Prof. Anchordoqui

Problems set # 2 **Physics 169** February 11, 2015

1. Figure 1 shows the electric field lines for two point charges separated by a small distance. *(i)* Determine the ratio q_1/q_2. *(ii)* What are the signs of q_1 and q_2?

2. An ion milling machine uses a beam of gallium ions ($m = 70u$) to carve microstructures from a target. A region of uniform electric field between parallel sheets of charge is used for precise control of the beam direction. Single ionized gallium atoms with initially horizontal velocity of 1.8×10^4 m/s enter a 2.0 cm-long region of uniform electric field which points vertically upward, as shown in Fig. 2. The ions are redirected by the field, and exit the region at the angle θ shown. If the field is set to a value of $E = 90$ N/C, what is the exit angle θ?

3. Two 2.0-g spheres are suspended by 10.0-cm-long light strings, see Fig. 3. A uniform electric field is applied in the x direction. If the spheres have charges of -5.0×10^{-8} C and 5.0×10^{-8} C, determine the electric field intensity that enables the spheres to be in equilibrium at $\theta = 10°$.

4. Three charges of equal magnitude q are fixed in position at the vertices of an equilateral triangle (Fig. 4). A fourth charge Q is free to move along the positive x axis under the influence of the forces exerted by the three fixed charges. Find a value for s for which Q is in equilibrium. You will need to solve a transcendental equation.

5. Eight solid plastic cubes, each 3.00 cm on each edge, are glued together to form each one of the objects *(i, ii, iii, iv)* shown in Fig. 5. *(a)* Assuming each object carries charge with uniform density 400 nC/m^3 throughout its volume, find the charge of each object. *(b)* Assuming each object carries charge with uniform density 15.0 nC/m^2 everywhere on its exposed surface, find the charge on each object. *(c)* Assuming charge is placed only on the edges where perpendicular surfaces meet, with uniform density 80.0 pC/m, find the charge of each object.

6. *(i)* Consider a uniformly charged thin-walled right circular cylindrical shell having total charge Q, radius R, and height h. Determine the electric field at a point a distance d from the right side of the cylinder as shown in Fig. 6. [Hint: Use the result of Example 2 given in lecture 2 and treat the cylinder as a collection of ring charges.] *(ii)* Consider now a solid cylinder with the same dimensions and carrying the same charge, uniformly distributed through its volume. Use the result of Example 3 given in lecture 2 to find the field it creates at the same point.

7. A uniformly charged rod of length 14.0 cm is bent into the shape of a semicircle as shown in Fig. 7. The rod has a total charge of -7.50 μC. Find the magnitude and direction of the electric field at O, the center of the semicircle.

8. A line of charge with uniform density 35.0 nC/m lies along the line $y = -15.0$ cm, between the points with coordinates $x = 0$ and $x = 40.0$ cm. Find the electric field it creates at the origin.

9. *(i)* A rod of length ℓ has a uniform positive charge per unit length λ and a total charge Q. Calculate the electric field at a point P that is located along the long axis of the rod and a distance a from one end. *(ii)* Identical thin rods of length $2a$ carry equal charges $+Q$ uniformly distributed along their lengths. The rods lie along the x axis with their centers separated by a distance $b > 2a$ (Fig. 8). Show that the magnitude of the force exerted by the left rod on the right one is given by $F = \frac{1}{4\pi\epsilon_0} \frac{Q^2}{4a^2} \ \ln\left(\frac{b^2}{b^2 - 4a^2}\right)$.

