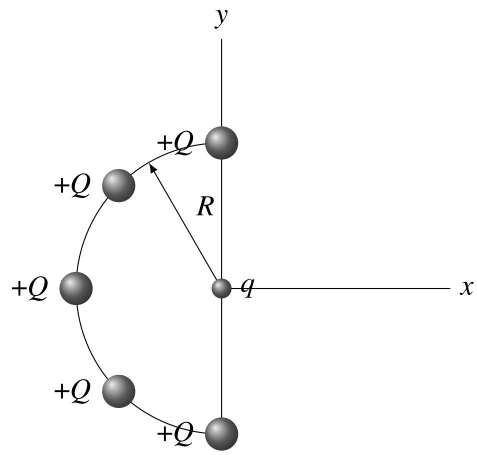
(A) is a vector quantity that depends on the direction of the electric field
(B) is a scalar quantity that depends on the magnitude and sign of charges in the vicinity
(C) is a scalar quantity that depends on the square of the distance from the charges in the vicinity
(D) is a vector quantity that depends on the sign of the charges in the vicinity
(E) is a vector quantity that must point from high to low potential

19. Which of the following statements is true of electric field and equipotential lines?

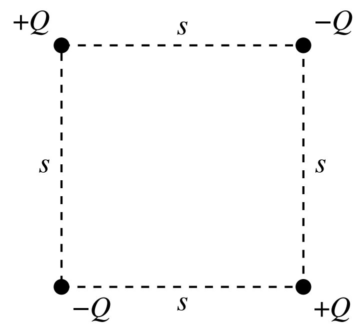
(A) The electric field vector always points in the same direction as the equipotential lines.
(B) The electric field always points in the opposite direction of the equipotential lines.
(C) The electric field always points perpendicular to the equipotential lines.
(D) The electric field is always equal to the equipotential lines.
(E) Equipotential lines always form a circle around electric field lines.



20. Two identical small spheres of mass m are suspended from a common point by threads of length L. When each sphere carries a charge q, each thread makes an angle θ with the vertical as shown in the figure below.
    (a) Express charge q in terms of θ, m, L and any other relevant constants
    (b) Compute q if $m = 10\,\mathrm{g}$, $L = 50\,\mathrm{cm}$ and $\theta = 10°$.



21. Five equal charges $+Q$ are equally spaced on a semicircle or radius R as shown in the figure below. Find the force on a charge q located at the center of the semi-circle. (Hint: Take advantage of symmetry.)



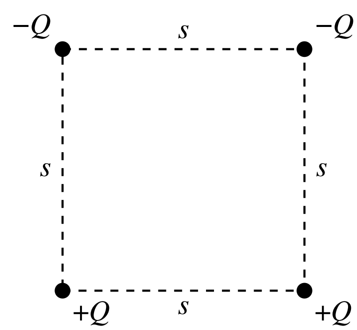
Arrangement 1

22. Four charged particles are held fixed at the corners of a square of side s. All the charges have the same magnitude Q, but two are positive and two are negative. In Arrangement 1, shown above, charges of the same sign are at opposite corners. Express your answers to parts (a) and (b) in terms of the given quantities and fundamental constants.

(a) For Arrangement 1, determine the following.

i. The electric potential at the center of the square

ii. The magnitude of the electric field at the center of the square



Arrangement 2

The bottom two charged particles are now switched to form Arrangement 2, shown above, in which the positively charged particles are on the left and the negatively charged particles are on the right.

