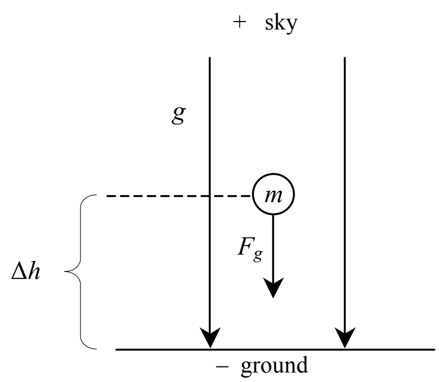
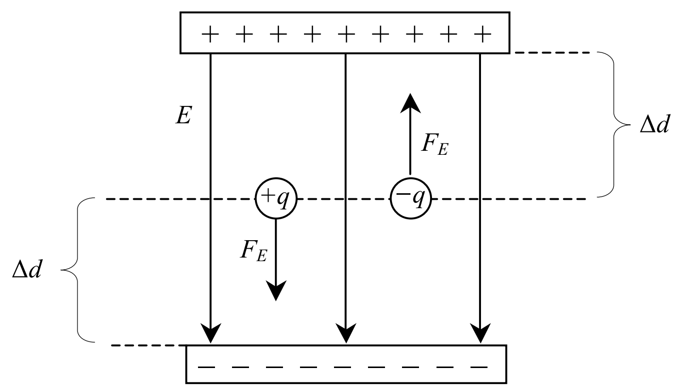
47 CHARGE			
1. What are the basic particles of charge?			
2. There are three variables for charge listed to the right. Tell the typical circumstances when each is used.	*e*	*q*	*Q*
3. Charge (A) What are the units of charge? (B) What is the charge on an electron? (C) What is the charge on a proton? (D) What is the charge on a neutron? (E) How many charged particles (electrons or protons) are contained in 1 coulomb ?	(A) Units of charge		
	(B) Electron charge	(C) Electron charge	(D) Electron charge
	(E) 1 C =		
4. What are the rules for attraction and repulsion for masses and charges?	Negative – Negative		
	Positive – Positive		
	Negative – Positive		
	Neutral – Any thing else		
5. What is meant when we say that charge is (A) conserved? (B) quantized?	(A)		
	(B)		
6. Does the term neutral charge mean no charge? If not what does it mean?			
7. If an object has a charge of 1 C, does it mean that it is made up of only 1 C of protons? If not what does it mean?			
8. Polarized objects. (A) Where are the charges located if the object is polarized? (B) If an object is initial uncharged, and is then polarized, what is its new net charge?	(A)		
	(B)		

9. Conductors (A) What makes something a good conductor of electricity? (B) What substances make excellent conductors? Why? (C) Where are excess charges found on a conductor?	(A)
	(B)
	(C)
10. Insulators (A) What makes something a good insulator of electricity? (B) What is an example of an insulator? (C) Where are excess charges found on an insulator?	(A)
	(B)
	(C)
11. Electroscope (A) What is its purpose? (B) How does it work?	(A)
	(B)
12. Charging (A) Charging by friction (B) Charging by conduction (C) How is charging by induction (show a diagram of the typical example)	(A)
	(B)
	(C)

48 UNIFORM ELECTRIC FIELDS AND FORCE

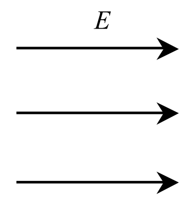
13. **Fields**: A property of both mass and charge is that they both alter the space around them. This disturbance is known as a **field** (the mathematical field, where a function has a value at every point in space x, y, and z). All masses generate **gravity fields** $\boldsymbol{g}$, and all charges generate **electric fields** $\boldsymbol{E}$. These fields surround masses and charges. The larger the mass or the charge, the larger its corresponding field. These fields radiate outward from masses and charges, and they can move through empty space. The field is strongest close to a mass or a charge and weakens with distance. Fields extend to infinity, but at some distance they will become weak enough to be considered negligible. Fields are vector quantities and have both magnitude and direction.

