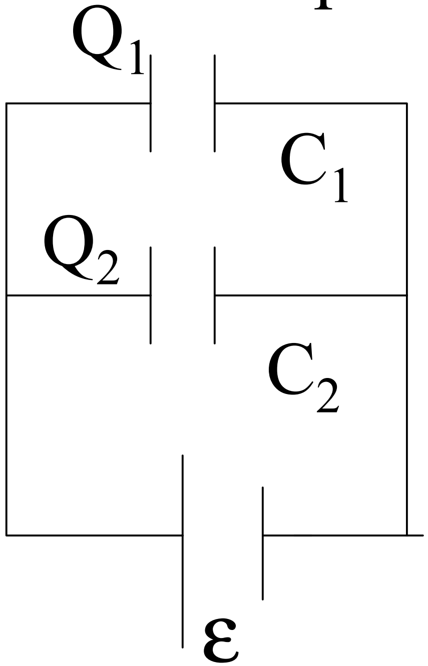
Combinations of Capacitors

- Parallel capacitors



$\Delta V = \varepsilon$ same for C_1 and C_2

$\Delta V = Q_1/C_1 = Q_2/C_2$

Total stored chg. $Q = Q_1+Q_2$

Total capacitance is :

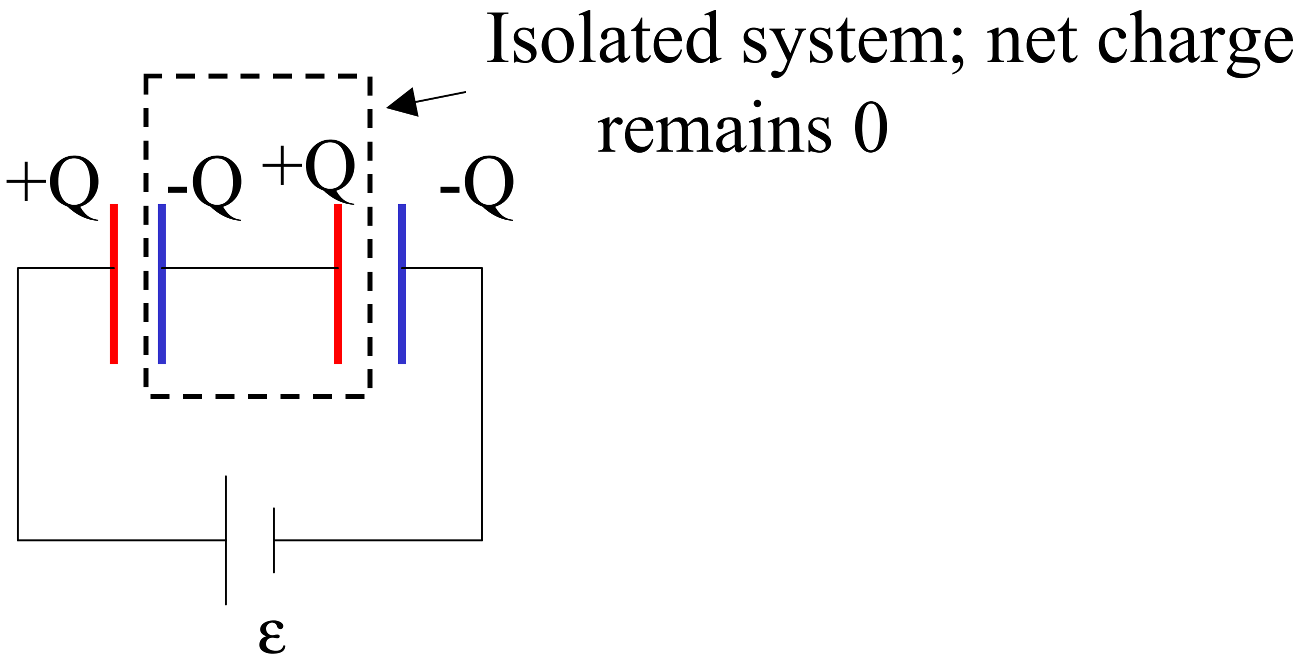
$$C_{\|} = \frac{Q_{total}}{\Delta V} = \frac{Q_1 + Q_2}{\Delta V} = C_1 + C_2$$

