Electrostatics

Advanced Placement Physics B
Mr. DiBucci

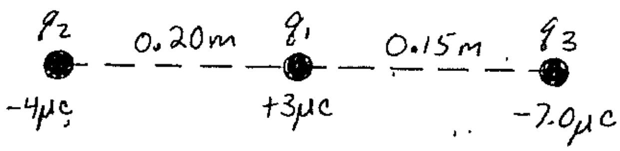
Name ______________________________ per. ____ Date _____
Electrostatic Forces DiBucci
AP Physics B

1. How many electrons are in one Coulomb of Charge?(6.25E+18)

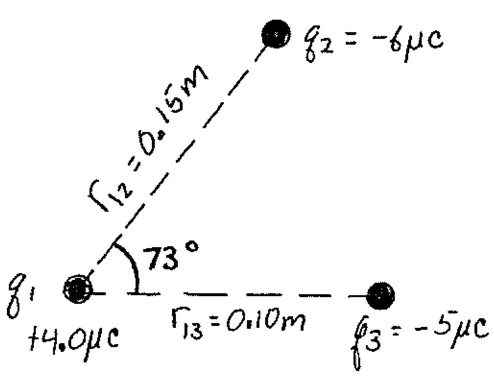
2. Two objects, whose charges are equal to +1.0 C and -1.0C, are separated by 1.0km. Compared to the 1.0km the size of the objects are very small. Calculate the magnitude of the attractive force that either charge exerts on the other.(9.0E+3)

3. The Bohr model of the Hydrogen atom the electron orbits the positive nucleus at a radius r = 5.29E-11m. Determine the speed of the electron.(Me=9.11E-31 kg) (2.18×10^6 m/s)

4. The figure below shows three charges in a line that lie located along the x-axis. Determine the magnitude and direction of the net electrostatic force on q1.(+5.7N)



5. In the figure below three charges lie in the x,y plane, Calculate the net electrostatic force on q1.(23N, 24 degrees)



Name ______________________________ Per ___ Date______
Electric Forces, Field Mapping and Electric Fields DiBucci

Directions:

1. On a separate sheet of graph paper construct a coordinate axis system near the center of the paper. Place a + 1 micro coulomb charge at the origin.
K= 9.0 E +9 Nm^2/C^2
All distances are in cm

a. Calculate the Electric field strength and sketch a the Electric field Vector at the following locations: (make sure to scale your vectors)
(0,1) (1,0) (0, -1) (-1, 0)

(0,2) (2,,0) (0,-2) (-2,0)

(0,4) (4,0) (0,-4) (-4,0)

(0,8) (8,0) (0,-8) (-8,0)

b. What types of conclusions can be found about the charge's E-field symmetry and its strength?

c. Sketch a small graph of the E-field as a function of the radius in the space below:

d. What other fundamental force of nature follows this same mathematical relationship?

e. On the same graph place a -2 micro coulomb at (4 cm, 0 cm), and calculate the force, magnitude and direction, that the first charge applies to this one.

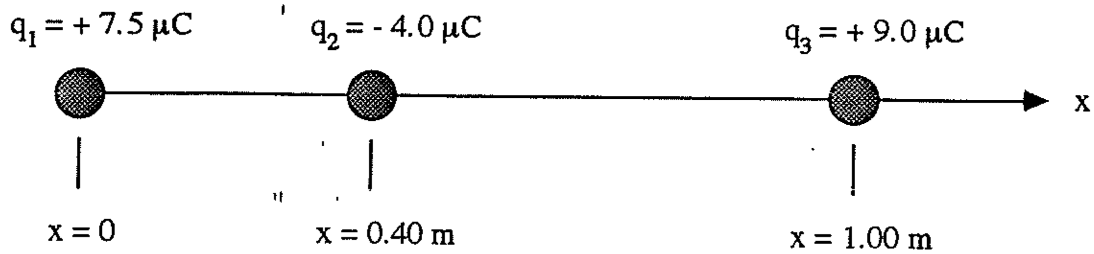
f. Verify you get the same results using coulomb's law

PRACTICE PROBLEMS

1. How many electrons must be removed from an electrically neutral silver dollar to give it a charge of +3.8 μC?

(2.4×10^{13})

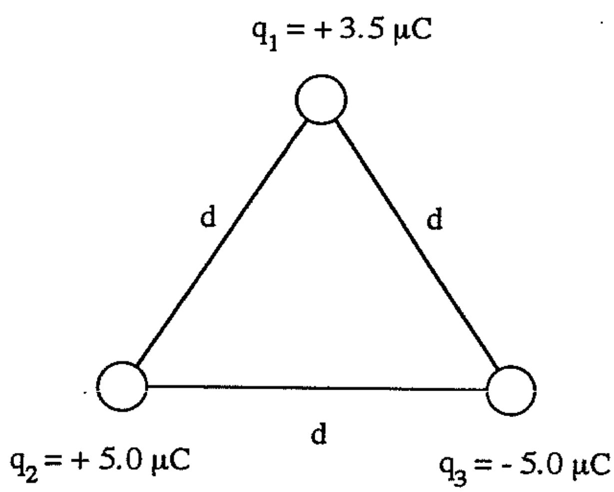
2. Three charges are located along a straight line, as shown below. What is the net electric force on charge q_2?



(0.8N left)

3. Three charges are located at the corners of an equilateral triangle, as shown below. What is the net electric force (magnitude and direction) acting on the top charge, q_1? Take d = 0.50 m.

(0.63 N in the +x DIRECTION)

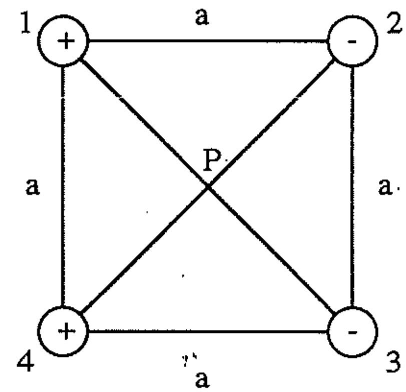


4. Two charges, $q_1 = +5.0\ \mu C$ and $q_2 = -3.0\ \mu C$, are separated by a distance of 1.0 m. Find the spot along the line between the charges where the net electric field is zero.

(X = 3.4m)

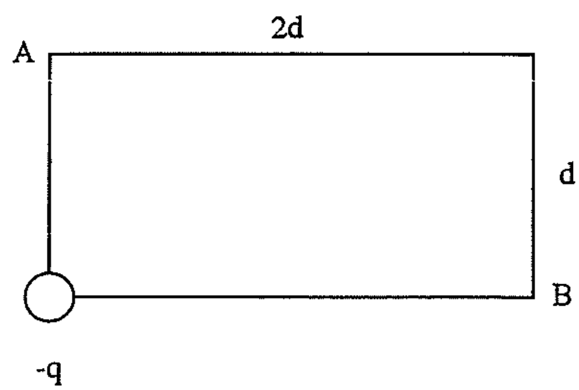
5. Four charges are arranged at the corners of a square, as shown below. Take $a = 0.25$ m. If all the charges have the same magnitude of 6.0 μC, what is the magnitude and direction of the electric field at the center of the square, at P?

$(4.8 \times 10^6\ N/C)$



6. A negative charge - q is fixed to one corner of a rectangle, as in the drawing. What positive charge must be fixed to corner A and what positive charge must be fixed to corner B, so the total electric field at the remaining corner is zero? Express your answer in terms of q.

$\{ q_A = 0.716q,\ q_B = 0.0895q \}$



Name ____ Per. ___ Date _____

Superposition of Electric Fields DiBucci

Directions:

On a separate piece of graph paper construct a coordinate axis system near the center. Place the following charges in the locations indicated. ***Note: all distances are in centimeters and all charges are in micro coulombs.***

Charge	X coordinate	Y coordinate
$+3\mu c$	-3cm	0
$-3\mu c$	+3cm	0

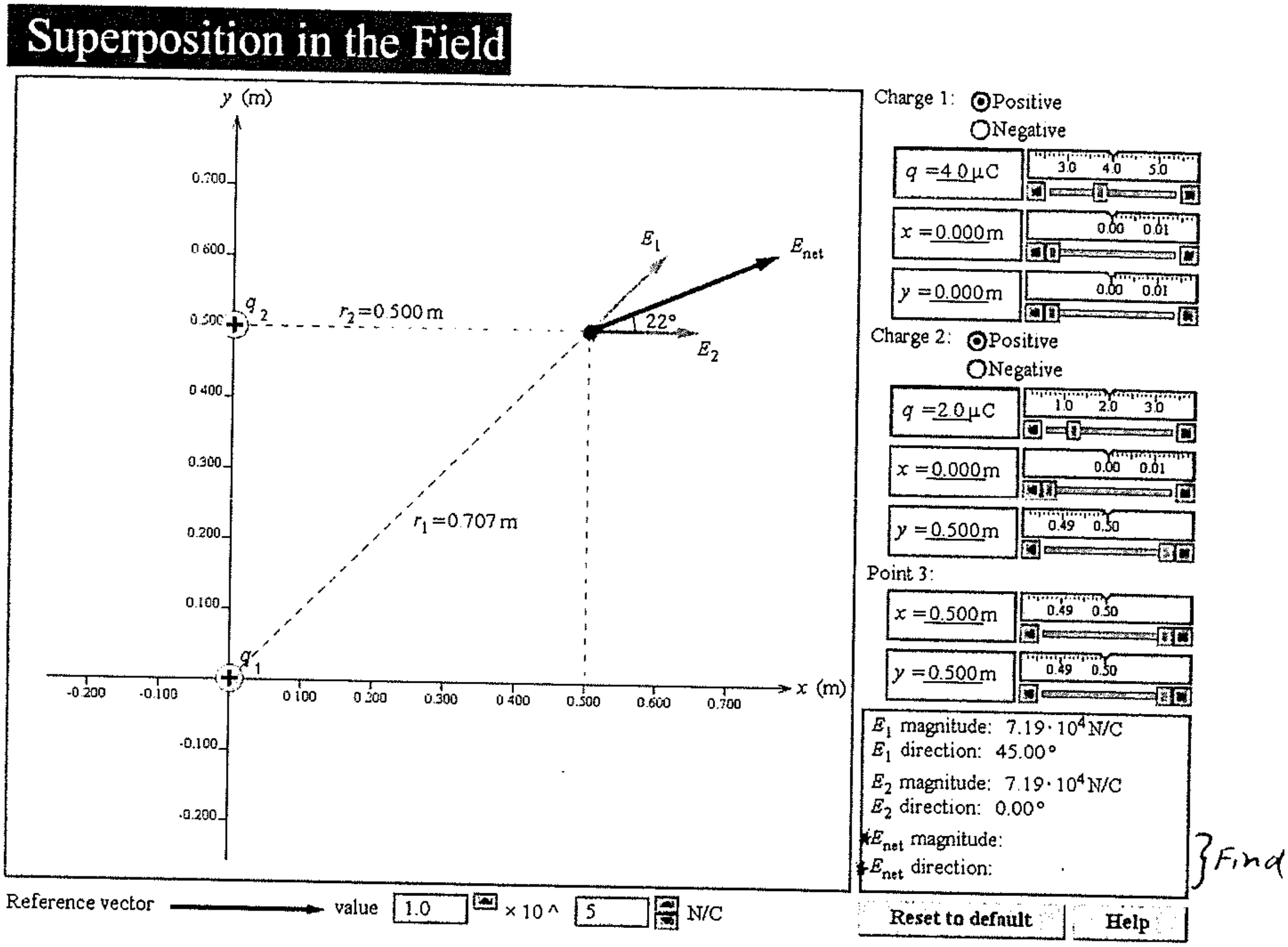
a. Use the formula for the electric field due to a point charge and calculate the Electric field strength for each charge at point P located at (0,4):

b. Use vector addition to calculate the resultant Electric field strength at P:

c. Calculate the amount of force on a +5 micro coulomb charge placed at P

d. Calculate the amount of force if a -5 micro coulomb charge were placed there instead.

e. Is there any difference between your answers from parts c and d, if yes explain why.



2. Calculate the net electric field at the indicated point.

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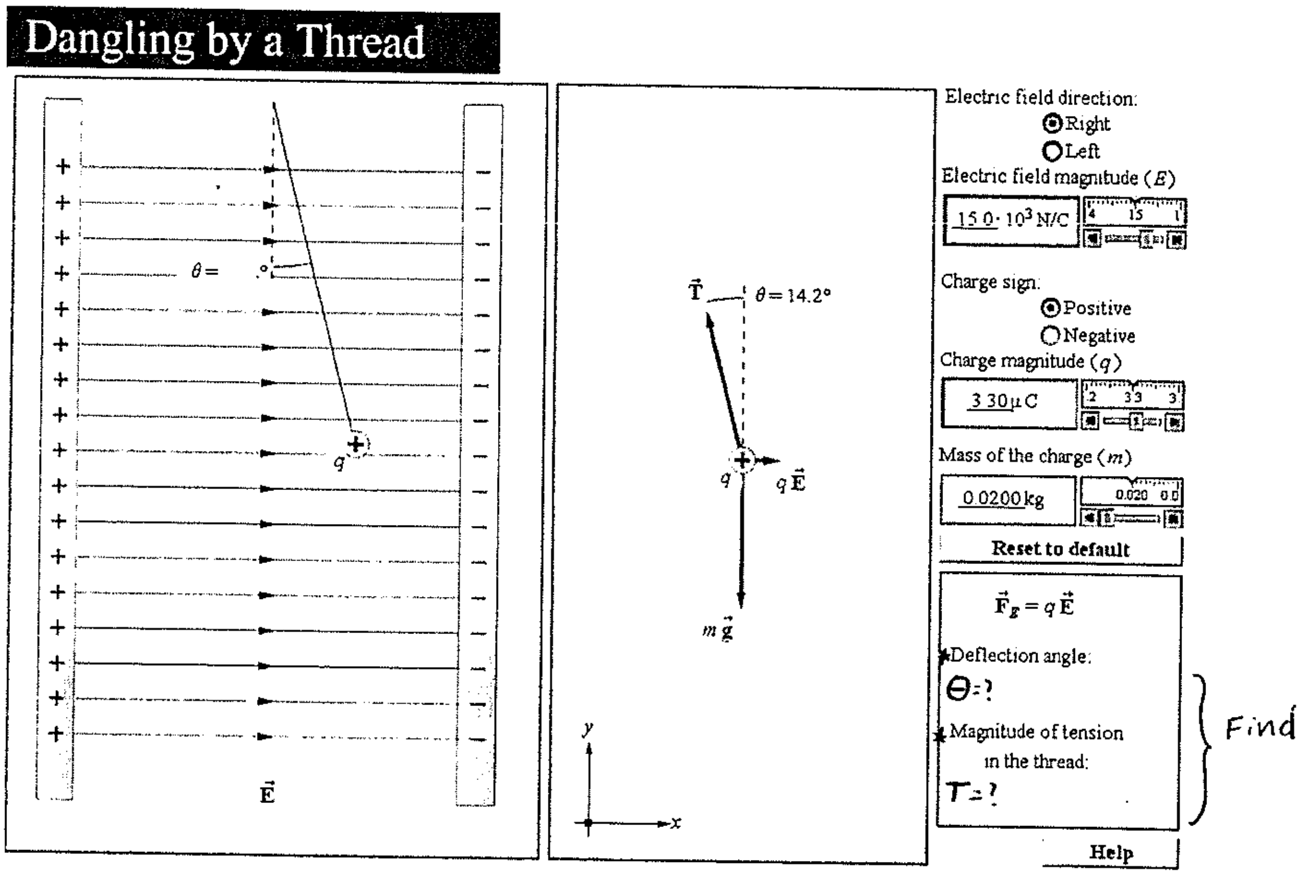
Electrostatics

Solve the following two problems in the space provided.

