ملزمة شرح وتدريبات الوحدة الرابعة Capacitors المكثفات

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اسم الطالب: ....

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In Physics

قديما كانت تمثل الفيزياء رعبا للطالب أما الآن

اسلوب جديد لعرض الفيزياء بعيدا عن التعقيد

Capacitors

Topic 4: Capacitors

- 4.1: Capacitance
- 4.2: Circuits
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Chapter 4

Capacitors

اينشتاين في الفيزياء

2025

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1 Capacitance

*A **capacitor** is a device that can store electric charge and potential energy, consists of two conducting objects placed near one another but not touching. The general definition of capacitance is given by the following relationship:*

$$C = \left|\frac{q}{\Delta V}\right|$$

Where

Δv: potential difference between the two plates.

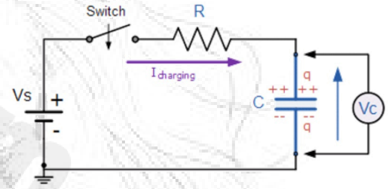
C: capacitance in $1F = 1\frac{C}{V}$ $\quad Farad = \frac{Coulomb}{Volt}$

which called Farad (F)

1 F is a large capacitance.

Most capacitors used in picofarads (10^{-12} F) and microfarads (10^{-6} F)

Notes



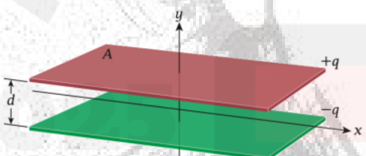
*Capacitor is a device that **stores** charge and electric potential energy.*

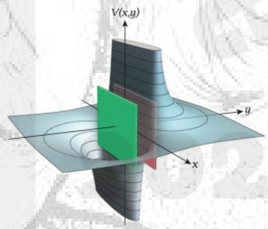
*- The circuit **symbol** for a capacitor is shown in the figure above.*

*- The net charge on the capacitor is **zero**, equal and opposite charges.*

- Charging a capacitor means transferring electrons from one plate to another plate and charging stops when the potential difference ΔV of the plates is equal of that battery.

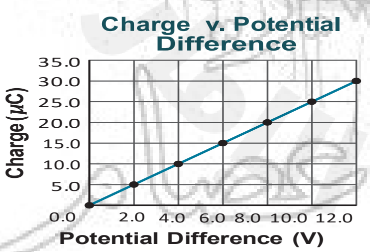
a parallel plate capacitor as a capacitor that consists of two parallel conducting plates, each with area A and separated by a distance d.





*The capacitance of a device depends on the **area** of the plates and the **distance** between them but not on the charge or the potential difference.*

- A capacitor initially has only air between its plates. The charge on the capacitor as a function of applied potential difference is measured, and the results are shown in graph



Data Table

Potential Difference (V)	Charge on a Plate (μC)
0.0	0.0
2.0	5.2
4.0	9.7
6.0	15.0
8.0	20.3
10.0	24.7
12.0	30.1

the potential difference results in a charge in each plate.

A graph of the data shows the relationship is linear.

The slope of this line is the capacitance of the capacitor.

the area under the graph is work done to charge the capacitor

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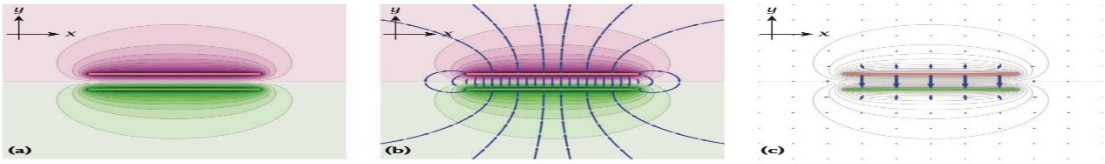
capacitance is an intrinsic property of the plates, that is constant for every example as shown in the figure, changing the charge will effect changing the voltage and so the potential energy to keep the capacitance constant



(a) Two-dimensional contour plot of the same potential as in Figure
(b) Contour plot with electric field lines superimposed.
(c) Electric field strength at regularly spaced points in the xy-plane represented by the sizes of the arrows.

1. *A parallel-plate capacitor stores 240nC when fully charged by the application of a 12 V potential difference across its plates. What is its capacitance?*

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2. *Two conductors having net charges of +10.0 µC and -10.0 µC have a potential difference of 10.0 V between them.*
   A. *Determine the capacitance of the system.*
   B. *What is the potential difference between the two conductors if the charges on each are increased to +100 µC and -100 µC?*

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3. *How much charge is on each plate of a 4.00 µF capacitor when it is connected to a 12.0 V battery? If this same capacitor is connected to a 1.50 V battery, what charge is stored?*

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A parallel-plate capacitor stores 240nC when fully charged by the application of a 12 V potential difference across its plates. What is its capacitance?

