Capacitance (II)

Text sections 26.3—26.5

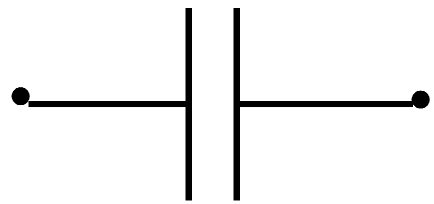
- Capacitors in circuits

Practice: chapter 26,
Objective Questions 1, 8, 11
Conceptual Question 8
Problems 15, 19, 25, 35, 38, 48, 49

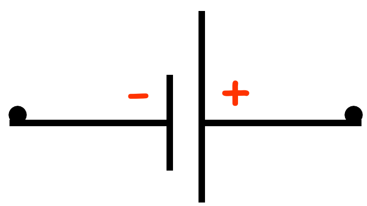
Capacitors in Circuits

Symbols:

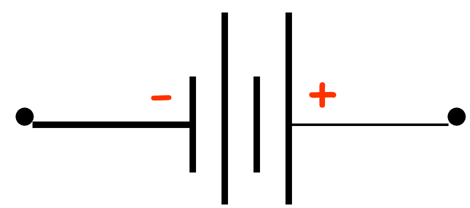
Capacitor ➔



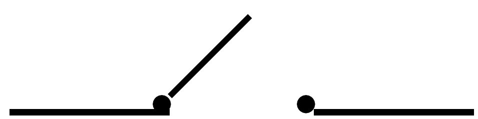
Battery ➔



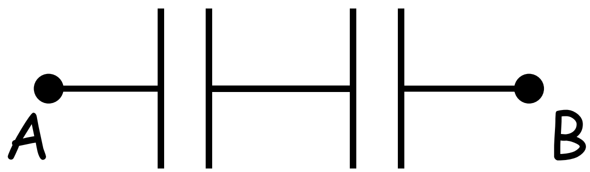
or



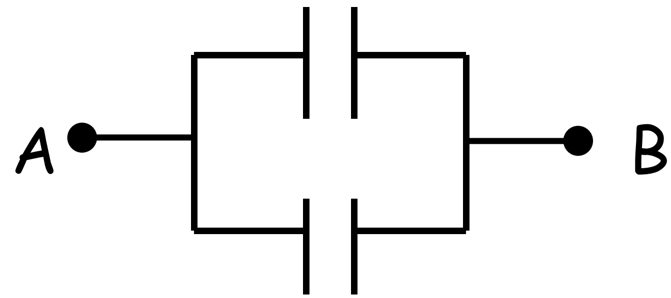
Switch ➔



Capacitor Combinations

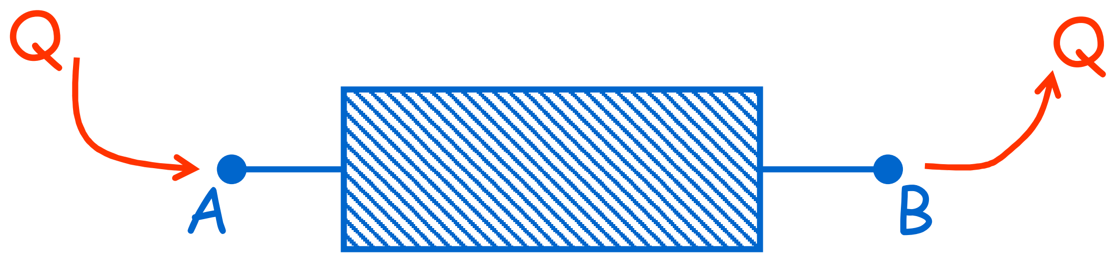


