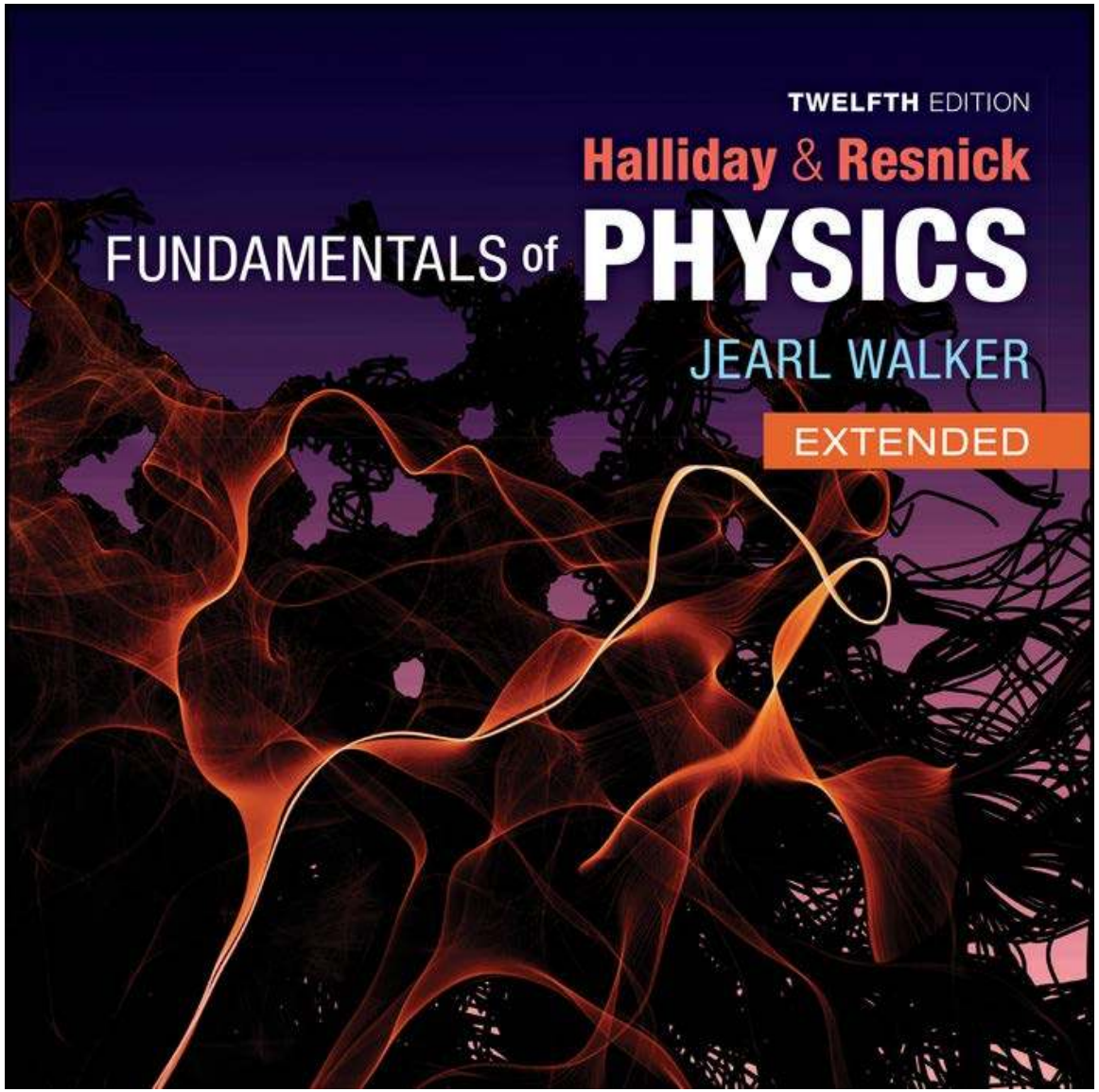
Wed 28 Jan

Fundamentals of Physics, Twelfth Edition. Halliday & Resnick, Walker

Chapter 25

Capacitance



Chapter 25
Capacitance

- min 4-5 grades
- more than 10 marks on Kirchoff's law

capacitor : store charge and energy (device)

lamps/ TV/ charger

- **25.1 Capacitance**
- **25.2 Calculating the Capacitance**
- **25.3 Capacitors in Parallel and in Series**
- **25.4 Energy Stored in an Electric field**
- **25.5 Capacitors with a Dielectric**

2 aluminum foil → store charge/energy
(Conducting plates)
between insulator : dielectric → before it was air/vacuum
when inserted can make as Thin as possible

spherical
cylendrical :

parallel-plate:

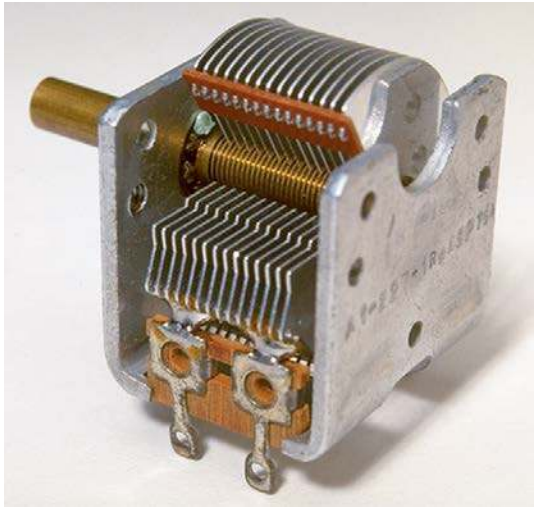
Section 25.1 Capacitance

Capacitance: Definition

A capacitor consists of two isolated conductors (the plates) with charges $+q$ and $-q$. Its **capacitance** C is defined from

$$q = CV.$$

$$1 \text{ farad} = 1 \text{ F} = 1 \text{ coulomb per volt} = 1 \text{ C/V}.$$



Where :

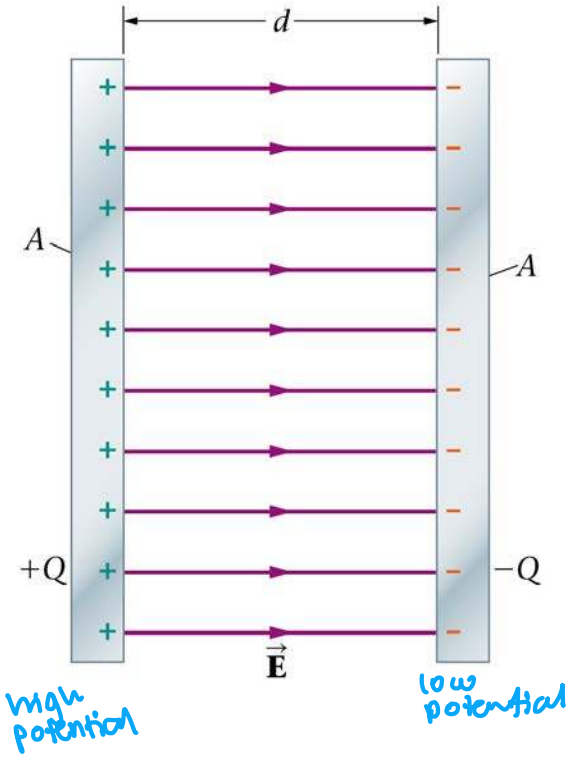
- C: is the capacitance and it's always a positive quantity
- Q: is the charge on each plate
- V: is the potential difference between the two plates

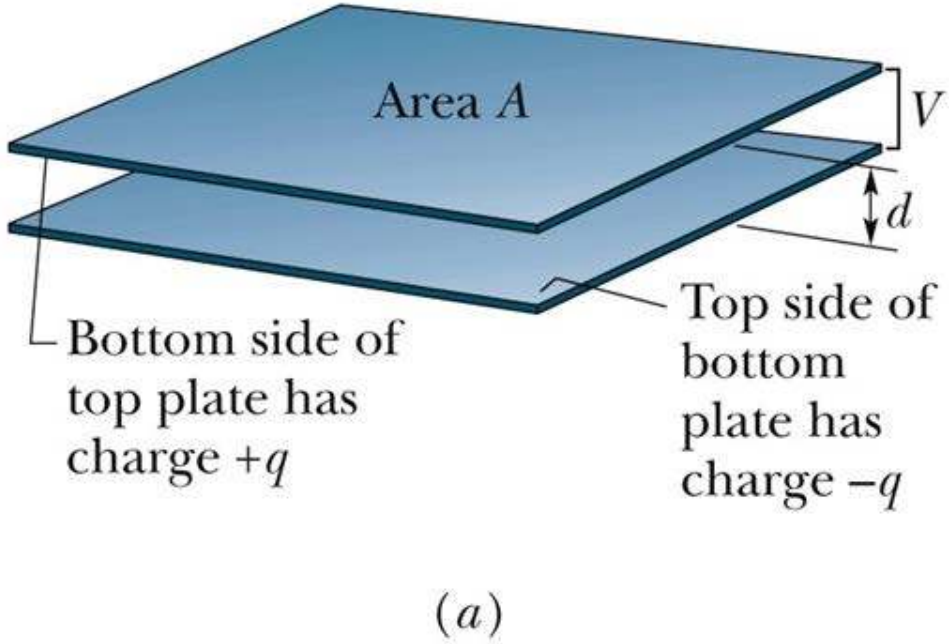


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Parallel Plate Capacitor

A parallel-plate capacitor, made up of two plates of area *A* separated by a distance *d*. The charges on the facing plate surfaces have the same magnitude *q* but opposite signs