14. Uniform fields			
15. Fields of flat objects such as a small section of the earth's surface or between two evenly spaced charged plates.	**Gravity**	**Electric**	
			
(A) Determining field direction (**fields are vectors**)			
(B) Rules for drawing field vectors			
(C) Field variables and units			
(D) Magnitude of force on an object located in each field.	$F_g = mg$ $F_g = m_{object\ in\ the\ field}\, g_{earth}$ F_g = force on the object and on the earth		
(E) Direction of the above force (vector)	Mass	Positive charge	Negative charge
(F) Acceleration of a mass in a gravity field and a charge in an electric field.	$\Sigma F = F_g$ $\cancel{m}a = \cancel{m}g$ $a = g$ The acceleration of gravity and the gravity field have the same magnitude.		
(G) Solving for time, speed, and distance			

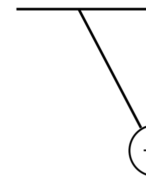
16. Often the plates creating a uniform electric field are not shown in the problem diagram.
    (A) The field may be described.
    (B) Field vectors may be shown.
    (C) Or, its presence may have to be deduced due to the odd nature of the given scenario.

A) An electric field is directed in the +*x* direction

B)



C) An object is suspended by a string as shown.



17. Static Equilibrium

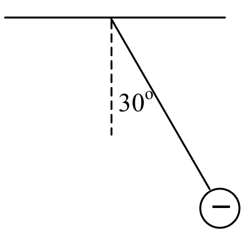
18. Milikan Oil Drop Experiment
    (A) Diagram of Experiment
    (B) Solve for charge on the oil drop
    (C) What did the experiment determine?

A)

B)

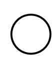
C)

19.

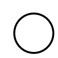


A spherical conductor has a charge of –8.0 μC and a mass of 5.0×10^{-2} kg. It is tied to a string attached to the ceiling. The room has an electric field passing through it, which causes the charged spherical mass to hang at an angle of 30° from the vertical as shown in the diagram above.
(A) Draw a FBD showing the forces acting on the sphere.
(B) Redraw the diagram with angled vectors split into components.
(C) Redraw the vectors added tip to tail.
(D) Determine the strength of the electric field.
(E) State the direction of the electric field.

A)



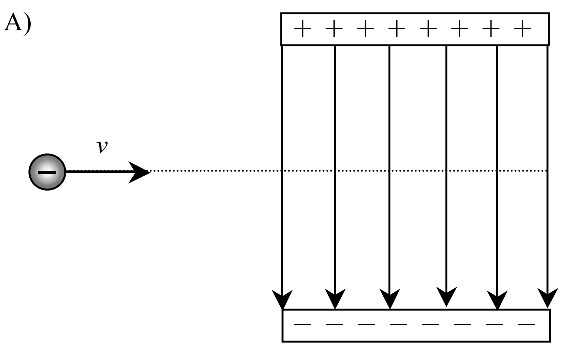
B)



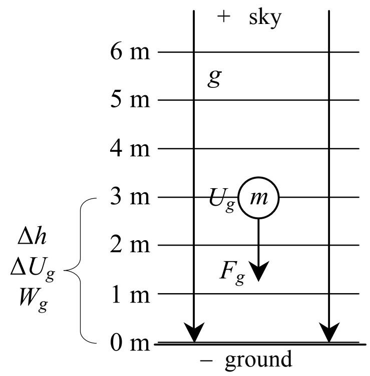
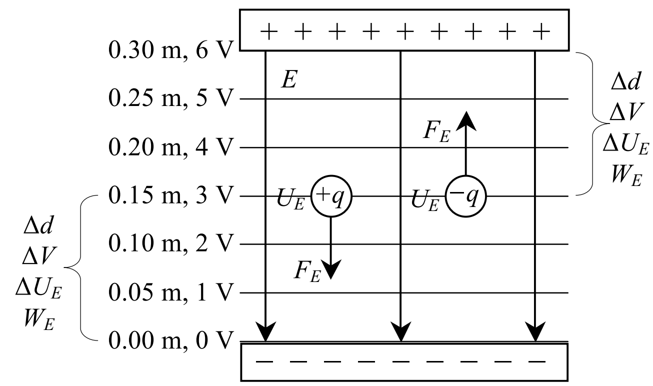
C)