Series



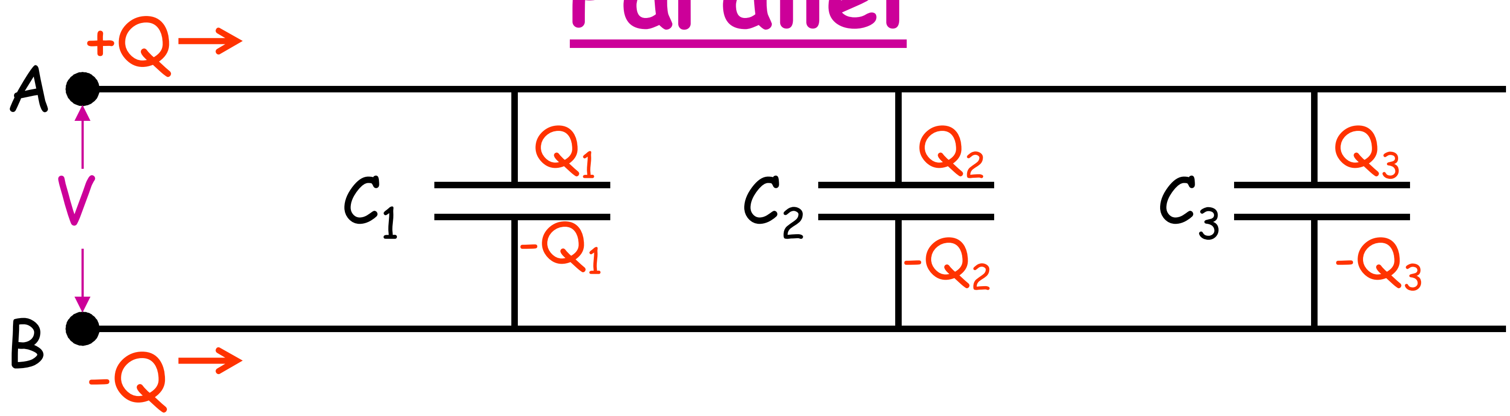
Parallel

What is the "effective capacitance" between A & B?



$$C_{eff} = \frac{\text{charge transferred}}{\text{voltage produced}}$$

Parallel



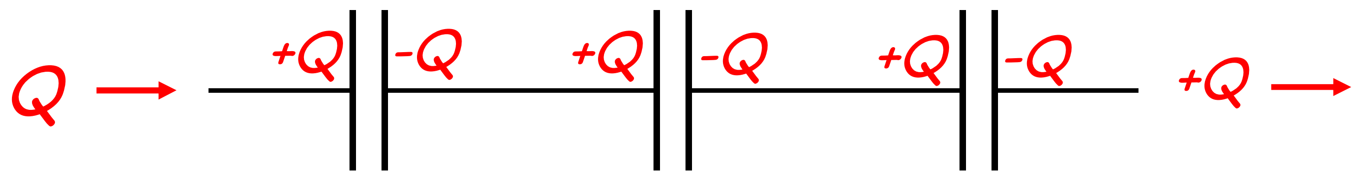
Voltages are the same: $V_1 = V_2 = V_3 = \ldots = V$

Charges add: $Q_1 + Q_2 + Q_3 + \ldots = Q$

But... $Q_1 = C_1 V, \quad Q_2 = C_2 V, \ \ldots$

$$\Rightarrow \boxed{C_{eff} = C_1 + C_2 + \ldots}$$

Series



Voltages add: $V_1 + V_2 + \ldots = V$

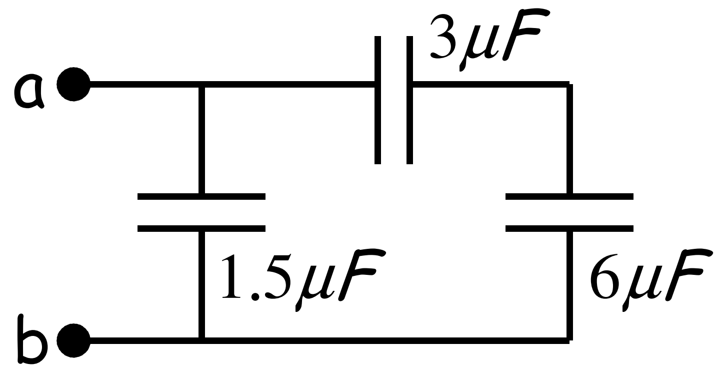
Charges are equal: $Q_1 = Q_2 = Q_3 = Q$