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Circuits 2

An ***electric circuit*** *consists of simple wires or other conducting paths that connect circuit elements.*
Circuits usually need some kind of ***power****, which can be provided either by a battery or by an AC (alternating current) power source*

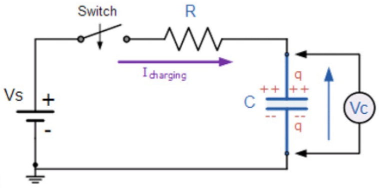
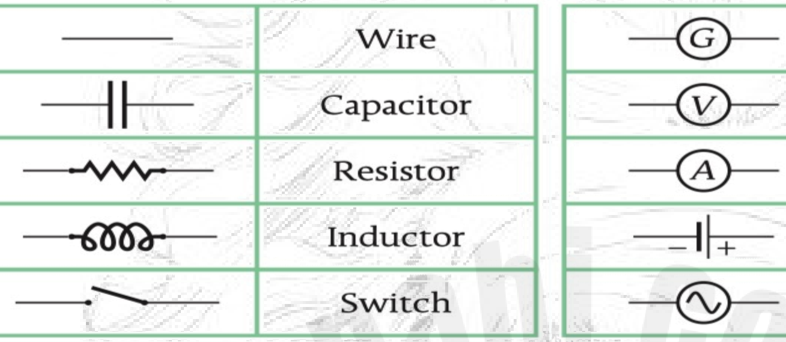
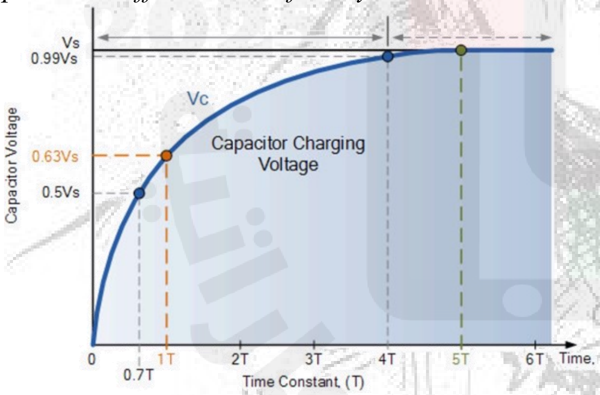


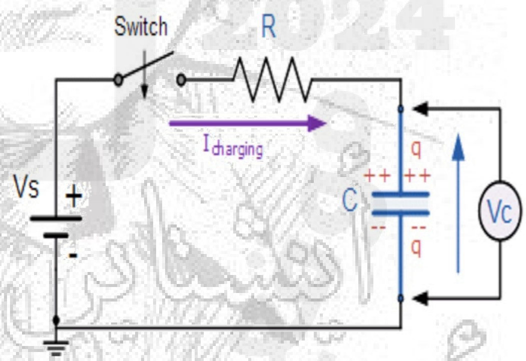
Figure shows the symbols for circuit elements

	Wire		Galvanometer
	Capacitor		Voltmeter
	Resistor		Ammeter
	Inductor		Battery
	Switch		AC source

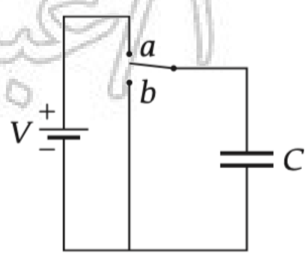
4.3Parallel plate capacitor and other types of capacitors

Charging a Capacitor
A capacitor is charged by connecting it to a battery or to a constant-voltage power supply to create a circuit. Charge flows to the capacitor from the battery or power supply until the potential difference across the capacitor is the same as the supplied voltage. If the capacitor is disconnected, it retains its charge and potential difference. A real capacitor is subject to charge leaking away over time. However, in this chapter, we'll assume that an isolated capacitor retains its charge and potential difference indefinitely.