1. Calculate the tension force in the string, and the angle the string makes from the vertical.



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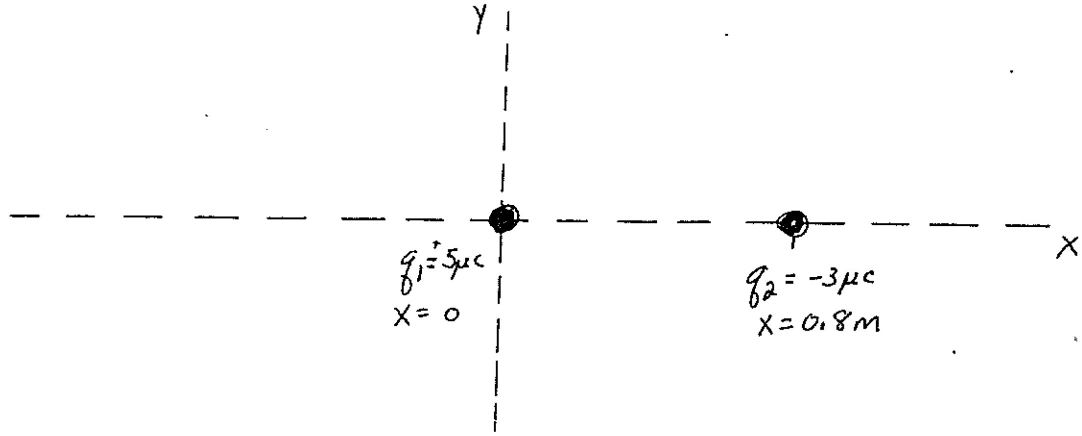
$Q = Ne$

Quiz: Electric Fields and Electric Forces — ***DiBucci***

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

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



$k = 9 \times 10^9 \frac{N \cdot m^2}{C^2}$

$e = 1.6 \times 10^{-19} C$

1. ***Consider the diagram above.***

   a) ***Calculate the force of q1 on q2***
   b) ***Calculate the position along the x-axis where the electric field is zero.***
   c) ***Calculate the number of excess protons on q1.***

Show your work below here:

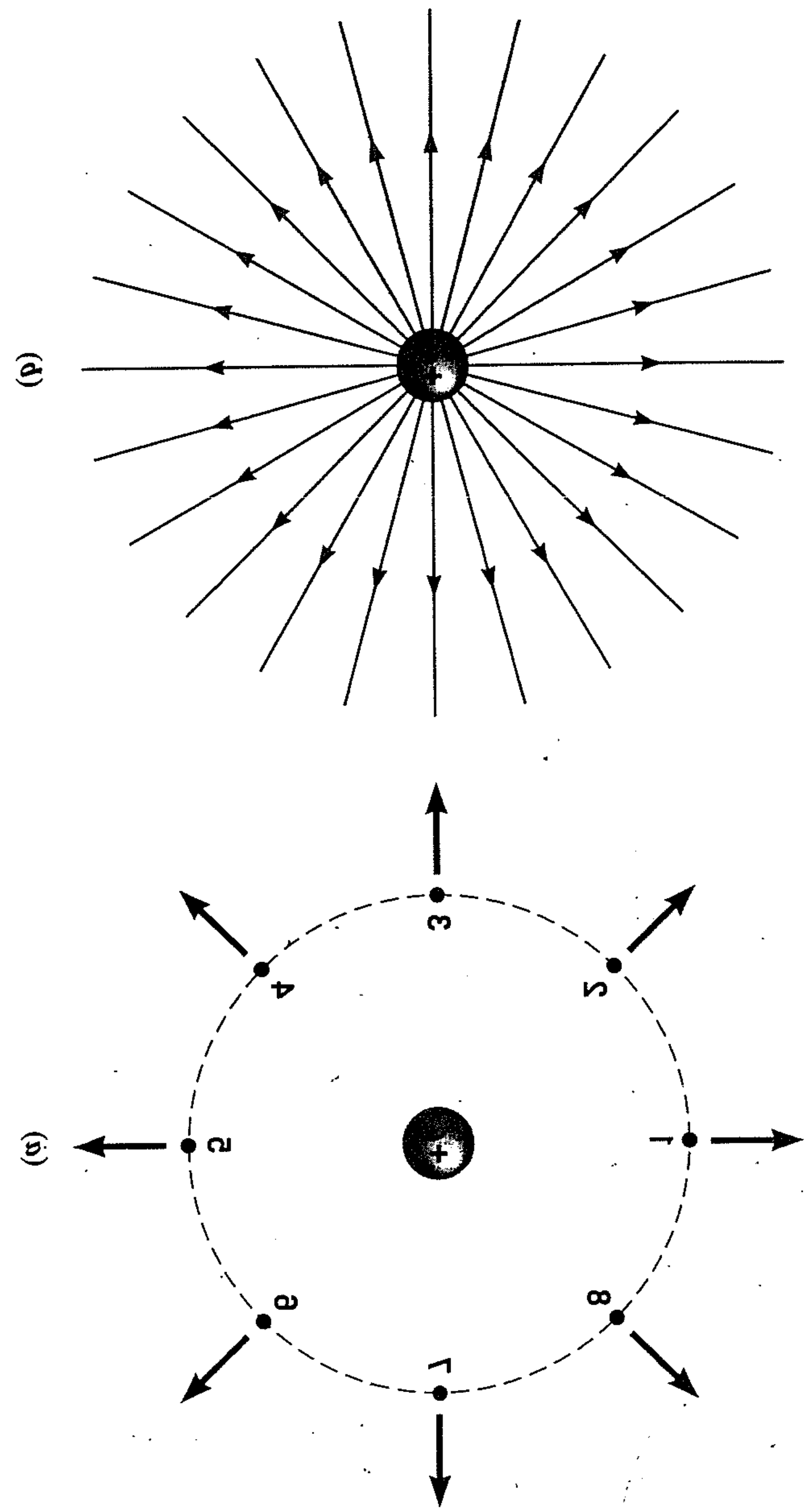


 FIGURE 18-24

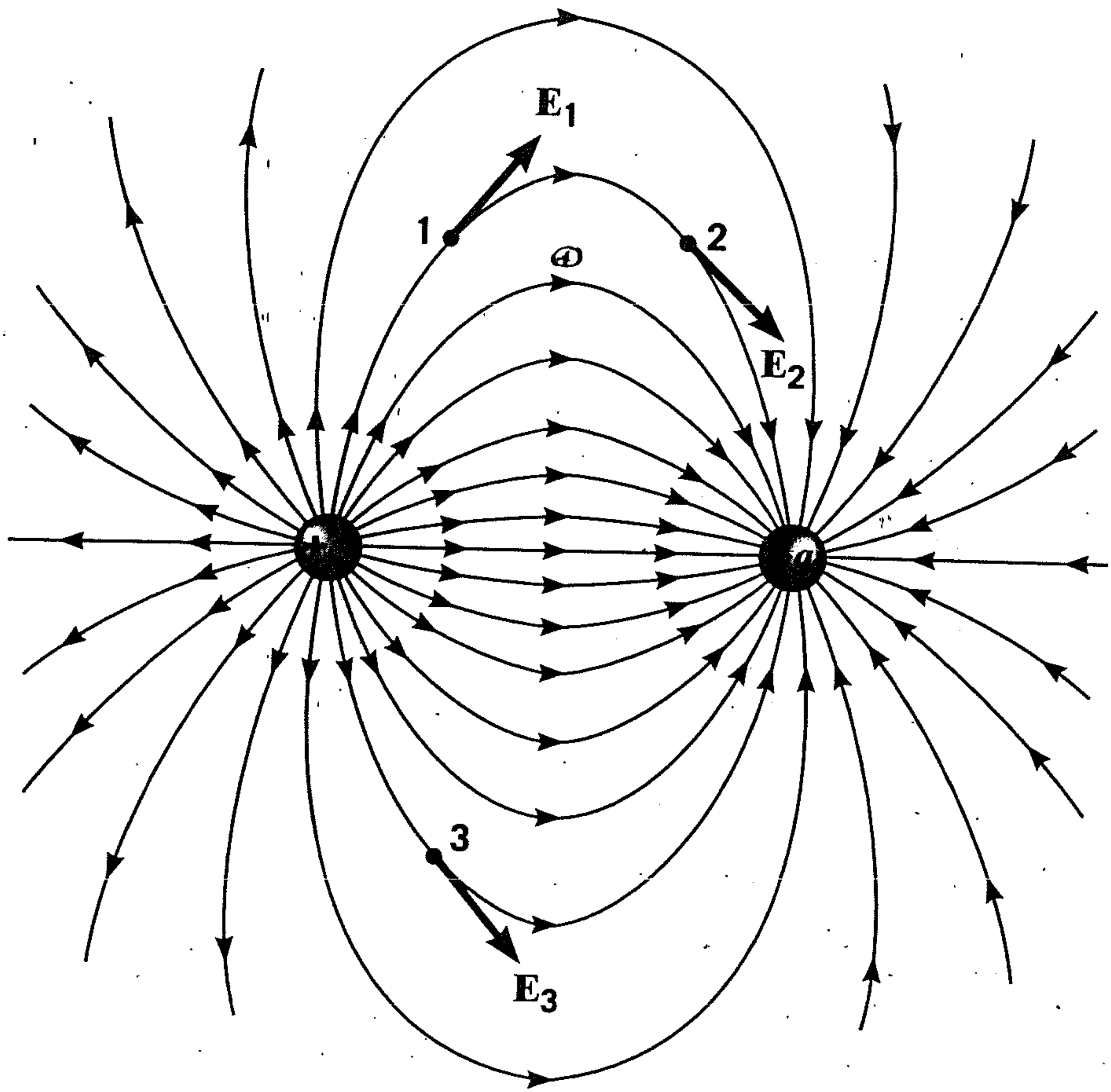


FIGURE 18-27

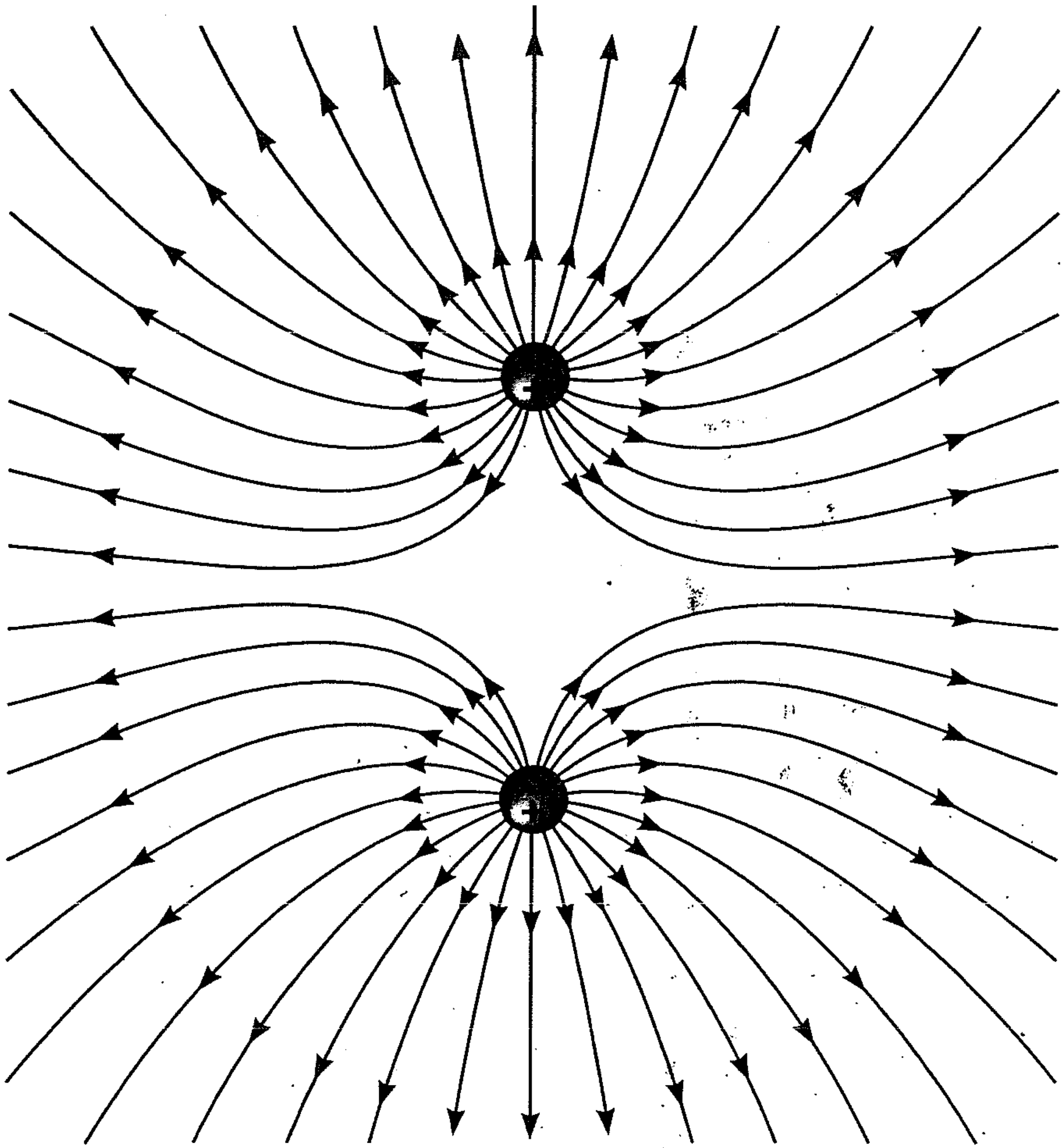


FIGURE 18-28

ELECTRIC FORCES AND ELECTRIC FIELDS WS #2

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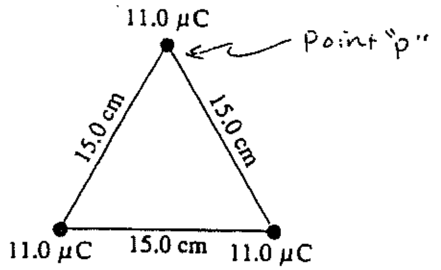


FIGURE 16–38 Problem 12.