- Same for any number of capacitors in parallel, so

$$C_{\|} = \sum_i C_i$$

- Adding capacitors in parallel similar to increasing plate area

Series Capacitors

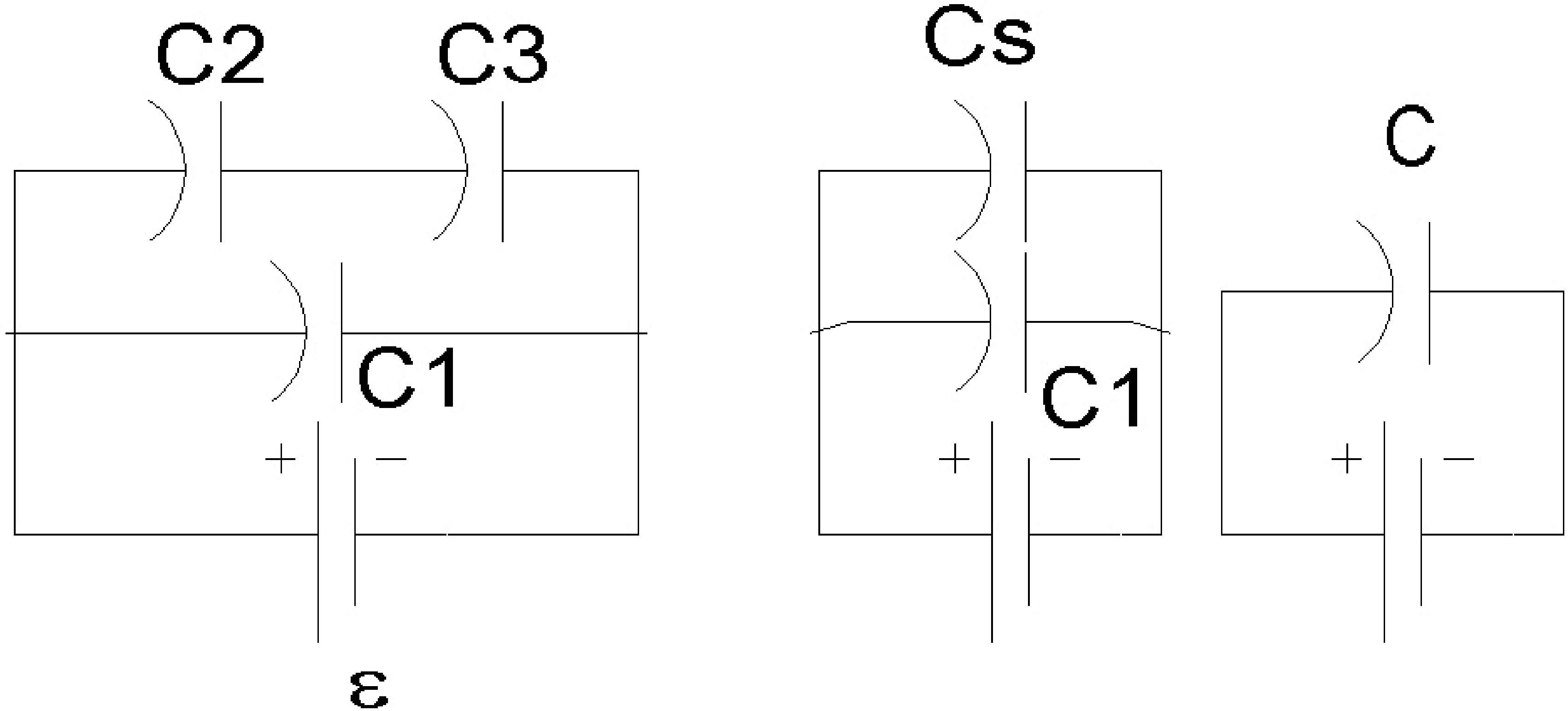


- Each of the series capacitors will have the same charge

$$\varepsilon = \Delta V = \Delta V_1 + \Delta V_2 = \frac{Q_1}{C_1} + \frac{Q_2}{C_2} = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right) = \frac{Q}{C_s}$$