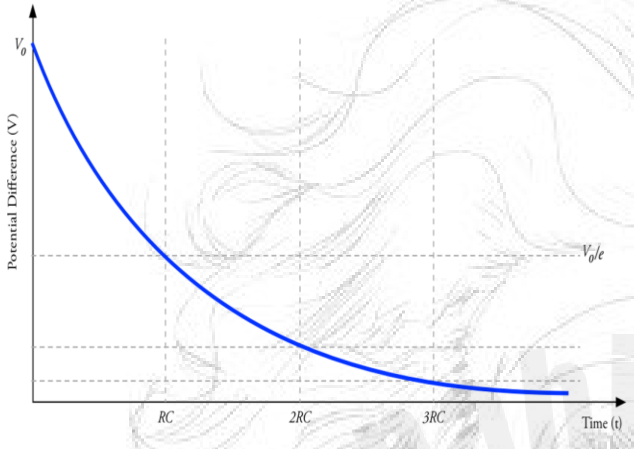


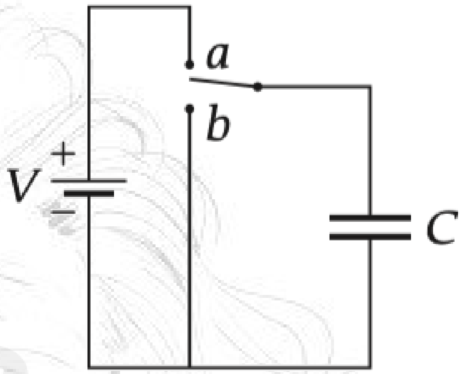
Charging a Capacitor
Figure illustrates this charging process with a circuit diagram. In this diagram,
- the ***lines*** *represent conducting wires.*
- The ***battery*** *(power supply) which is labeled with plus and minus signs indicating the potential assignments of the terminals and with the potential difference, V.*
- The ***capacitor*** *which is labeled C.*
- This circuit also contains a ***switch****. When the switch is between positions a and b, the battery is not connected, and the circuit is open. When the switch is at position a, the circuit is closed; the battery is connected across the capacitor, and the capacitor charges.*



Discharging a Capacitor

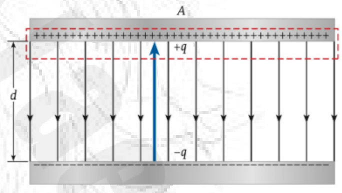
When the switch is at position b, the circuit is closed in a different manner. The battery is removed from the circuit, the two plates of the capacitor are connected to each other, and charge can flow from one plate to the other through the wire, which now forms a physical connection between the plates. When the charge has dissipated on the two plates, the potential difference between the plates drops to zero, and the capacitor is said to be discharged.





Uniform Electric field

This section examines how to determine the electric field strength between the plates and the potential difference between the two plates. Let's consider an ideal parallel plate capacitor in the form of a pair of parallel conducting plates in a vacuum with charge +q on one plate and charge -q on the other plate. When the plates are charged, the upper plate has charge +q and the lower plate has charge -q. The electric field between the two plates points from the positively charged plate downward toward the negatively charged plate.



The field near the ends of the plates, the fringe field can be neglected.

We can assume that the electric field is constant, with magnitude E, everywhere between the plates and zero elsewhere. The electric field is always perpendicular to the surface of the two parallel plates.

$$V = Ed$$

Notes

the capacitance of a parallel plate capacitor depends only on

the ***area*** *of the plates*

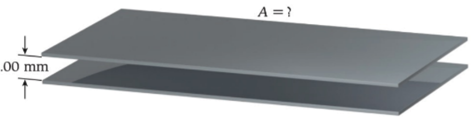
the ***distance*** *between the plates. In other words, only*

the geometry of a capacitor affects its capacitance.

The amount of charge on the capacitor or the potential difference between its plates does not affect its capacitance.

$$C = \frac{|Q|}{V} = \frac{\varepsilon_0 \times A}{d}$$

1. A parallel plate capacitor has plates that are separated by 1.00 mm. What is the area required to give this capacitor a capacitance of 1.00 F?



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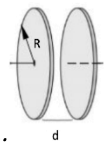
2. A capacitor with circular parallel plates of radius R that are separated by a distance d has a capacitance of C. If the plates had radius 2R and were separated by a distance $d/2$?
What would be the new capacitance?



