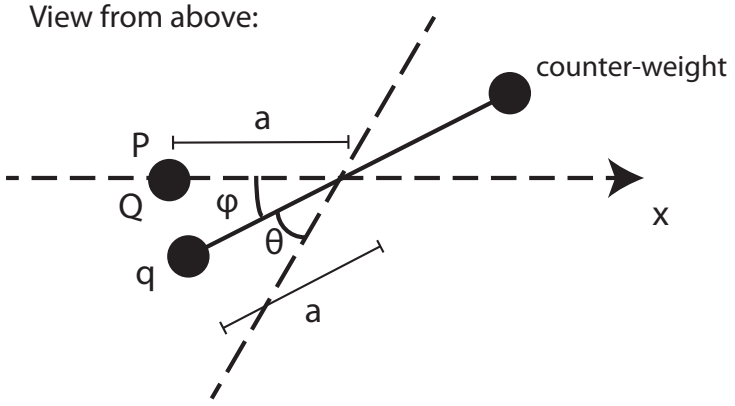
Physics 4B: Collected Homework 1

1. Coulomb torsion balance. A torsion balance is a device for making delicate measurements of small forces. A horizontal bar is suspended from a torsion fibre, which is a wire or string that has supplies a known torque, τ per unit angle it is twisted by. Such a fibre obeys the rotational version of Hooke's Law: $\tau = \kappa\theta$. The angle θ is the angle of twist, and κ is the torsion coefficient for the fiber. When the device is in equilibrium, the torque from the force between two objects is balanced by the torque of the torsion fibre that suspends the bar.

   A small positively charged sphere, charge $q = 8.20 \times 10^{-8}$ C, is attached to one end of a torsion balance bar, suspended from a torsion fibre. The fibre has a torsion coefficient of 2.10 Nm/rad. When the torsion fibre is relaxed (in its equilibrium position) the bar makes an angle of $(\theta + \varphi) = \pi/25$ rad with the x-axis. A small negatively charged sphere, charge $Q = -8.50 \times 10^{-8}$ C, is placed on the x-axis at point P in the diagram and the bar rotates to a new equilibrium position. Using $a = 12.0$ cm, $\theta = \pi/50$, and assuming that Coulomb's law holds, calculate the value of Coulomb's constant k_e including units. How does this value compare to the accepted value of k_e?

   For simplicity, since all of the angles in this problem are small, use the approximation that the distance between two points on the circumference of a circle approximately equal to the arc length along the circle between them. ($s = \varphi a$, where a is the radius of the circle.) Also, note that under this approximation the force on the charge q is perpendicular to the bar.



2. Electric field at a distance from a charged ring.

   (a) Look at example 23.8 in the textbook. There is a charged ring that lies in the yz-plane and the example finds the electric field at a distance x from the plate along the x-axis. Write down the expression for the E-field as a function of x. Rigorously complete the argument sketched in the example to find the form of the electric field when $x \to \infty$. You should make use of some of the properties of limits. (Hint: as $x \to \infty$, terms with x^{-p}, where p is a positive integer, will go to zero.)

   (b) At what value(s) of x does the magnitude of the E-field strength reach its maximum value? What is the maximum magnitude of the E-field?

   (c) Sketch an approximate plot of the function $E(x)$ on an x-axis that includes negative and positive values.

3. Two charges of equal magnitude and opposite sign are arranged as shown in the diagram, separated by a distance 2ℓ. Consider a circle of radius R drawn equidistant between them in a plane perpendicular to a line drawn between them. What is the electric flux through the circle? Choose the circle's surface normal vector to point to the right in the diagram. (Hint: you might like to think about solid angle.)