Elementary Charge and Conservation of Charge

1 An object contains 50 protons and 14 electrons. Determine its elementary charge and charge in coulombs.

2 Demonstrate that it is not possible for an object to have a charge of -2.8×10^{-19} coulombs.

3 A neutral wooden rod is rubbed on neutral piece of cloth, causing the rod to gain a charge of -4.5 nC. What is the charge on the cloth? How many electrons were transferred and from what to what?

4 A metal sphere with a charge of -3.0 µC is touched to an identical metal sphere with a charge of +9.4 µC. What is the total charge on the two spheres? What is the charge on each if they are separated after touching?

5 A positively charged body touches a neutral body. The neutral body will:

(1) gain protons (3) gain electrons
(2) lose protons (4) lose electrons

Charging Processes and Sensing Charge

6 A positively charged rod is brought near the top of a charged electroscope, causing the leaves of the electroscope to converge. What charge does the electroscope have: +, - or 0?

7 Object X is charged positively by object Y without any contact between the two.

a. What charging process does this require?
b. What charge did object Y have?
c. What must you assume about object X during this process?

8 What is the purpose of grounding an object?

9 How would the leaves of a positively charged electroscope behave if a negatively charged rod were brought near the electroscope, then taken away?

10 A pith ball is observed to be attracted to a negatively charged rod. What charge does the pith ball have?

11 Object A is negatively charged. Objects C and D are repelled from one another. Object C is attracted to object A. Object B is attracted to objects A and D. What are the charges on the four objects?

12 What test could you perform to definitively show that an object is negatively charged? What test would demonstrate that a similar object is uncharged?

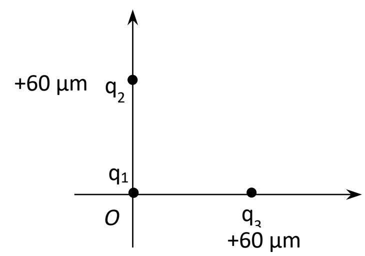
Electrostatic Force

13 What is the electrostatic force acting on two electrons that are separated by a distance of 5.0 nm?

14 Charges q_1 and q_2 are positioned a distance R apart, causing them to be attracted by force F.

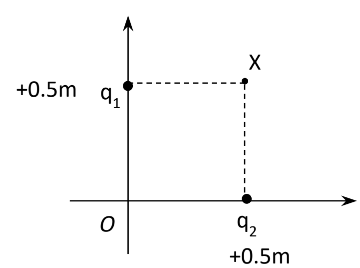
a. What can you conclude about charges q_1 and q_2?
b. What would the force between them be if:
   i. the distance between them was halved?
   ii. both charges were doubled?
   iii. one charge is tripled and the distance between them is doubled?

15 A set of three charges are distributed as shown in the diagram below. Charge q_1 is -2nC, charges q_2 and q_3 are -4nC. Calculate the net electrostatic force on charge q_1.



Electric Fields

16 Two charges are distributed as shown in the diagram below. Charge q_1 is +8nC and charge q_2 is -4nC. Calculate the electrostatic field strength at the origin and at point X.

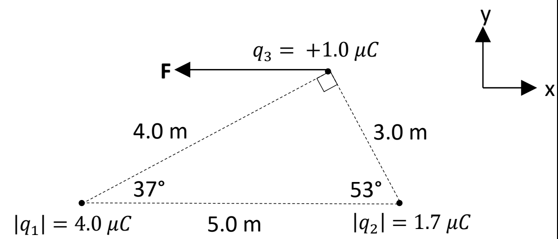


17 An electron is in an electric field with a strength of 2.0×10^{-10} N/C.

a. What is the net force on the electron?
b. What acceleration will the electron experience while in the electric field?

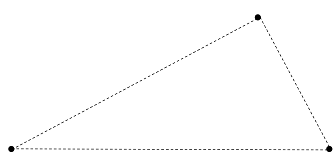
18 What is the strength of the electric field generated by a +4 C charge at a distance of 10 cm?

19 Three particles are fixed in a horizontal plane, as shown in the figure below. Particle 3 at the top of the triangle has charge q_3 of +1.0 μC, and the electrostatic force **F** on it due to the charge on the other two particles is measured entirely in the negative x-direction. The magnitude of the charge q_1 on particle 1 is known to be 4.0 μC and the magnitude of the charge q_2 on particle 2 is known to be 1.7 μC, but their signs are not known.



a. Determine the signs of the charges q_1 and q_2.