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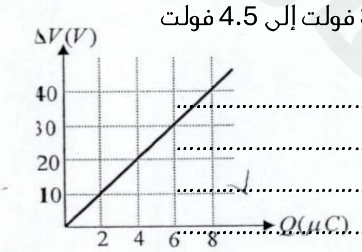
Decide if the variables are increasing or decreasing based on the following cases:

Capacitor is **disconnected** to the battery	Charge constant	Capacitance $C = \frac{\varepsilon_0 \times A}{d}$	Voltage $V = Q/C$	Electric field $E = V/d = q/dC$
Area doubled	***constant***			
Area reduced to half				
Separation Doubled				
Separation reduced to half				
Radius reduced to half				

The adjacent graph is based on represents the changes in potential difference between two plates of a capacitor in terms of the change in the amount of charge on each of its plates:
What is the capacitance of the capacitor.
What is the change in the electrical potential energy stored in the capacitor when the voltage between its plates changes from 3V to V4.5

يعتمد التمثيل البياني المجاور على تمثيل التغيرات في فرق الجهد بين لوحي مكثف بدالة التغير في كمية الشحنة على كل لوح من لوح:
ما السعة الكهربية للمكثف.
ما هو التغيُّر في طاقة الوضع الكهربي المخزَّنة في المكثِّف عندما يتغيَّر الجهد بين لوحيه من 3 فولت إلى 4.5 فولت



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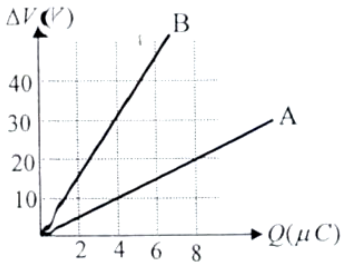
The graphical relationship between the change in charge of a capacitor and the potential difference between its terminals for capacitors A and B is shown in the diagram:
1) Which capacitor has more capacitance and why?
2) Calculate the ratio of the capacitance of capacitor (B) to the capacitance of capacitor (A).
3) Which capacitor stores more energy when the same potential difference is applied to it and why?

توضح العلاقة البيانية بين تغيرشحنة مكثف وفرق الجهد بين طرفيه لمكثفين (A)و (B) كما فى الشكل:



أ ى المكثفين سعته أكبر ولماذا؟
احسب نسبة سعة المكثف (B) إلى سعة (A) المكثف؟
أى المكثف يختزن طاقة أكبر عندما يطبق عليها نفس فرق الجهد؟ ولماذا؟

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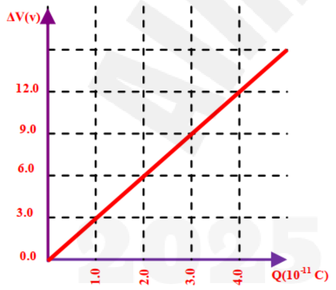
Flat capacitor charging by connecting its plates to a 12.0 V battery
The adjacent graph represents the curve of the potential difference between the two plates of the capacitor as its charge changes during the charging process. If the distance between the plates is (1.2mm:1- The area of the two plate of the capacitor.

مكثف مسطح يشحن عن طريق توصيل لوحيه ببطارية $12.0\ V$
يمثل التمثيل البياني المجاور منحنى فرق الجهد بين لوحي المكثف مع تغير شحنته أثناء عملية الشحن.
إذا كانت المسافة بين اللوحين $(1.2mm)$ ،1− مساحة صفيحتي المكثف.



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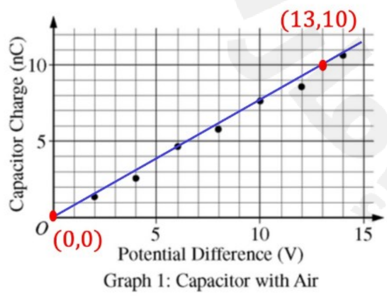
The adjacent graph is based on represents the changes in potential difference between two plates of a capacitor in terms of the change in the amount of charge on each of its plates:
What is the capacitance of the capacitor.

يعتمد التمثيل البياني المجاور على تمثيل التغيرات في فرق الجهد بين لوحي مكثف بدلالة التغير في كمية الشحنة على كل لوح من لوح:
ما السعة الكهربية للمكثف.



Graph 1: Capacitor with Air

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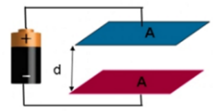
According to the figure of parallel plate capacitor, if (A=0.02m²) and $1.77 \times 10^{-12} F$
What is the distance d



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According to the figure of parallel plate capacitor, if(A=0.01m²) and (d=0. 10m)
What is the capacitance (C)

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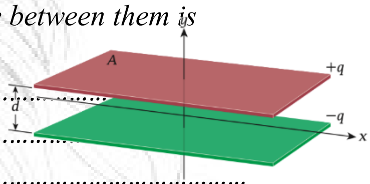
in vacuum consisting of two conducting plates, each having area A and opposite charges, separated by a distance d. If the electric potential difference between the two plates of the capacitor is 8V
What is electric potential difference between the two plates when the distance between them is equal to (0.5d)



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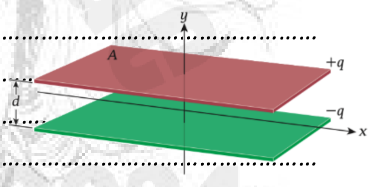
According to the figure, a parallel plate capacitor in vacuum consists of two conducting plates, each having area A and opposite charges, separated by a distance d. If the electric potential difference between the two plates of the capacitor is (8.0V). What is the electric potential difference between the two plates, when the distance between them is equal to (2d)?