And ... $V = \dfrac{Q}{C_{eff}}, \quad V_1 = \dfrac{Q_1}{C_1} = \dfrac{Q}{C_1}, \quad \ldots.$

$$\Rightarrow \boxed{\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots}$$

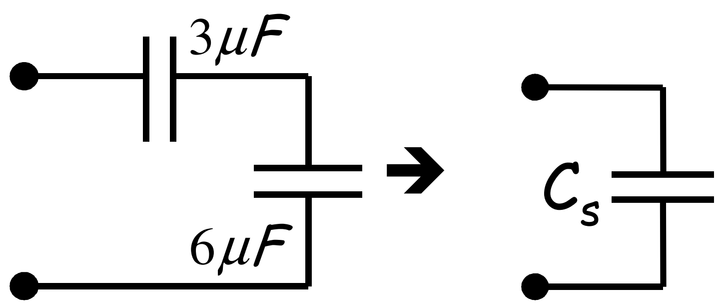
Example

Find the capacitance between a and b.



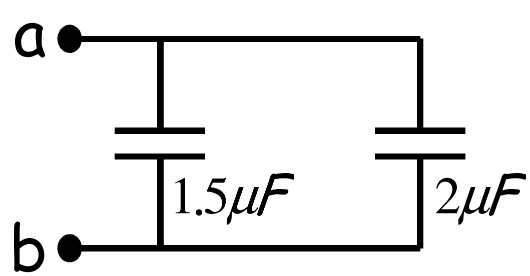
Solution:

(1)



$$C_s = \frac{1}{(\frac{1}{3}+\frac{1}{6})}\mu F = 2\mu F$$

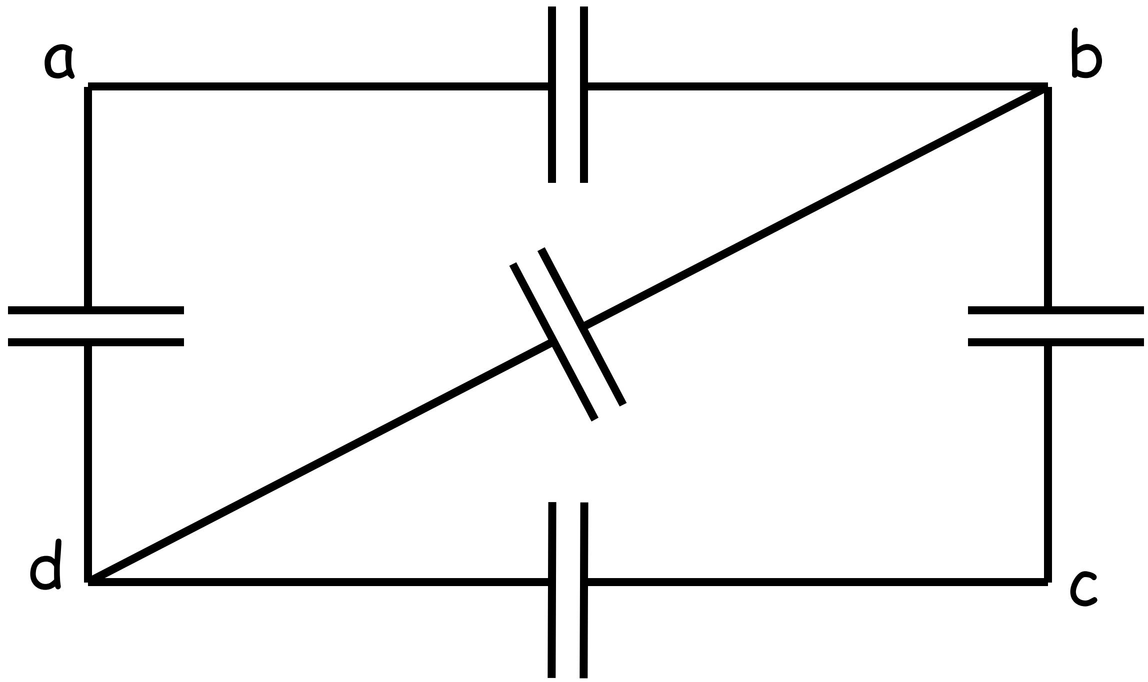
(2)



