Applied Physics for Engineers (PHY121)

Electrostatics

LECTURE #

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A Point Charge in an Electric field

we know that an electric field $\vec{\mathbf{E}}$ experiences a force $\vec{\mathbf{F}}$ given by

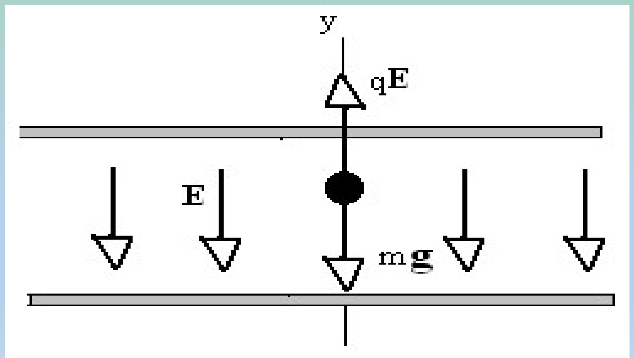
$$\vec{\mathbf{F}} = q\vec{\mathbf{E}}.$$

To study the motion of the particle in the electric field, all we need do is use Newton's second law, $\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}}$, where the resultant force on the particle includes the electric force and any other forces that may act.

PROBLEM

A charged drop of oil of radius R = 2.76 μm and density ρ = 918 kg/m^3 is maintained in equilibrium under the combined influence of its weight and a downward uniform electric field of magnitude E = 1.65×10^6 N/C (Fig-1).

i. Calculate the magnitude and sign of the charge on the drop.
ii. Express the result in terms of the elementary charge *e*.
iii. The drop is exposed to a radioactive source that emits electrons. Two electrons strike the drop and are captured by it, changing its charge by two units. If the electric field remains at its constant value, *evaluate* the resulting acceleration of the drop.



(Fig-1)

Solution (*a*) To keep the drop in equilibrium, its weight mg must be balanced by an equal electric force of magnitude qE acting upward. Because the electric field is given as being in the downward direction, the charge q on the drop must be negative for the electric force to point in a direction opposite the field. The equilibrium condition is

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{g}} + q\vec{\mathbf{E}} = 0.$$

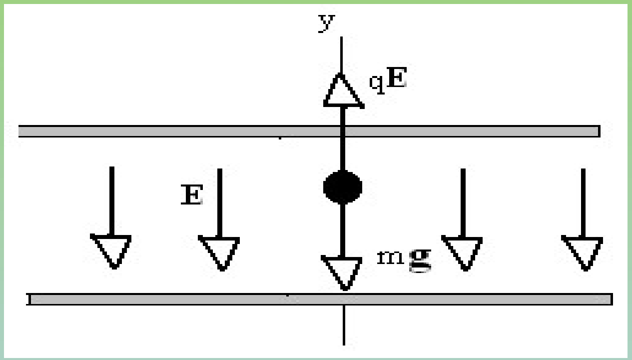
Taking y components, we obtain

$$-mg + q(-E) = 0$$

or, solving for the unknown q,

$$\because \rho = \frac{m}{V} \Rightarrow m = \rho V = \rho\left(\frac{4}{3}\pi R^3\right)$$

$$q = -\frac{mg}{E} = -\frac{\frac{4}{3}\pi R^3 \rho g}{E}$$



(Fig-1)

$$= -\frac{\frac{4}{3}\pi(2.76 \times 10^{-6}\ \mathrm{m})^3(918\ \mathrm{kg/m^3})(9.80\ \mathrm{m/s^2})}{1.65 \times 10^6\ \mathrm{N/C}}$$

$$= -4.80 \times 10^{-19}\ \mathrm{C}.$$

If we write q in terms of the electronic charge $-e$ as $q = n(-e)$, where n is the number of electronic charges on the drop, then

$$n = \frac{q}{-e} = \frac{-4.80 \times 10^{-19}\,\mathrm{C}}{-1.60 \times 10^{-19}\,\mathrm{C}} = 3.$$

(b) If we add two additional electrons to the drop, its charge will become

$$q' = (n + 2)(-e) = 5(-1.60 \times 10^{-19}\,\mathrm{C}) = -8.00 \times 10^{-19}\,\mathrm{C}.$$

Newton's second law can be written

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{g}} + q'\vec{\mathbf{E}} = m\vec{\mathbf{a}}$$

and, taking y components, we obtain

$$-mg + q'(-E) = ma.$$

We can now solve for the acceleration:

$$a = -g - \frac{q'E}{m}$$

$$= -9.80 \text{ m/s}^2 - \frac{(-8.00 \times 10^{-19} \text{ C})(1.65 \times 10^6 \text{ N/C})}{\frac{4}{3}\pi(2.76 \times 10^{-6} \text{ m})^3(918 \text{ kg/m}^3)}$$

$$= -9.80 \text{ m/s}^2 + 16.3 \text{ m/s}^2 = +6.5 \text{ m/s}^2.$$

The drop accelerates in the positive y direction.

END OF LECTURE