12. (II) Three positive particles of charges 11.0 μC are located at the corners of an equilateral triangle of side 15.0 cm (Fig. 16–38). Calculate the magnitude and direction of the net force on each particle. (ANY ONE)
13. (II) A charge of 6.00 mC is placed at each corner of a square 1.00 m on a side. Determine the magnitude and direction of the force on each charge. (ANY ONE CHARGE)
14. (II) Repeat Problem 13 for the case when two of the positive charges, on opposite corners, are replaced by negative charges of the same magnitude (Fig. 16–39).

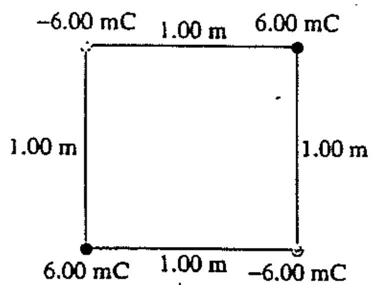


FIGURE 16–39 Problem 14.

21. (I) What is the magnitude of the acceleration experienced by an electron in an electric field of 600 N/C? How does the direction of the acceleration depend on the direction of the field at that point? How does the direction of the acceleration depend on the electron's velocity at that point?
22. (I) What is the magnitude and direction of the electric force on an electron in a uniform electric field of strength 3500 N/C that points due east?
23. (I) A proton is released in a uniform electric field, and it experiences an electric force of 3.2×10^{-14} N toward the south. What are the magnitude and direction of the electric field?
24. (I) A force of 8.4 N is exerted on a −8.8-μC charge in a downward direction. What is the magnitude and direction of the electric field at this point?
25. (I) What is the magnitude and direction of the electric field 30.0 cm directly above a 33.0×10^{-6} C charge?
26. (II) What is the magnitude and direction of the electric field at a point midway between a −8.0-μC and a +6.0-μC charge 4.0 cm apart?
27. (II) An electron is released from rest in a uniform electric field and accelerates to the north at a rate of 125 m/s^2. What is the magnitude and direction of the electric field?
28. (II) The electric field midway between two equal but opposite point charges is 1750 N/C, and the distance between the charges is 16.0 cm. What is the magnitude of the charge on each?

#29) Repeat problem #12, But Remove the charge at the top OF the TRIANGLE, AND CAlculate the Electric Field at that Point, (Point P) DUE TO the other Two charges.

ANS. 7.6×10^{6} N/C

* MAKE SURE YOU UNDERSTAND This problem

ANSWERS

12) 83.8 N Away from center

13) 6.20×10^{5} N

14) 2.96×10^{5} N

21) 1.05×10^{14} m/s^2 opposite E-Field

22) 5.66×10^{-16} N west

23) 2×10^{5} N/C south

24) 9.5×10^{5} N/C up

25) 3.3×10^{6} N/C up

26) 3.2×10^{8} N/C toward Negative

27) 7.12×10^{-10} N/C south

28) 6.2×10^{-10} C

ection 18.1 The Origin of Electricity, Section 18.2 Charged Objects and the Electric Force, Section 18.3 Conductors and Insulators, Section 18.4 Charging by Contact and by Induction

1. **ssm** How many electrons must be removed from an electrically neutral silver dollar to give it a charge of $+2.4\ \mu C$?

2. A metal sphere has a charge of $+8.0\ \mu C$. What is the net charge after 6.0×10^{13} electrons have been placed on it?

3. A rod has a charge of $-2.0\ \mu C$. How many electrons must be removed so that the charge becomes $+3.0\ \mu C$?

4. Four identical metal objects each carry different charges. The charges are +1.6, +6.2, −4.8, and $-9.4\ \mu C$. These objects are brought simultaneously into contact, so that each touches the others. Then they are separated. What is the final charge on each object?

5. **ssm** Consider three identical metal spheres, A, B, and C. Sphere A carries a charge of $+5q$. Sphere B carries a charge of $-q$. Sphere C carries no net charge. Spheres A and B are touched together and then separated. Sphere C is then touched to sphere A and separated from it. Lastly, sphere C is touched to sphere B and separated from it. (a) How much charge ends up on sphere C? What is the total charge on the three spheres (b) before they are allowed to touch each other and (c) after they have touched?

*6. Object A is metallic and electrically neutral. It is charged by induction so that it acquires a charge of -3.0×10^{-6} C. Object B is identical to object A and is also electrically neutral. It is charged by induction so that it acquires a charge of $+3.0 \times 10^{-6}$ C. Find the *difference* in mass between the charged objects and state which has the greater mass.

Section 18.5 Coulomb's Law

7. The nucleus of the helium atom contains two protons that are separated by about 3.0×10^{-15} m. Find the magnitude of the electrostatic force that each proton exerts on the other. (The protons remain together in the nucleus because the repulsive electrostatic force is balanced by an attractive force called the strong nuclear force.)

8. A proton and an electron, at a given separation distance, exert both an electrostatic and a gravitational force on each other. Find the ratio of the magnitude of the electrostatic force to the magnitude of the gravitational force.

9. **ssm www** Two very small spheres are initially neutral and separated by a distance of 0.50 m. Suppose that 3.0×10^{13} electrons are removed from one sphere and placed on the other. (a) What is the magnitude of the electrostatic force that acts on each sphere? (b) Is the force attractive or repulsive? Why?

10. In a vacuum, at what separation distance do two point charges of +1.5 and $-1.5\ \mu C$ exert a force of attraction on each other that is 330 N?

11. The force of repulsion that two like charges exert on each other is 3.5 N. What will the force be if the distance between the charges is increased to five times its original value?

12. An object has a mass of 215 kg and is located at the surface of the earth (radius = 6.38×10^6 m). Suppose that this object and the earth each have an identical positive charge q. Assuming that the earth's charge is located at the center of the earth, determine q such that the electrostatic force exactly cancels the gravitational force.

ELECTROSTATICS

[redacted]

1) 1.5×10^{13} electrons
2) $-1.6\mu c$
3) 3.1×10^{13}
4) $-1.6\mu c$
5) $+1.5q, +4q, +4q$
6) 3.4×10^{-17} kg, object A
7) 26N
8) 2.27×10^{39}
9) 0.83 N ATTRACTIVE
10) 7.8×10^{-3} m
11) 0.14 N
12) 3.09×10^{3} C

13. **ssm** Three charges are fixed to an xy coordinate system. A
charge of $+18\ \mu C$ is on the y axis at $y = +3.0$ m. A charge of
$-12\ \mu C$ is at the origin. Lastly, a charge of $+45\ \mu C$ is on the x
axis at $x = +3.0$ m. Determine the magnitude and direction of the
net electrostatic force on the charge at $x = +3.0$ m. Specify the
direction relative to the $-x$ axis.

14. A charge $+q$ is located at the origin, while an identical
charge is located on the x axis at $x = +0.50$ m. A third charge of
$+2q$ is located on the x axis at such a place that the net electrosta-
tic force on the charge at the origin doubles, its direction remain-
ing unchanged. Where should the third charge be located?

15. Three positive charges are fixed along a line. From left to
right they are q_1, q_2, and q_3. The charge q_2 is situated one-fourth
of the way between q_1 and q_3, with q_2 being nearer q_1, and experi-
ences no net electrostatic force. Find the ratio q_3/q_1.

16. An equilateral triangle has sides of 0.15 m. Charges of -9.0,
$+8.0$, and $+2.0\ \mu C$ are located at the corners of the triangle. Find
the magnitude of the net electrostatic force exerted on the $2.0\text{-}\mu C$
charge.

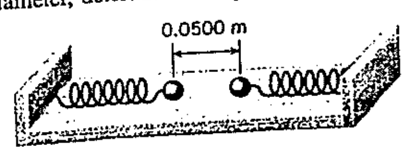
17. **ssm www** Two particles, with identical positive charges
and a separation of 2.60×10^{-2} m, are released from rest. Imme-
diately after the release, particle 1 has an acceleration $\mathbf{a}_1$ whose
magnitude is $4.60 \times 10^3\ m/s^2$, while particle 2 has an accelera-
tion $\mathbf{a}_2$ whose magnitude is $8.50 \times 10^3\ m/s^2$. Particle 1 has a
mass of 6.00×10^{-6} kg. Find (a) the charge on each particle and
(b) the mass of particle 2.

*18. A point charge of $-0.70\ \mu C$ is fixed to one corner of a
square. An identical charge is fixed to the diagonally opposite cor-
ner. A point charge q is fixed to each of the remaining corners.
The net force acting on either of the charges q is zero. Find the
magnitude and algebraic sign of q.

*19. Two small objects, A and B, are fixed in place and separated
by 2.00 cm in a vacuum. Object A has a charge of $+1.00\ \mu C$, and
object B has a charge of $-1.00\ \mu C$. How many electrons must be
removed from A and put onto B to make the electrostatic force
that acts on each object an attractive force whose magnitude is
45.0 N?

*20. A charge is placed on the x axis ($q = +7.00\ \mu C$, $x =$
0.600 m), and another charge is placed on the y axis ($q =$
$+9.00\ \mu C$, $y = 0.400$ m). A third charge ($q = -6.00\ \mu C$,
$m = 5.00 \times 10^{-8}$ kg) is placed at the coordinate origin. If the
charge at the origin were free to move, what would be (a) the
magnitude of its acceleration and (b) the direction of its accelera-
tion? Specify your answer in part (b) as an angle relative to the
$+x$ axis.

*21. **ssm** Two spheres are mounted on identical horizontal
springs and rest on a frictionless table, as in the drawing. When
the spheres are uncharged, the spacing between them is 0.0500 m,
and the springs are unstrained. When each sphere has a charge of
$+1.60\ \mu C$, the spacing doubles. Assuming that the spheres have a
negligible diameter, determine the spring constant of the springs.



*22. Two positive charges, when combined, give a total charge of
$+9.00\ \mu C$. When the charges are separated by 3.00 m, the force
exerted by one charge on the other has a magnitude of $8.00 \times$
10^{-3} N. Find the amount of each charge.

13) 0.38N 49° S of W
14) 0.71 N
15) 9
16) 6.8N
17) 4.56×10^{-8} C
18) 2 μC
19) 2.6×10^{12}
20) 6.42×10^7 m/s
21) 92.0 N/m
22) 1×10^{-6} C, 8×10^{-6} C

Section 18.6 The Electric Field, Section 18.7 Electric Field Lines, Section 18.8 The Electric Field Inside a Conductor: Shielding

•27. An electric field of 260 000 N/C points due west at a certain spot. What are the magnitude and direction of the force that acts on a charge of $-7.0\ \mu C$ at this spot?

28. Review Conceptual Example 12 as an aid in working this problem. Charges of $-4q$ are fixed to opposite corners of a square. A charge of $+5q$ is fixed to one of the remaining corners, and a charge of $+3q$ is fixed to the last corner. Assuming that ten electric field lines emerge from the $+5q$ charge, sketch the field lines in the vicinity of the four charges.

29. **ssm** A charge of $+3.0 \times 10^{-5}$ C is located at a place where there is an electric field that points due east and has a magnitude of 15 000 N/C. What are the magnitude and direction of the force acting on the charge?

~~30.~~ A long, thin rod (length = 4.0 m) lies along the x axis, with its midpoint at the origin. In a vacuum, a $+8.0\ \mu C$ point charge is fixed to one end of the rod, while a $-8.0\ \mu C$ point charge is fixed to the other end. Everywhere in the x, y plane there is a constant external electric field (magnitude = 5.0×10^3 N/C) that is perpendicular to the rod. With respect to the z axis, find the magnitude of the net torque applied to the rod.

•31. In a vacuum, the electric field at a distance of 0.50 m from a charge is 9.0×10^5 N/C, directed toward the charge. Find the magnitude and algebraic sign of the charge.

32. Conceptual Example 13 in the text deals with the hollow spherical conductor in Figure 18.32. The conductor is initially electrically neutral, and then a charge $+q$ is placed at the center of the hollow space. Suppose the conductor initially has a net charge of $+2q$ instead of being neutral. What is the total charge on the interior and on the exterior surface when the $+q$ charge is placed at the center?

33. **ssm** A 3.0-μC point charge is placed in an external uniform electric field of 1.6×10^4 N/C. At what distance from the charge is the net electric field zero?

•34. A charge of $q = +7.50\ \mu C$ is located in an electric field. The x and y components of the electric field are $E_x = 6.00 \times 10^3$ N/C and $E_y = 8.00 \times 10^3$ N/C, respectively. (a) What is the magnitude of the force on the charge? (b) Determine the angle that the force makes with the $+x$ axis.

35. The magnitude of the electric field between the plates of a parallel plate capacitor is 2.4×10^5 N/C. Each plate carries a charge whose magnitude is 0.15 μC. What is the area of each plate?

•36. A charge of $+3.5\ \mu C$ is fixed on the x axis at $x = +0.55$ m, while a charge of $-15\ \mu C$ is fixed at the origin. (a) Determine the net electric field (magnitude and direction) on the x axis at $x = +0.80$ m. (b) What force (magnitude and direction) would act on a charge of $-8.0\ \mu C$ placed on the x axis at $x = +0.80$ m?

37. **ssm www** A tiny ball (mass = 0.012 kg) carries a charge of $-18\ \mu C$. What electric field (magnitude and direction) is needed to cause the ball to float above the ground?

~~38.~~ Review Conceptual Example 11 before attempting this problem. The magnitude of each of the charges in Figure 18.22 is 8.60×10^{-12} C. The lengths of the sides of the rectangles are 3.00 cm and 5.00 cm. Find the magnitude of the electric field at the center of the rectangle in Figure 18.22b and c.

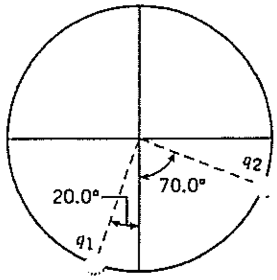
*39. A small object has a mass of 2.0×10^{-3} kg and a charge of $-25\ \mu C$. It is placed at a certain spot where there is an electric field. When released, the object experiences an acceleration of $3.5 \times 10^3\ m/s^2$ in the direction of the $+x$ axis. Determine the magnitude and direction of the electric field.

*40. A particle of mass 3.8×10^{-5} kg and charge $+12\ \mu C$ is released from rest in a region where there is a constant electric field of 480 N/C. How long does it take the particle to travel 0.020 m?

*41. **ssm www** A rectangle has a length of $2d$ and a height of d. Each of the following three charges is located at a corner of the rectangle: $+q_1$ (upper left corner), $+q_2$ (lower right corner), and $-q$ (lower left corner). The net electric field at the (empty) upper right corner is zero. Find the magnitudes of q_1 and q_2. Express your answers in terms of q.

