September 16th

Chapter 26

Capacitance

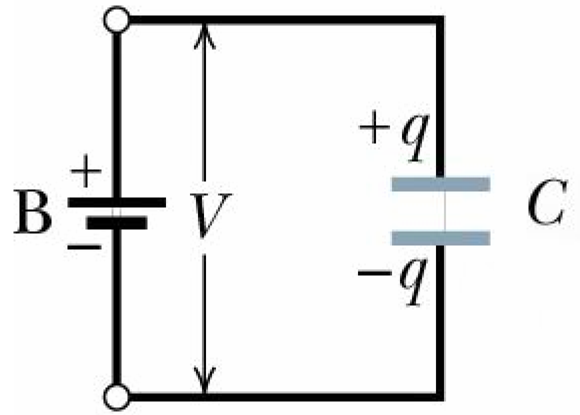
Capacitance

- Parallel-plate capacitor charged to potential *V* by battery
- Disconnect battery to have an isolated system
- If the distance, *d*, between the plates is decreased what happens to *C*?

LARGER

- What happens to *V* ?

Isolated system *q* stays same so *V* decreases if *C* increases



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

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

Capacitance

- Observe what happens if I put material between the plates?
- V decreases

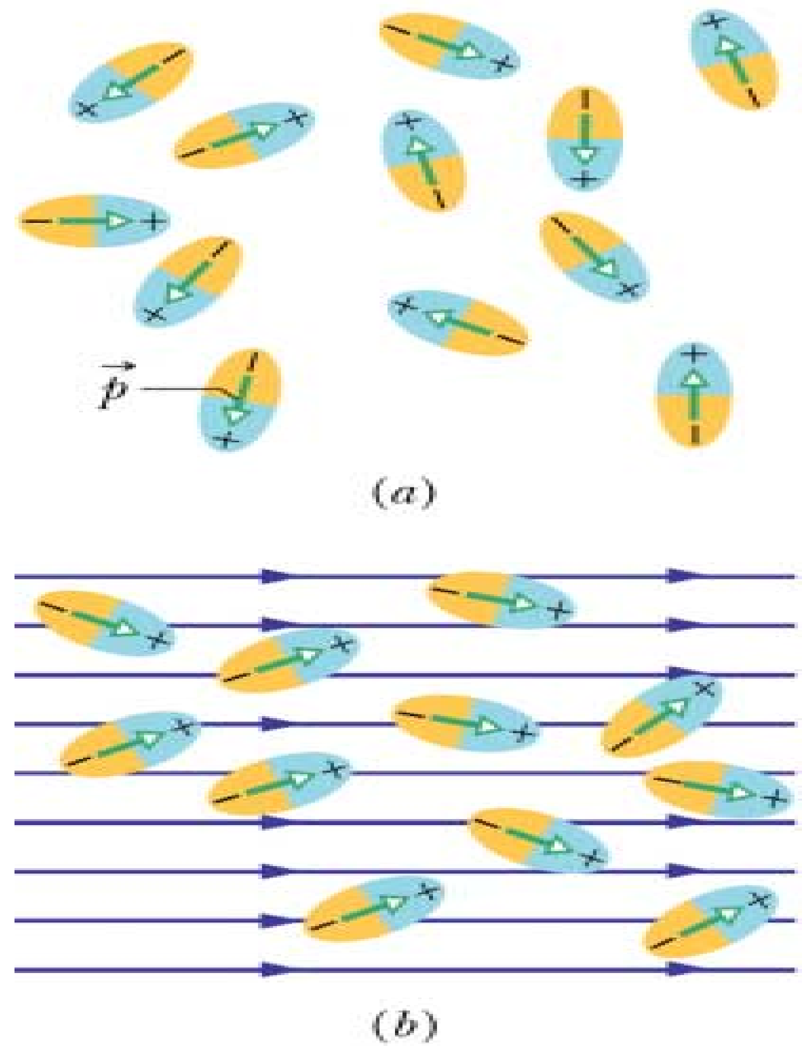
$$C = \frac{q}{V}$$

- so C must increase – why?