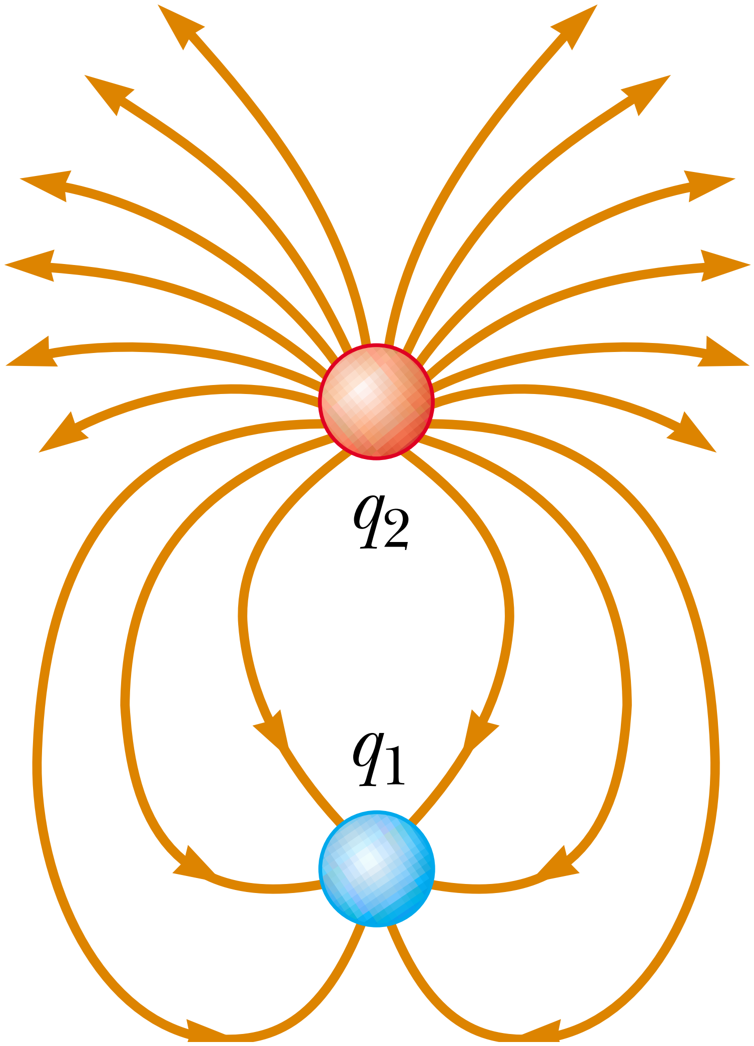

Figure 1: Problem 1.

10. An electric dipole in a uniform electric field is displaced slightly from its equilibrium position, as shown in Fig. 9, where $\theta$is small. The separation of the charges is $2a$, and the moment of inertia of the dipole is I. Assuming the dipole is released from this position, show that its angular orientation exhibits simple harmonic motion with a frequency $f = \frac{1}{2\pi}\sqrt{\frac{2qaE}{I}}$.

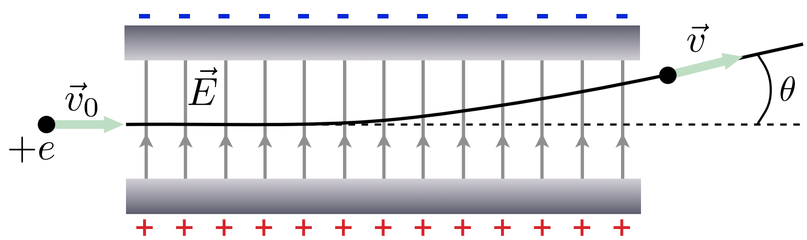

Figure 2: Problem 2.

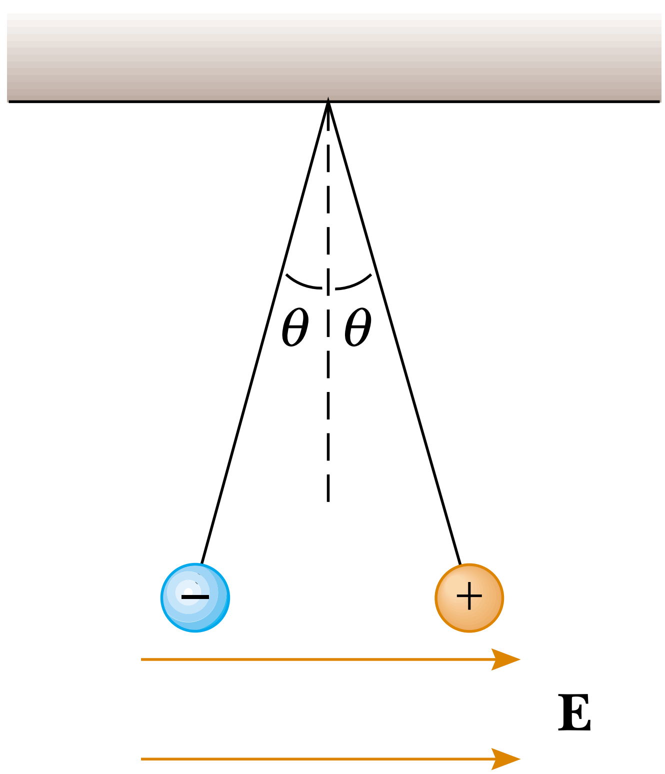

Figure 3: Problem 3.