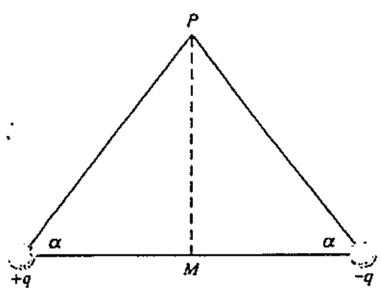
27) 1.8N east
28) See my diagram
29) +0.45N east
30) 0.16 N·m
31) 2.5×10^{-5} C
32) $-q$, $+3q$
33) 1.3 m
34) 7.5×10^{-2} N
35) $7.1 \times 10^{-2}\ m^2$
36) 2.3 N, −x dir
37) 6.5×10^3 N/C downward
38) 1.81×10^2 N/C, 3.11×10^2 N/C
39) 2.8×10^5 N/C −x dir
41) 0.716q, 0.0895q

*43. The drawing shows two positive charges q_1 and q_2 fixed to a circle. At the center of the circle they produce a net electric field that is directed upward along the vertical axis. Determine the ratio q_2/q_1.

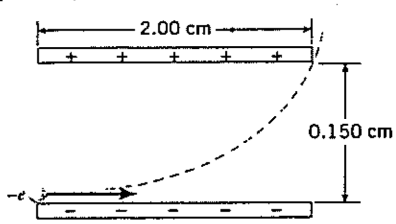


**44. The magnitude of the electric field between the plates of a parallel plate capacitor is 480 N/C. A silver dollar is placed between the plates and oriented parallel to the plates. (a) Ignoring the edges of the coin, find the induced charge density σ on each face of the coin. (b) Assuming the coin has a radius of 1.9 cm, find the magnitude of the total charge on each face of the coin.

45. **ssm Two point charges of the same magnitude but opposite signs are fixed to either end of the base of an isosceles triangle, as the drawing shows. The electric field at the midpoint M between the charges has a magnitude E_M. The field directly above the midpoint at point P has a magnitude E_P. The ratio of these two field magnitudes is $E_M/E_P = 9.0$. Find the angle α in the drawing.

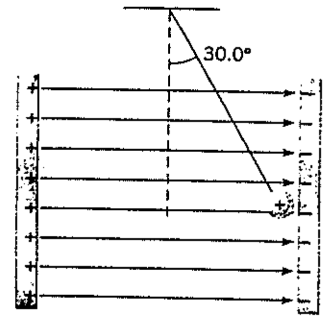


**46. The drawing shows an electron entering the lower left side of a parallel plate capacitor and exiting at the upper right side. The



initial speed of the electron is 7.00×10^6 m/s. The capacitor is 2.00 cm long, and its plates are separated by 0.150 cm. Assume that the electric field between the plates is uniform everywhere and find its magnitude.

**47. A small plastic ball of mass 6.50×10^{-3} kg and charge $+0.150\ \mu C$ is suspended from an insulating thread and hangs between the plates of a capacitor (see the drawing). The ball is in equilibrium, with the thread making an angle of 30.0° with respect to the vertical. The area of each plate is 0.0150 m^2. What is the magnitude of the charge on each plate?



43) 0.364

44) 4.2×10^{-9} C/m²

4.8×10^{-12} C

45) 61°

46) 2.09×10^3 N/C

47) 3.25×10^{-8} C

Electric Potential

Name ____ Per. ___ Date ______

Potential due to a point charge, equipotential surfaces, work and potential energy

Directions:

On a separate piece of graph paper construct a coordinate axis system near the center. Place a +2 micro coulomb charge at the origin. ***<u>Note: all distances are in centimeters.</u>***

a. Calculate the potential at the following radaii:
1, 2, 3, 4

b. Sketch equipotential surfaces (circles) at the same radaii

c. Sketch 8 equally spaced electric field lines coming from the charge.

d. What relationship can be made between the equipotential surfaces and the electric field?

e. How much potential energy would a + 4 micro coulomb charge have if it were placed at the 2cm radius?

f. How much potential energy would it have if it were moved to the 4 cm mark?

g. If the +4 micro coulomb charge was moved from the 2 cm to the 4 cm radius by the electric force, calculate the work done by the force.

h. Is the amount of work done dependent on the path taken, and why.

i. How is the answer in part g related to the charge's change in kinetic energy?

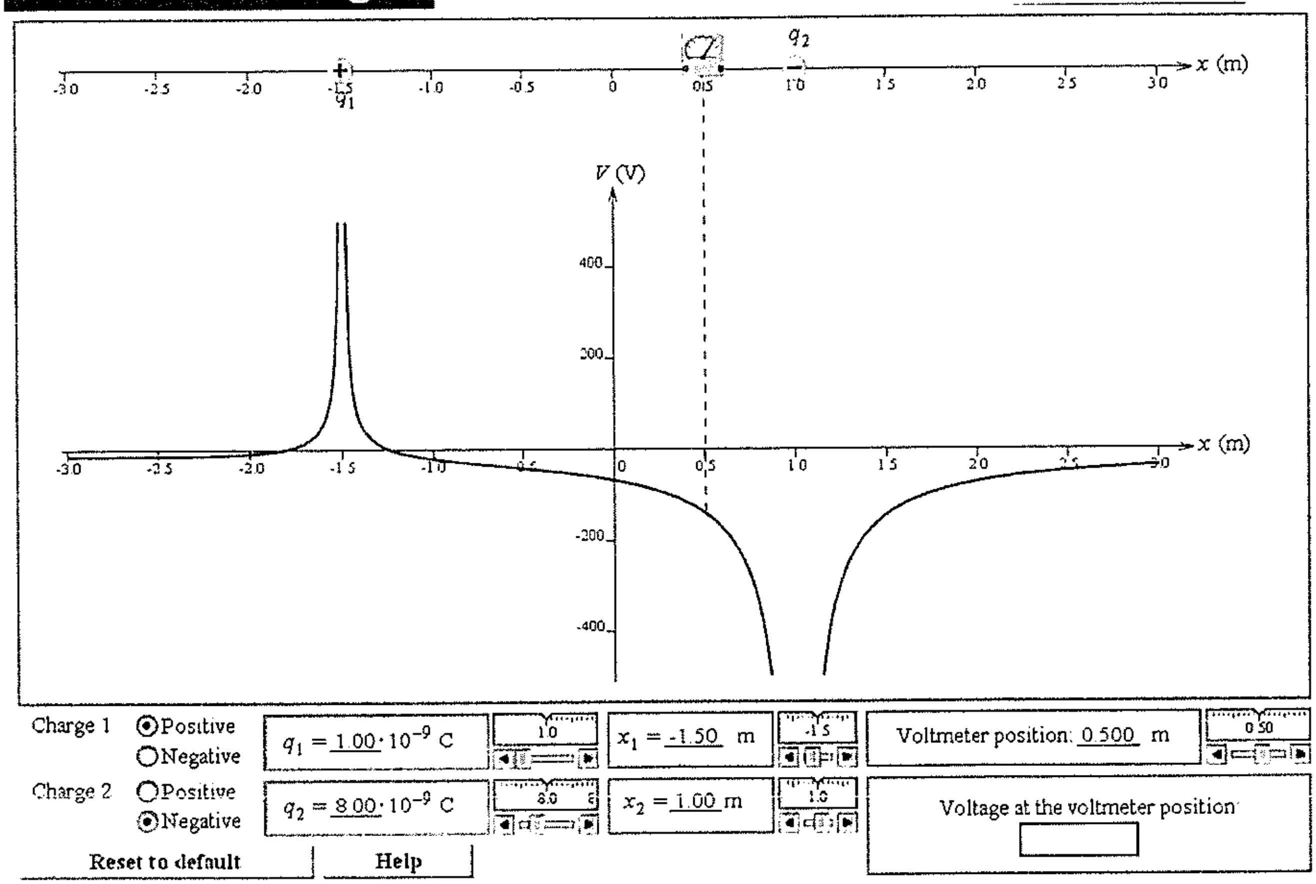
j. How would the motion of the second charge be different if it was a -4 micro coulomb charge?

Name________________________________ per. ___ Date_______

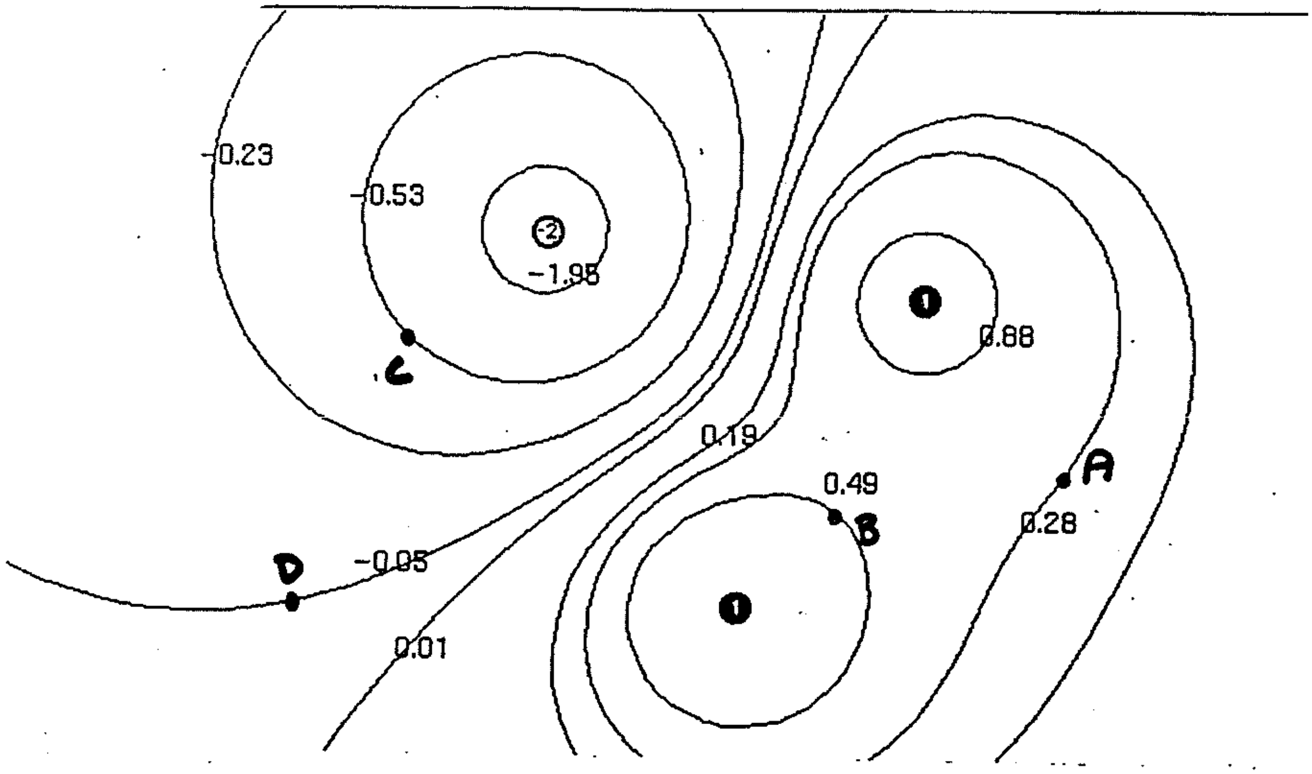
Potential due to more than one point charge

Directions: From the information given, calculate the potential at 0.500m.

Two Point Charges



Name____ per.___ date ________
Work and Electric Potential DiBucci



Assume all Charges are in micro Coulombs and all potentials are in Volts

1. Calculate the mount of work done by the electric field when a -2.0 micro Coulomb charge moves from a to b.

2. How much work does the field do in moving a +3.0 micro coulomb charge from d to c?

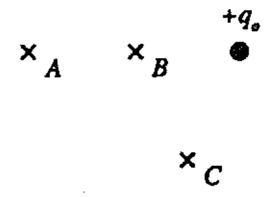
3. Sketch 10 electric field lines on the diagram above.

4. A +5.0 micro coulomb charge, with a mass of 3.0 x 10^ -8 Kg, is released from point a. Calculate the speed of the particle when it reaches point C. (assume the force of the electric field is the only force acting on the particle)

ELECTRIC POTENTIAL DIFFERENCE

2. A positive charge of magnitude q_o is shown in the diagram below.

   a. Points B and C are a distance r_o away from the charge and point A is a distance $2r_o$ from it.



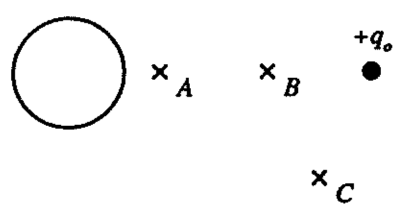
      i. Indicate the direction of the electric field at points A, B, and C on the diagram.

      ii. Compared to the absolute value of the work done by an external agent in moving a small test charge from A to B:

      - Would the absolute value of the work done by an external agent in moving the same test charge from B to C be *larger, smaller,* or *the same?* Explain your reasoning.

      - Would the absolute value of the work done by an external agent in moving the same test charge from A to C be *larger, smaller,* or *the same?* Explain your reasoning.

   b. A large metal sphere with zero net charge is now placed to the left of point A as shown.



      i. Sketch the charge distribution on the metal sphere in the diagram at right.

      ii. Has the *magnitude* of the electric field at the following points *increased, decreased,* or *remained the same?* Explain.

      - point B

      - point C

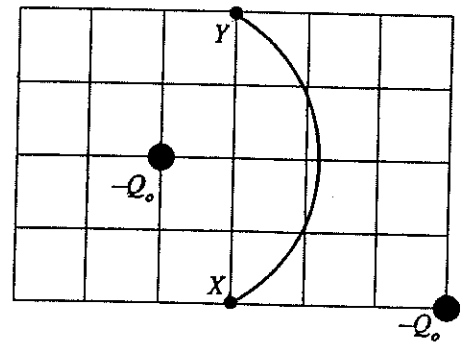
ELECTRIC POTENTIAL DIFFERENCE

Name ____________

1. Two charged rods, each with net charge $-Q_o$, are held in place as shown in the top view diagram below.

   a. A small test charge $-q_0$ travels from point X to point Y along the circular arc shown.