D)

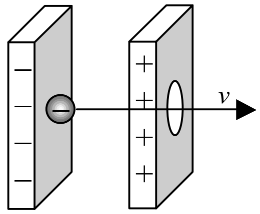
E)

20. Dynamics		
21. **Motion parallel to the field** (perpendicular to the plates, even if they are not shown) An electron is located at a point in space where the electric field is uniform and has a magnitude 30 N/C in the negative *y*-direction. (A) Draw a diagram of this scenario (B) Determine the force on the electron (magnitude and direction) (C) Determine the acceleration of the electron. (D) If the electron is released from rest how long will it take to travel 20 cm? (E) Determine the electrons speed.	a. c.	b. d. e.
22. **Motion perpendicular to the field** (parallel to the plates). The electric field between the plates is 150 N/C and the plates have a length of 30 cm. An electron with a velocity of 8.0×10^6 m/s is fired horizontally between the plates as shown in the diagram at the right. Edge effects are negligible. (A) Draw the path of the electron, and mark the vertical deflection of the electron as it exits the plates, and label it Δy. (B) Determine the acceleration of the electron as it moves between the plates. (C) Determine the vertical deflection of the electron as it exits the field.	A)  B) C)	

49 UNIFORM ELECTRIC FIELDS, POTENTIAL, AND ENERGY

23. Fields	**Gravity**	**Electric**
		
(A) Field	$g = 9.8\,\mathrm{m/s^2}$	$E = given$ or $\boxed{E = -\frac{V}{d}}$ (V is explained below)
(B) Force	$F_g = mg$	$F_E = qE$
(C) Potential energy	$U_g = mgh$	$U_E = qEd$
(D) Potential Potential is essentially the ability to create motion or speed.	Gravity is a weak force and there must be large changes in distance in order for gravity g to change significantly. As a result, changes in energy and speed are associated mainly with changes in height. $\Delta U_g = mg\boxed{\Delta h}$	Electricity is often billions and billions of times larger than gravity. Even a small change in distance can result in a large change in the electric field (non-uniform fields). Both field and distance often change, and their combined effect changes energy and charge speed. $\Delta U_E = q\boxed{\Delta E \Delta d}$ Potential in electricity is a combination of field and distance. $V = Ed$ Potential (measured in volts) can be thought of as electric pressure.
(E) Potential energy revisited	$U_g = mgh$	$U_E = qEd$ or $\boxed{U_E = qV}$
(F) Work	$W_g = mg\Delta h$	When working with charged plates the electric field is uniform. Changes in distance cause changes in both voltage and energy. You can work with Δd or ΔV. $W_E = qE\Delta d$ or $W_E = q\Delta V$
(G) Conservation of energy	$mg\Delta h = \frac{1}{2}mv^2$	$qE\Delta d = \frac{1}{2}mv^2$ or $q\Delta V = \frac{1}{2}mv^2$
(H) Visualizing potential		
(I) Equipotential lines		

24. The plates generate a 20 N/C electric field, and are separated by 15 cm. Determine the speed of the electron when it exits the plates.



(A) Determine the initial potential energy of the electron.

(B) Determine the work done on the electron as it moves from the negative to the positive plate.

(C) Determine the speed of the proton as it exits the hole in the positive plate.

(D) What type of motion will the electron experience after passing through the hole in the plate?

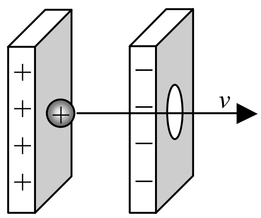
A)

B)

C)

D)

25. The plates have a potential difference of 20 V. Determine the speed of the proton exiting the plates.



26. What is significant about the phrase, "Accelerated through a potential difference?"

27. A charged particle is accelerated through a potential difference of 40 V in a set of vertical plates. After exiting these plates it enters a set of horizontal plates. These plates are 10 cm long and the electric field between them is 20 N/C. The field direction is indicated in the diagram at the right.