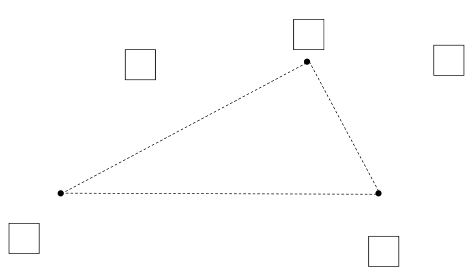
b. On the diagram below, draw and label arrows to indicate the direction of the force F_1 exerted by particle 1 on particle 3 and the force F_2 exerted by particle 2 on particle 3.



c. Calculate the magnitude of F, the electrostatic force on particle 3.

d. Calculate the magnitude of the electric field at the position of particle 3 due to the other two particles.

e. On the diagram below, draw a small X in the box that is a position at which another positively charged particle could be placed so that the electrostatic force on particle 3 is zero.



20 The picture below shows a set of electric field lines.

a. At which point is the field likely to be the strongest?
b. At which point is the field likely the weakest?
c. Sketch a dotted line through point A that represents an equipotential line. (Note how field lines should correlate to equipotential lines!)
d. In which areas near the edges of the diagram of field lines would you likely find positive/negative charges?

Electrical Potential

21 What is the electric potential 15 cm from a 4 μC point charge?

22 A charge q creates an electric potential of +125 V at a distance of 15 cm. What is charge q?

23 A +30 nC charge is placed 3 m from an identical +30 nC charge. How much work is needed to move a +0.50 nC charge from a point midway between the two +30 nC charges to a point that is 1 m closer to either of them?

24 How much work is needed to bring three electrons from a very large distance apart to a distance of 1.0×10^{-10} meter from one another?

25 A point charge of -3.8μC is 70 cm south of point A and 80 cm east of point B.

a. What is the difference in electrical potential between the two points?
b. How much work is needed to move a -1.5 nC charge from point A to point B? Is the work done by the electric field or does an external force need to do the work?

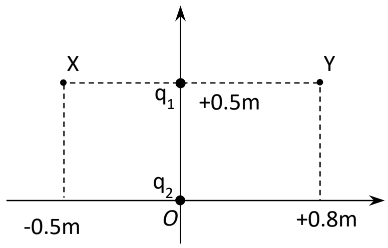
26 An electron begins from rest at a point 72.5 cm from a fixed point charge (q = -0.125 μC). How fast will the electron be moving when it is very far from this charge?

27 An electron is accelerated from rest through an electric field to a kinetic energy of 40 electron-volts.

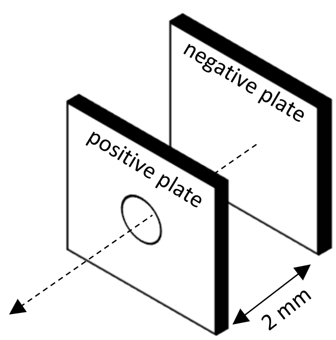
a. What is the electric potential through which the electron was accelerated?
b. What is the final speed of the electron?

28 A charge of -7.50 μC is moved from point A to point B by an external force. If the charge began from rest and had 4.82×10^{-4} joules of kinetic energy at point B, what is the potential difference between A and B?

29 Two charges are distributed as shown in the diagram below. Charge q_1 is +6nC and charge q_2 is -6nC. Determine the amount of energy needed to move an electron from point X to point Y.



30 A set of charged parallel plates are shown below. An electron is released very close to the negatively charged plate and approaches the positive plate to emerge into the space outside the plates. The potential difference between the plates is 0.5 volts.



a. Calculate the electric field strength between the plates.
b. At what rate will the electron accelerate when placed between the plates?
c. At what kinetic energy (in eV) will the electron leave the space between the plates?
d. What speed will the electron have when it passes the positive plate?

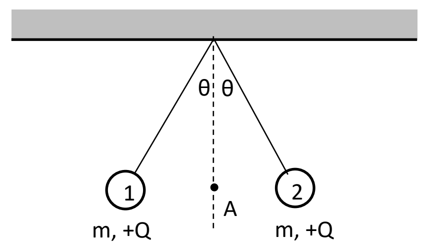
31 A -5 C charge is placed near a positively charged plate of charge. As the charge is moved away from the plate…

a. …does the electrical potential energy of the charge increase or decrease?
b. …does the electrical potential of the charge increase or decrease?
c. …is work done by the electric field or by a non-conservative force?