(a)

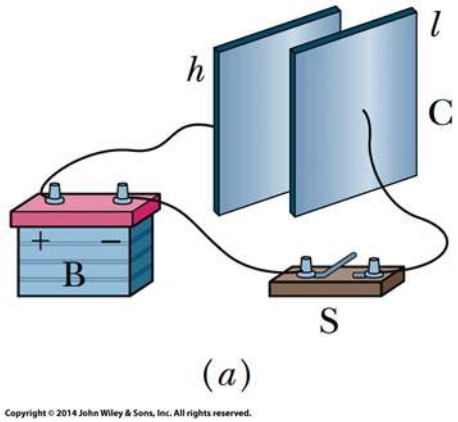
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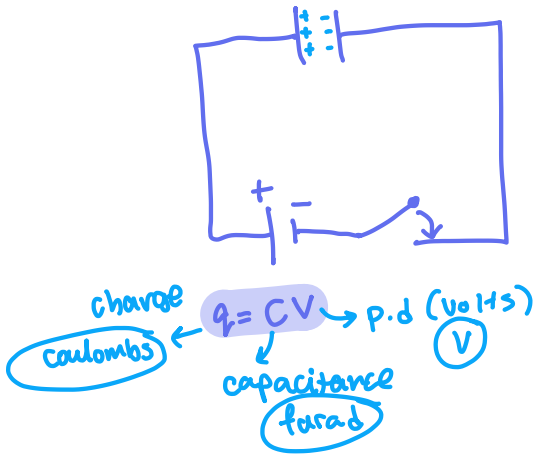
Charging a Capacitor

When a circuit with a battery, an open switch, and an uncharged capacitor is completed by closing the switch, conduction electrons shift, leaving the capacitor plates with opposite charges.

ohms law : resistor

capacitor symbol





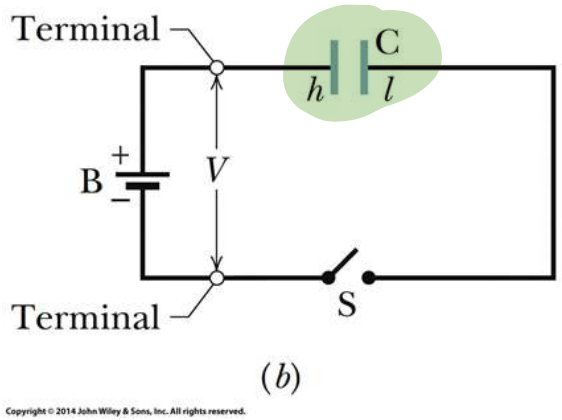
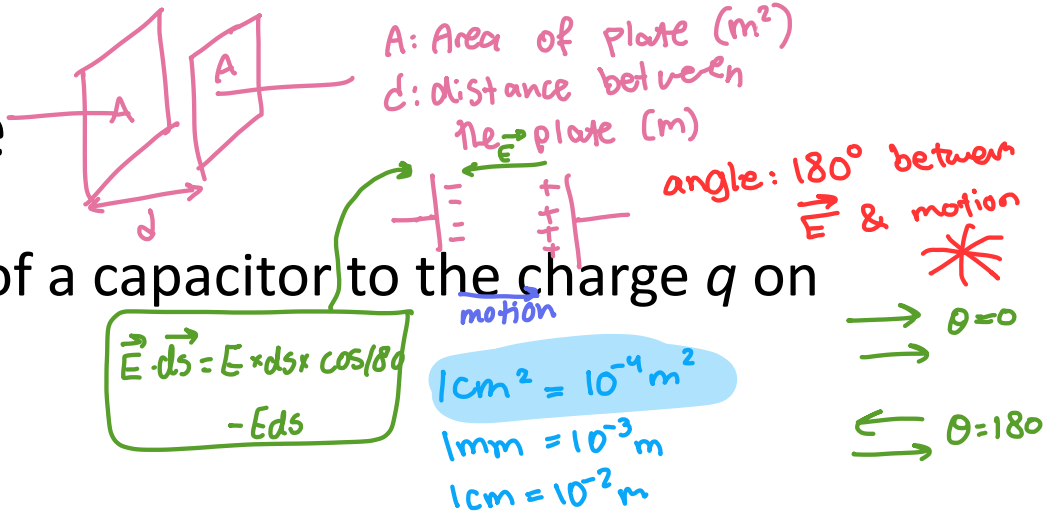


Fig. (*a*), a battery B, a switch S, an uncharged capacitor C, and interconnecting wires form a circuit. The same circuit is shown in the schematic diagram of Fig. (*b*), in which the symbols for a battery, a switch, and a capacitor represent those devices. The battery maintains potential difference *V* between its terminals. The terminal of higher potential is labeled + and is often called the positive terminal; the terminal of lower potential is labeled − and is often called the negative terminal.

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Gauss' Law for Calculating Capacitance



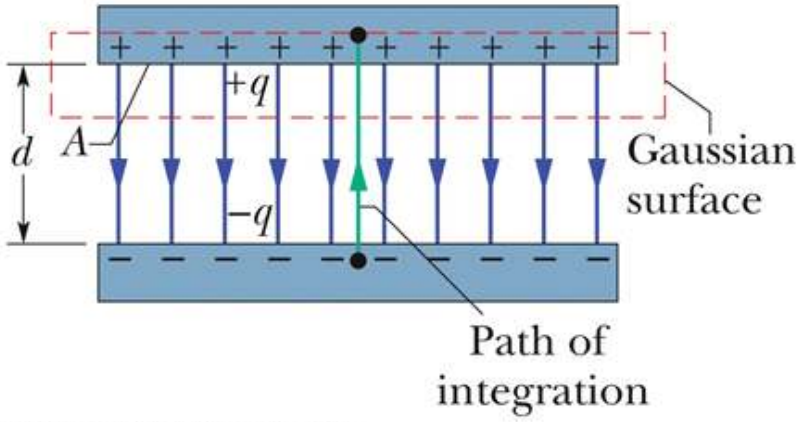
To relate the electric field $\vec{E}$ between the plates of a capacitor to the charge q on either plate, we shall use Gauss' law:

$$\varepsilon_0 \oint \vec{E} \cdot d\vec{A} = q.$$

A Gaussian surface encloses the charge on the positive plate. The integration is taken along a path extending directly from the negative plate to the positive plate. We obtain :

$$q = \varepsilon_0 EA$$

We use Gauss' law to relate q and E. Then we integrate the E to get the potential difference.



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- The potential difference between the plates of a capacitor is related to the field by:

going from − to +

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$$

$\Phi = \frac{q}{\epsilon_0}$ (gauss law) $\int \vec{E} \, d\vec{A} = \frac{q}{\epsilon_0}$

$EA = \frac{q}{\epsilon_0}$, $q = EA\epsilon_0$, $\Delta V = V = V_f - V_i$

- Letting *V* represent the difference $V = V_f - V_i$, we can then recast the above equation as :

$$V = \int_-^+ E \, ds = E\int_0^d ds = Ed.$$

slide above ✱ $\cos(180) = -1$ −ve cancel each other so we get + Ed

$q = CV$

$EA\epsilon_0 = CEd$

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

- For this path, the vectors $\vec{E}$ and $d\vec{s}$ will have opposite directions ; so, the dot product will be (*-Eds).*

area ↑ capacitor ↑

d ↑ capacitance ↓

- Now if we substitute $q=\varepsilon_0 EA$ *and* $V = Ed$ into $q = CV$, we get,

$$C = \frac{\varepsilon_0 A}{d} \quad \text{(parallel-plate capacitor)}.$$

parallel plate

$q = CV$ (C, F, V)

$V = Ed$

$C = \frac{\epsilon_0 A}{d}$ (↑ ↓ ↑ ↑)

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Example

- A parallel plate capacitor is constructed with plates of area ($0.028\ m^2$) and separation (0.55 mm).
  - Find the magnitude of the charge on each plate of this capacitor when the potential difference between the plates is (20.1 V) .
  - What is the magnitude of the electric field between the plates of the capacitor.

