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Demonstration: Measure Static Charge Using an Electrostatic Fieldmeter

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Electrostatic Answers

Abstract

Three important insights from this demonstration are:

1. The electrostatic fieldmeter responds to the charge on both sides of the web.
2. Electrostatic fieldmeter measurements do not reveal which side of the sheet is charged.
3. The electric field may be measured from either side of the sheet. The readings from either side should be identical.

An electrostatic fieldmeter responds to the charge on both surface of a web. The total charge density (sum of the charge densities on both surfaces) on the web in Figure 1 is estimated using an electrostatic fieldmeter to measure electric field E.

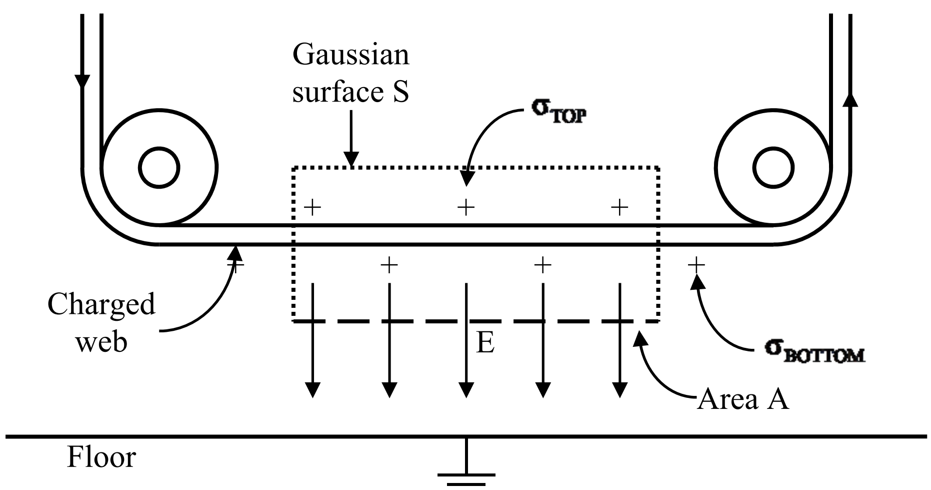

Figure 1: The electric field E is proportional to the charge on both sides of the web.

The electric field penetrating Gaussian surface S is proportional to the total enclosed charge as in (1).

Gauss's Law
$$\oint_S \varepsilon_0 \vec{E}\cdot\vec{ds} = q_{ENCLOSED} = (\sigma_{TOP} + \sigma_{BOTTOM})A \quad (1)$$

Evaluate the integral in (1) to obtain (2).

$$\varepsilon_0\, E\, A = (\sigma_{TOP} + \sigma_{BOTTOM})\, A \quad (2)$$

Solve for the sum of the charge densities in (2) to obtain (3).

$$\sigma_{TOP} + \sigma_{BOTTOM} = \varepsilon_0\, E \quad (3)$$

In (4), an electric field of 1 KV/cm ($1\times10^{+5}$ V/m) results from a charge density of about 1 μC/m^2 (1×10^{-6} C/m^2).

$$\sigma_{TOP} + \sigma_{BOTTOM} = \left(8.9\times10^{-12}\,\frac{F}{m}\right)\left(1.0\times10^{+5}\,\frac{V}{m}\right) = 8.9\times10^{-7}\,\frac{C}{m^2} = 0.89\times10^{-6}\,\frac{C}{m^2} = 0.89\,\frac{\mu C}{m^2} \approx 1\,\frac{\mu C}{m^2} \tag{4}$$

In this demonstration, the charge Q on an insulating 5 cm × 20 cm PVC sheet having a surface area A of 100 cm^2 will be measured using a Faraday cup and a nano-Coulombmeter. Suppose the charge Q measures 100 nC. The charge density σ_{SHEET} is estimated in (5) to be 10 μC/m^2.

$$\sigma_{SHEET} = \frac{Q}{A} = \frac{100\,nC}{100\,cm^2} = \frac{0.100\,\mu C}{0.01\,m^2} = 10\,\frac{\mu C}{m^2} \tag{5}$$

Next, the electric field near the sheet will be measured with an electrostatic fieldmeter. For a charge density of 10 μC/m^2, the electric field E is estimated in (6) using (3) to be 11 KV/cm.

$$E_{SHEET} = \frac{\sigma_{SHEET}}{\varepsilon_0} = \frac{\left(10\,\frac{\mu C}{m^2}\right)\left(10^{-6}\,\frac{C}{\mu C}\right)}{8.9\times10^{-12}\,\frac{F}{m}} = 1.1\times10^{+6}\,\frac{V}{m} = 11\,\frac{KV}{cm} \tag{5}$$

Given a fieldmeter reading of 1 KV/cm, the charge density is approximately 1 μC/m^2 with an accuracy of about 11%.

Estimate
$$E = 1\,\frac{KV}{cm} \quad\Rightarrow\quad \sigma_{SHEET} \approx 1\,\frac{\mu C}{m^2} \tag{6}$$