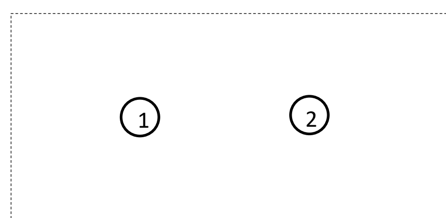
32 A -0.6 nC charge is placed in an open space.

a. What is the magnitude of the electric field strength at a point 3.2 meters from this charge?
b. If a -0.4 nC charge is moved from a great distance to a point 3.2 meters from the -0.6 nC charge…
   i. What change in electrical potential did the -0.4 nC charge experience?
   ii. What change in electrical potential energy did it experience?
   iii. What is the magnitude of the electrostatic force between the two charges at this distance? Find it TWO ways!

33 Two small objects, labeled 1 and 2 in the diagram below are suspended in equilibrium from strings of length L. Each object has a mass m and charge +Q. Assume that the strings have negligible mass and are insulating and electrically neutral. Express all algebraic answers in terms of m, L, Q, θ and fundamental constants.

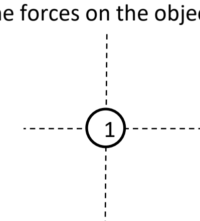


a. On the following diagram, sketch lines to illustrate a 2-dimensional view of the net electric field due to the two objects in the region enclosed by the dashed lines.



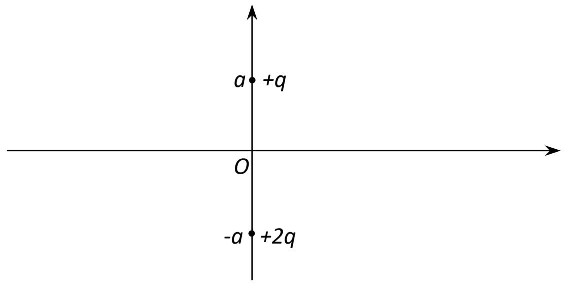
b. Derive an expression for the electric potential at point A, shown in the diagram above. Assume that point A is midway between the two charged objects.

c. On the following diagram of object 1, draw and label vectors to represent the forces on the object.



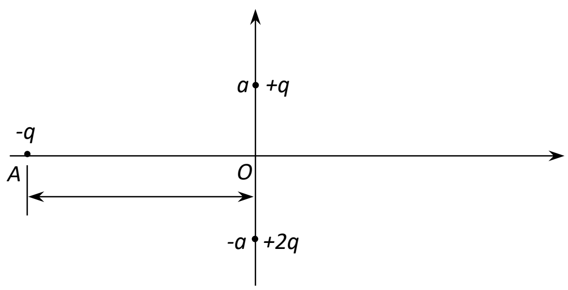
d. Using the conditions of equilibrium, write – but do not solve – two equations that could, together be solved for θ and the tension in the left-hand string.

34 Two point charges are fixed on the y-axis at the locations shown in the diagram below. 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.



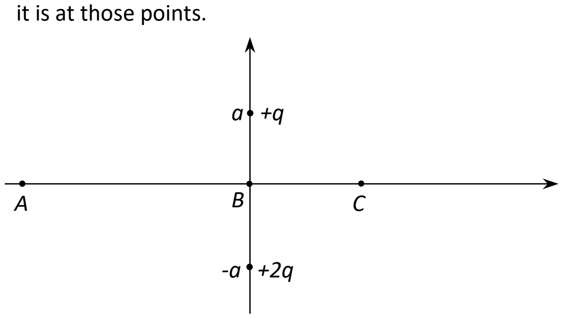
a. Determine the magnitude and direction of the electric field at the origin.
b. Determine the electric potential at the origin.

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



c. Write expressions in terms of q, a, x_O 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 in which the net force on the –q charge due to the other two charges when it is at those points.



Capacitance

35 A set of parallel plates with an area of 0.35 m^2 are separated by air and are arranged so that they are 2.45 mm apart. If the electric field strength desired between the plates if 8.5 x 10^5 V/m, what charge must be accumulated on the plates?

