PHYS 2604
Assignment #2

Given: Thursday, September 24, 2009
Due: Thursday, October 1, 2009 **in class**

1. A mystery particle enters the region between the horizontal plates of a Thomson apparatus; its initial velocity is parallel to the surface of the plates. The separation of the plates is $d = 2.00\ cm$ and the length of the plates is $l = 10.0\ cm$. When the potential difference between the plates is $V = 2000\ V$, the deflection angle of the particle (as it leaves the region between the plates) is measure to be 0.20 radians. If a perpendicular magnetic field of magnitude $B = 4.57 \times 10^{-2}\ T$ is applied simultaneously with the electric field, the mystery particle instead passes through the apparatus undeflected.

   Find the charge to mass ratio q/m for this particle.

   It's a common particle; identify it.

   Find the horizontal speed with which the particle entered the region between the plates.

2. A deuteron is an ionized hydrogen isotope of mass number 2 (it consists of a proton and a neutron). For the purposes of this question, approximate the deuteron mass by twice the proton mass. Suppose protons and deuterons start at rest and are accelerated through a potential difference of $150\ V$, pass through a small slit, and then enter an area of uniform magnetic field (directed perpendicular to their velocity) where the magnetic induction is $B = 0.010\ T$. The field causes the two types of particles to move in circular paths. This is the idea behind the mass spectrometer.

   What is the separation of the beams of protons and deuterons after completing a semicircle?

3. A charged oil droplet falls 4.0 mm in 16.0 s at constant (terminal) speed in air in the absence of an electric field. The viscosity of the air is $\eta = 1.81 \times 10^{-5}\ N \cdot s/m^2$. The density of the oil is $\rho = 0.92 \times 10^3\ kg/m^3$ and the density of the air is $\rho_a = 1.2\ kg/m^3$. Find the radius of the droplet and the mass of the droplet. If the droplet carries one electronic unit of charge (e) and is now in an electric field of $E = 2000\ V/cm$, what is the ratio of the electric force to the gravitational force on the droplet?

4. A variation of the Millikan oil drop experiment has the electric field applied horizontally, rather than vertically, giving charged droplets an acceleration in the horizontal (x) direction. The result is that the droplets fall in a straight line that makes an angle θ with the vertical axis (y-axis). Show that

$$sin\theta = \frac{qE}{6\pi\eta r v}$$

where v is the terminal speed along the angled path. Show that

$$v = \sqrt{\left(\frac{qE}{6\pi\eta r}\right)^2 + \left(\frac{\frac{4}{3}\pi r^3(\rho - \rho_a)g}{6\pi\eta r}\right)^2}.$$