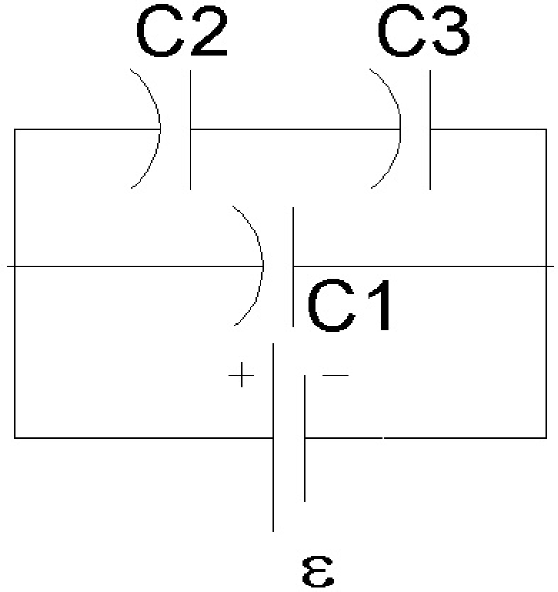
- Thus

$$\boxed{\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} = \sum_i \frac{1}{C_i}}$$

- Note that series capacitors combine like parallel resistors and vice versa
- Q1: Capacitance of 6μF and 3 μF capacitors in series?
- 

$$\frac{1}{C_s} = \frac{1}{C_2} + \frac{1}{C_3} \ldots\ldots\ldots\ldots\ldots C = C_s + C_1$$

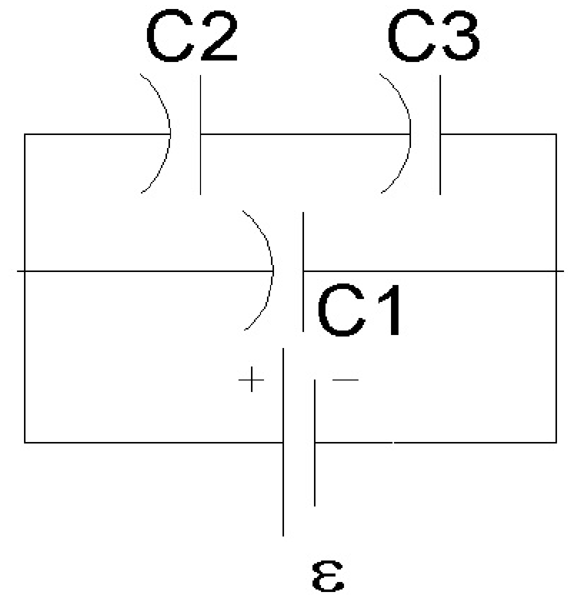
Example Calculations: Q,ΔV, and Stored Energy



Find Q,ΔV, and stored energy for C_3. Let C_S - series combination of C_2 and C_3.

Q2: What is true concerning Q_3 ?

$$Q_3 = Q_2 = Q_S = C_S \varepsilon$$



$$C_S = \left(\frac{1}{C_2} + \frac{1}{C_3} \right)^{-1}$$

$$\Delta V_2 + \Delta V_3 = \varepsilon$$

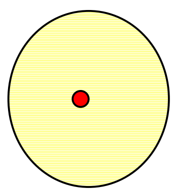
$$Q_2 = Q_3 = Q \Rightarrow C_2 \Delta V_2 = C_3 \Delta V_3 = C_S \varepsilon$$