36 A set of parallel plates with an area of 0.02 m^2 that are separated by a distance of 2.5 mm are subjected to a voltage difference of 12 volts.

a. What is the capacitance of the two plates?
b. What is the strength of the electric field between the plates?
c. How much charge do the plates accumulate?
d. What amount of energy is stored between the plates?

37 A 7500 pF capacitor holds 16.5 x 10^{-8} C of charge. What is the voltage difference between the plates?

38 What is the area of the plates of a 0.20 μF capacitor if its plates are separated by a 2.2 mm air gap?

39 Determine the energy stored in a 7200 μF capacitor when a 550 V potential difference is applied to it.

40 A 1.5 nF capacitor is built from two opposite and equally charged, parallel plates positioned a distance of 3.5 mm apart with air in between them. When the capacitor is fully charged, the electric field between the plates has a strength of 2000 newtons per coulomb.

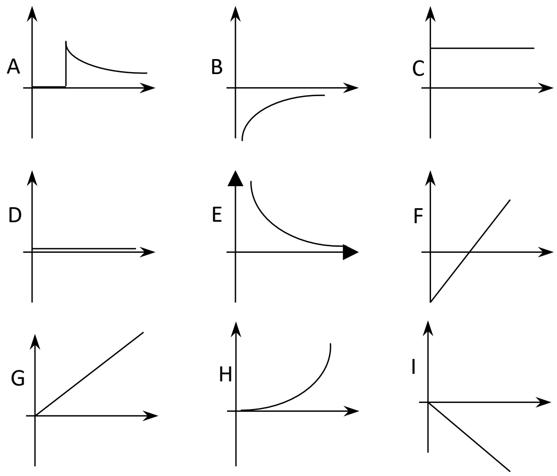
a. What is the potential difference between the plates?
b. How much charge accumulates on the plates when the capacitor is fully charged?
c. What is the area of the plates?

41 0.5 joules of energy are stored in an air-filled capacitor with plates positioned 20μm apart when a potential difference of 3.0 kV is applied to its plates.

a. What is the charge on the plates?
b. What is its capacitance?
c. What is the area of the plates?

Graphs

Use the graphs below to answer the next six questions.



42 A negative point charge is located in empty space.

a. Which graph best shows the relationship between electrical potential and distance from the point charge?

b. Which graph best shows the relationship between the magnitude of the electric field strength and distance from the point charge?

43 A positively charged conducting sphere is placed on an insulated stand. Which graph best shows how the magnitude of the electric field strength varies when measured from the center of the sphere outward? How would this graph be different if it were an insulating sphere with a uniform charge distribution throughout its interior?

44 Two equal and oppositely charged plates are arranged parallel to each other.

a. Which graph best shows the relationship between the magnitude of the electric field strength between the plates and distance from the positively charged plate?

b. Which graph best shows how electrical potential changes as a charge is moved from the negatively charged plate to the positively charged one?

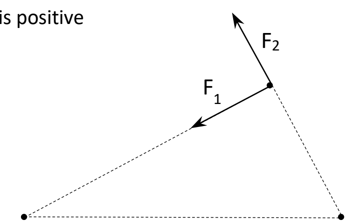
45 Which graph best represents the relationship between the force that two point charges exert on one another and the distance between them?

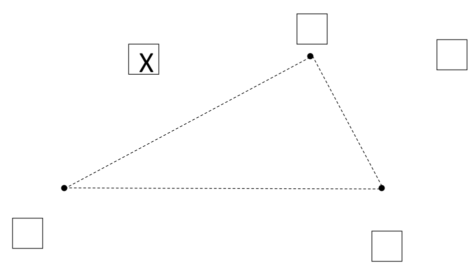
46 Which graph best represents the magnitude of the strength of the electric field between two parallel charged plates and the potential difference between the two plates?

47 Which graph best represents the relationship between the energy stored in a capacitor and the potential difference across its plates?