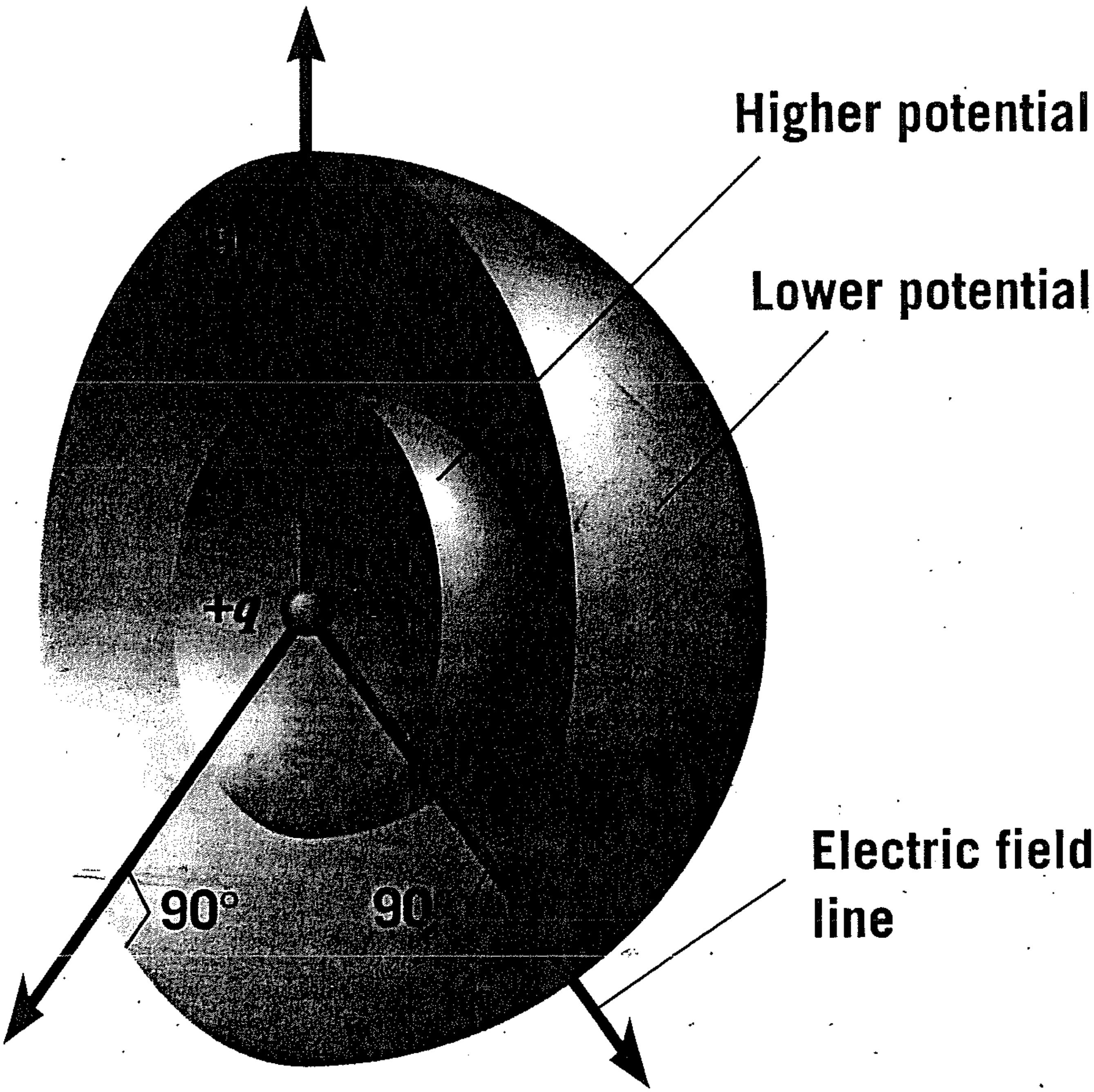
      i. Draw an arrow on the diagram at each point (X and Y) to show the direction of the electric force on the test charge at that point. Explain why you drew the arrows as you did.



      ii. Is the work done on the charge by the electric field *positive, negative,* or *zero?* Explain.

      iii. Is the electric potential difference ΔV_{XY} *positive, negative,* or *zero*? Explain.

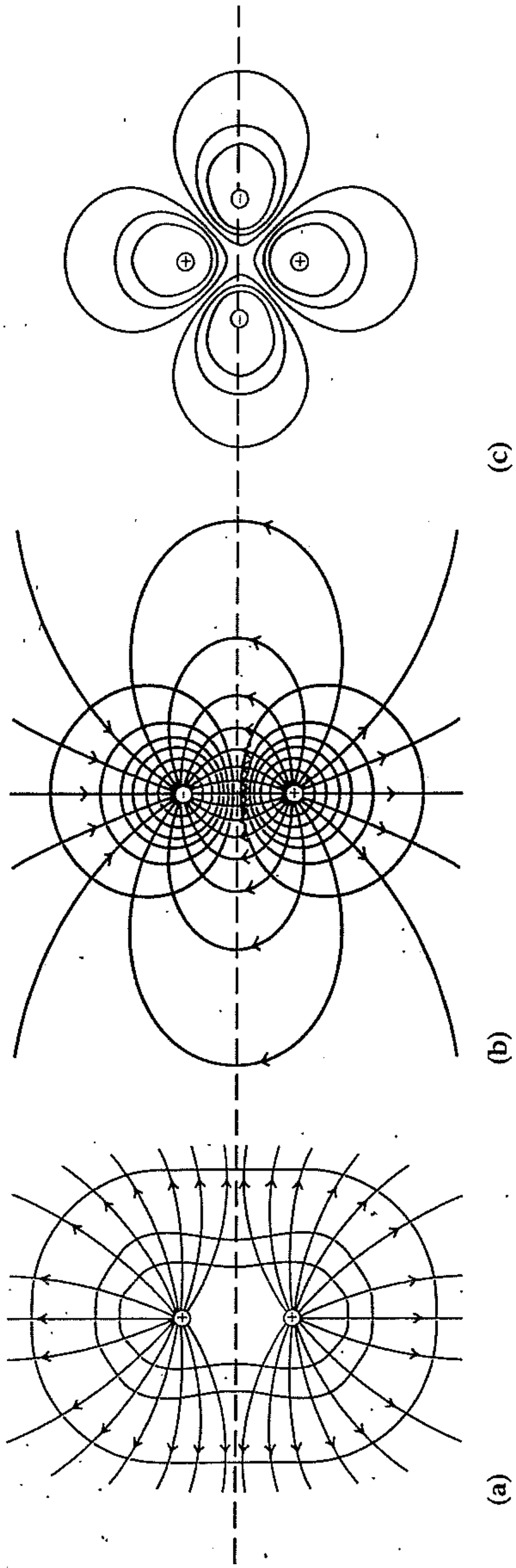
   b. The test charge is launched from point X with an initial speed v_o and is observed to pass through point Y. Is the speed of the test charge at point Y *greater than, less than,* or *equal to* v_o? Explain your reasoning.



Higher potential
Lower potential
+q
90°
90
Electric field
line

FIGURE 19-14

73. Equipotential surfaces around like and unlike charges. (Fig. 17.9)



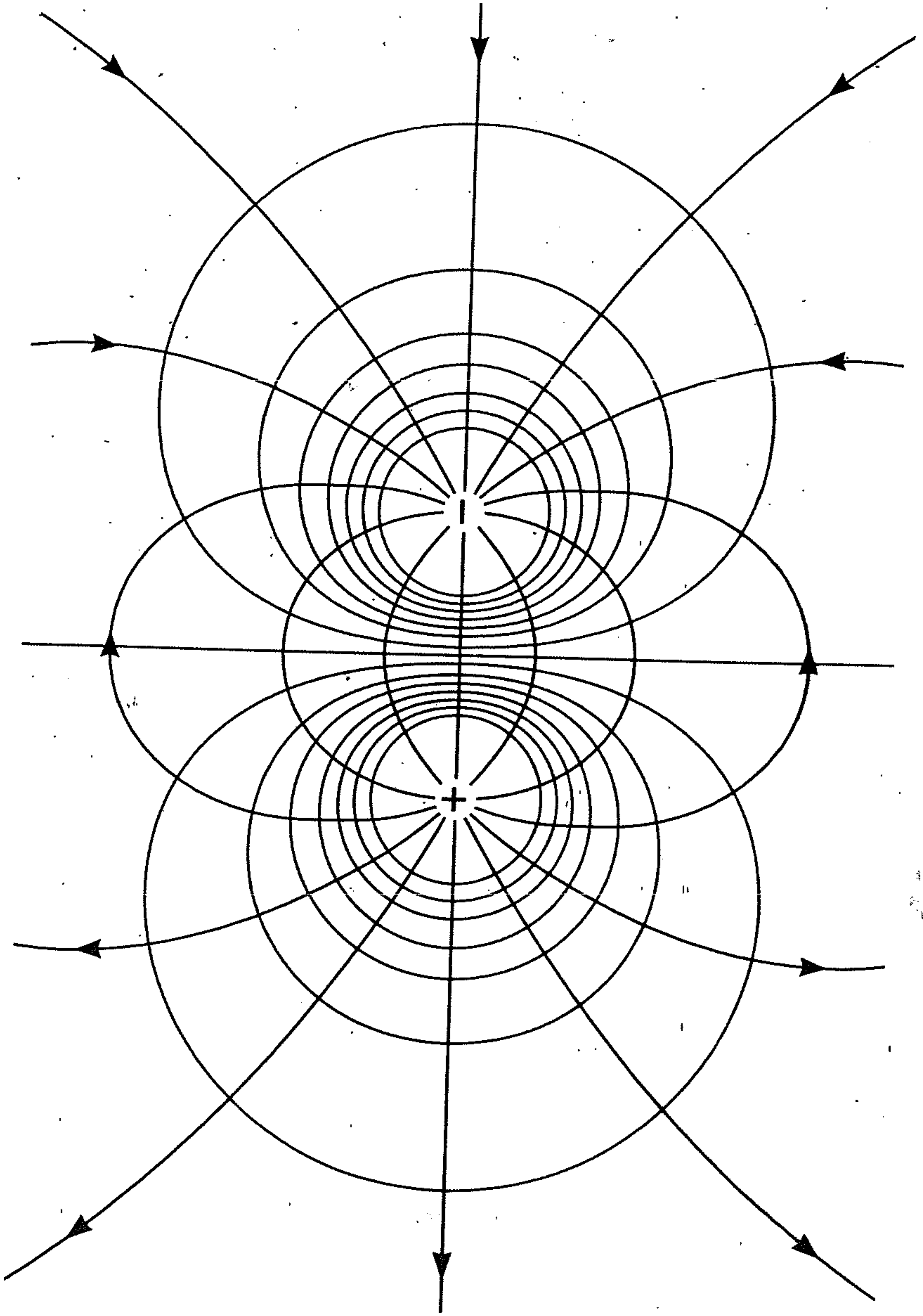
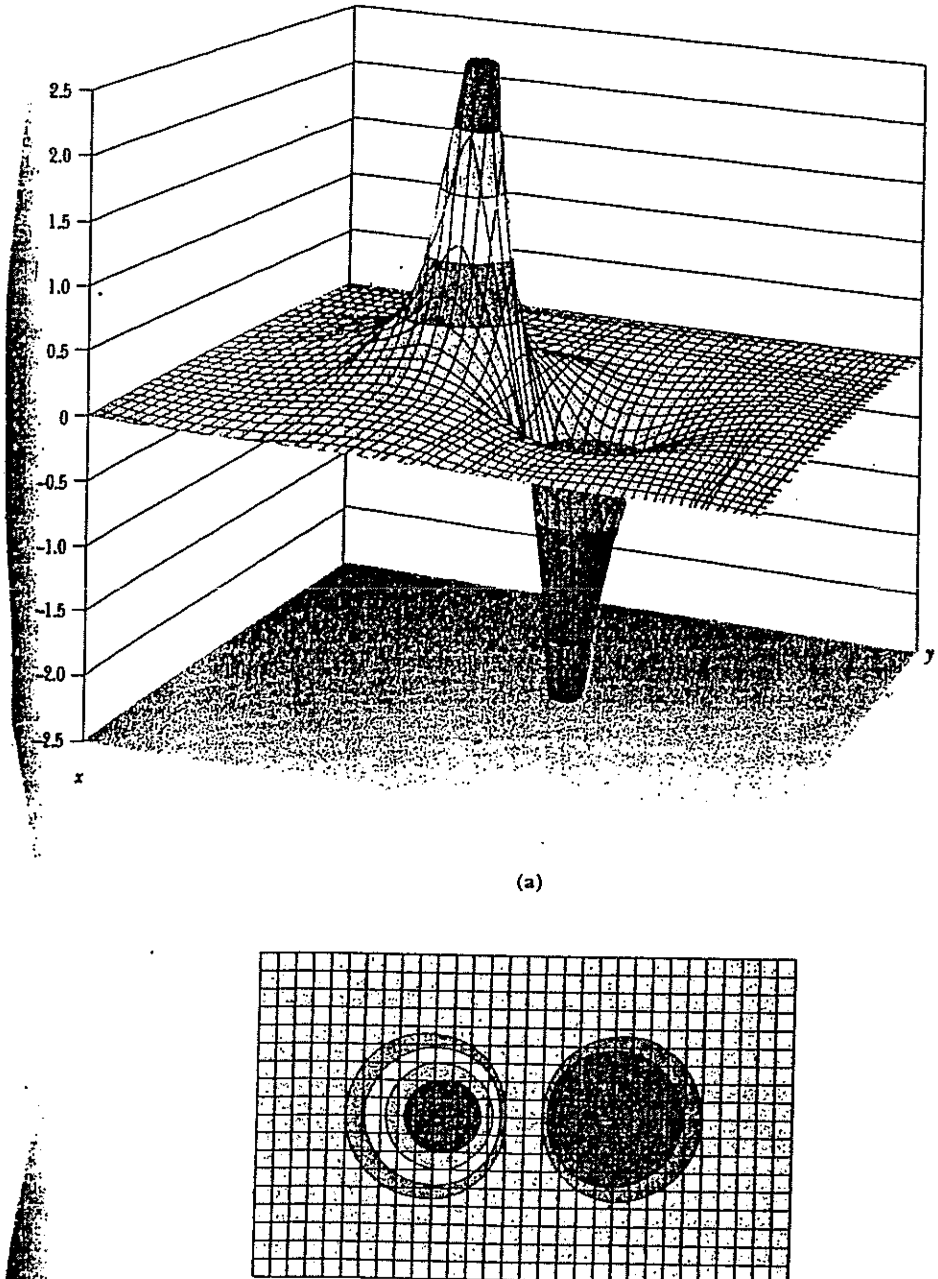


FIGURE 19-15



(a)

(b)

25.8 (a) The electric potential in the plane containing a dipole. (b) Top view of the tion graphed in part (a).