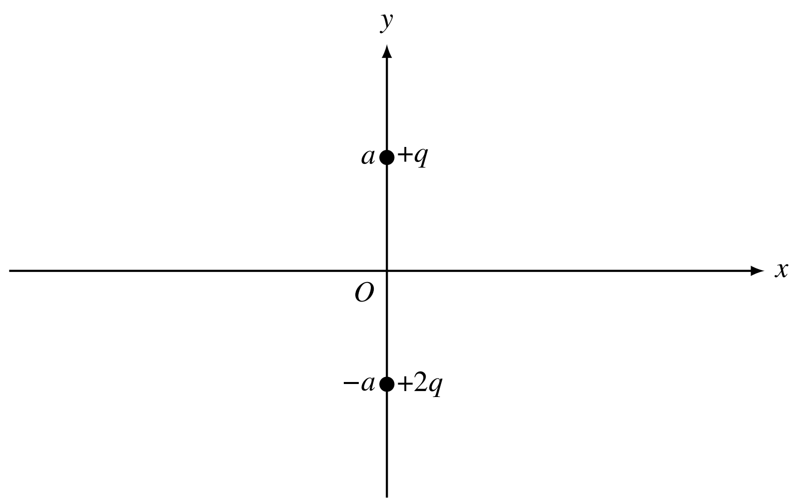
(b) For Arrangement 2, determine the following.

i. The electrostatic potential at the center of the square

ii. The magnitude of the electric field at the center of the square

(c) In which of the two arrangements would more work be required to remove the particle at the upper right corner from its present position to a distance a long way away from the arrangement? Justify your answer.

____Arrangement 1 ____Arrangement 2

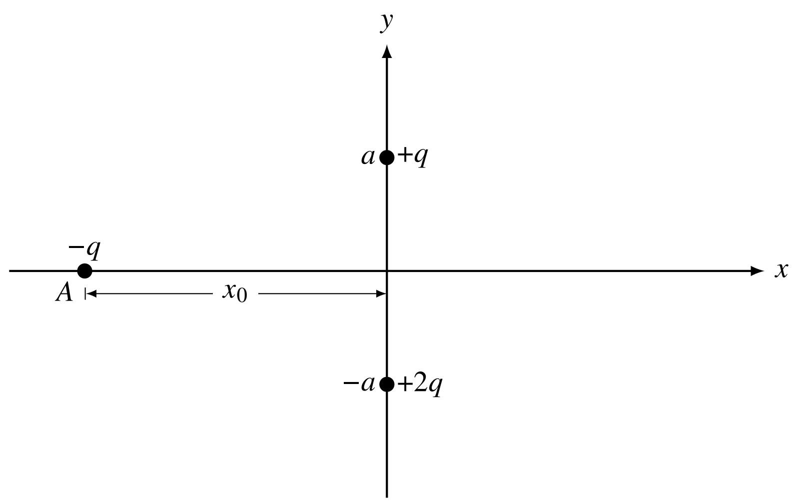


23. Two point charges are fixed on the y-axis at the locations shown in the figure above. A charge of $+q$ is located at $y = +a$ and a charge of $+2q$ is located at $y = -a$. Express your answers to parts (a) and (b) in terms of q, a, and fundamental constants.

(a) Determine the magnitude and direction of the electric field at the origin.

(b) Determine the electric potential at the origin.

A third charge of $-q$ is first placed at an arbitrary point A ($x = -x_0$) on the x-axis as shown in the figure below.

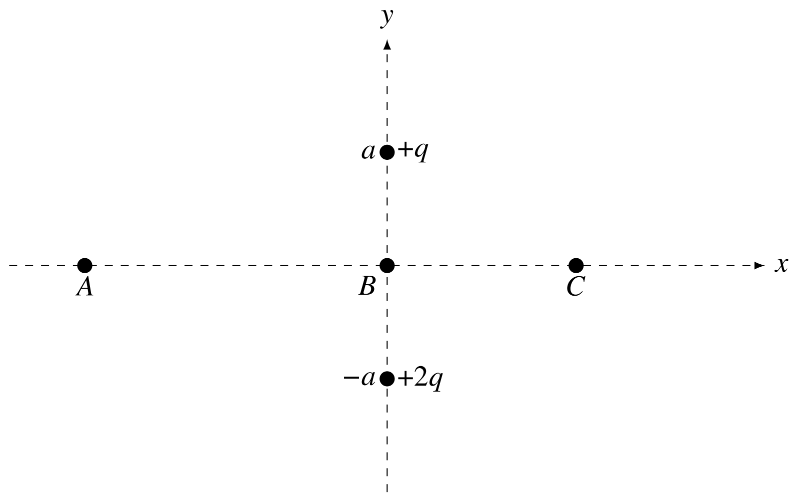


(c) Write expressions in terms of q, a, x_0, and fundamental constants for the magnitudes of the forces on the $-q$ charge at point A caused by each of the following.

