

AP

Unit 2 - Worksheet 5 - Capacitance

ANSWERS

(Check a unit 3 thing)

1. The plates of a parallel-plate capacitor are 5mm apart and 2 meters squared in area. The plates are separated only by air. A potential difference of 10,000 V is applied across the capacitor.

$$C = \frac{\epsilon_0 A}{d} = \frac{(8.85 \times 10^{-12}) (2)}{5 \times 10^{-3}} = 3.54 \times 10^{-9} \text{ F}$$

a. Find the capacitance

b. Find the charge on each plate

$$Q = CV = (3.54 \times 10^{-9}) (10,000) = 3.54 \times 10^{-5} \text{ C}$$

c. Find the electric field in the space between them.

$$E = \frac{V}{d} = \frac{10,000}{5 \times 10^{-3}} = 2 \times 10^6 \text{ V/m}$$

2. A capacitor is charged by connecting it to a potential difference of 120 V. If the capacitor has a capacitance of 8 microfarads, find the energy stored in the capacitor.

$$V = 120$$

$$C = 8 \times 10^{-6}$$

$$U = \frac{1}{2} CV^2 = \frac{1}{2} (8 \times 10^{-6}) (120)^2 = 0.0576 \text{ J}$$

9/26

3. The parallel plates of a capacitor have an area of 2×10^{-1} meters squared and are 1 cm apart. The original potential difference between them is 3000 V. It decreases to 1000 V when a sheet of dielectric is inserted between the plates.

a. Find the original capacitance.

$$C = \frac{\epsilon_0 A}{d} = \frac{(8.85 \times 10^{-12}) (2 \times 10^{-1})}{0.01} = 1.77 \times 10^{-10} \text{ F}$$

b. Find the charge on each plate.

$$Q = CV = (1.77 \times 10^{-10}) (3000) = 5.31 \times 10^{-7} \text{ C}$$

c. Find the capacitance after the dielectric is inserted.

$$C = \frac{Q}{V} = \frac{5.31 \times 10^{-7}}{1000} = 5.31 \times 10^{-10} \text{ F}$$

d. Find the dielectric constant.

$$C = \frac{k \epsilon_0 A}{d} \quad C_{\text{new}} = k C_{\text{old}} \quad \frac{5.31 \times 10^{-10}}{1.77 \times 10^{-10}} = k = 3$$

4. A parallel plate capacitor filled with benzene has a capacitance of 500 pF (picofarads is 1×10^{-12}) and a charge of 2×10^{-7} C on each plate. The plates are 0.2 mm apart.

a. What is the potential difference between the plates?

$$V = \frac{Q}{C} = \frac{2 \times 10^{-7}}{500 \times 10^{-12}} = 400 \text{ V}$$

b. What is the area of each plate?

$$A = \frac{Cd}{\epsilon_0} = \frac{(500 \times 10^{-12}) (0.0002)}{8.85 \times 10^{-12}} = 1.13 \times 10^{-3} \text{ m}^2$$

c. What is the electric field between the plates?

$$E = \frac{V}{d} = \frac{400}{0.0002} = 2 \times 10^6 \text{ V/m}$$

d. What is the surface charge density of each plate?

$$\sigma = \frac{Q}{A} = \frac{2 \times 10^{-7}}{1.13 \times 10^{-3}} = 1.77 \times 10^{-4} \text{ C/m}^2$$

5. A parallel plate capacitor (air) has a capacitance of 1×10^{-9} F.

a. What potential difference is required for a charge of 1×10^{-7} C on each plate?

$$V = \frac{Q}{C} = \frac{1 \times 10^{-7}}{1 \times 10^{-9}} = 100 \text{ V}$$

b. What is the stored energy?

$$U = \frac{1}{2} CV^2 = \frac{1}{2} (1 \times 10^{-9}) (100)^2 = 5 \times 10^{-6} \text{ J}$$

c. If the plates are 1 mm apart, what is the area of the plates?

$$C = \frac{\epsilon_0 A}{d} \quad 1 \times 10^{-9} = \frac{(8.85 \times 10^{-12}) A}{0.001} \quad A = 1.13 \times 10^{-3} \text{ m}^2$$

6. An 8×10^{-6} F capacitor has a plate separation of 4mm and is charged to a potential difference of 500 V. Calculate the energy density in the region between the plates (in J/m^3).

$$d = 4 \times 10^{-3} \text{ m}$$

$$V = 500 \text{ V}$$

$$C = 8 \times 10^{-6} \text{ F}$$

$$\text{Energy density} = \frac{U}{V_{\text{plate}}}$$

$$U = \frac{1}{2} CV^2$$

$$U = \frac{1}{2} (8 \times 10^{-6}) (500)^2 = 1 \text{ J}$$

$$V_{\text{plate}} = \frac{1}{2} \frac{CV^2}{d} = \frac{1}{2} \frac{(8 \times 10^{-6}) (500)^2}{0.004} = 0.0625 \text{ J/m}^3$$

$$0.0625 \text{ J/m}^3$$

$$0.07 \text{ J/m}^3$$

Decreases
due to
dielectric
forming

3000

Does
charge
area of
charge

$$E = \frac{V}{d}$$

① Find A of plate
② Find U (energy)
③ Find energy density

$$C = \frac{\epsilon_0 A}{d} \quad 8 \times 10^{-6} = \frac{(8.85 \times 10^{-12}) A}{0.004} \quad A = 3.61 \times 10^{-3} \text{ m}^2$$

$$U = \frac{1}{2} CV^2 = \frac{1}{2} (8 \times 10^{-6}) (500)^2 = 1 \text{ J}$$