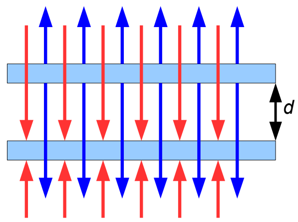
Chapter 5 Problem 82 [†]



Given

$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$
$l = 25.0\ cm = 0.250\ m$
$d = 5.0\ mm = 5.0 \times 10^{-3}\ m$
$q = 10^{11}\ e^-$ (Note: The textbook has an error. You can't transfer a fraction of an electron.)

Solution

Find the electric field between the two plates.

Since the distance between the plates is small compared to the dimensions of the plates (less than an order of magnitude, at least 10x smaller), then we can use the approximation assuming we are dealing with infinite planes.

$$E = \frac{\sigma}{2\epsilon_0}$$

From the diagram, we see that each plate contributes an electric field in the region between the plates. Above both plates, the fields are in opposite directions and, therefore, cancel resulting in a very weak field. If the plates extented to infinity, there would be no electric field here. The same is true below both plates. Between both plates the electric fields add. Therefore, the electric field between the plates is approximately twice as large as that due to the presence of only one plate. Therefore,

$$E = \frac{\sigma}{\epsilon_0}$$

The number of electrons transfered between the plates is known. After the transfer is done, each plate has a charge of Q on it. The top plate will be $+Q$ and the bottom plate will be $-Q$. σ is the charge per area on each plate so,

$$\sigma = \frac{Q}{A} = \frac{Q}{l^2}$$

Q is the number of electrons times the value of the fundamental charge giving

$$Q = (10^{11}\ e^-)(-1.60 \times 10^{-19}\ C/e^-) = -1.60 \times 10^{-8}\ C$$

This would be the charge on the bottom plate. The top plate has $+1.60 \times 10^{-8}\ C$. Therefore,

$$\sigma = \frac{Q}{l^2} = \frac{1.60 \times 10^{-8}\ C}{(0.25\ m)^2} = 2.56 \times 10^{-7}\ C/m^2$$

The electric field is

$$E = \frac{\sigma}{\epsilon_0} = \frac{2.56 \times 10^{-7}\ C/m^2}{8.85 \times 10^{-12}\ \frac{C^2}{Nm^2}} = 2.89 \times 10^4\ N/C$$

[†]Problem from Univesity Physics by Ling, Sanny and Moebs (OpenStax)