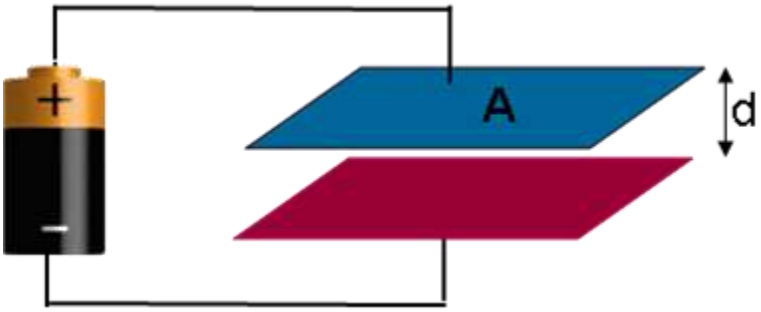
Physics 2220 Homework 7 Solutions

Parallel Plate Capacitor and Battery



Two parallel plates, each having area A = 3002 cm^2 are connected to the terminals of a battery of voltage V_b = 6 V as shown. The plates are separated by a distance d = 0.38 cm.

1)

What is Q, the charge on the top plate?

4.19E-9 C

We know from the definition of capacitance that:

$$C = \frac{Q}{V}$$

And for two plates the potential difference is:

$$|V| = |\int \boldsymbol{E} \cdot \boldsymbol{dl}| = \frac{2\sigma}{2\varepsilon_0} d = \frac{Q}{A\varepsilon_0} d$$

The factor of 2 comes from the fact that there's an E field from 2 different plates.
Taken altogether this means that:

$$C = \frac{A\varepsilon_0}{d}$$

And

$$Q = V * \frac{A\varepsilon_0}{d}$$

2)

What is U, the energy stored in this capacitor?

1.257E-8 J

For a capacitor the energy can be written as:

$$\frac{1}{2} C V^2$$

Or also as:

$$\frac{QV}{2}$$

3)

The battery is now *disconnected* from the plates and the separation of the plates is doubled (= 0.76 cm). What is the energy stored in this new capacitor?

2.514E-8 J

Since the battery is first disconnected, it can do no work and so the charge on the plates remains constant. However moving the plate apart does work and changes the voltage. We saw above that the

voltage is directly proportional to the distance. So doubling the distance doubles the voltage. From above we saw that energy is given by:

$$\frac{QV}{2}$$

So the net effect is that the energy doubles.

4)

What is E, the magnitude of the electric field in the region between the plates?

1579 N/C

The E field from one plate is:

$$E = \frac{\sigma}{2\varepsilon_0}$$

Since we have two plates with the same magnitude of charge but opposite signs the strength of the E field doubles. So the strength is now:

$$E = \frac{\sigma}{\varepsilon_0}$$

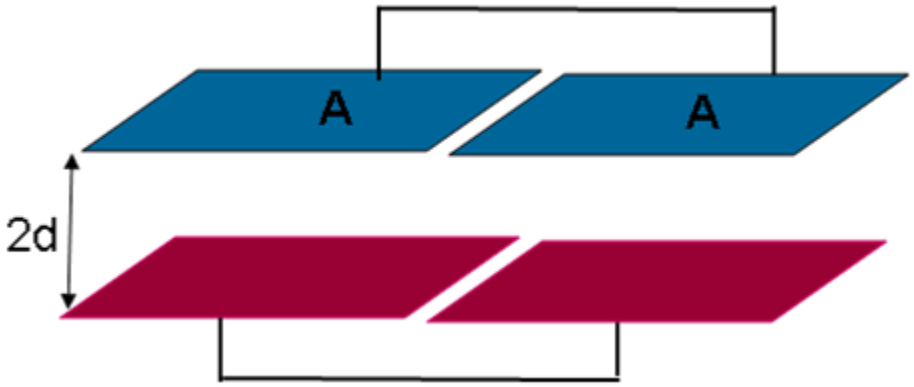
5)

Compare V, the magnitude of the new potential difference across the plates, to V_b, the voltage of the battery.

- $V > V_b$

Like we showed in (3) doubling the distance while the charge stays the same means the potential difference doubles from what it was before.

6)



Two uncharged parallel plates are now connected to the initial pair of plates as shown. How will the electric field, E, and potential difference across the plates, V, change, if at all?

- Both E and V will decrease

With the two plates connected the charge will divide evenly between the two of them. Because the total charge stays the same but the area has doubled the charge density and thus the E field decreases. Because the E field had decreased the integral of the E field, which is the potential difference, also decreases.