$$C_{ab} = 2 + 1.5$$

$$= 3.5\mu F$$

Quiz

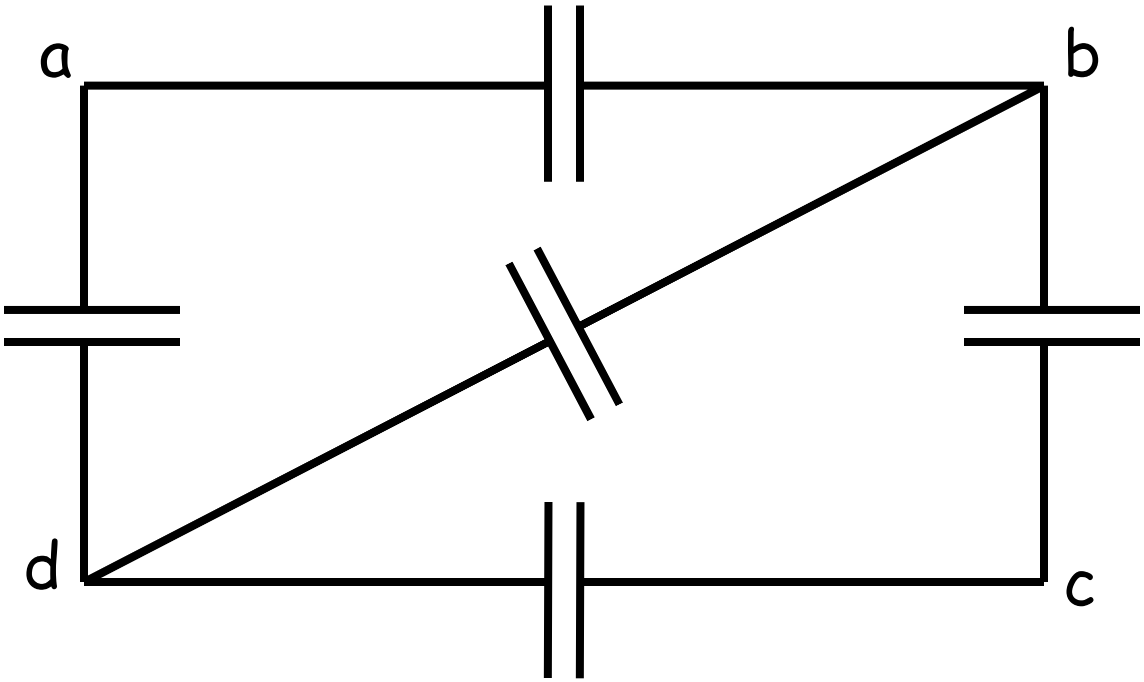


All Capacitors are $12\mu F$

The capacitance between points b and d is

A) 12μF B) 6μF C) 2.4μF D) 24μF E) 60μF

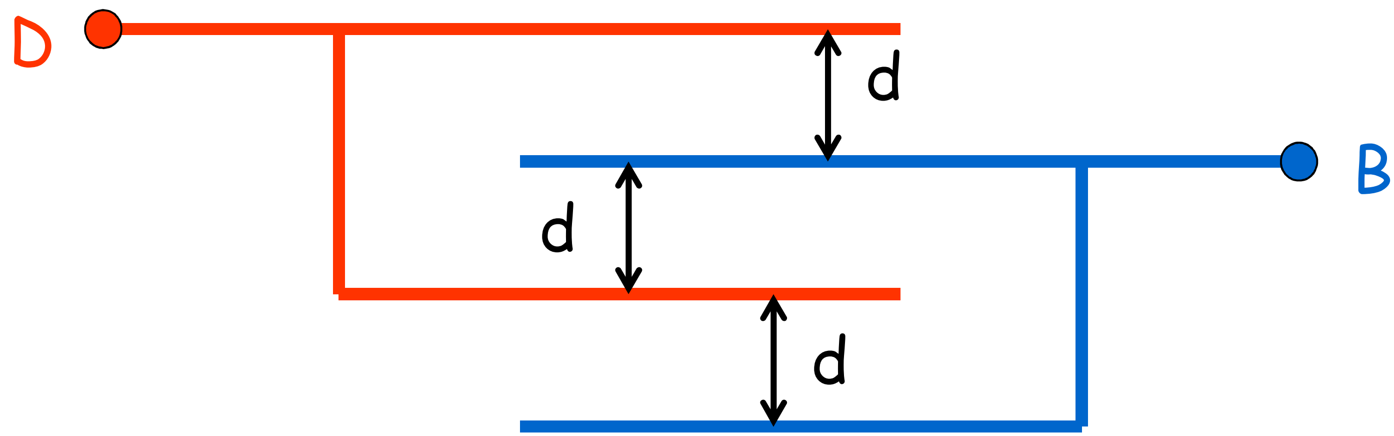
Exercise



All Capacitors are $12\mu F$

Find the capacitance between points a and d.

Quiz



4 plates, each of area A, are connected as shown.
What is the capacitance between B and D?

A) $\frac{1}{2}\ \varepsilon_0 A/d$

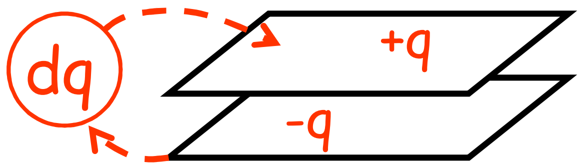
B) $\frac{1}{4}\ \varepsilon_0 A/d$

C) $^1/_3\ \varepsilon_0 A/d$

D) $3\ \varepsilon_0 A/d$

E) $4\ \varepsilon_0 A/d$

Energy Stored in a Capacitor



Remove dq from lower plate and add to upper plate:

Increase in P.E., $dU = V dq = \frac{q}{C} dq$

Start at q = 0, finish at q = Q: $U = \int_0^Q \frac{q\,dq}{C} = \frac{Q^2}{2C}$

$$\Rightarrow U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV = \frac{1}{2}CV^2$$

We can think of this energy as ***stored in the electric field*** set up when the capacitor is charged:

Parallel-Plate Capacitor: $C = \frac{\varepsilon_o A}{d}$ and $V = E \cdot d$

$$\Rightarrow \quad U = \frac{1}{2} C V^2 = \frac{1}{2} \varepsilon_o E^2 \cdot \underbrace{(Ad)}_{\text{Volume between plates}}$$

"Energy density"