A

d $0.55\ mm \times \frac{10^{-3}\ m}{1\ mm} = 5.5 \times 10^{-4}\ m$

V

Givens: $A = 0.028\ m^2$, $d = 5.5 \times 10^{-4}\ m$, $V = 20.1\ V$

Should Know → $\epsilon_0 = 8.85 \times 10^{-12}$

(a) $q = CV = \frac{\epsilon_0 A}{d} V$

$\frac{8.85 \times 10^{-12}(0.028)}{(5.5 \times 10^{-4})}(20.1) = 9.05 \times 10^{-9}\ C$

(b) $E = \frac{V}{d} = \frac{20.1}{5.5 \times 10^{-4}} = 36545.45\ \frac{V}{m}$

Thu 29 Jan

Section 25.3 Capacitors in Parallel and In Series

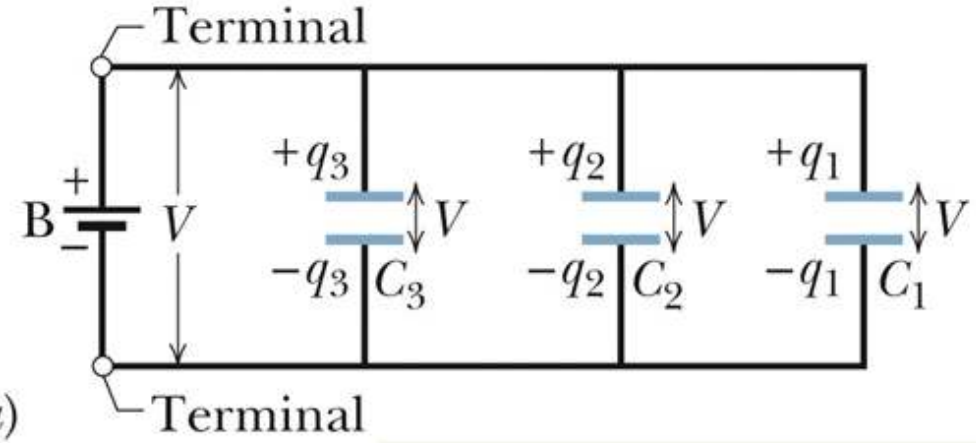
Net/Equivalent Capacitance for Capacitors in Parallel

When a potential difference *V* is applied across several capacitors connected in parallel, **that potential difference *V* is the same across each capacitor**. The total charge *q* stored on the capacitors is the sum of the charges stored on all the capacitors.

$$q_1 = C_1 V, \quad q_2 = C_2 V, \quad \text{and} \quad q_3 = C_3 V.$$

The total charge on the parallel combination is then:

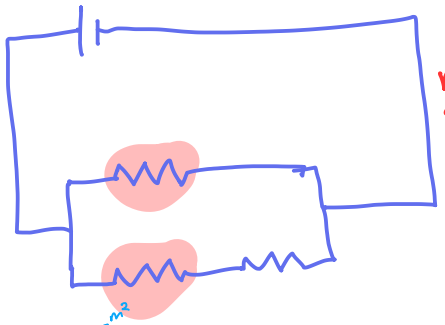
$$q = q_1 + q_2 + q_3 = (C_1 + C_2 + C_3)V.$$



(a)

Parallel capacitors and their equivalent have the same *V* ("par-V").

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neither series nor parallel

$C = \frac{\epsilon_0 A}{d}$ → m^2 (air / vacuum)

series: (same current / charge) — resistor, capacitor — q

parallel: (same potential difference / voltage) — $V = E\phi$ — V

↳ same letters

$q = CV$ (C, V)

not everytime split it's parallel ✗ incorrect

letters won't be given
I must know them

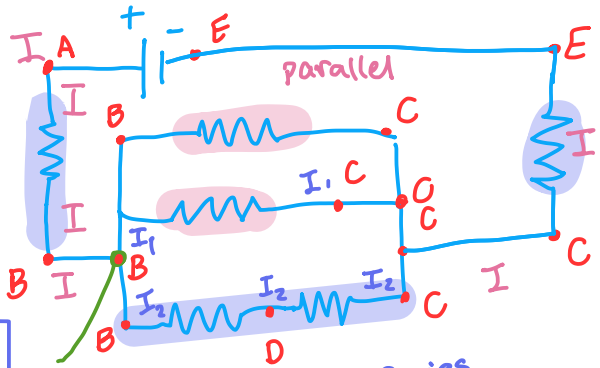
to ✗
and ✓

doesn't change leaves and enter same

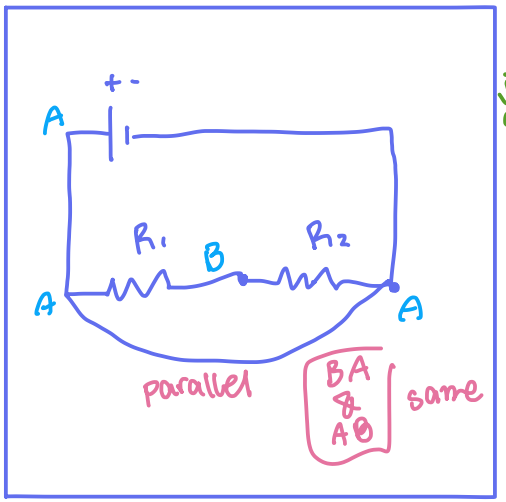
I: charges / time
current

wire: letter don't change

anything else: change



junction: where wires split



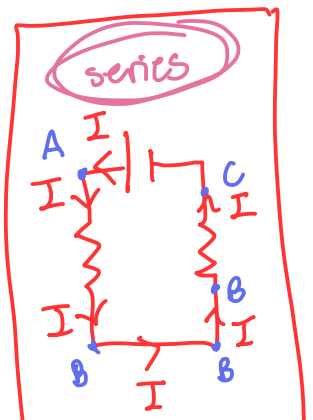
current passing through / into / in

p.d across / between



letter₁

letter₂ → to be parallel must have same



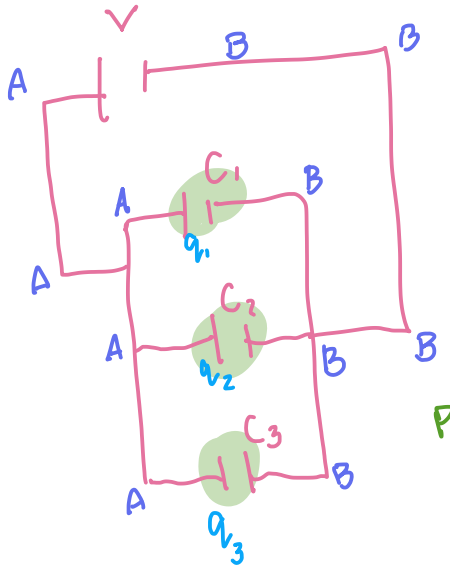
$C = \frac{\epsilon_0 A}{d}$ (A: m^2, d: m)

(air / vacuum — plate capacitor)

F

$V = Ed$

$q = CV$ (q: C, C: F, V: V)



Farad prob wrong

pico, nano } more accurate

parallel

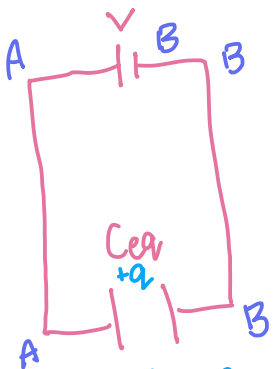
$q_1 = C_1 V_{AB}$

$q_2 = C_2 V_{AB}$

$q_3 = C_3 V_{AB}$

} But $V_{AB} = V$

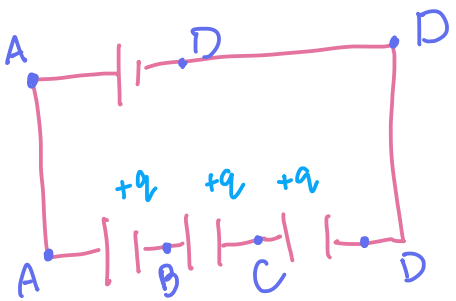
$q = C_{eq} V_{AB}$

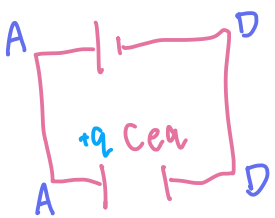


$q = q_1 + q_2 + q_3$

$C_{eq} V_{AB} = C_1 V_{AB} + C_2 V_{AB} + C_3 V_{AB}$

$\boxed{C_{eq} = C_1 + C_2 + C_3}$ parallel





$V_{AD} = V_{AB} + V_{BC} + V_{CD}$

$\frac{q}{C_{eq}} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$C_{eq}^{-1} = C_1^{-1} + C_2^{-1} + C_3^{-1}$