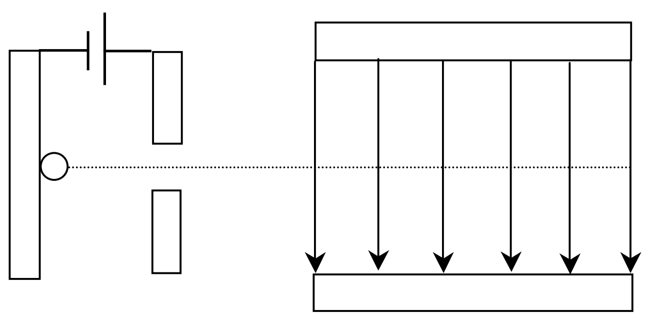
(A) Label the signs on each plate, the charge that will move through the plates (it is either an electron or a proton), draw the charges path, and label the vertical deflection.

(B) State the direction of the electric field between the left set of plates.

(C) Determine the speed of the moving charge as it exits the hole in the first set of plates.

(D) Determine the vertical deflection in the second set of plates.

A)



B)

C)

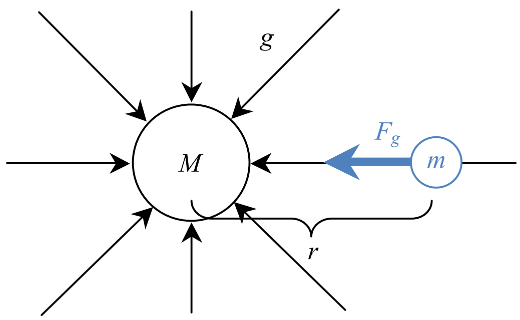
D)

50 ELECTRIC FIELD OF POINT CHARGES AND COULOMB'S LAW

28. What is a point charge?

29. Fields around spherical objects such as planets and point charges.

GRAVITY



In all of these diagrams the field of the larger mass M and the larger charge Q are shown acting on the smaller mass m and smaller charge q and creating a force of attraction or repulsion on it.

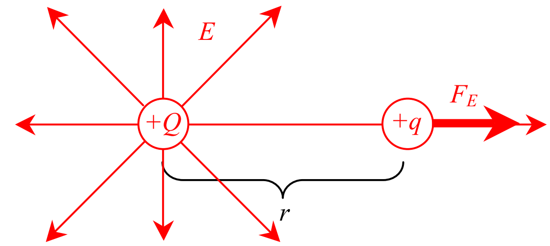
(Note: a larger charges does not necessarily have a larger size. It just contains more excess charges.)

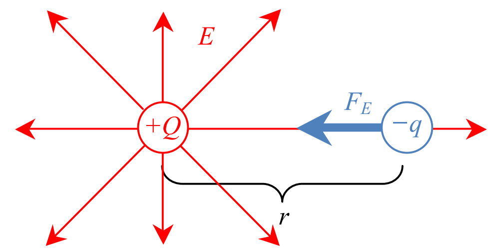
The smaller mass and smaller charge also have field surrounding them, which act on the larger mass and larger charge, creating a force on them.

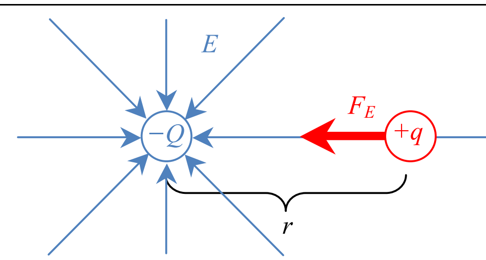
Newton's Third Law states that whenever two objects interact there is an equal and opposite force between them. Therefore, it does not matter whether we analyze the field of the larger object creating a force on the smaller object, or the field of the smaller objects creating a force on the larger object.

