

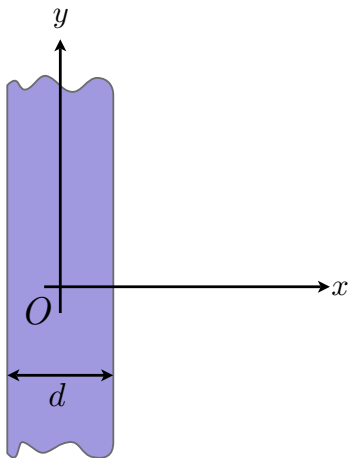
### Problem Set 3: Gauss' Law & Electric Potential

#### Instructions:

1. Answer all questions below. Show your work for full credit.
2. Due before the end of 12 September 2008
3. Email: pleclair@ua.edu; hard copies: Gallalee 206 or Bevill 228
4. You may collaborate, but everyone must turn in their own work

1. A solid sphere of radius  $R$  has a uniform charge density  $\rho$  and total charge  $Q$ . Derive an expression for its total electric potential energy. (Suggestion: imagine that the sphere is constructed by adding successive layers of concentric shells of charge  $dq = (4\pi r^2 dr)\rho$  and use  $dU = V dq$ .)

2. An insulated spherical shell of radius  $a$  has a charge  $Q$  spread uniformly over its surface. If the sphere is cut evenly into two hemispheres, what force is required to hold the two hemispheres together?



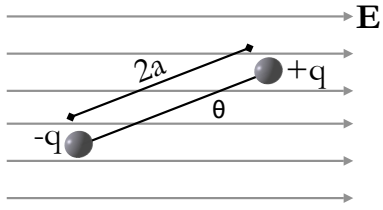
3. A slab of insulating material, infinite in two of its three dimensions, has a uniform positive charge density  $\rho$ , shown at left. (a) Show that the magnitude of the electric field a distance  $x$  from the center and inside the slab is  $E = \rho x / \epsilon_0$ . (b) Suppose an electron of charge  $-e$  and mass  $m_e$  can move freely within the slab. It is released from rest at a distance  $x$  from the center. Show that the electron exhibits simple harmonic motion with a frequency

$$f = \frac{1}{2\pi} \sqrt{\frac{\rho e}{m_e \epsilon_0}}$$

4. Consider an infinite number of identical charges (each of charge  $q$ ) placed along the  $x$  axis at distances  $a, 2a, 3a, 4a, \dots$ , from the origin. (a) What is the electric field at the origin due to this distribution? (b) What is the electric potential at the origin?

5. Find the electric potential at an arbitrary point  $P(x, y, z)$  in the vicinity of a charged rod of length  $L$  with linear charge density  $\lambda$ .

6. A sphere the size of a basketball is charged to a potential of  $-1000$  V. About how many extra electrons are on it, per  $\text{cm}^2$  of surface?



7. An electric dipole in a uniform electric field  $E$  is displaced slightly from its equilibrium position, as shown at left, 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

$$f = \frac{1}{2\pi} \sqrt{\frac{2qaE}{I}}$$