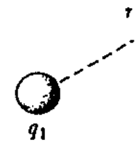


Figure 25.9 If are separated by a potential energy charges is given b

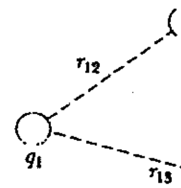
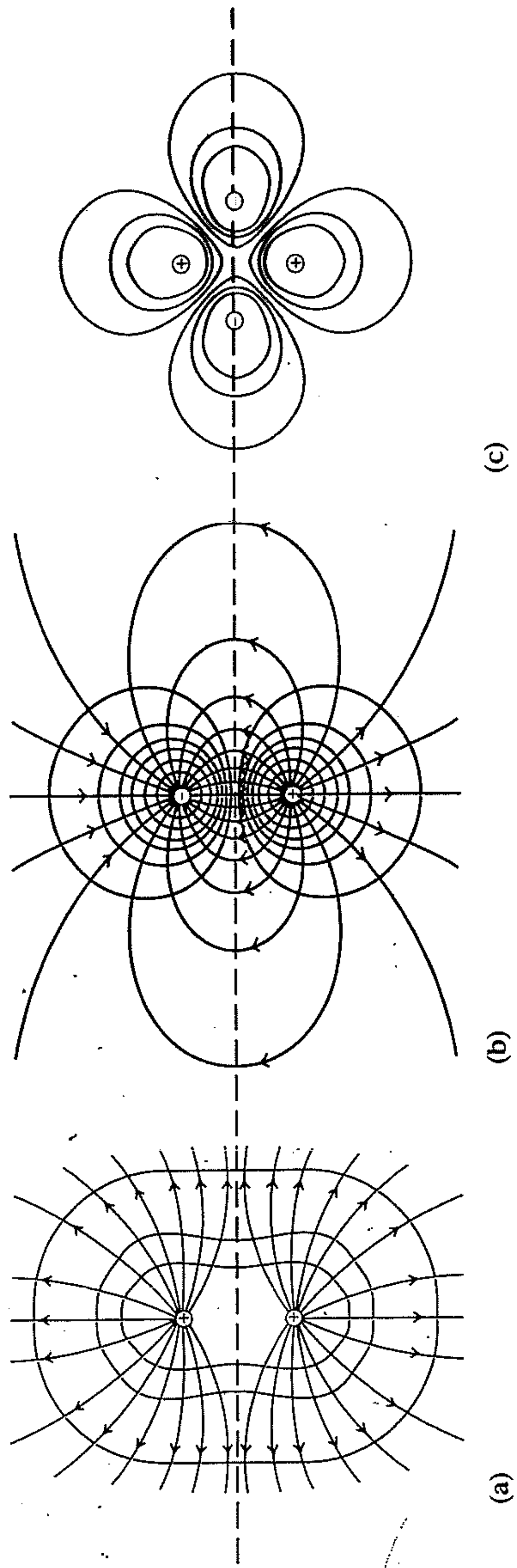
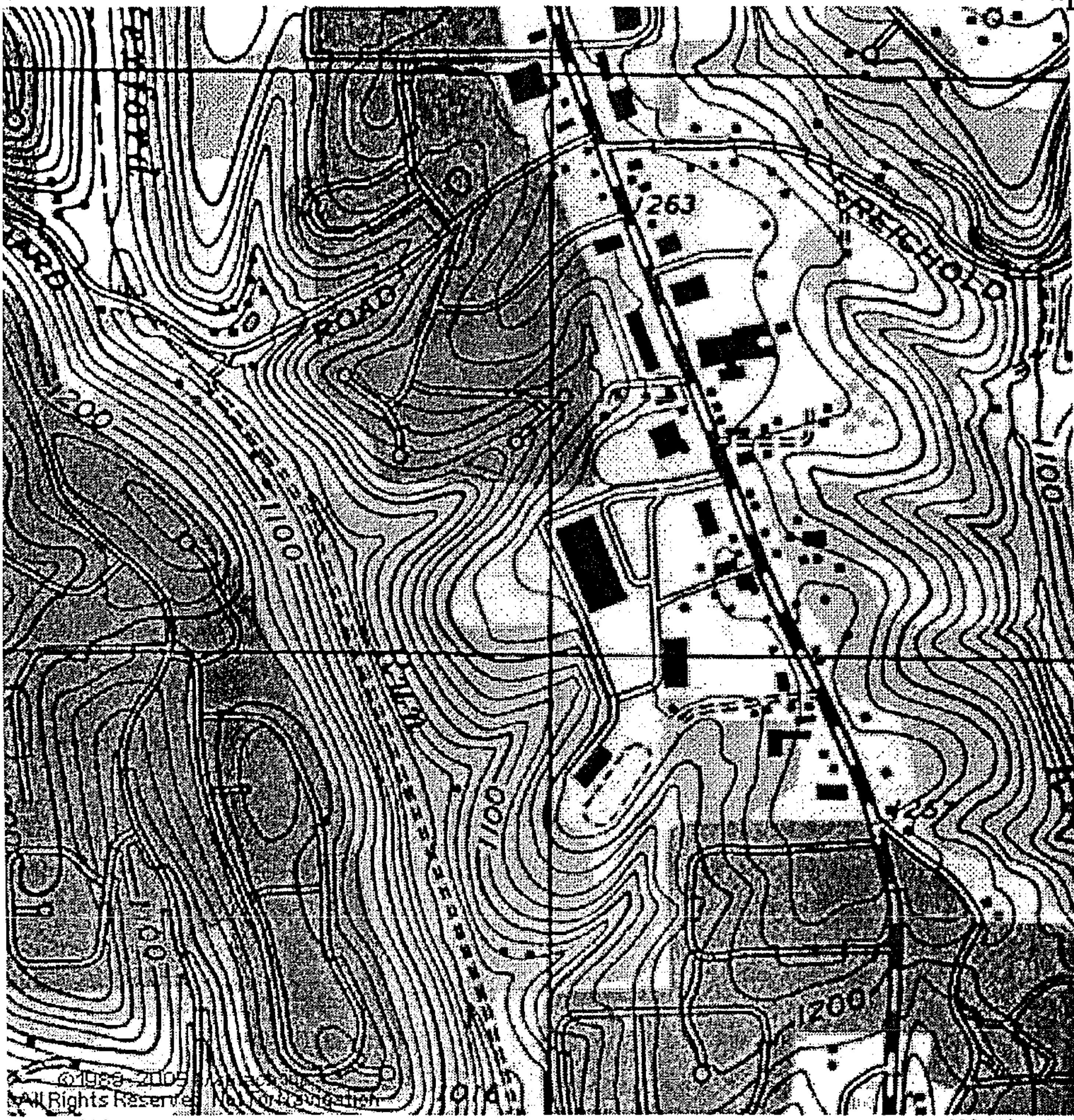


Figure 25.10 Th charges are fixed at shown. The potenti system of charges is tion 25.14.

73. **Equipotential surfaces around like and unlike charges.** (Fig. 17.9)



36' 42" N | 40° 36' 42" N
3' 59" W | 80° 2' 38" W



35' 41" N | 40° 35' 41" N
3' 59" W | 80° 2' 38" W

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Section 19.1 Potential Energy, Section 19.2 The Electric Potential Difference

1. **ssm** Suppose that the electric potential outside a living cell is higher than that inside the cell by 0.070 V. How much work is done by the electric force when a sodium ion (charge = $+e$) moves from the outside to the inside?

2. Under the influence of a constant electric field, a proton moves from point A to point B, a distance of 0.15 m. The direction of the motion is the same as the direction of the field, whose magnitude is 2.0×10^4 N/C. (a) What is the change, $EPE_A - EPE_B$, in the proton's electric potential energy? (b) Answer part (a) if the proton moves opposite to the electric field.

3. Just as you touch a metal door knob, a spark of electric (electrons) jumps from your hand to the knob. The electric po tial of the knob is 2.0×10^4 V greater than that of your hand. The work done by the electric force on the electrons is 1.5×10 How many electrons jump from your hand to the knob?

4. The anode (positive terminal) of an X-ray tube is at a poten of +125 000 V with respect to the cathode (negative terminal). How much work (in joules) is done by the electric force whe electron is accelerated from the cathode to the anode? (b) If electron is initially at rest, what kinetic energy does the elec electron have when it arrives at the anode?

5. **ssm** In a television picture tube, electrons strike the sc after being accelerated from rest through a potential difference of 25 000 V. The speeds of the electrons are quite large, and for accurate calculations of the speeds, the effects of special relatively must be taken into account. Ignoring such effects, find the electron speed just before the electron strikes the screen.

6. Point A is at a potential of +250 V, and point B is at a potential of −150 V. An α-particle is a helium nucleus that contains two protons and two neutrons; the neutrons are electrically neutral. An α-particle starts from rest at A and accelerates toward B. When the α-particle arrives at B, what kinetic energy (in electron volts) does it have?

7. An electric car accelerates for 8.0 s by drawing energy from its 320-V battery pack. During this time, 1300 C of charge pass through the battery pack. Find the minimum horsepower rating of the car.

*8. The energy in a lightning bolt is enormous. Consider, for example, a lightning bolt in which 29 C of charge moves through a potential difference of 1.4×10^8 V. With the amount of energy in this bolt, how many kilograms of water at 100 °C could be boiled into steam at 100 °C?

*9. **ssm www** The potential at location A is 452 V. A positively charged particle is released there from rest and arrives at location B with a speed v_B. The potential at location C is 791 V, and when released from rest from this spot, the particle arrives at B with twice the speed it previously had, or $2v_B$. Find the potential at B.

*10. An electron and a proton, starting from rest, are accelerated through an electric potential difference of the same magnitude. In the process, the electron acquires a speed v_e, while the proton acquires a speed v_p. Find the ratio v_e/v_p.

**11. A particle is uncharged and is thrown vertically upward from ground level with a speed of 25.0 m/s. As a result, it attains a maximum height h. The particle is then given a positive charge $+q$ and reaches the same maximum height h when thrown vertically upward with a speed of 30.0 m/s. The electric potential at the height h exceeds the electric potential at ground level. Finally, the particle is given a negative charge $-q$. Ignoring air resistance, determine the speed with which the negatively charged particle must be thrown vertically upward, so that it attains exactly the maximum height h. In all three situations, be sure to include the effect of gravity.

1) 1.1×10^{-20} J
2) 4.8×10^{-16} J, -4.8×10^{-16} J
3) 4.7×10^{7}
4) 2×10^{-14} J, 2×10^{-14} J
5) 9.4×10^{7} m/s
6) 8.0×10^{2} eV
7) 70 hp
8) 1.8×10^{3} kg
9) 339 V
10) 42.8
11) 18.7 m/s
12) 41 V
13) 3.6×10^{-9} C
14) -4.35×10^{-18} J

Section 19.3 The Electric Potential Difference Created by Point Charges

12. At a distance of 0.20 m from a charge, the electric potential is 164 V. What is the potential at a distance of 0.80 m?

13. **ssm** There is an electric potential of +130 V at a spot that is 0.25 m away from a charge. Find the magnitude and sign of the charge.

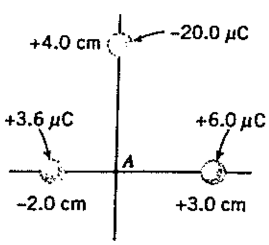
14. An electron and a proton are initially very far apart (effectively an infinite distance apart). They are then brought together to form a hydrogen atom, in which the electron orbits the proton at an average distance of 5.29×10^{-11} m. What is $EPE_{final} - EPE_{initial}$, which is the change in the electric potential energy?

15. A charge of +125 μC is fixed at the center of a square that is 0.64 m on a side. How much work is done by the electric force as a charge of +7.0 μC moves from one corner of the square to any other empty corner? Explain.

16. Two positive point charges are held in place, 0.74 m apart. They are then moved so that their electric potential energy doubles. What is the new separation between the charges?

17. **ssm www** Two identical point charges are fixed to diagonally opposite corners of a square that is 0.500 m on a side. Each charge is $+3.0 \times 10^{-6}$ C. How much work is done by the electric force as one of the charges moves to an empty corner?

18. Three point charges are located as shown in the drawing. (a) Determine the electric potential at point *A* due to these charges. (b) What is the electric potential energy of a +3.5-μC charge placed at *A*?



19. A charge of $+9q$ is fixed to one corner of a square, while a charge of $-8q$ is fixed to the opposite corner. Expressed in terms of q, what charge should be fixed to the center of the square, so the potential is zero at each of the two empty corners?

20. Review Conceptual Example 7 as background for this problem. Two charges are fixed in place with a separation d. One charge is positive and has twice the magnitude of the other charge, which is negative. The positive charge lies to the left of the negative charge, as in Figure 19.11. Relative to the negative charge, locate the two spots on the line through the charges where the total potential is zero.

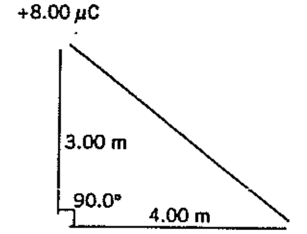
***21.** **ssm** A charge of −3.00 μC is fixed in place. From a horizontal distance of 0.0450 m, a particle of mass 7.20×10^{-3} kg and charge −8.00 μC is fired with an initial speed of 65.0 m/s directly toward the fixed charge. How far does the particle travel before its speed is zero?

***22.** A square is 0.50 m on a side. Four identical charges (5.0 μC each) are brought from infinity and placed on the square, one to a corner. Find the electric potential energy of the group.

***23.** Two protons are moving directly toward one another. When they are very far apart, their initial speeds are 1.5×10^{6} m/s. What is the distance of closest approach?

***24.** Identical point charges of +1.7 μC are fixed to diagonally opposite corners of a square. A third charge is then fixed at the center of the square, such that it causes the potentials at the empty corners to change signs without changing magnitudes. Find the sign and magnitude of the third charge.

***25.** **ssm** Determine the electric potential energy for the array of three charges shown in the drawing, relative to its value when the charges are infinitely far away.



****26.** A positive charge of $+q_1$ is located 3.00 m to the left of a negative charge $-q_2$. The charges have different magnitudes. On the line through the charges, the net *electric field* is zero at a spot 1.00 m to the right of the negative charge. On this line there are also two spots where the potential is zero. Locate these two spots relative to the negative charge.

****27.** Charges q_1 and q_2 are fixed in place, q_2 being located at a distance d to the right of q_1. A third charge q_3 is then fixed to the line joining q_1 and q_2 at a distance d to the right of q_2. The third charge is chosen so the potential energy of the group is zero; that is, the potential energy has the same value as that of the three charges when they are widely separated. Determine q_3, assuming that (a) $q_1 = q_2 = q$ and (b) $q_1 = q$ and $q_2 = -q$. Express your answers in terms of q.

****28.** One particle has a mass of 3.00×10^{-3} kg and a charge of +8.00 μC. A second particle has a mass of 6.00×10^{-3} kg and the same charge. The two particles are initially held in place and then released. The particles fly apart, and when the separation between them is 0.100 m, the speed of the 3.00×10^{-3}-kg particle is 125 m/s. Find the initial separation between the particles.

12) 41 V
13) + 3.6×10^{-9} C
14) -4.35×10^{-18} J
15) No work is done
16) 0.37 m
17) -4.7×10^{-2} J
18) -1.1×10^{6} V, −3.8 J
19) $Q = -q/\sqrt{2}$
20) $x = d/3$
21) 0.0342 m
22) 2.4 J

23) 6.1×10^{-14} m
24) -4.8×10^{-6} C
25) −0.764 J
26) x = 0.200 Rt. of neg. charge
x = 0.176 Left of neg. charge
27) $q_3 = -2/3\ q$
$q_3 = -2q$
28) 1.41×10^{-2} m

Section 19.4 Equipotential Surfaces and Their Relation to the Electric Field

29. **ssm** An equipotential surface that surrounds a $+3.0 \times 10^{-7}$ C point charge has a radius of 0.15 m. What is the potential of this surface?