$$\Delta V_3 = \frac{C_S}{C_3} \varepsilon$$

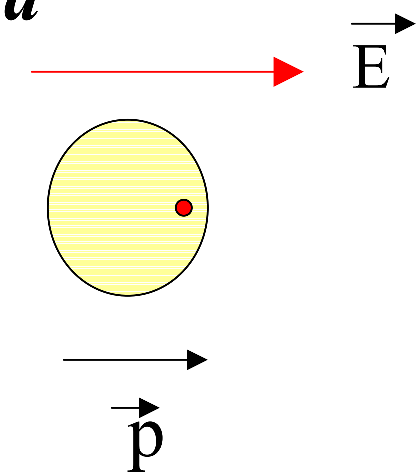
$$U_3 = 0.5 C_3 (\Delta V_3)^2$$
$$= 0.5 Q_3{}^2 / C_3$$

Dielectric Material in Capacitors (Electric Fields in Materials)

- Dielectric is an insulating material whose atoms or molecules can be ***polarized***

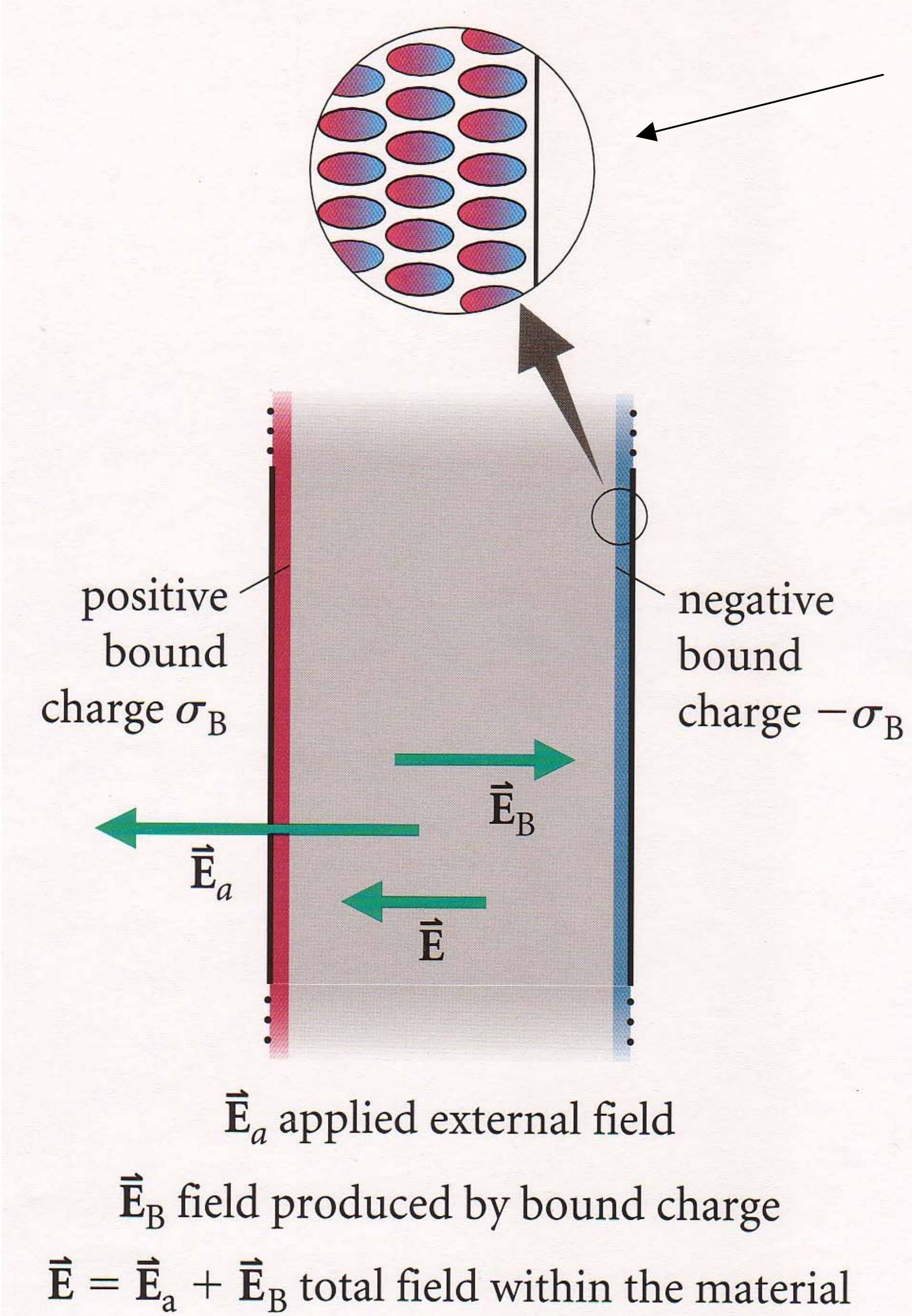


Neutral,
unpolarized atom



Polarized atom; still neutral, but applied electric field produces dipole moment $\vec{p}$

- Charge in the polarized atom is ***bound*** - not free to move.In a block of polarized material, bound charge cancels out except at surfaces:



In interior of block, bound charge cancels out.

Left with sheet of positive bound surface charge & sheet of negative bound surface charge

Applied field strength E_A

Field of bound charge E_B

Net field $E = E_A - E_B$ is **smaller** than E_A

Dielectric Constant κ

- Describe effect of material on electric field in terms of material's dielectric constant κ (dimensionless)