The equivalent capacitance, with the same total charge q and applied potential difference V as the combination, is then

$$C_{\text{eq}} = \frac{q}{V} = C_1 + C_2 + C_3,$$

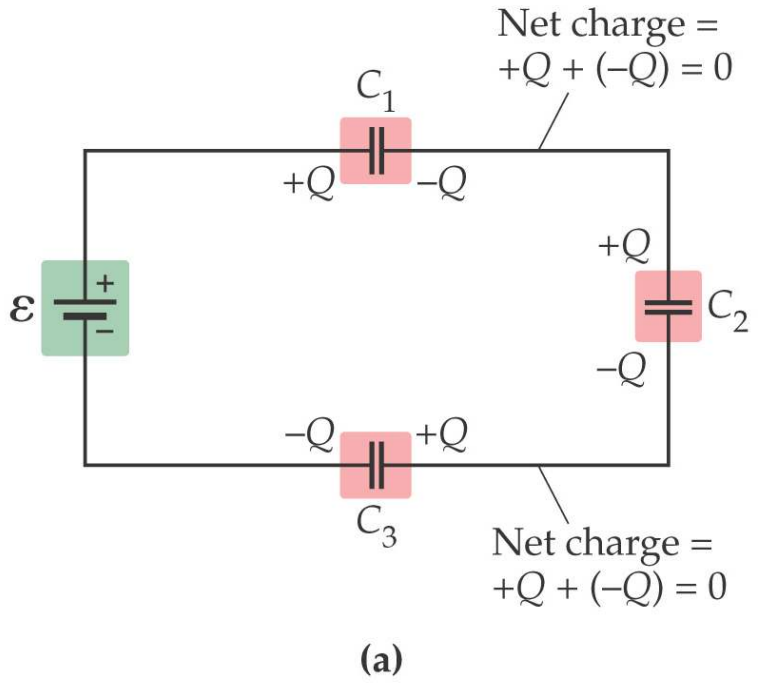
a result that we can easily extend to any number n of capacitors, as

$$C_{\text{eq}} = \sum_{j=1}^{n} C_j \quad (n \text{ capacitors in parallel}).$$

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Net/Equivalent Capacitance for Capacitors in Series

When a potential difference *V* is applied across several capacitors connected in series, **the capacitors have same charge *q***. The sum of the potential differences across all the capacitors is equal to the applied potential difference *V*.



$$V_1 = \frac{q}{C_1}, \quad V_2 = \frac{q}{C_2}, \quad \text{and} \quad V_3 = \frac{q}{C_3}.$$

The total potential difference *V* due to the battery is the sum:

$$V = V_1 + V_2 + V_3 = q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right).$$

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The equivalent capacitance is then:

$$C_{\text{eq}} = \frac{q}{V} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}},$$

or

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

$$\frac{1}{C_{\text{eq}}} = \sum_{j=1}^{n} \frac{1}{C_j} \quad (n \text{ capacitors in series}).$$

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$m = \times 10^{-3}$
$\mu = \times 10^{-6}$
$n = \times 10^{-9}$
$p = \times 10^{-12}$

$C_{eq} = \frac{q}{V}$

Example

Steps: must work backwards
1. letters / label C_1, C_2
2. Go from back, check relation → series: $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$; parallel: $C_{eq} = C_1 + C_2$
3. Merge them (letters) C_{eq_1} with next C
4. Repeat ....

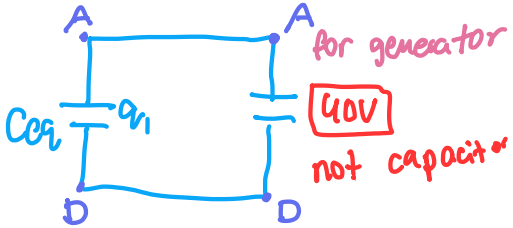
technique in solving: backwards

Find the equivalent capacitance of the shown circuit

charge in capacitor

(a) C_{eq}? 20 μF C_4 & C_5 : series

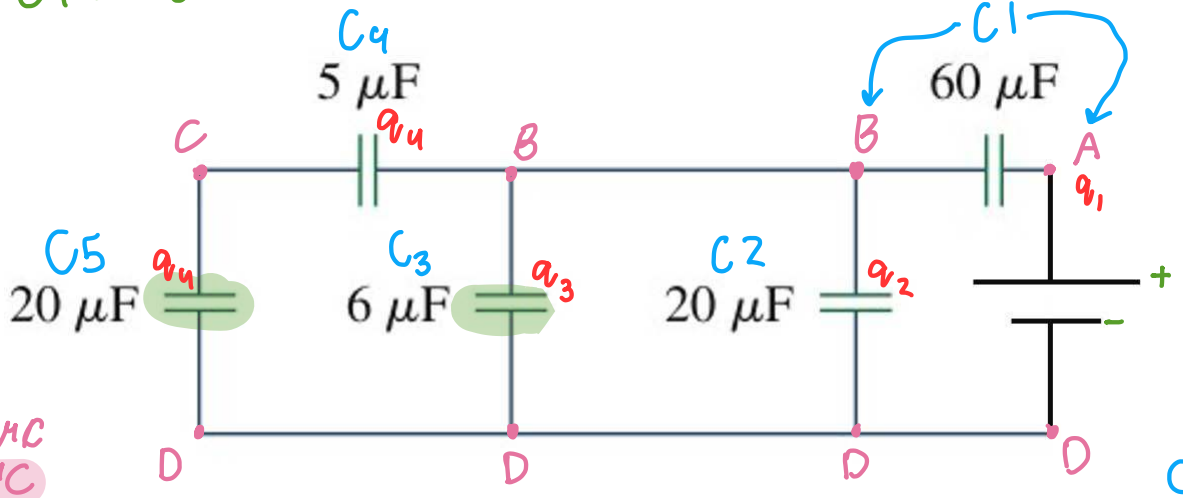
(b) q C_1?



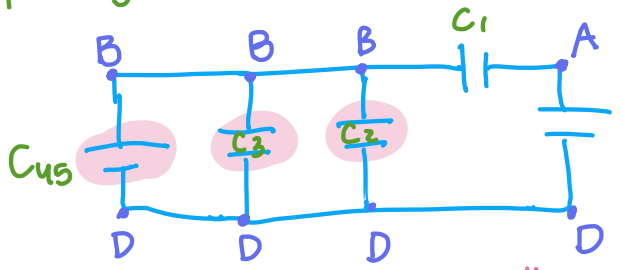
$q_1 = C_{eq} \times V_{AD} = 20\,\mu F \times 40V = 800\,\mu C = 8 \times 10^{-4} C$

(c) V C_1

$V_{C_1} = \frac{q_1}{V_1} = \frac{8 \times 10^{-4}}{60 \times 10^{-6}} V$

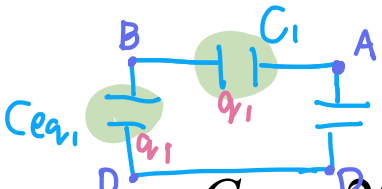


$\frac{1}{C_{45}} = \frac{1}{C_4} + \frac{1}{C_5} = \frac{1}{20} + \frac{1}{5} = \frac{1}{4}$ $C_{45} = 4\,\mu F$



C_2, C_3, C_{45} in parallel

$C_{eq_1} = 4 + 6 + 20 = 30\,\mu F$



$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_{eq_1}} = \frac{1}{60} + \frac{1}{30}$

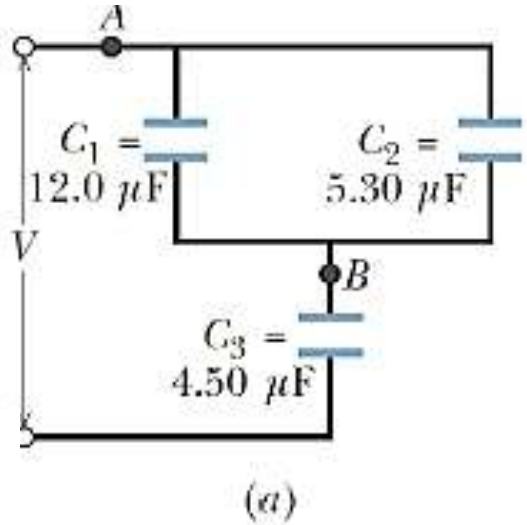
$ans.\ C_{eq} = 20\,\mu F$ $C_{eq} = 20\,\mu F$

Extra Practice

(a) Find the equivalent capacitance for the combination of capacitances shown in Fig. 25.3.3*a*, across which potential difference V is applied. Assume

$C_1 = 12.0\ \mu\text{F},\ \ C_2 = 5.30\ \mu\text{F},\ \ \text{and}\ C_3 = 4.50\ \mu\text{F}.$

(b) The potential difference applied to the input terminals in Fig. 25.3.3*a* is $V = 12.5\ \text{V}$. What is the charge on C_1?