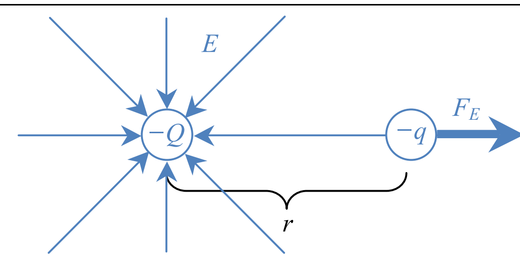
The norm is to consider the field of the larger object (which is usually stationary) pulling on the smaller object. This is what is diagrammed in each scenario, above and to the right.

ELECTRICITY









(A) Magnitude of force on an object located in each field.

Gravity: Newton's Law of Universal Gravitation

$$F_g = -G\frac{m_1 m_2}{r^2}$$

Universal gravity constant

$$G = 6.67\times10^{-11}\ \mathrm{m^3/kg\cdot s^2}$$

Electricity: Coulomb's Law

$$F_E = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2} \quad \text{or} \quad F_E = k\frac{q_1 q_2}{r^2}$$

$$\epsilon_0 = 8.85\times10^{-12}\ \mathrm{C^2/N\cdot m^2}$$

$$k = \frac{1}{4\pi\epsilon_0} = 9.0\times10^{9}\ \mathrm{N\cdot m^2/C^2}$$

(B) Magnitude of the electric field

Gravity:

$$F_g = G\frac{M\ m}{r^2}$$

$$\cancel{m}g = G\frac{M\ \cancel{m}}{r^2}$$

$$g = G\frac{M}{r^2}$$

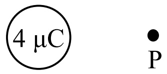
Electricity:

$$F_E = k\frac{Q\ q}{r^2}$$

$$\cancel{q}E = k\frac{Q\ \cancel{q}}{r^2}$$

$$E = k\frac{Q}{r^2}$$

30.



A spherical conductor has a charge of 4.0 μC. Point P is located 30 cm to the right of the charge.

(A) How are the charges distributed on a conductor?

(B) Determine the magnitude and direction of the electric field at point P.

A –0.5 μC point charge is inserted at point *P*.

(C) Determine the magnitude and direction of the force on this charge.

A)

B)

C)

31. The minus signs in the formulas

Objects	Formula with signs	Resulting Interaction
Masses	$\boxed{-F_g} = -G\dfrac{+m_1 + m_2}{r^2}$	
Opposite charges	$\boxed{-F_E} = k\dfrac{+q_1 - q_2}{r^2}$ or $\boxed{-F_E} = k\dfrac{-q_1 + q_2}{r^2}$	
Like Charges	$\boxed{+F_E} = k\dfrac{+q_1 + q_2}{r^2}$ or $\boxed{+F_E} = k\dfrac{-q_1 - q_2}{r^2}$	

32. Handling the signs for fields and the forces they create.

Positive E or F_E means away (repel) and negative E or F_E means toward (attract).

For magnitude use absolute values for charge: $E = k\dfrac{|q|}{r^2}$ $F_E = k\dfrac{|q_1|\ |q_2|}{r^2}$

33. **Use the diagram to determine direction of electric field and force.**

(A) **Rules for field direction**

(B) **Rules for force direction**

(A)

(B)

34. 1.0 C of protons has a mass of 1.0×10^{-8} kg, and 1 C of electrons has a mass of 5.7×10^{-12} kg. They are separated by 1.0 m.

(A) Determine the magnitude of the force of gravity between the charges.

(B) Determine the magnitude of the force of electricity between the charges.

(C) How does the force of gravity compare to the force of electricity?

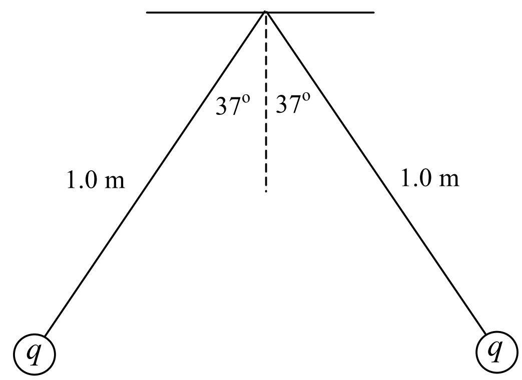
A) Force of Gravity

B) Force of Electricity

C)

35. Describe the Millikan Oil Drop experiment. Include a diagram, FBD, equations, and state the major findings.

36. Two identical positively charged spheres, each with a mass of 300 g, are suspended by massless strings as shown in the diagram. Determine the charge on each sphere.



