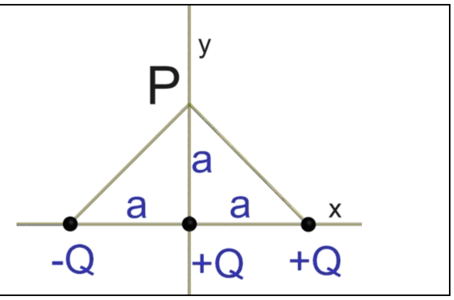
Electric Fields, Dipoles and Torque

Challenge Problems

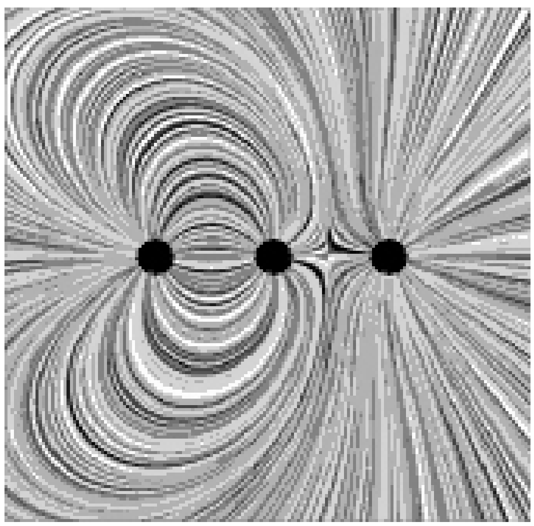
Problem 1:

Three charges equal to –Q, +Q and +Q are located a distance a apart along the x axis (see sketch). The point P is located on the positive y-axis a distance a from the origin.

(a) What is the electric field $\vec{\mathbf{E}}$ at point P?

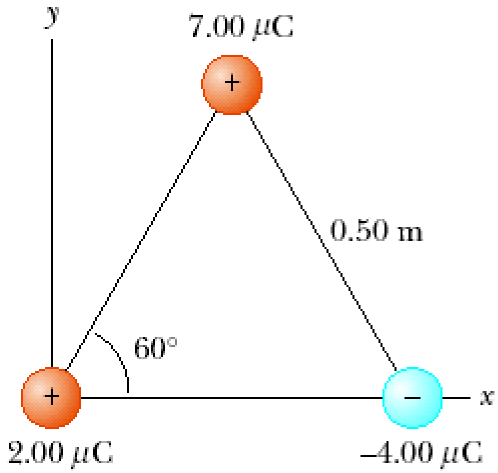


(b) _(f)_ (enter one letter) is the correct field line representation for this problem



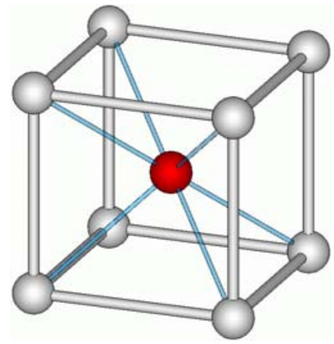
Problem 2:

Consider three point charges located at the corners of an equilateral triangle, as shown in figure. Calculate the resultant electric force on the 7.00-μC charge. Be sure to specify both the magnitude and direction.



Problem 3:

Cesium Chloride is a salt with a crystal structure in which cubes of Cs^+ ions (side length $a \sim 0.4$ nm) surround Cl^- ions, as pictured at right.



(a) What is the magnitude of the net electrostatic force on the Cl^- ion due to its eight nearest neighbor Cs^+ ions?

(b) Occasionally defects arise in which one of the Cs^+ ions is missing. We call this a vacancy. In this case, what is the magnitude and direction (relative to the vacancy) of the net electrostatic force on the Cl^- ion due to its remaining seven?

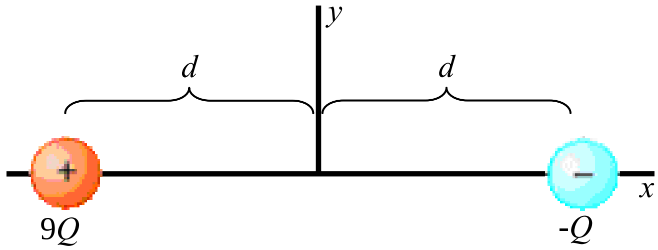
Problem 4:

One version of an electroscope consists of two small conducting balls of mass m hanging on **long** strings of length L. If a charge $2q$ is transferred to the system (so each ball acquires the same charge q), they will repel.

(a) Neglecting gravitational attraction between the balls, by what distance x do they move apart when charged?

(b) Is it reasonable to ignore this gravitational attraction? More precisely, if we were to put a very small charge, say one electron, on each of the balls, how light would the balls have to be before we could ignore gravitational attraction between them? Could we make the balls that light?

Problem 5:
Two massless point charges $+9Q$ and $-Q$ are fixed on the x-axis at $x = -d$ and $x = d$:



(a) There is one point on the x-axis, $x = x_0$, where the electric field is zero. What is x_0?

(b) A third point charge q of mass m is free to move along the x-axis. What force does it feel if it is placed at $x = x_0$ (the location you just found)?

(c) Now q is displaced along the x-axis by a small distance a to the right. What sign of charge should q be so that it feels a force pulling it back to $x = x_0$?

(d) Show that if a is small compared to d ($a << d$) q will undergo simple harmonic motion. Determine the period of that motion. [NOTE: The motion of an object is simple harmonic if its acceleration is proportional to its position, but oppositely directed to the displacement from equilibrium. Mathematically, the equation of motion can be written as $d^2x/dt^2 = -\omega^2 x$, where ω is the angular frequency. See Review Module E for more detail. HINT: a/d is REALLY SMALL. Taylor expand]

(e) How fast will the charge q be moving when it is at the midpoint of its periodic motion?

Problem 6:

Consider two equal but opposite charges, both mass m, on the x-axis, $+Q$ at $(a,0)$ and $-Q$ at $(-a,0)$. They are connected by a rigid, massless, insulating rod whose center is fixed to a frictionless pivot at the origin. This is a dipole. A uniform field $\vec{\mathbf{E}} = E\hat{\mathbf{i}}$ is now applied.

(a) What is the force on the dipole due to this external field?

Now the dipole is rotated and held at a small angle θ_0 (c.c.w.) from the x-axis.

(b) Now what is the force on the dipole?

(c) How much did the potential energy of the dipole change when it was rotated?

(d) What is the torque on the dipole?

(e) Now the dipole is released and allowed to rotate due to this torque. Describe the motion that it undergoes (i.e. what is its angle $\theta(t)$?)

(f) Where is the positive charge when it is moving the fastest? How fast is it moving?