30. What is the radius of the +12-V equipotential surface that surrounds a charge of $+2.0 \times 10^{-10}$ C?

31. A spark plug in an automobile engine consists of two metal conductors that are separated by a distance of 0.75 mm. When an electric spark jumps between them, the magnitude of the electric field is 2.8×10^6 V/m. What is the magnitude of the potential difference ΔV between the conductors?

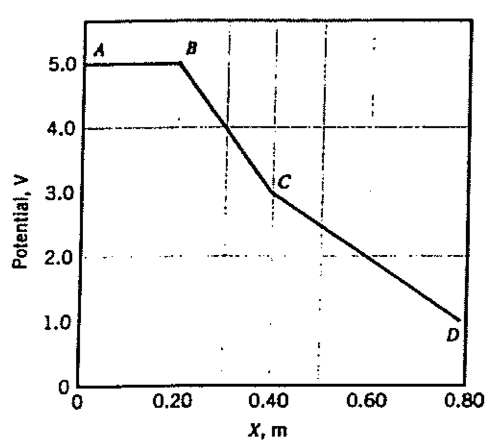
32. The inner and outer surfaces of a cell membrane carry a negative and positive charge, respectively. Because of these charges, a potential difference of about 0.070 V exists across the membrane. The thickness of the membrane is 8.0×10^{-9} m. What is the magnitude of the electric field in the membrane?

33. **ssm** **www** When you walk across a rug on a dry day, your body can become electrified, and its electric potential can change. When the potential becomes large enough, a spark of negative charges can jump between your hand and a metal surface. A spark occurs when the electric field strength created by the charges on your body reaches the dielectric strength of the air. The dielectric strength of the air is 3.0×10^6 N/C and is the electric field strength at which the air suffers electrical breakdown. Suppose a spark 3.0 mm long jumps between your hand and a metal doorknob. Assuming that the electric field is uniform, find the potential difference ($V_{knob} - V_{hand}$) between your hand and the doorknob.

34. Surrounding a positive point charge there are two equipotential surfaces. Surface *A* has twice the area of surface *B*. Find the ratio V_A/V_B of the potentials of these surfaces.

***35.** The electric field has a constant value of 3.0×10^3 V/m and is directed downward. The field is the same everywhere. The potential at a point *P* within this region is 135 V. Find the potential at the following points: (a) 8.0×10^{-3} m directly above *P*, (b) 3.3×10^{-3} m directly below *P*, (c) 5.0×10^{-3} m directly to the right of *P*.

***36.** The drawing shows the electric potential as a function of distance along the *x* axis. Determine the magnitude of the electric field in the region (a) *A* to *B*, (b) *B* to *C*, and (c) *C* to *D*.



***37.** **ssm** Equipotential surface *A* has a potential of 5650 V, while equipotential surface *B* has a potential of 7850 V. A particle has a mass of 5.00×10^{-2} kg and a charge of $+4.00 \times 10^{-5}$ C. The particle has a speed of 2.00 m/s on surface *A*. An outside force is applied to the particle, and it moves to surface *B*, arriving there with a speed of 3.00 m/s. How much work is done by the outside force in moving the particle from *A* to *B*? (*Hint: According to Equation 6.8, the work W done is equal to the final total energy E_B minus the initial total energy E_A: $W = E_B - E_A$.*)

****38.** At a distance of 1.60 m from a point charge of $+2.00 \times 10^{-6}$ C, there is an equipotential surface. At greater distances there are additional equipotential surfaces. The potential difference between any two successive surfaces is 1.00×10^3 V. Starting at a distance of 1.60 m and moving radially outward, how many of the additional equipotential surfaces are crossed by the time the electric field has shrunk to one-half its initial value? Do not include the starting surface.

29) 18,000 V
30) 0.15 m
31) 2.1×10^3 v
32) 8.8×10^6 V/m
33) $+9.0 \times 10^3$ V
34) 0.707
35) V_A = 159 v
V_B = 125 v
V_C = 135 V
36) a) 0 V/m
b) 10 V/m
c) 5.0 V/m
37) 0.213 J
38) 3

1. (I) How much work is needed to move a $-8.6\text{-}\mu C$ charge from ground to a point whose potential is $+75$ V?

2. (I) How much work is needed to move a proton from a point with a potential of $+100$ V to a point where it is -50 V? Express your answer both in joules and electron volts.

3. (I) How much kinetic energy will an electron gain (in joules and eV) if it falls through a potential difference of 21,000 V in a TV picture tube?

4. (I) An electron acquires 3.45×10^{-16} J of kinetic energy when it is accelerated by an electric field in a computer monitor from plate A to plate B. What is the potential difference between the plates, and which plate is at the higher potential?

13. (I) What is the electric potential 15.0 cm from a 4.00-[illegible] point charge?

14. (I) A charge Q creates an electric potential of $+12$[illegible] at a distance of 15 cm. What is Q?

15. (II) A $+30\text{-}\mu C$ charge is placed 32 cm from an id[illegible]tical $+30\text{-}\mu C$ charge. How much work would be [illegible]quired to move a $+0.50\text{-}\mu C$ test charge from a p[illegible] midway between them to a point 10 cm closer [illegible] either of the charges?

16. (II) (a) What is the electric potential a distance of 2.5×10^{-15} m away from a proton? (b) What is the electric potential energy of a system that consists of two protons 2.5×10^{-15} m apart—as might occur inside a typical nucleus?

17. How much voltage must be used to accelerate a proton (radius 1.2×10^{-15} m) so that it has sufficient energy to just penetrate a silicon nucleus? A silicon nucleus has a charge of $+14e$ and its radius is about 3.6×10^{-15} m. Assume the potential is that for point charges.

18. (II) How much work must be done to bring three electrons from a great distance apart to within 1.0×10^{-10} m from one another?

19. (II) Consider point a which is 70 cm north of a $-3.8\text{-}\mu C$ point charge, and point b which is 80 cm west of the charge (Fig. 17–23). Determine (a) $V_{ba} = V_b - V_a$, and (b) $\mathbf{E}_b - \mathbf{E}_a$ (magnitude and direction).

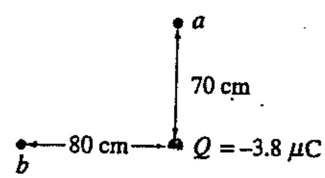


FIGURE 17–23 Problem 19.

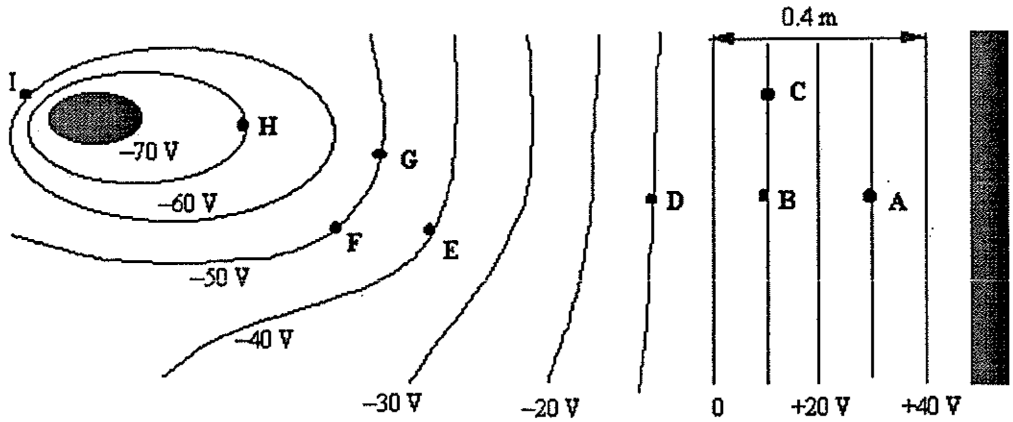
20. (II) An electron starts from rest 72.5 cm from a fixed point charge with $Q = -0.125\ \mu C$. How fast will the electron be moving when it is very far away?

1) -6.5×10^{-4} J
2) -2.4×10^{-17} J
-150 eV
3) 3.4×10^{-15} J
21 KEV
4) 2.16×10^{3} V, B
13) 2.4×10^{5} V
14) 2.1×10^{-7} C
15) 1.08 J
16) 5.8×10^{5} V
9.2×10^{-14} J
17) 4.2×10^{6} V
18) 6.9×10^{-18} J
19) 6.1×10^{3} V
53° N of E
8.8×10^{4} N/C
20) 2.33×10^{7} m/s

Name____ per. ______ Date ______

Equipotential Surfaces DiBucci

1. The sketch below shows cross sections of equipotential surfaces between two charged conductors that are shown in solid black. Various points on the equipotential surfaces near the conductors are labeled **A, B, C, ..., I.**



a. Where would you say the electric field is the strongest?

b. Where would a proton have the greatest potential energy? An Electron? Why?

c. What is the potential difference between points **B** and **F**?

d. What is the direction of the electric field at **A**?

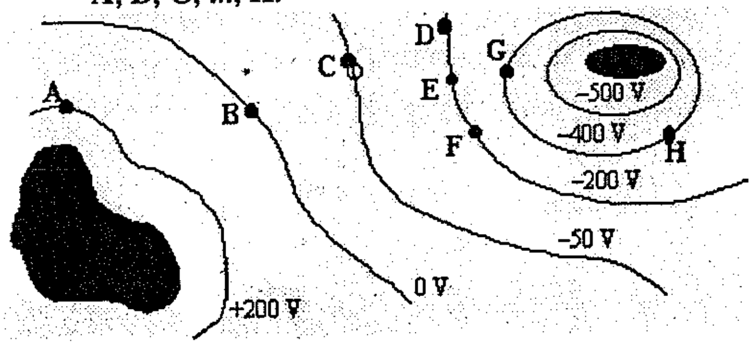
e. How much work is required to move a +2 microCoulomb charge from **A** to **F**?

f. How much work is required to move a +2 microCoulomb charge from **B** to **D** to **E** to**C**?

g. What is the magnitude of the electric field at point **B**?

h. If a positive 3 microCoulomb charge, with a mass of 3.0E -8 kg were released at point D, how fast would it be traveling at point E.

2. The sketch shows cross sections of equipotential surfaces between two charged conductors shown in solid black. Points on the equipotential surfaces near the conductors are labeled **A, B, C, ..., H.**



a. What is the magnitude of the potential difference between points **A** and **H**?
b.

b. Where is the electric field the strongest, and why?

c. If this were compared to a contour map, where would the areas above sea level be in the diagram? The areas below?

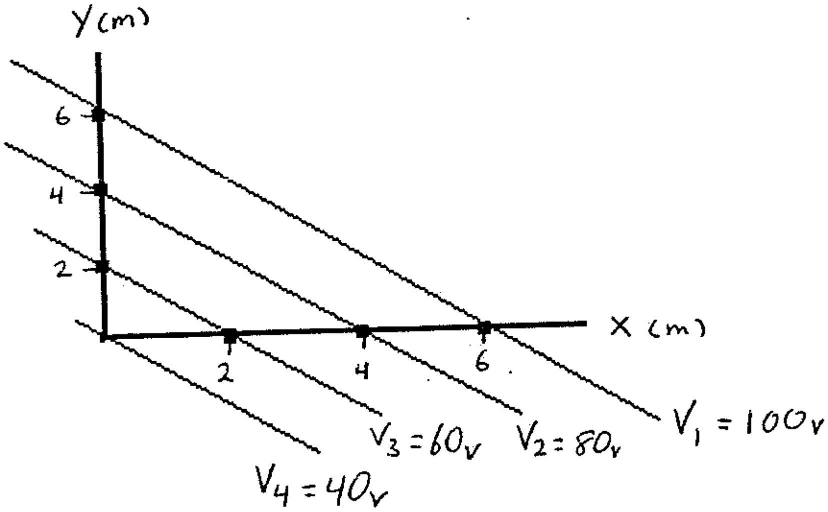
d. What is the direction of the electric field at point **E**?

e. How much work is required , by an external agent, to move a +6 μC point charge from **B** to **F** to **D** to **A**?

Equipotential Surfaces

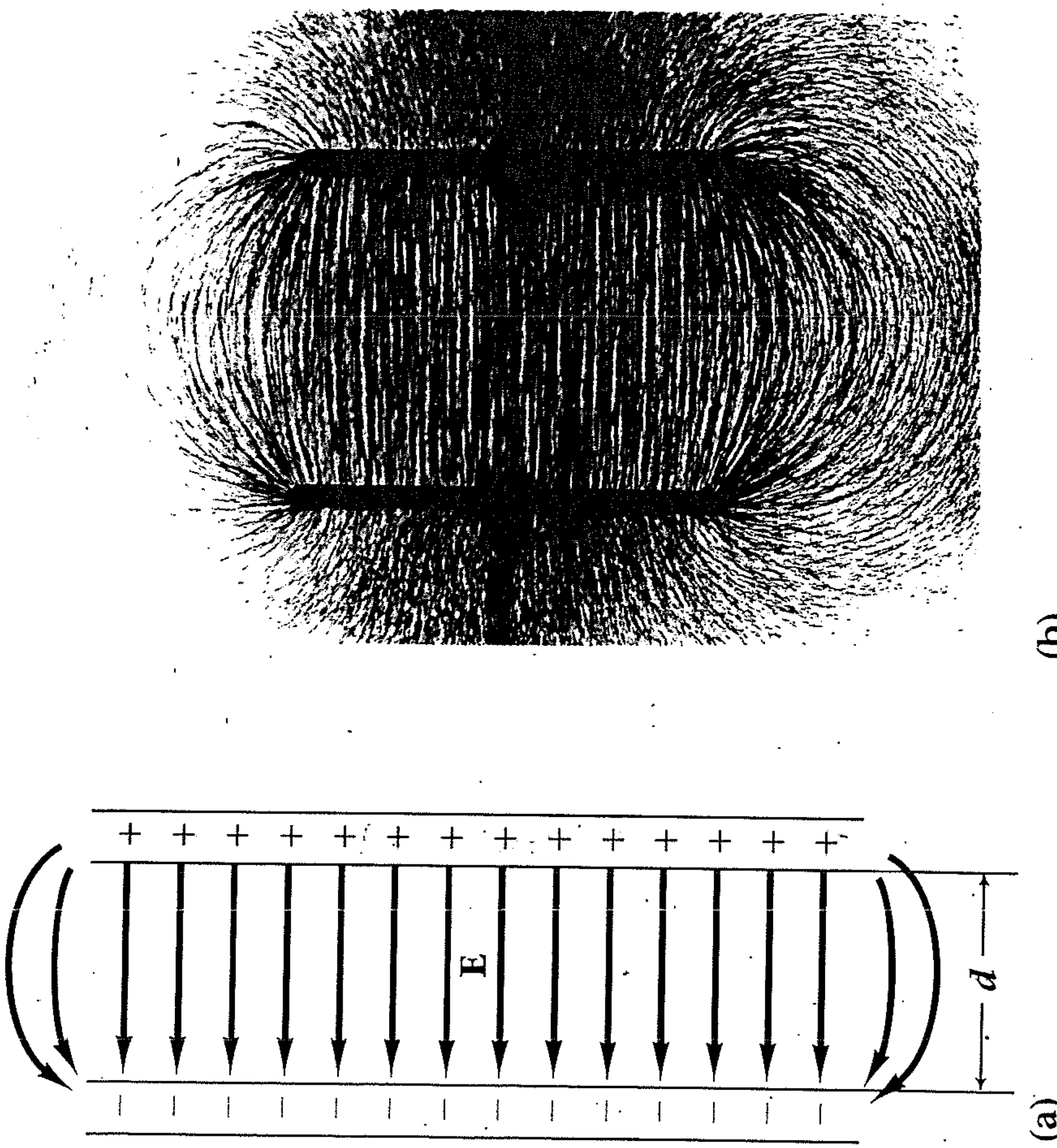
AP Physics B

Calculate the magnitude and direction of the electric field given a system that has the following equipotential surfaces.