Capacitance (Fig. 26-14)

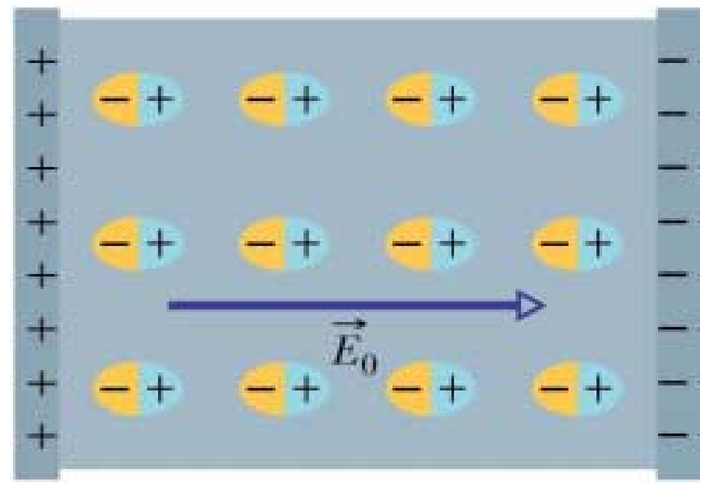
- Why does *C* increase if add material?

- Material made up of molecules which are dipoles
- Molecules align with *E* field from capacitor

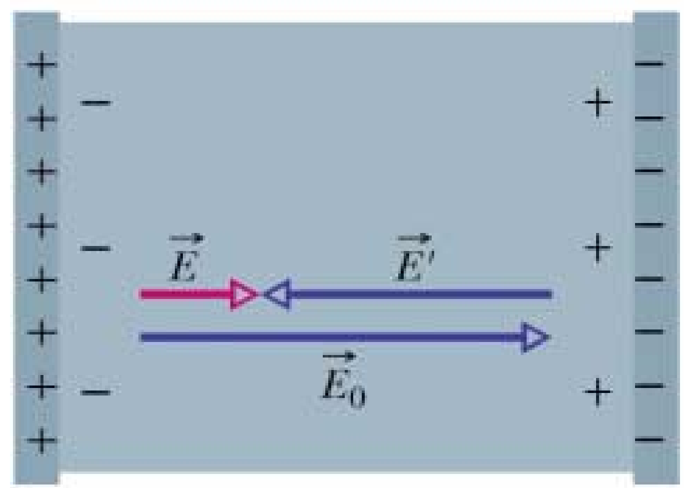


Capacitance (Fig. 26-15)

- Dipoles set up field E' which opposes capacitors field E_o
- Total field E is smaller than original E_o
- Material is called a dielectric



(b)



(c)

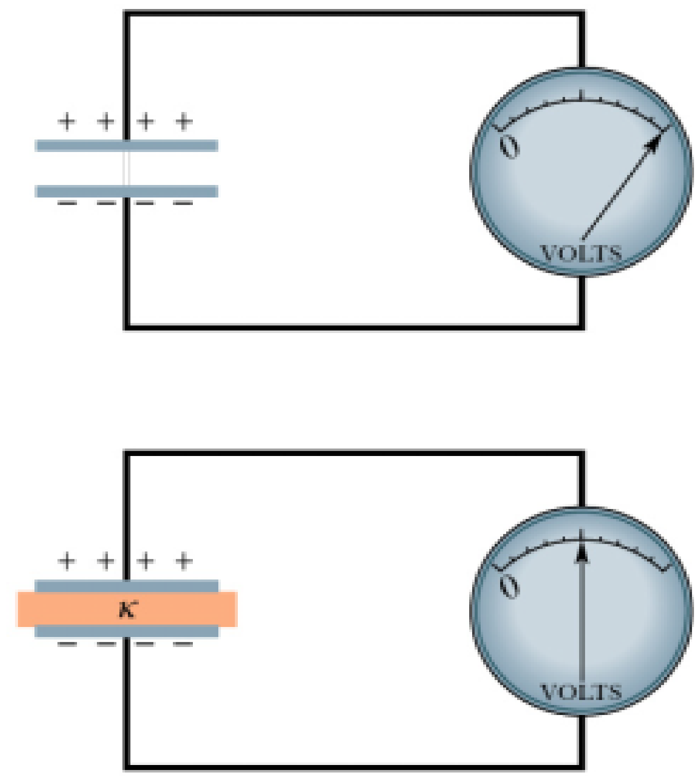
Capacitance (Fig. 26-13b)

$$V = Ed$$

- *E* field is weaker so *V* decreases

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

- *q* is constant so *C* INCREASES



q = a constant

(*b*)