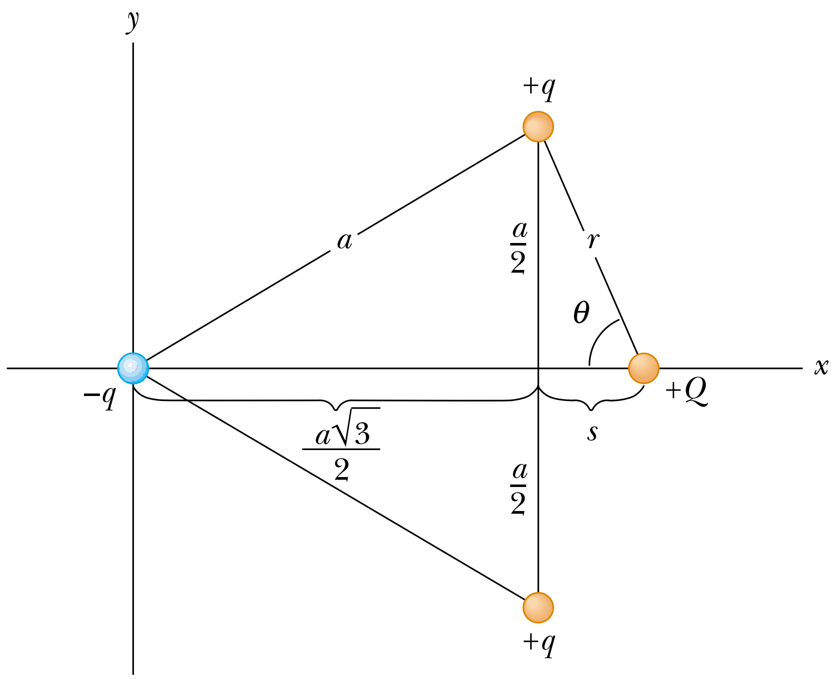

Figure 4: Problem 4.

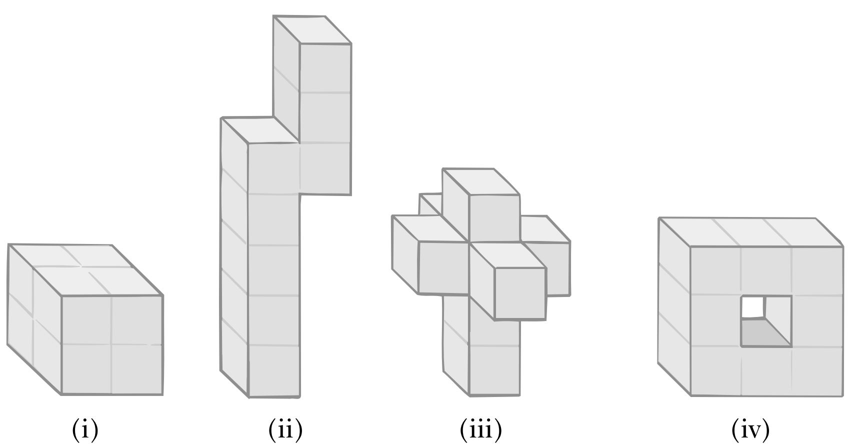

Figure 5: Problem 5.

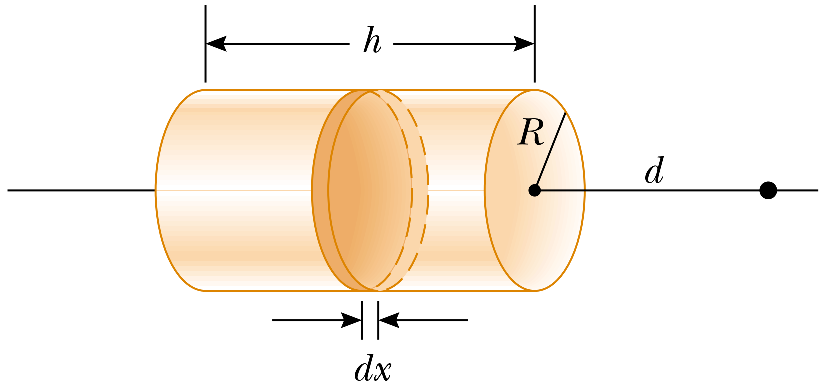

Figure 6: Problem 6.