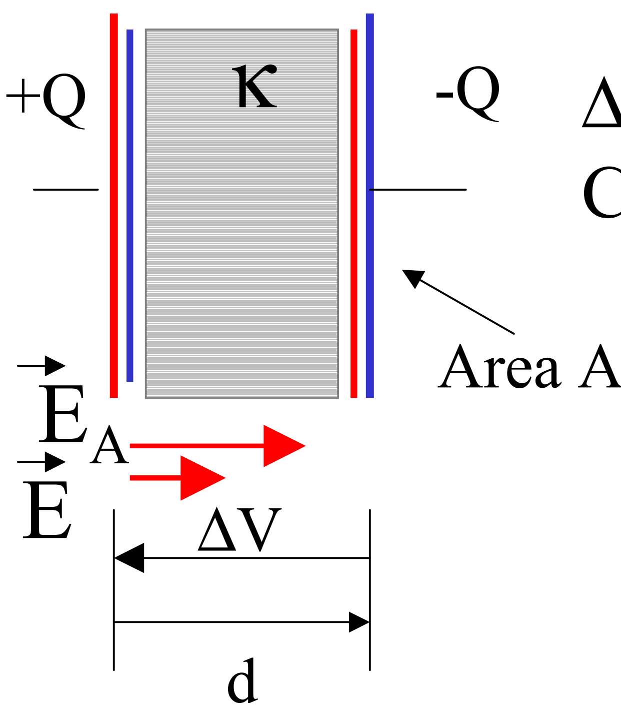
$$\kappa \equiv \frac{\left|\vec{E}_A\right|}{\left|\vec{E}\right|}$$

- Some values of κ:

Vacuum	1.0000
Air	1.0006
Polyethylene	2.4
Mylar	3
Alum. Oxide	11

Dielectric in a Capacitor

- If we fill space between capacitor plates with material of dielectric constant κ, then for a given charge on the capacitor, the electric field between the plates is reduced, the potential difference between the plates is smaller, and the capacitance is larger:



ΔV without dielectric = $E_a d$

C without dielectric=(Q/ ΔV)=$\varepsilon_0 A/d$

With dielectric: $E = E_A/\kappa$

$\Delta V' = Ed = \Delta V/\kappa$

$C' = Q/\Delta V' = \kappa C$

Effect of Dielectric on Capacitance

- Capacitance C' with dielectric in terms of capacitance C without dielectric: $C' = \kappa C$
- Example: what is capacitance of parallel plate capacitor with 0.5 m^2 plates 8.85×10^{-4} m apart with Mylar dielectric ($\varepsilon_0 = 8.85 \times 10^{-12}$ F/m)? (Q3)