(a)

Solution:

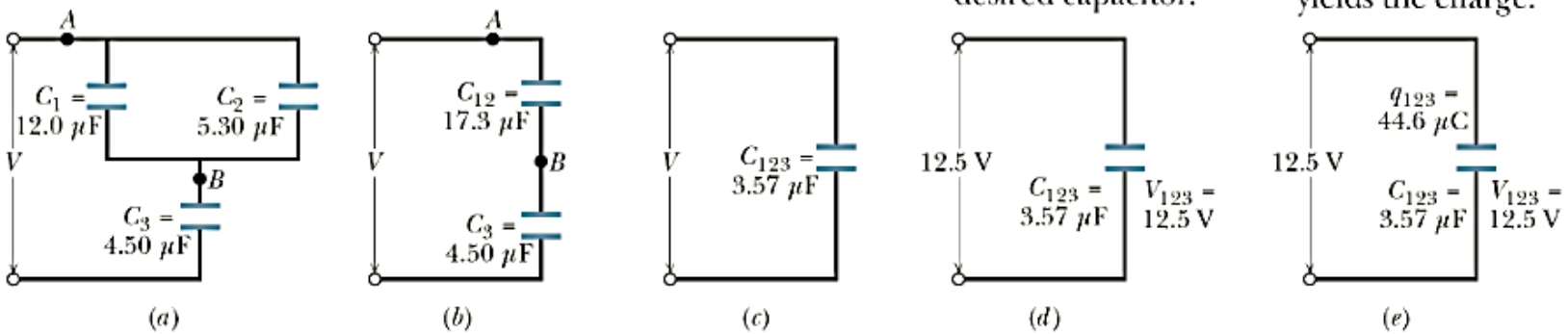
We first reduce the circuit to a single capacitor.

The equivalent of parallel capacitors is larger.

The equivalent of series capacitors is smaller.

Next, we work backwards to the desired capacitor.

Applying $q = CV$ yields the charge.

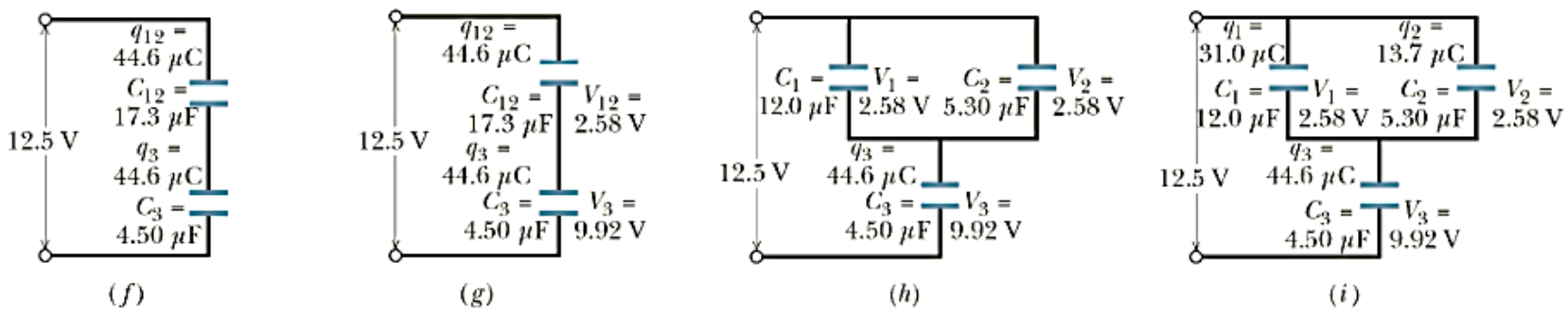


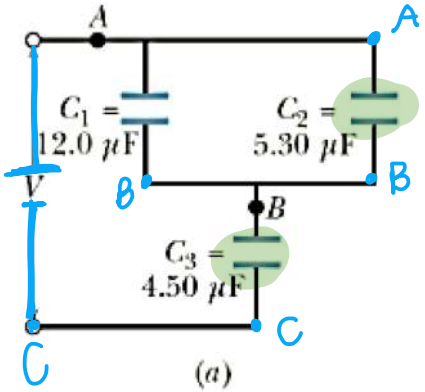
Series capacitors and their equivalent have the same q ("seri-q").

Applying $V = q/C$ yields the potential difference.

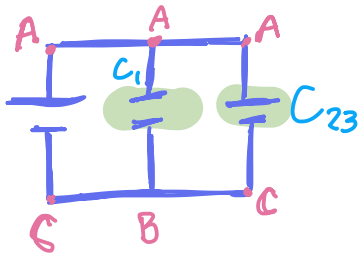
Parallel capacitors and their equivalent have the same V ("par-V").

Applying $q = CV$ yields the charge.

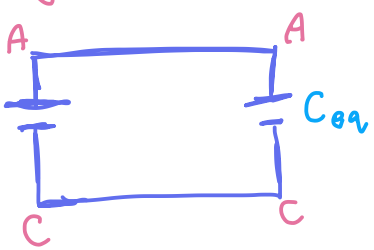




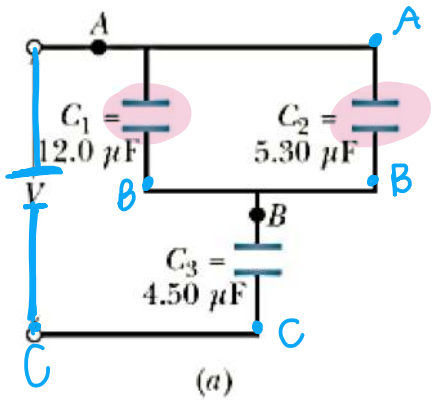
(a)



C_2 C_3 series $= \frac{1}{C_2} + \frac{1}{C_3} = 0.411\,MF = C_{23}$

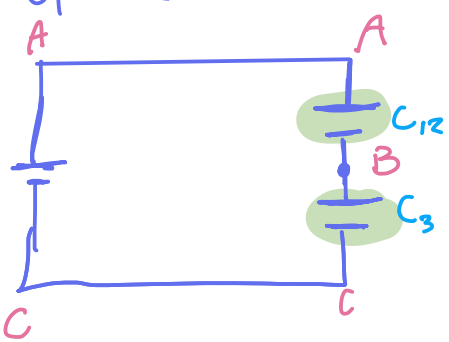


C_1 C_{23} series $= \frac{1}{C_{23}} + \frac{1}{C_1} = 2.516\,MF = C_{eq}$



(a)

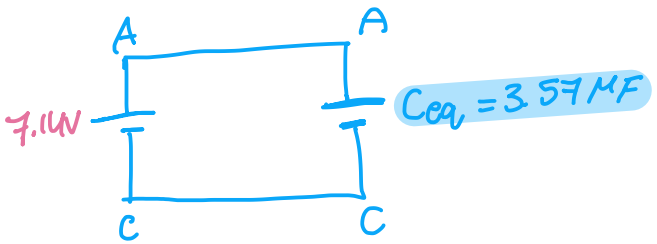
C_1 & C_2 Parallel : $C_{12} = C_1 + C_2 = 12 + 5.3 = 17.3\,MF$



C_{12} & C_3 series

$\frac{1}{C_{eq}} = \frac{1}{C_{12}} + \frac{1}{C_3} = \frac{1}{17.3} + \frac{1}{4.5}$