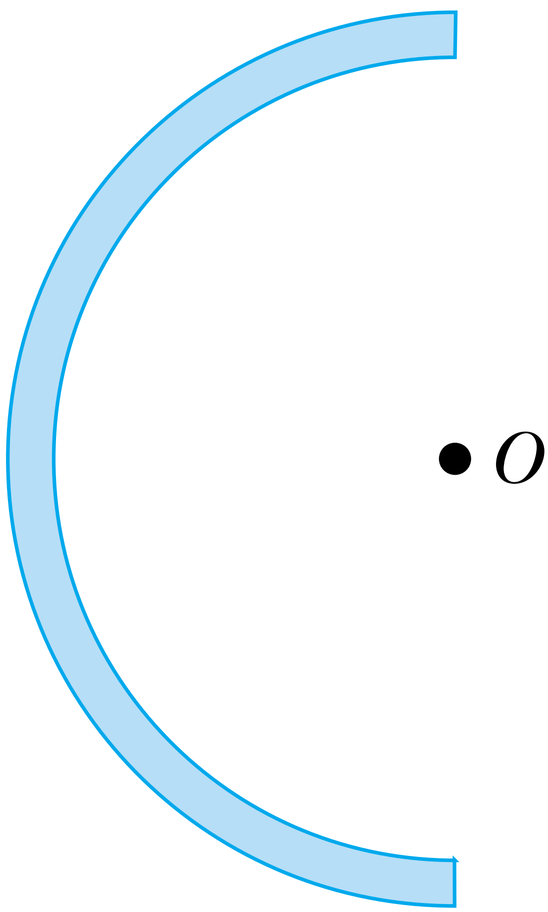

Figure 7: Problem 7.

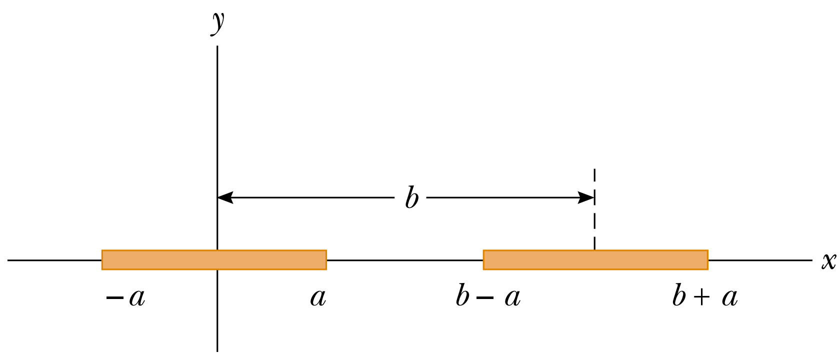

Figure 8: Problem 9.

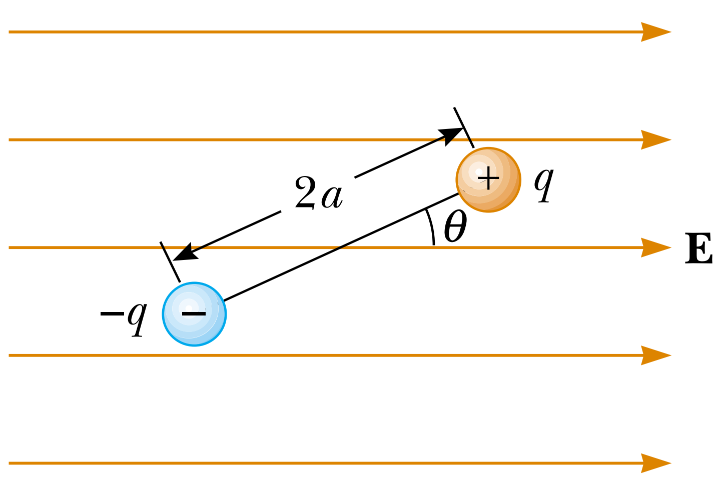

Figure 9: Problem 10.