Capacitance

- Place a dielectric in capacitor its capacitance increases by numerical factor.
- Called dielectric constant, κ

$$C_{dielectric} = \kappa C_{air}$$

- If problem has dielectric replace C with KC

TABLE 26-1 Some Properties of Dielectrics[a]

Material	Dielectric Constant κ	Dielectric Strength (kV/mm)
Air (1 atm)	1.00054	3
Polystyrene	2.6	24
Paper	3.5	16
Transformer oil	4.5	
Pyrex	4.7	14
Ruby mica	5.4	
Porcelain	6.5	
Silicon	12	
Germanium	16	
Ethanol	25	
Water (20°C)	80.4	
Water (25°C)	78.5	
Titania ceramic	130	
Strontium titanate	310	8

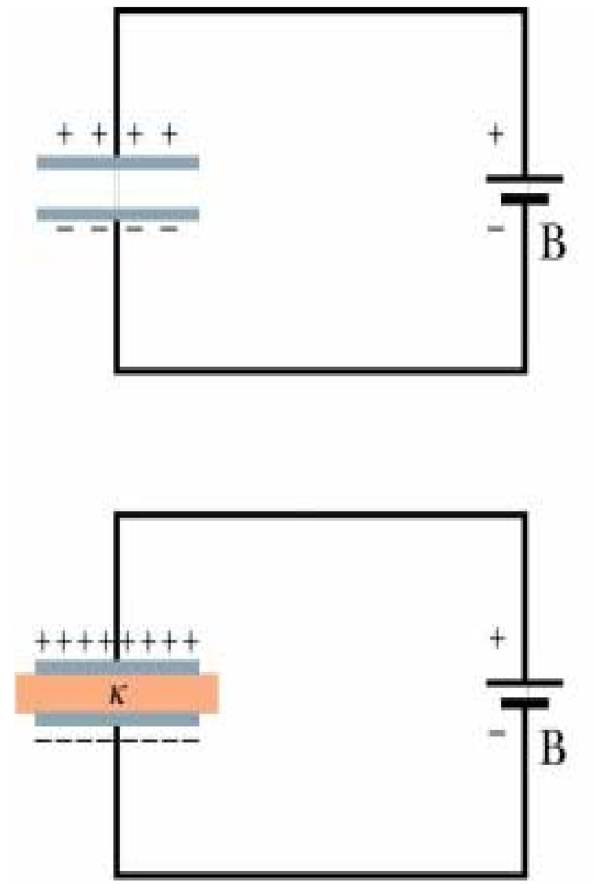
For a vacuum, κ = unity.

[a]Measured at room temperature, except for the water.

Capacitance (Fig. 26-13)

- If system is connected to a battery, V is a constant
- C increases with dielectric so q must increase

$$q = CV$$



V = a constant

Capacitance

- What is the potential energy, *U*, of a charged capacitor?
- Think of *U* as being stored in *E* field between plates
- Calculate *W* required to charge plates to potential *V*

$$\Delta U = W = \Delta V q$$

- Recover energy by discharging capacitor

Capacitance

- Charge capacitor by transferring electrons with a battery

- More charge moved, E field between plates gets bigger, harder to move charges so takes positive work to charge capacitor

Capacitance

- At given instance potential across plates is

$$V' = \frac{q'}{C}$$

- Transfer increment of charge dq ´, work required is

$$W = V\ q$$

$$dW = V'\,dq' = \frac{q'}{C}\,dq'$$

Capacitance

- Work required from 0 to total charge q is

$$W = \frac{1}{C}\int_0^q q'\,dq' = \frac{q^2}{2C}$$

- Potential energy = work

$$U = \frac{q^2}{2C}$$

- Or, use

$$q = CV$$

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

Capacitance

- Advantage of capacitor
  - Get more power than from just a battery

$$U = \frac{1}{2}CV^2 \quad \text{or} \quad U = \frac{q^2}{2C}$$

  - Slowly charge capacitor with battery and then discharge quickly
  - Examples – photo flash, medical defibrillator

Capacitance

- Energy Density u - potential energy per unit volume between the plates

$$u = \frac{U}{Vol.} = \frac{U}{Ad}$$

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

- Substituting for U and C

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

$$u = \frac{CV^2}{2Ad} = \frac{1}{2}\varepsilon_0\left(\frac{V}{d}\right)^2$$