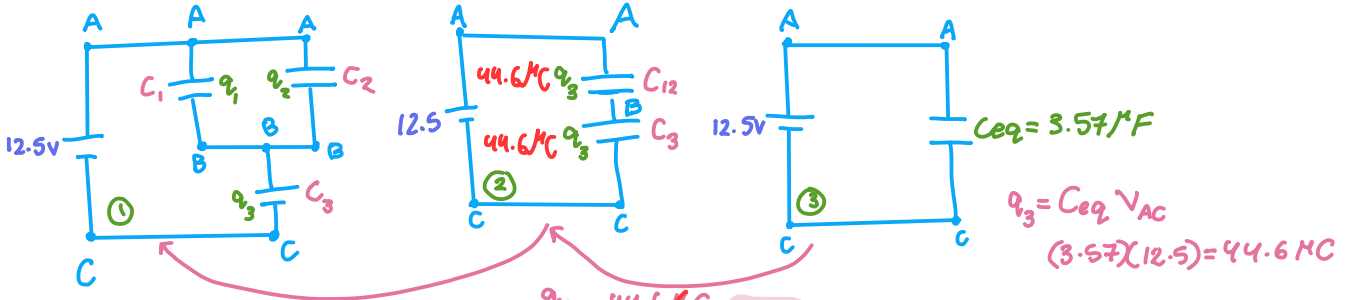
$C_{eq} = \left(\frac{1}{17.3} + \frac{1}{4.5}\right)^{-1} = 3.57\,MF$



V_{AB} have

V_{AC} have

Wed 4 Feb



$q_3 = C_{eq} V_{AC}$

$(3.57)(12.5) = 44.6\,\mu C$

$V_{BC} = \frac{q_3}{C_3} = \frac{44.6\,\mu C}{4.5\,\mu F} = 9.91V$

$C_{12} = 17.3\,\mu F$

$C_{eq} = 3.57\,\mu F$

$q_1 = C_1 V_{AB} = (12\,\mu F)2.6 = 31.2\,\mu C$

$q_2 = C_2 V_{AB} = (5.3)(2.6) = 13.4\,\mu C$

OR

$q_2 = q_3 - q_1 = 44.6 - 31.2 = 13.4\,\mu C$

Two ways:

① $V_{AB} = V_{C12} = \frac{q_3}{C_{12}} = \frac{44.6\,\mu C}{17.3\,\mu F} = 2.6V$

② $V_{AB} = V_{AC} - V_{BC} = 12.5 - 9.91 = 2.59$

Tips:

- Write equation

Tue 10 Feb

Capacitors:

$U = qV$ Potential difference

energy stored in capacitor

very imp ① $U = \frac{1}{2} qV$

② $q = CV$

③ $U = \frac{1}{2} CV \cdot V = \frac{1}{2} CV^2$

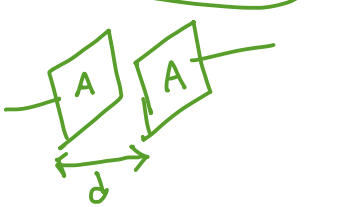
④ $U = \frac{1}{2} q \times \frac{q}{C} = \frac{q^2}{2C}$

Way of thinking of energy:

Jood is 6
can I compare him with 12 yr old?
No there's no factor that's constant

Recap

$C = \frac{\epsilon_0 A}{d}$ — F, m^2, γ_m



Section 25.4 Energy Stored in an Electric Field

The **electric potential energy** *U* of a charged capacitor,

$$U = \frac{q^2}{2C} \quad \text{(potential energy)}.$$

and

$$U = \tfrac{1}{2}CV^2 \quad \text{(potential energy)}.$$

and

$$U = \frac{1}{2}QV$$

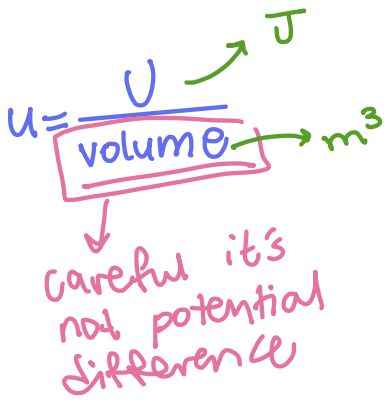
is equal to the work required to charge the capacitor. This energy can be associated with the capacitor's electric field

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Energy Stored in an Electric Field

The potential energy of a charged capacitor may be viewed as being stored in the electric field between its plates.

Every electric field, in a capacitor or from any other source, has an associated stored energy. In vacuum, the **energy density** u (potential energy per unit volume) in a field of magnitude E is



$$u = \tfrac{1}{2}\varepsilon_0 E^2 \quad \text{(energy density)}.$$

electric field

$\frac{J}{m^3}$

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Example

- A parallel plate capacitor is fully charged by a 300 V battery. If the area of each plate is 35 cm^2 and the gap between them is 1.77 mm. What is the charge carried by the capacitor and the energy stored in it?

$V = 300V$

$A = 35cm^2 = 35 \times 10^{-4} m^2$

$d = 1.77\ mm = 1.77 \times 10^{-3} m$

$q = CV$

$\epsilon_0 = 8.85 \times 10^{-12}$

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

$q = \frac{\epsilon_0 A}{d}(V) = 0.00000000525\ C$

$U = \frac{q^2}{2C} = \frac{(0.00000000525)^2}{2(1.75 \times 10^{-11})} = 0.000\,000\,7875\ J$

$7.9 \times 10^{-7}\ J$

Example

IMP

↳ doctor says ab analysis

- A parallel plate capacitor of plate area 82 cm^2 carries a charge of 55 nC when charged at 220 volt. What is the plate separation (d) of this capacitor and the energy stored in it?

$A = 82 cm^2 = 82 \times 10^{-4} m^2$
$q = 55 nC = 55 \times 10^{-9} C$
$V = 220 V$
$d = ?$

$q = CV$

$55 \times 10^{-9} = \frac{\epsilon_0 A}{d}(220)$

$d = \frac{(8.85 \times 10^{-12})(82 \times 10^{-4})(220)}{55 \times 10^{-9}}$

$= 0.00029028 = \boxed{2.9 \times 10^{-4} m}$

$U = \frac{1}{2} q V$

$= \frac{1}{2}(55 \times 10^{-9})(220)$

$\boxed{= 6.05 \times 10^{-6} J}$

Tip
use question given

m $\times 10^{-3}$

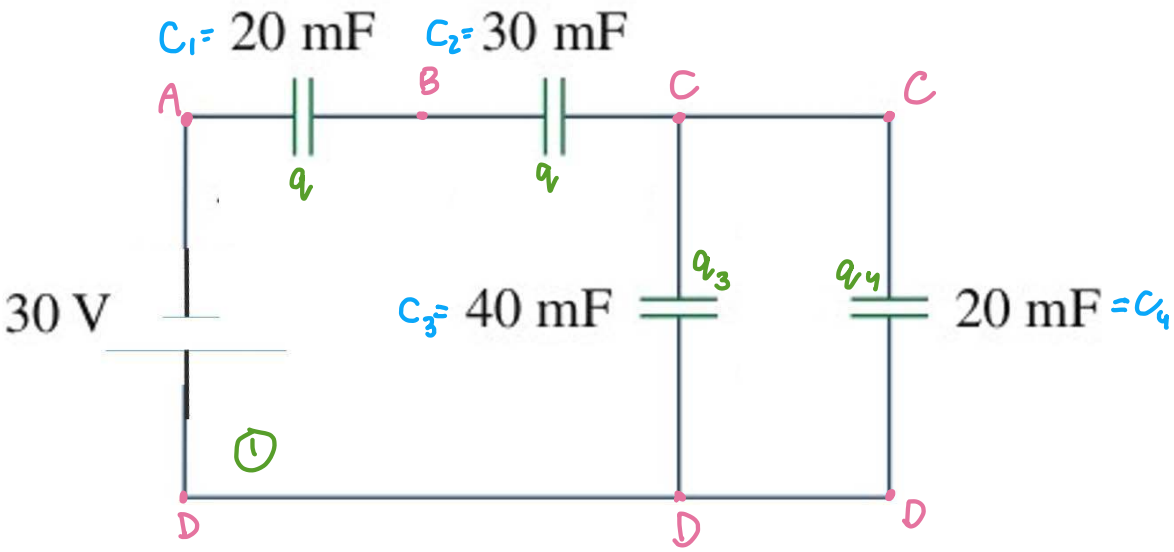
Example

For the circuit shown, find the voltage, charge and energy stored for each capacitor.

(a) V

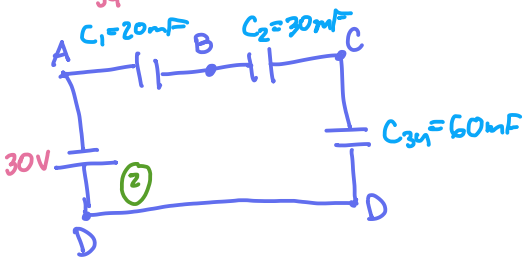
(b) q

(c) energy?



