

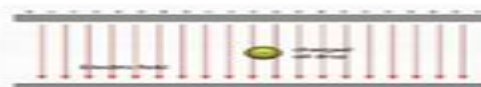
## 1 of 3

## HOMEWORK 4

Mastering Physics HW due online on Friday, 2/17/2023 at 11:59PM.

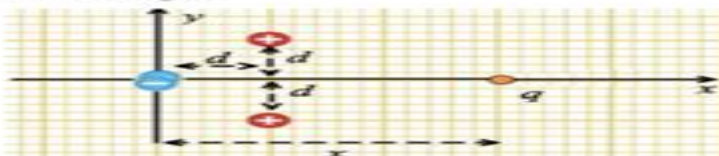
Hand-written solutions to the following questions are due on Wednesday 2/15/2023, on paper, at the beginning of your recitation session.

- 1) (40 pts) In the "Millikan oil drop experiment", an atomizer (a sprayer with a fine nozzle) is used to introduce many tiny droplets of oil between two oppositely charged parallel metal plates held in a vacuum chamber. The original apparatus and a simplified schematic are shown. The two plates are just above and below the small magnifying scope sticking out on the right of the apparatus. The entire apparatus is about 1 meter high.



Some of the droplets pick up one or more excess electrons as they are sprayed into the chamber. The charge on the plates is adjusted so that the electric force on these excess electrons exactly balances the weight of the whole droplet. The idea is to look for a droplet that requires the smallest electric force, and assume that it has only one excess electron. This lets the observer measure the charge on the electron. Estimate the radius of an oil drop that would be balanced by a voltage difference of 10 kV (10,000 Volts). Draw a **free body diagram** to support your answer, and **do not use a calculator**! Hint: you may find it useful to know that the density of water is  $1 \text{ g/cm}^3$ . Oil is not water, however. . . .

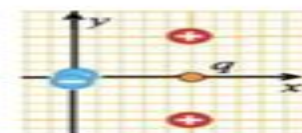
- 2) (50 pts total) In this problem we will explore the electric effects produced by a neutral molecule on charges nearby. We will consider a "toy" (very simple) model of a water molecule that has charge  $-2e$  localized on the oxygen atom and charges of  $+e$  localized on each hydrogen atom. In addition, for simplicity of calculations, we will consider the OH bonds to be perpendicular to each other as shown in the figure.



- A. (20 pts) First consider the electrostatic potential,  $V$ , produced by this molecule along its line of symmetry (aka the x-axis). A positive test charge,  $q$ , is exploring the electrostatic potential along the positive x axis. If the locations of the charges in the water molecule are located as shown, which of the following equations could correctly represent the potential measured by the test charge? For each option that doesn't work, explain why it doesn't work, and identify the electrostatic property it could represent instead.

- a.  $V = 2 \frac{kqe}{\sqrt{(x-d)^2 + d^2}} - 2 \frac{kqe}{\sqrt{x^2}}$   
 b.  $V = 2 \frac{ke}{\sqrt{(x-d)^2 + d^2}} - 2 \frac{ke}{\sqrt{x^2}}$   
 c.  $V = 2 \frac{kqe}{(x-d)^2 + d^2} - 2 \frac{kqe}{x^2}$   
 d.  $V = 2 \frac{ke}{(x-d)^2 + d^2} - 2 \frac{ke}{x^2}$

- B. (10 pts) Now consider the electric field that the test charge would measure. Suppose that the test charge is negative and is moved to the position between the H atoms shown in the figure at right. What can you say about the electric potential and the electric field measured by the negative test charge? **Explain your reasoning.** Support your answer by treating the three water molecule atoms as *individual point sources* and calculating the total electric potential  $V$  at the test charge's location. (Note: this is not the same situation as in the previous question, but it's very possible to leverage



# Mastering Physics Solutions Chapter 17

**Barton Zwiebach**



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