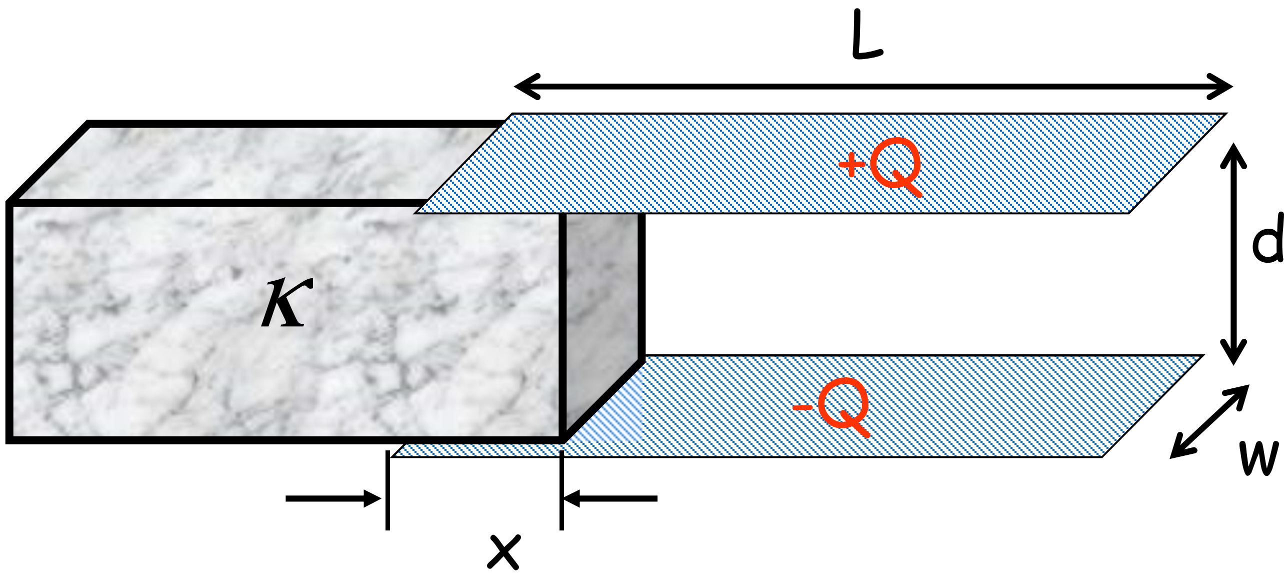
$$u_E = \frac{U}{\text{volume}} = \frac{1}{2} \varepsilon_o |\mathbf{E}|^2$$

(Units: J/m^3)

This also applies to *any* electric field.

Quiz

Dielectric



A dielectric is slid into the space between the plates of a charged capacitor. What happens?

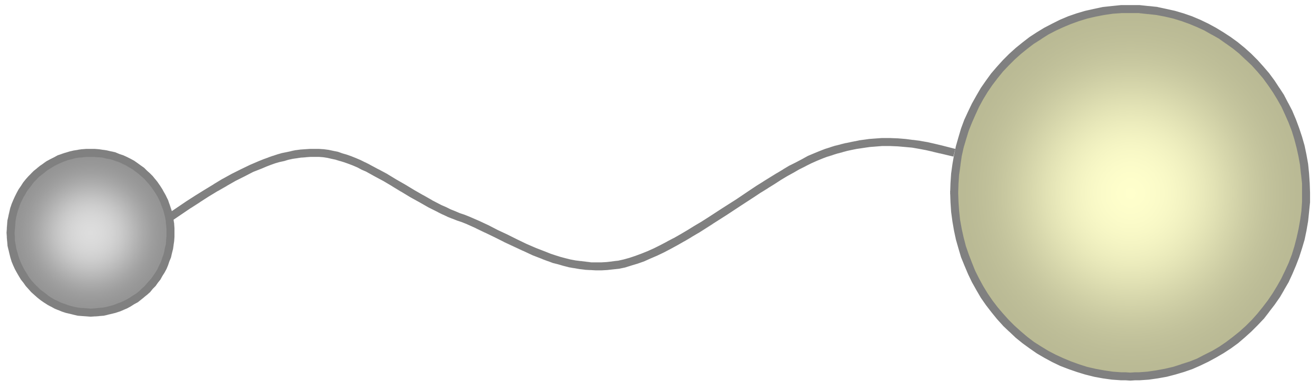
A) The energy stored in the capacitor increases
B) The energy stored in the capacitor decreases
C) No change

What is the direction of the electrostatic force on the dielectric?

What is the magnitude of this force?

Quiz

Conducting spheres and a long wire:



$r_1 = 10cm$ $r_2 = 30cm$

A total charge +12 μC is placed on one sphere. Some of the charge will move to the other sphere until

A) the electric fields outside the spheres are equal
B) the electric potentials on the spheres are equal
C) the electric charges on the spheres are equal
D) all of the above