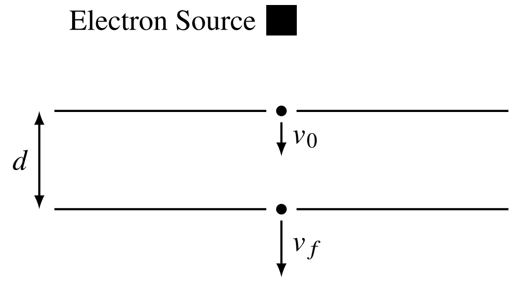
i. The $+q$ charge

ii. The $+2q$ charge

(d) The $-q$ charge can also be placed at other points on the x-axis. At each of the labeled points (A, B, and C) in the following diagram, draw a vector to represent the direction of the net force on the $-q$ charge due to the other two charges when it is at those points.



y
a
+q
A
B
C
x
−a
+2q



Note: Figure not drawn to scale.

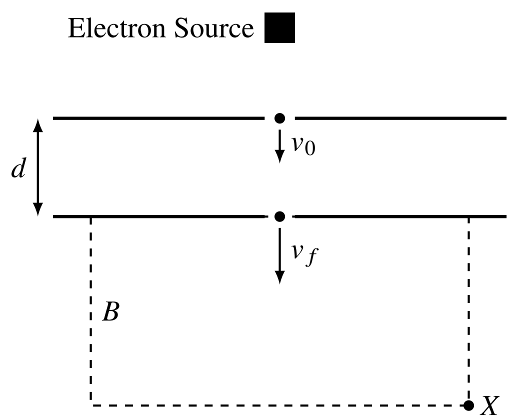
24. The apparatus shown in the figure above consists of two oppositely charged parallel conducting plates, each with area $A = 0.25\,\text{m}^2$, separated by a distance $d = 0.010\,\text{m}$. Each plate has a hole at its center through which electrons can pass. High velocity electrons produced by an electron source enter the top plate with speed $v_0 = 5.40 \times 10^6\,\text{m/s}$, take 1.49 ns to travel between the plates, and leave the bottom plate with speed $v_f = 8.02 \times 10^6\,\text{m/s}$.

(a) Which of the plates, top or bottom, is negatively charged? Support your answer with a reference to the direction of the electric field between the plates.

(b) Calculate the magnitude of the electric field between the plates.

(c) Calculate the magnitude of the charge on each plate.

