

Physics

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(Chapter – 2) (Electrostatic Potential and Capacitance)

(Class - XII)

Question 2.33:

A parallel plate capacitor is to be designed with a voltage rating 1 kV, using a material of dielectric constant 3 and dielectric strength about 10^7 Vm^{-1} . (Dielectric strength is the maximum electric field a material can tolerate without breakdown, i.e., without starting to conduct electricity through partial ionisation.) For safety, we should like the field never to exceed, say 10% of the dielectric strength. What minimum area of the plates is required to have a capacitance of 50 pF?

Answer 2.33:

Potential rating of a parallel plate capacitor, $V = 1 \text{ kV} = 1000 \text{ V}$

Dielectric constant of a material, $\epsilon_r = 3$

Dielectric strength = 10^7 V/m

For safety, the field intensity never exceeds 10% of the dielectric strength.

Hence, electric field intensity, $E = 10\% \text{ of } 10^7 = 10^6 \text{ V/m}$

Capacitance of the parallel plate capacitor, $C = 50 \text{ pF} = 50 \times 10^{-12} \text{ F}$ Distance between the plates is given by,

$$d = \frac{V}{E}$$
$$= \frac{1000}{10^6} = 10^{-3} \text{ m}$$

Capacitance is given by the relation,

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

Where,

A = Area of each plate

$$\epsilon_0 = \text{Permittivity of free space} = 8.85 \times 10^{-12} \text{ N}^{-1} \text{ C}^2 \text{ m}^{-2}$$

$$\therefore A = \frac{Cd}{\epsilon_0 \epsilon_r}$$
$$= \frac{50 \times 10^{-12} \times 10^{-3}}{8.85 \times 10^{-12} \times 3} \approx 19 \text{ cm}^2$$

Hence, the area of each plate is about 19 cm^2 .

Question 2.34:

Describe schematically the equipotential surfaces corresponding to

- a constant electric field in the z-direction,
- a field that uniformly increases in magnitude but remains in a constant (say, z) direction,
- a single positive charge at the origin, and
- a uniform grid consisting of long equally spaced parallel charged wires in a plane.

Answer 2.34:

- Equidistant planes parallel to the x-y plane are the equipotential surfaces.
- Planes parallel to the x-y plane are the equipotential surfaces with the exception that when the planes get closer, the field increases.
- Concentric spheres centered at the origin are equipotential surfaces.
- A periodically varying shape near the given grid is the equipotential surface. This shape gradually reaches the shape of planes parallel to the grid at a larger distance.

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