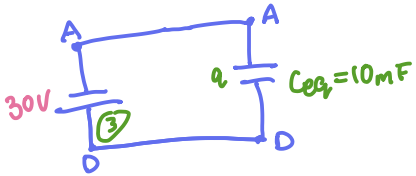
C_3 & C_4 parallel:

$C_{34} = 40 + 20 = 60\text{mF}$



C_1, C_2, C_{34} are in series

$$C_{eq} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_{34}}\right)^{-1} = 10\text{mF}$$



C_{12} & C_{34} series $= C_{eq} = 10\text{mF}$

Thu 5 Feb

Same question continued

Example

- Two capacitors, $C_1 = C$, $C_2 = 2C$, are connected to a battery.
- Which capacitor will store more energy when they are connected to the battery in series? Explain

q is the same

$U = \frac{1}{2}qV$ don't have voltage for all capacitors

$U = \frac{1}{2}CV^2$ eliminated (I'm stupid)

$U = \frac{q^2}{2C}$ ✓ because q doesn't change in series

$U_1 = \frac{q^2}{2C_1} = \frac{q^2}{2C}$ greater

$U_2 = \frac{q^2}{2C_2} = \frac{q^2}{2(2C)} = \frac{q^2}{4C}$

$U_1 > U_2$

- Which capacitor stores more energy when they are connected in parallel? Explain.

$U = \frac{1}{2}CV^2$ = volt in constant parallel

$U_1 = \frac{1}{2}C_1V^2 = \frac{1}{2}CV^2$

$U_2 = \frac{1}{2}C_2V^2 = \frac{1}{2}(2)CV^2 = CV^2$ greater

$U_1 < U_2$

Section 25.5 Capacitor with a Dielectric

Definition of a Dielectric

insulator between 2 capacitors

If the space between the plates of a capacitor is completely filled with a **dielectric material**, which is an insulator, the capacitance C in vacuum (or, effectively, in air) is multiplied by the material's **dielectric constant** κ, (Greek kappa) which is a number greater than 1.

In a region completely filled by a dielectric material of dielectric constant κ, all electrostatic equations containing the permittivity constant ε_0 are to be modified by replacing ε_0 with $\boxed{\kappa\varepsilon_0}$. KAPPA

capacitance even more with an dielectric constant



Figure 25.5.1 The simple electrostatic apparatus used by Faraday. An assembled apparatus (second from left) forms a spherical capacitor consisting of a central brass ball and a concentric brass shell. Faraday placed dielectric materials in the space between the ball and the shell.

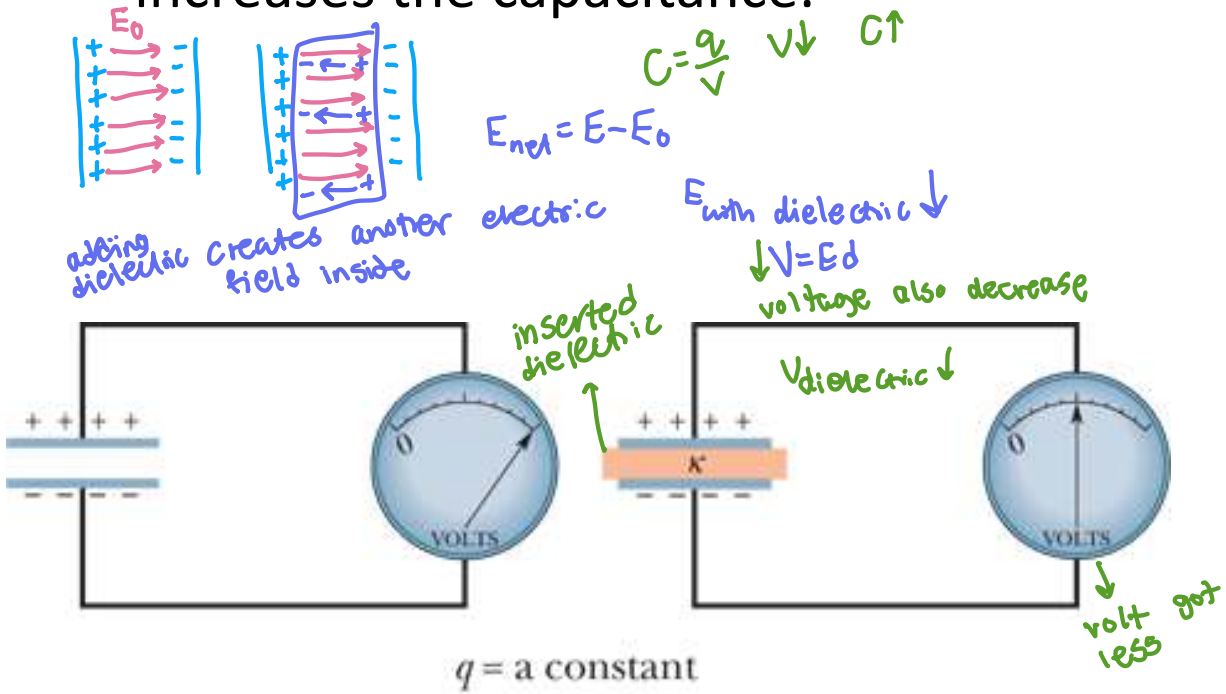
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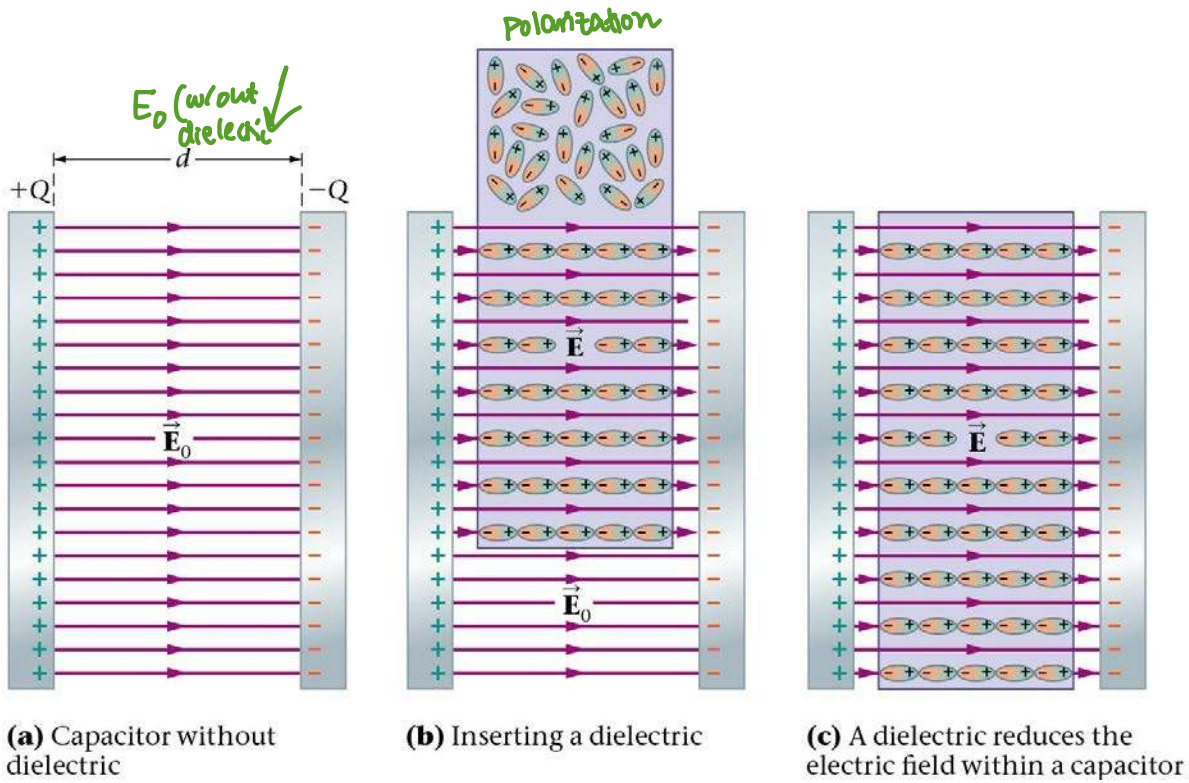
Dielectric In a Parallel Plate Capacitor (same charge)

- If a dielectric is placed between the plates of a capacitor it gives a lower potential difference with **the same charge**, due to the polarization of the material. This increases the capacitance.

