PhysicsTutor

Capacitor

Giambattista 17.54

Problem:

- A parallel-plate capacitor with C=2.2μF has a plate separation of 1.0 mm.
- A) How much potential difference will the capacitor take before dielectric breakdown of air (critical field: $E_{br}=3\times10^{6}$ V/m)?
- B) What is the magnitude of the greatest charge the capacitor can store before breakdown?

Relevant ideas:

Relevant ideas:

- Electric potential difference across cap. plates and *E* field inside related by separation *d*.

$$\Delta V_c = E d$$

Relevant ideas:

- Electric potential difference across cap. plates and *E* field inside related by separation *d*.
- Maximum allowed field before breakdown then implies maximum voltage for given *d*.

$$\Delta V_{br} = E_{br}\, d$$

Relevant ideas:

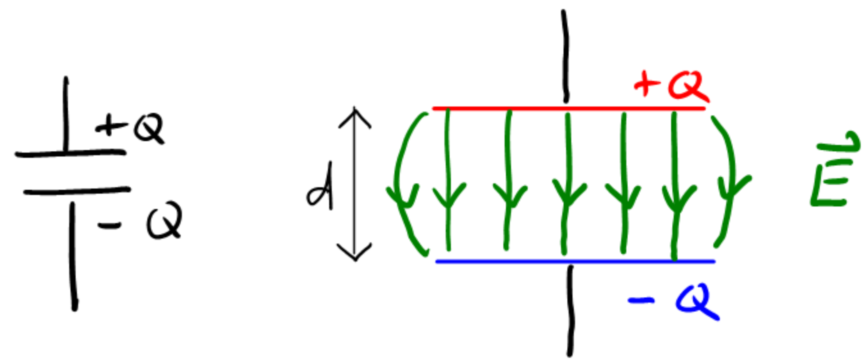
- Electric potential difference across cap. plates and *E* field inside related by separation *d*.
- Maximum allowed field before breakdown then implies maximum voltage for given *d*.
- Charge on the plates and voltage across plates are related. Proportionality is controlled by the capacitance *C*, which is given.

$C \Delta V_C = Q$

Equations associated with ideas:

$$\Delta V_c = E d \qquad \Delta V_{br} = E_{br} d$$

$$C \, \Delta V_c = Q$$



Strategy

Strategy

- Use the voltage (=potential difference) to field strength relation to obtain the breakdown voltage for this capacitor.

Strategy

- Use the voltage (=potential difference) to field strength relation to obtain the breakdown voltage for this capacitor.
- Using the known capacitance C relate the breakdown voltage to charge Q on the plates.

Strategy

- Use the voltage (=potential difference) to field strength relation to obtain the breakdown voltage for this capacitor.
- Using the known capacitance C relate the breakdown voltage to charge Q on the plates.
- This is the maximum charge one can store on the plates (under breakdown the charge equilibrates).

Solution

Solution

- $\Delta V_{br} = E_{br} d = 3 \times 10^6 \frac{V}{m} \cdot 10^{-3} m = 3{,}000 V$

Solution

- $\Delta V_{br} = E_{br} d = 3 \times 10^{6} \frac{V}{m} \cdot 10^{-3} m = 3{,}000 V$
- $Q = C \Delta V \therefore Q_{max} = C \Delta V_{br}$

Solution

- $\Delta V_{br} = E_{br} d = 3 \times 10^6 \frac{V}{m} \cdot 10^{-3} m = 3,000 V$
- $Q = C \Delta V \therefore Q_{max} = C \Delta V_{br}$
- $Q_{max} = 2.2 \times 10^{-6} F \cdot 3.0 \times 10^3 V = 6.6 \, mC$

Solution

- $\Delta V_{br} = E_{br} d = 3 \times 10^{6} \frac{V}{m} \cdot 10^{-3} m = 3{,}000 V$
- $Q = C \Delta V \therefore Q_{max} = C \Delta V_{br}$
- $Q_{max} = 2.2 \times 10^{-6} F \cdot 3.0 \times 10^{3} V = 6.6 mC$
- When $Q_{+} = 6.6 mC$ and $Q_{-} = -6.6 mC$ "face each other" across the 1 mm gap in this (huge-plate) set-up, some electrons get ripped from the surface of the neg. plate and are accelerated strongly towards the pos. plate $\longrightarrow$ they ionize air molecules and a charge avalanche sets in.