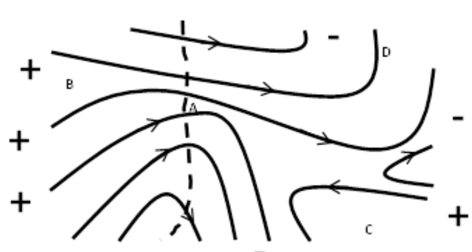
Answers

1. +36e or 5.76E-18C
2. -1.75e is not a possible charge
3. cloth has a charge of +4.5nC. 2.8125E10 electrons transferred
4. +6.4µC total. They will have +3.2µC each.
5. (4)
6. negative
7. a: charging by induction b: negative c. it was grounded during the charging process
8. to make it neutral
9. converge and then diverge back to their initial state
10. positive or neutral
11. A is negative, B is neutral, C and D are positive
12. It must repel something negative.
    It must be attracted to both positive and negative charges.
13. 9.21E-12 N
14. a: They have opposite charges bi: 4x greater ii: 4x greater iii: ¾ as great
15. -20N$\hat{\imath}$ – 20N$\hat{\jmath}$
16. E_X = +288N/C $\hat{\imath}$ – 144 N/C $\hat{\jmath}$
    E_O = +144N/C $\hat{\imath}$ – 288 N/C $\hat{\jmath}$
17. a: 3.2E-29 N b: 35 m/s^2
18. 3.6E12 N/C
19. a. q_1 is negative and q_2 is positive
    b.
    c. 2.8E-3N
    d. 2.8E3 N/C
    e.



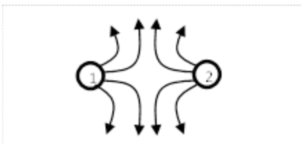


20. a. A – the field lines are densest in that area
    b. C – fewest fields lines nearby

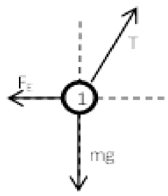


21. 240 kV
22. 2.08 nC
23. 1.44E-7 J
24. 6.9E-18J
25. a: A = -48857 V B = -42750V ΔV = +6107 V b: 9.16 J of work will be done by the electric field
26. 2.33E7 m/s
27. a: 40V b: 3.75E6 m/s
28. 64.3V

29. 21.4eV
30. a. 250 N/C b. 4.4E13 m/s^2 c. 0.5 eV d. 4.2E5 m/s
31. a. Electrical potential decreases (getting farther from a positive charge)
    b. Electrical potential energy increases (energy is stored in the electric field)
    c. Work must be done by a non-conservative force
32. a. 0.53 N/C
    b. i. electrical potential goes from 0 to -1.6875 V
    ii. electrical potential energy goes from 0 to 6.75E-10 J
    iii. 2.12E-10 N

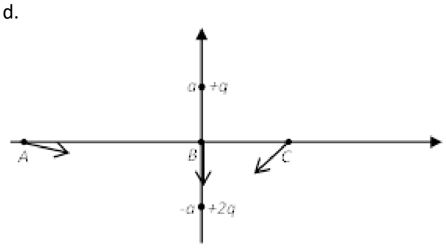


33. a.
    b. $V = \frac{2kQ}{Lsin\theta}$
    c.



    d. $Tcos\theta = mg \quad Tsin\theta = \frac{kQ^2}{(Lsin\theta)^2}$

34. a. $\frac{kq}{a^2}\hat{j}$ b. $\frac{3kq}{a}$ c. $\frac{kq^2}{x_O^2+a^2}$ $\frac{2kq^2}{x_O^2+a^2}$
    d.



35. 2.63µC
36. a: 7.08E-11 F b: 4800 V/m c: 8.5E-10 C d: 5.1E-9 J
37. 22V
38. 49 m^2
39. 1089J
40. a: 7V b: 1.05E-8 C c: 0.59 m^2
41. a. 3.33E-4 C b. 1.11E-7 F c. 0.25 m^2
42. a. B – the electrical potential is a large negative value near a negative charge
    b. E – electric field strength reduces in magnitude with distance
43. A – electric field is zero inside the sphere and jumps to its maximum value right at the edge. If the sphere were a uniformly charged insulator the first part of the graph would begin at zero and increase directly until reaching the edge of the sphere – after that the graph would be the same.
44. a. C – the field strength between two charged plates is a constant value
    b. F – close to the negative plate the potential is a large negative value, near the positive one it is a large positive value.
45. E – $|\vec{F}_E| = \frac{1}{4\pi\varepsilon_o}\frac{|q_1 q_2|}{r^2}$
46. G – $|\vec{E}| = \left|\frac{\Delta V}{\Delta r}\right|$
47. H – $U_C = \frac{1}{2}C(\Delta V)^2$