37. An electron orbits a proton at a radius of 1.2×10^{-10} m. Determine the speed of the orbiting electron. Assume the orbit to be circular.

51 SUPERPOSITION

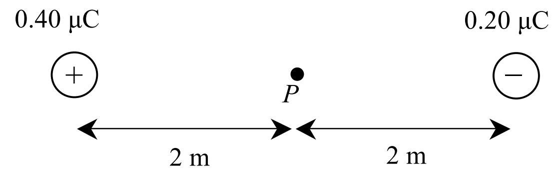
38. For the charge configuration shown at the right
    (A) Determine the magnitude and direction of the electric field at point *P*.
    (B) Determine the magnitude of the electric potential at point *P*.

    A –0.30 μC charge with a mass of 5.0×10^{-10} kg is inserted at point *P*.

    (C) Determine the magnitude and direction of the force acting on this charge.
    (D) Determine the energy of this charge.

    The –0.30 μC charge is released.

    (E) Determine the maximum speed acquired by the charge.



(A)

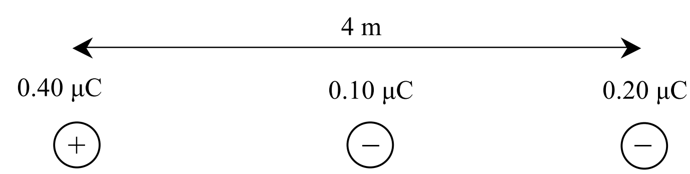
(B)

(C)

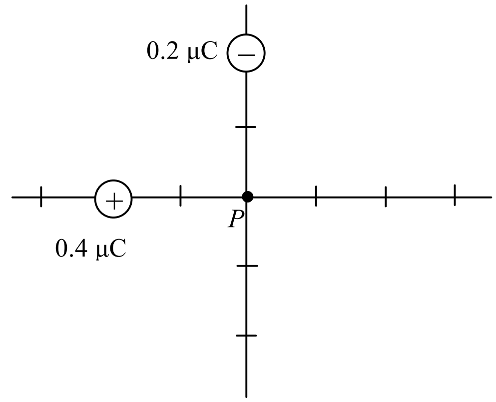
(D)

(E)

41. Determine the net force acting on the 0.10 μC charge, which is located at the midpoint between the other two charges in the diagram below.



42. For the charge configuration shown at the right
    (A) Determine the magnitude and direction of the electric field at point P .
    (B) Determine the magnitude of the electric potential at point P .
    A –0.3 μC charge with a mass of 5.0×10^{-10} kg is inserted at point *P*.
    (C) Determine the magnitude and direction of the force acting on this charge.
    (D) Determine the energy of this charge.
    The –0.3 μC charge is released.
    (E) Determine the maximum speed acquired by the charge.



(A)

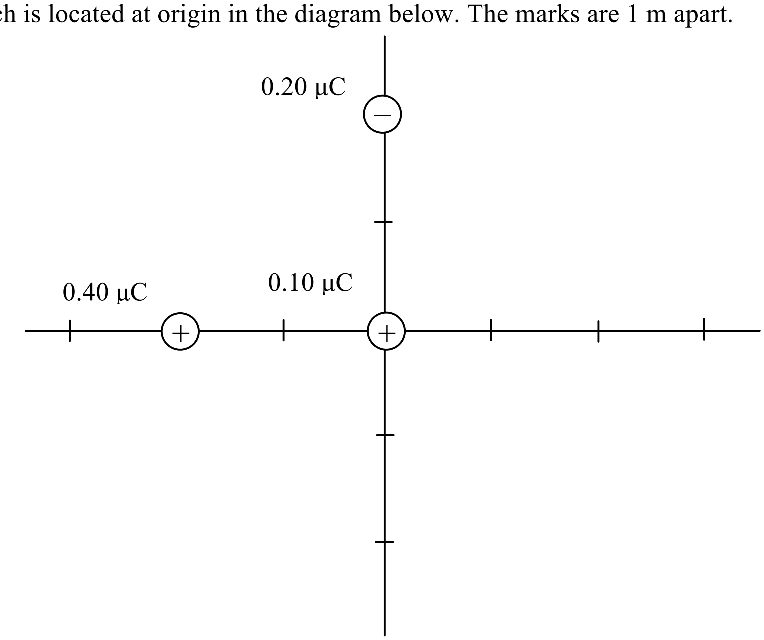
(B)