Young & Friedman

will have opposing





(a) Capacitor without dielectric

(b) Inserting a dielectric

(c) A dielectric reduces the electric field within a capacitor

- The polarization of the dielectric results in a lower electric field within it; the new field is given by dividing the original field by the dielectric constant κ:

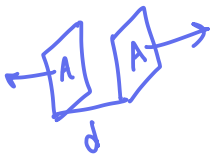
$$E = \frac{E_0}{\kappa}$$

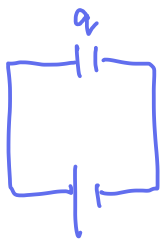
- Therefore, the capacitance becomes:

$$C = \frac{Q}{V} = \frac{Q}{(V_0/\kappa)} = \kappa\frac{Q}{V_0} = \kappa C_0$$

Ch25

Capacitor





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

C series: same charge (q)

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$$

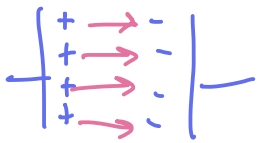
C parallel: same P.d "V"

$$C_{eq} = C_1 + C_2 + \cdots$$

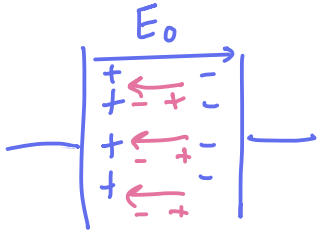
$$V = Ed$$

Dielectric:

① q constant



dielectic



$$E_{net} = E_0 - E \qquad E = \frac{E_0}{K}$$

E_{net} ↓

$V = Ed$ E↓ V↓

constant q $= CV$

C↑ V↓

$$\epsilon_0 \equiv K\epsilon_0$$

↓ dielectric constant

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

- The dielectric constant is a property of the material; here are some examples:

TABLE 20-1 Dielectric Constants

Substance	Dielectric constant, κ
Water	80.4
Neoprene rubber	6.7
Pyrex glass	5.6
Mica	5.4
Paper	3.7
Mylar	3.1
Teflon	2.1
Air	1.00059
Vacuum	1

given

usually ←

- If the electric field in a dielectric becomes too large, it can tear the electrons off the atoms, thereby enabling the material to conduct. This is called **dielectric breakdown**; the field at which this happens is called the dielectric strength.

voltage too high, insulators get e^- too charged they can start conducting

don't forget the minus in previous chapters

TABLE 20-2 Dielectric Strengths

Substance	Dielectric Strength (V / m)
Mica	100×10^6
Teflon	60×10^6
Paper	16×10^6
Pyrex glass	14×10^6
Neoprene rubber	12×10^6
Air	3.0×10^6

$\left(\frac{N}{C}\right)\left(\frac{V}{m}\right)$ electric field

Example

- Determine (a) the capacitance and (b) the maximum potential difference that can be applied to a Teflon-filled parallel-plate capacitor having a plate area of 1.75 cm^2 and plate separation of 0.04 mm. (κ for Teflon = 2.1)

$A = 1.75\times10^{-4}\ m^2$ $\quad d = 0.04\times10^{-3}\ m$

(a) $C = \frac{\epsilon_0 A}{d} = \frac{(8.85\times10^{-12})(2.1)(1.75\times10^{-4})}{0.04\times10^{-3}} = 8.13\times10^{-11}\ F$

(b) ϵ_0 to table: $60\times10^6\ \frac{V}{m}$

$V = Ed = (60\times10^6)(0.04\times10^{-3}) = 2.4\times10^3\ V$

Example

- A parallel-plate capacitor is constructed using a dielectric material whose dielectric constant is 3 and whose dielectric strength is 2×10^8 N/C. The desired capacitance is 0.25 μF, and the capacitor must withstand a maximum potential difference of 4000 V. Find the minimum area of the capacitor plates.

$C = 0.25\times10^{-6}\,F$

$V = 4000\,V$

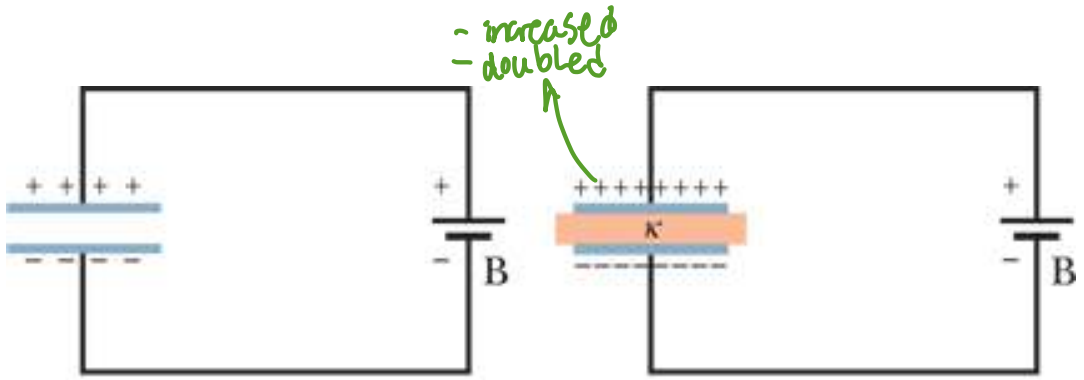
$K = 3$

$A = ?$

$V = Ed \rightarrow d = \frac{V}{E} = \frac{4000}{2\times10^8} = 2\times10^{-5}\ m$

$C = \frac{K\epsilon_0 A}{d} \rightarrow \frac{C\cdot d}{K\epsilon_0} = \frac{K\epsilon_0 A}{K\epsilon_0} \rightarrow A = \frac{Cd}{K\epsilon_0} = 1.88\times10^{-1}\ m^2$

Dielectric In a Parallel Plate Capacitor (same potential difference)



V = a constant

(a)

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If the **potential difference** between the plates of a capacitor is maintained, as by the presence of battery B, the effect of a dielectric is to increase the charge on the plates.

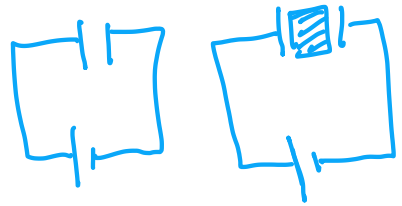
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q constant
$U = \frac{1}{2}CV^2$
$= 1.05 \times 10^{-9}$ J

$C = 13.5 \times 10^{-12}$ F
$V = 12.5$ V
$K = 6.50$

Extra Practice

plot to understand:

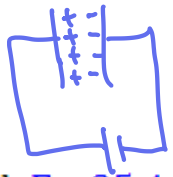


Same voltage: battery
$U = \frac{1}{2}CV^2$

A parallel-plate capacitor whose capacitance C is 13.5 pF is charged by a battery to a potential difference $V = 12.5$ V between its plates. The charging battery is now disconnected, and a porcelain slab ($\kappa = 6.50$) is slipped between the plates.

(a) What is the potential energy of the capacitor before the slab is inserted?

but if I said I charged it



same charge



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

KEY IDEA

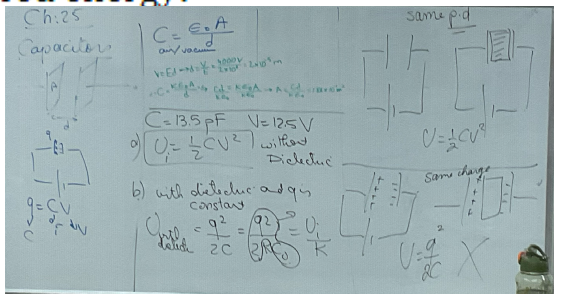
We can relate the potential energy U_i of the capacitor to the capacitance C and either the potential V (with Eq. 25.4.2) or the charge q (with Eq. 25.4.1):

$$U_i = \frac{1}{2}CV^2 = \frac{q^2}{2C}.$$

!! final exam !!

Calculation: Because we are given the initial potential V $(= 12.5$ V$)$, we use Eq. 25.4.2 to find the initial stored energy:

$$U_i = \frac{1}{2}CV^2 = \frac{1}{2}(13.5 \times 10^{-12}\text{ F})(12.5\text{ V})^2$$
$$= 1.055 \times 10^{-9}\text{ J} = 1055\text{ pJ} \approx 1100\text{ pJ}. \quad \text{(Answer)}$$



UCS in units of graphs

(b) What is the potential energy of the capacitor–slab device after the slab is inserted?

$U = \frac{q^2}{2\kappa C_0} = \frac{U_i}{\kappa}$

with dielectric

KEY IDEA

Because the battery has been disconnected, the charge on the capacitor cannot change when the dielectric is inserted. However, the potential *does* change.

Calculations: Thus, we must now use Eq. 25.4.1 to write the final potential energy U_f, but now that the slab is within the capacitor, the capacitance is κC. We then have

$$U_f = \frac{q^2}{2\kappa C} = \frac{U_i}{\kappa} = \frac{1055\text{ pJ}}{6.50}$$
$$= 162\text{ pJ} \approx 160\text{ pJ}. \quad \text{(Answer)}$$

When the slab is introduced, the potential energy decreases by a factor of κ.