Capacitors

75. Electric field between two oppositely charged plates. (Fig. 17.12)



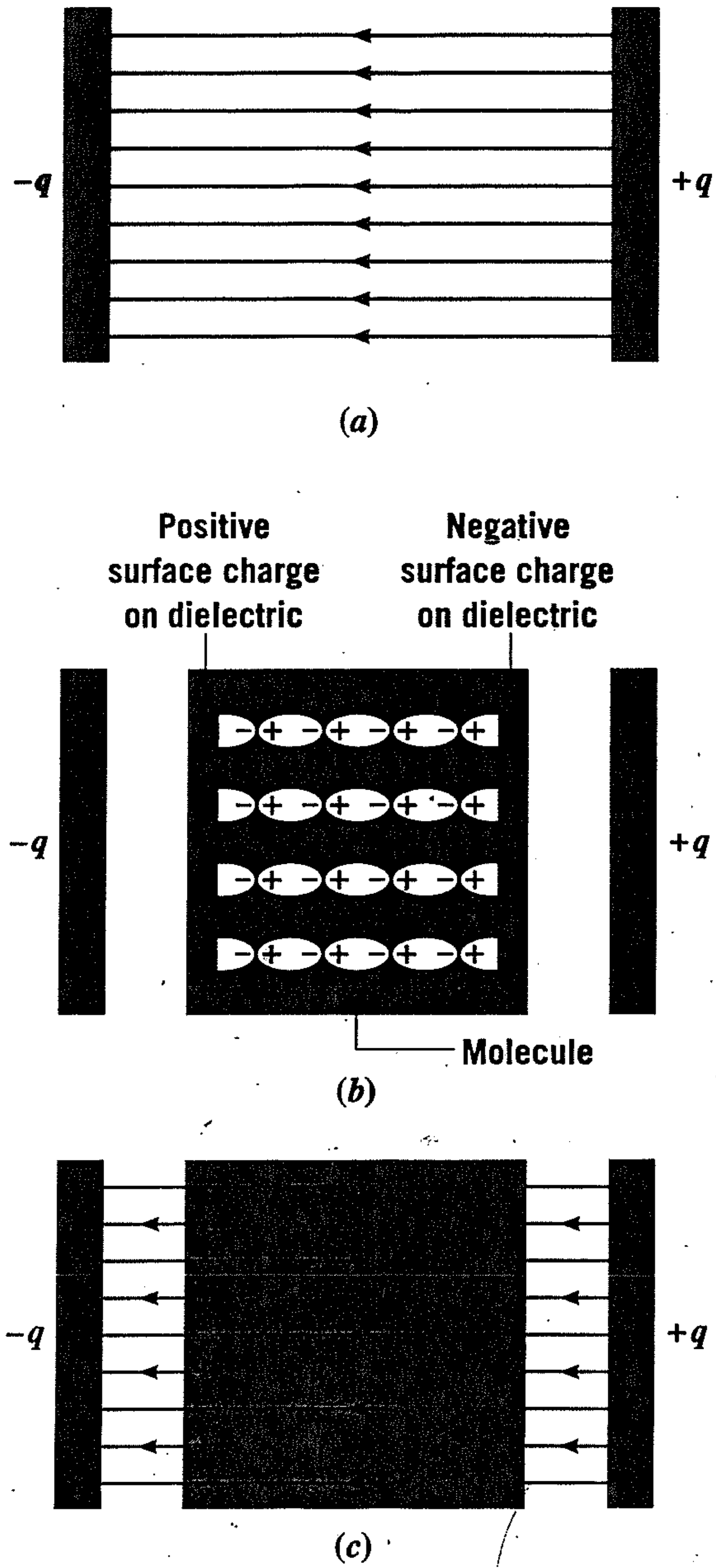

−q
+q
(a)
Positive surface charge on dielectric
Negative surface charge on dielectric
−q
+q
Molecule
(b)
−q
+q
(c)

FIGURE 19-20

Section 19.5 Capacitors and Dielectrics

39. What voltage is required to store 7.2×10^{-5} C of charge on the plates of a 6.0-μF capacitor?

40. One farad is a large capacitance. To see just how large, determine the area of each plate of an empty, one-farad parallel plate capacitor whose plate separation is one meter. Express your answer in square miles (1 square mile $= 2.59 \times 10^6$ m^2).

41. **ssm** A parallel plate capacitor has a capacitance of 7.0 μF when filled with a dielectric. The area of each plate is 1.5 m^2 and the separation between the plates is 1.0×10^{-5} m. What is the dielectric constant of the dielectric?

42. An axon is the relatively long tail-like part of a neuron, or nerve cell. The outer surface of the axon membrane (dielectric constant = 5, thickness $= 1 \times 10^{-8}$ m) is charged positively, and the inner portion is charged negatively. Thus, the membrane is a kind of capacitor. Assuming that an axon can be treated like a parallel plate capacitor with a plate area of 5×10^{-6} m^2, what is its capacitance?

43. A capacitor has a capacitance of 2.5×10^{-8} F. In the charging process, electrons are removed from one plate and placed on the other plate. When the potential difference between the plates is 450 V, how many electrons have been transferred?

44. A parallel plate capacitor is filled with ruby mica, and the area of each plate is 3.8 m^2. The capacitor stores 2.7 μC of charge when a 1.5-V flashlight battery provides the potential difference between the plates. What is the plate separation?

45. **ssm** The membrane that surrounds a certain type of living cell has a surface area of 5.0×10^{-9} m^2 and a thickness of 1.0×10^{-8} m. Assume that the membrane behaves like a parallel plate capacitor and has a dielectric constant of 5.0. (a) If the potential on the outer surface of the membrane is +60.0 mV greater than that on the inside surface, how much charge resides on the outer surface? (b) If the charge in part (a) is due to K^+ ions (charge $+e$), how many such ions are present on the outer surface?

46. The plates of a parallel plate capacitor are separated by a distance of 11 mm and each contains a charge of magnitude 1.9×10^{-5} C. The electric field inside the capacitor has a magnitude of 640 V/m. What is the capacitance?

47. The electronic flash attachment for a camera contains a capacitor for storing the energy used to produce the flash. In one such unit, the potential difference between the plates of a 750-μF capacitor is 330 V. (a) Determine the energy that is used to produce the flash in this unit. (b) Assuming that the flash lasts for 5.0×10^{-3} s, find the effective power or "wattage" of the flash.

*48. Two hollow metal spheres are concentric with each other. The inner sphere has a radius of 0.1500 m and a potential of 85.0 V. The radius of the outer sphere is 0.1520 m and its potential is 82.0 V. If the region between the spheres is filled with Teflon, find the electric energy contained in this space.

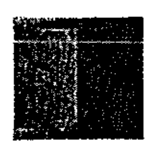
*49. **ssm** What is the potential difference between the plates of a 3.3-F capacitor that stores sufficient energy to operate a 75-W light bulb for one minute?

*50. The dielectric strength of an insulating material is the maximum electric field strength to which the material can be subjected without electrical breakdown occurring. Suppose a parallel plate capacitor is filled with a material whose dielectric constant is 3.5 and whose dielectric strength is 1.4×10^7 N/C. If this capacitor is to store 1.7×10^{-7} C of charge on each plate without suffering breakdown, what must be the radius of its circular plates?

*51. An empty capacitor has a capacitance of 2.7 μF and is connected to a 12-V battery. A dielectric material ($\kappa = 4.0$) is inserted between the plates of this capacitor. What is the magnitude of the surface charge on the dielectric that is adjacent to either plate of the capacitor? *(Hint: The surface charge is equal to the difference in the charge on the plates with and without the dielectric.)*

**52. The plate separation of a charged capacitor is 0.0800 m. A proton and an electron are released from rest at the midpoint between the plates. Ignore the attraction between the two particles, and determine how far the proton has traveled by the time the electron strikes the positive plate.

53. **ssm The drawing shows a parallel plate capacitor. One-half of the region between the plates is filled with a material that has a dielectric constant κ_1. The other half is filled with a material that has a dielectric constant κ_2. The area of each plate is A, and the plate separation is d. The potential difference across the plates is V. Note especially that the charge stored by the capacitor is $q_1 + q_2 = CV$, where q_1 and q_2 are the charges on the area of the plates in contact with materials 1 and 2, respectively. Show that $C = \epsilon_0 A(\kappa_1 + \kappa_2)/(2d)$.



39) 12 V
40) 4.36×10^4 mi^2
41) 5.3
42) 2×10^{-8} F
43) 7.0×10^{13}
44) 1×10^{-4} m
45) 1.3×10^{-12} C
8.1×10^6 K^+ ions
46) 2.7×10^{-6} F
47) 41 J, 8200 W
48) 1.2×10^{-8} J
49) 52 V
50) 1.1×10^{-2} m
51) 1.0×10^{-4} C
52) 2.18×10^{-5} m
53) $C = \dfrac{\epsilon_0 A(\kappa_1 + \kappa_2)}{2d}$

The plates of a parallel plate capacitor each have an area of 0.40 m^2 and are separated by a distance of 0.02 m. They are charged until the potential difference between the plates is 3000 V. The charged capacitor is then isolated.

1. Determine the magnitude of the electric field between the capacitor plates.
(a) 60 V/m
(b) 120 V/m
(c) 1.0×10^5 V/m
(d) 1.5×10^5 V/m
(e) 3.0×10^5 V/m

2. Determine the value of the capacitance.
(a) 9.0×10^{-11} F
(b) 1.8×10^{-10} F
(c) 3.6×10^{-10} F
(d) 4.8×10^{-10} F
(e) 6.4×10^{-10} F

3. Determine the magnitude of the charge on either capacitor plate.
(a) 1.8×10^{-7} C
(b) 2.7×10^{-7} C
(c) 4.9×10^{-7} C
(d) 5.4×10^{-7} C
(e) 6.8×10^{-7} C

4. How much work is required to move a -4 μC charge from the negative plate to the positive plate of this system?
(a) -1.2×10^{-2} J
(b) $+1.2 \times 10^{-2}$ J
(c) -2.4×10^{-2} J
(d) $+2.4 \times 10^{-2}$ J
(e) -5.4×10^{-2} J

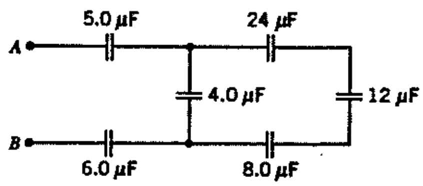
5. Suppose that a dielectric sheet is inserted to completely fill the space between the plates and the potential difference between the plates drops to 1000 V. What is the capacitance of the system after the dielectric is inserted?
(a) 1.8×10^{-10} F
(b) 2.7×10^{-10} F
(c) 5.4×10^{-10} F
(d) 6.2×10^{-10} F
(e) 6.8×10^{-10} F

Section 20.12 Capacitors in Series and Parallel

90. A 2.00-μF and a 4.00-μF capacitor are connected to a 60.0-V battery. How much charge is supplied by the battery in charging the capacitors when the wiring is (a) in parallel and (b) in series?

91. A 4.0-μF and an 8.0-μF capacitor are connected in parallel across a 25-V battery. Find (a) the equivalent capacitance and (b) the total charge stored on the two capacitors.

92. Determine the equivalent capacitance between A and B for the group of capacitors in the drawing.



93. **ssm** A 3.0-μF capacitor and a 4.0-μF capacitor are connected in series across a 40.0-V battery. A 10.0-μF capacitor is also connected directly across the battery terminals. Find the total charge that the battery delivers to the capacitors.

94. Three capacitors (4.0, 6.0, and 12.0 μF) are connected in series across a 50.0-V battery. Find the voltage across the 4.0-μF capacitor.

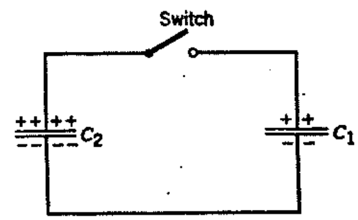
95. Three capacitors have identical geometries. One is filled with a material whose dielectric constant is 2.50. Another is filled with a material whose dielectric constant is 4.00. The third capacitor is filled with a material whose dielectric constant κ is such that this single capacitor has the same capacitance as the series combination of the other two. Determine κ.

96. Suppose two capacitors (C_1 and C_2) are connected in series. Show that the sum of the energies stored in these capacitors is equal to the energy stored in the equivalent capacitor. *[Hint: The energy stored in a capacitor can be expressed as $q^2/(2C)$.]*

***97.** **ssm** A 7.0-μF and a 3.0-μF capacitor are connected in s ries across a 24-V battery. What voltage is required to charge parallel combination of the two capacitors to the same to energy?

***98.** A 3.00-μF and a 5.00-μF capacitor are connected in ser across a 30.0-V battery. A 7.00-μF capacitor is then connected parallel across the 3.00-μF capacitor. Determine the volta across the 7.00-μF capacitor.

****99.** The drawing shows two fully charged capacitors (C_1 2.00 μF, $q_1 = 6.00$ μC; $C_2 = 8.00$ μF, $q_2 = 12.0$ μC). T switch is closed, and charge flows until equilibrium is reest lished (i.e., until both capacitors have the same voltage acr their plates). Find the resulting voltage across either capacitor.



90) 3.6×10^{-6} C, 8×10^{-5} C

91) 12.0 μF, 3.0×10^{-4} V

92) 2.0 μF

93) 4.96×10^{-4} C

94) 25V

95) 1.54

96) $Q^2/2C$

97) 11V

98) 10V

99) 1.80V