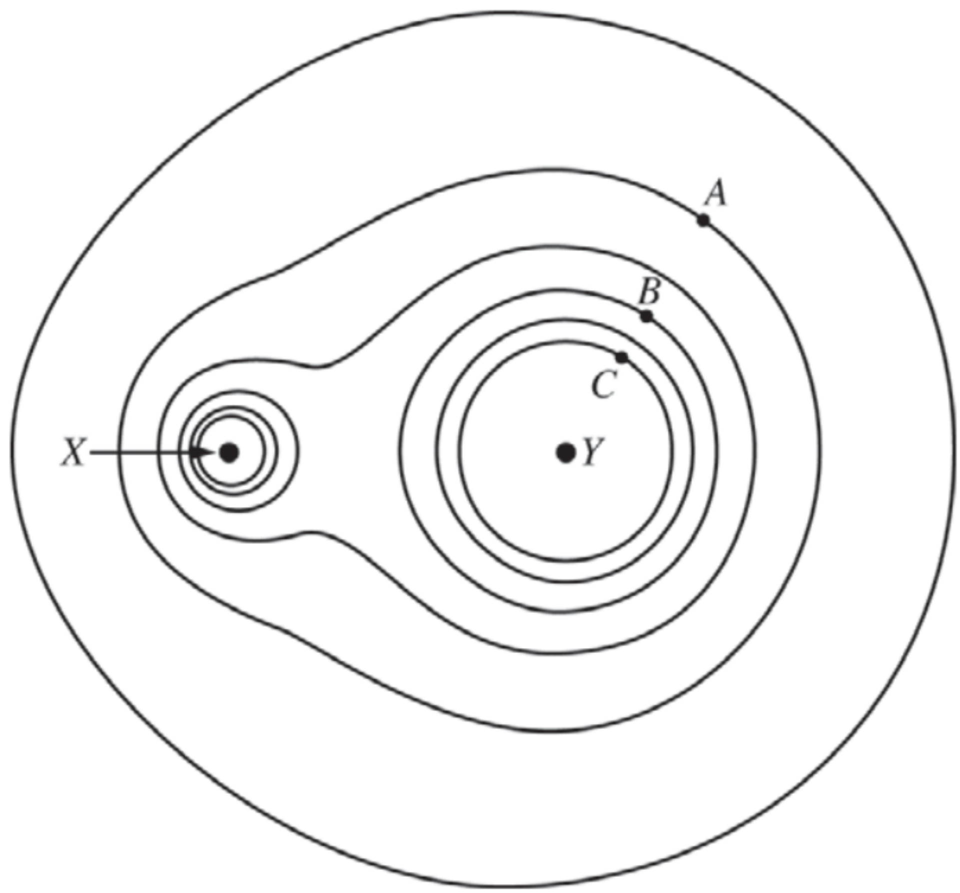
(d) The electrons leave the bottom plate and enter the region inside the dashed box shown below, which contains a uniform magnetic field of magnitude B that is perpendicular to the page. The electrons then leave the magnetic field at point X.



Note: Figure not drawn to scale.

i. On the figure above, sketch the path of the electrons from the bottom plate to point X. Explain why the path has the shape that you sketched.

ii. Indicate whether the magnetic field is directed into the page or out of the page. Briefly explain your choice.



25. The dots in the figure above represent two identical spheres, X and Y, that are fixed in place with their centers in the plane of the page. Both spheres are charged, and the charge on sphere Y is positive. The lines are isolines of electric potential, also in the plane of the page, with a potential difference of 10 V between each set of adjacent lines. The absolute value of the electric potential of the outermost line is 50 V.

(a) Indicate the values of the potentials, including the signs, at the labeled points A and B.

Potential at point A _______ Potential at point B _______

(b) i. How do the magnitudes and the signs of the charges of the spheres compare? Explain your answer in terms of the isolines of electric potential shown.

ii. The spheres at points X and Y have masses in the same ratio as the magnitudes of their charges. The isolines of gravitational potential for the spheres have shapes similar to those of the isolines shown. Explain why the two sets of isolines have similar shapes.

Let the potentials at the three labeled points be V_A, V_B, and V_C. A proton with charge $+q$ and mass m is released from rest at point B.

(c) Based on your answer to part (b)(ii), briefly describe one similarity and one difference between the electric and gravitational forces exerted on the proton by the system of the two spheres. The similarity and difference you describe must not be ones that generally apply to all forces.

(d) At some time after being released from rest at point B, the proton has moved through a potential difference of magnitude 20 V.

i. Determine the change in electric potential energy of the proton-spheres system when the proton has moved through the 20 V potential difference. Express your answer symbolically in terms of q, V_A, V_B, V_C, and physical constants, as appropriate.

ii. As it moved through the 20 V potential difference, the proton was displaced a distance d by the electric force. Determine a symbolic expression for the total work done on the proton by the electric field in terms of the average magnitude E avg of the electric field over that distance.

iii. Two students are discussing how and why the kinetic energy of the proton would change after it is released.

- Student 1 says that if the system is defined as the proton and the spheres, the increase in the protons kinetic energy is due to a change in the system's potential energy as the proton moves through the 20 V potential difference.
- Student 2 says that if the system is defined as only the proton, the kinetic energy of the proton increases because positive work is done on the proton by the electric field as the proton moves through the 20 V potential difference.

Discuss each student's claims, explaining why each is correct or incorrect.