(C)

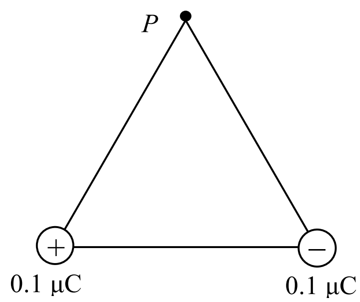
(D)

(E)

45. Determine the net force acting on the 0.10 μC charge, which is located at origin in the diagram below. The marks are 1 m apart.



46. The arrangement forms an equilateral triangle, with sides that are 1 m long.



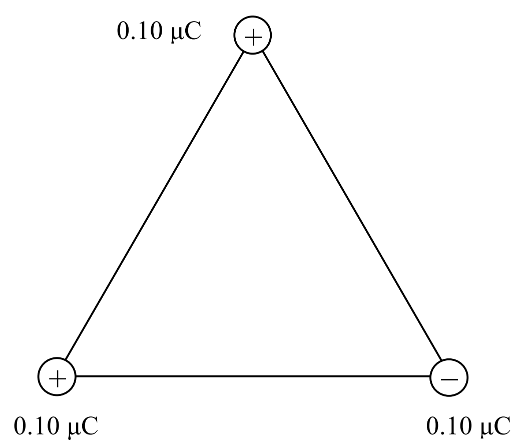
(A) Determine the electric field at P.

(B) Determine the electric potential at P.

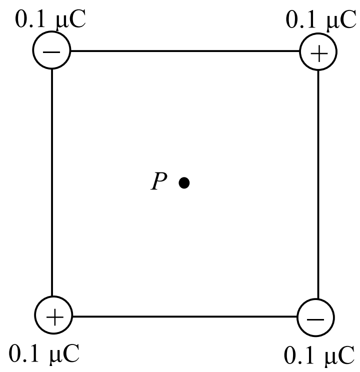
A)

B)

47. Determine the net force acting on the 0.10 μC charge, which is located at top of the equilateral triangle shown below. The sides of the triangle are 1 m in length.



48. The arrangement forms a square, with sides that are 1 m long and point P is at the center.



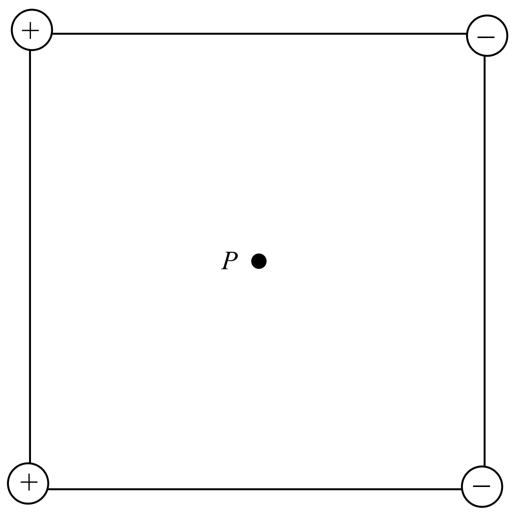
(A) Determine the electric field at point P.

(B) Determine the electric potential at point P.

A)

B)

49. The arrangement forms a square, with sides that are 1 m long. All charges have a magnitude of 0.1 μC. Determine the electric field at point P, located at the center of the square.



50. Four 0.10 μC charges occupy the corners of a square with sides of 1.0 m. Determine the net force acting the top right charge.