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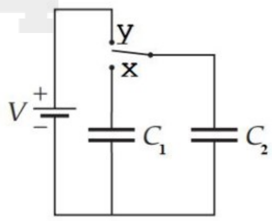
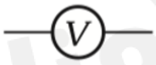
The circuit below contains a battery and two capacitors with the same capacitance. If the switch was closed in (y) for a period of time then it was closed in (x),
What is correct about the charge of each of the capacitors after the switch is closed in (x)?



$q_1 = q_2 \neq 0$ $q_1 = q_2 = 0$ $q_1 = 0,\ q_2 \neq 0$ $q_1 \neq 0,\ q_2 = 0$

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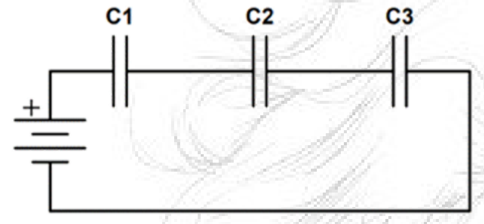
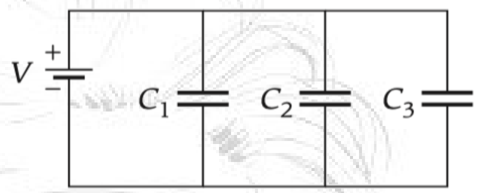
4 Capacitors in circuits

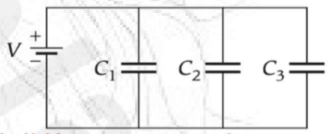
*Capacitors can be wired in circuits in different ways, but the two most fundamental ones are **parallel** connection and **series** connection.*

Series capacitor circuit	Parallel capacitor circuit
	
Charge divider (constant voltage)	Voltage divider (constant charge)

- ***Capacitors in Parallel***

*Capacitors in **parallel** have the same **potential difference**, which is the same value that their equivalent capacitor has.*

Figure shows a circuit with three capacitors in parallel connection.



*Each of the three capacitors has one plate wired directly to the positive terminal of a battery with **potential difference V and** one plate wired directly to the negative terminal of that battery **potential difference** V = 0*

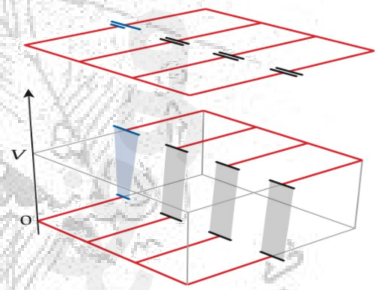
all capacitor plates connected to the positive terminal of the battery are at the same potential. The other plates of the capacitors are all at the potential of the negative terminal of the battery.

The key insight provided by Figure is that the potential difference across each of the three capacitors is the same ΔV. Thus, for the three capacitors in this circuit, we have

$$q_1 = C_1 \Delta V$$

$$q_2 = C_2 \Delta V$$

$$q_3 = C_3 \Delta V$$



*In general, the charge on each capacitor can have a different value. The three capacitors can be viewed as **one equivalent capacitor** that holds a total charge q, given by:*

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

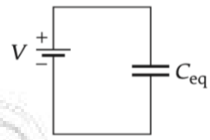
Thus, the equivalent capacitance for this capacitor is:

$$C_{eq} = C_1 + C_2 + C_3 .$$

This result can be extended to any number, n, of capacitors connected in parallel:

$$C_{eq} = \sum_{i=1}^{n} C_i$$

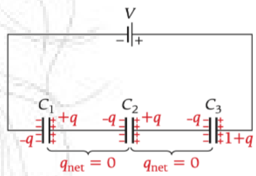
*The equivalent capacitance of a system of capacitors in parallel is **the sum of the capacitances**. So, several capacitors in parallel in a circuit can be replaced with an equivalent capacitance as shown in Figure.*



*The total capacitance of two capacitors connected in parallel is **greater** the greatest value capacitor*

- ***Capacitors in Series***

*Capacitors in **series** have **the same charge**, which is the same value that their equivalent capacitor has.*
Figure shows a circuit with three capacitors in series connection. In this configuration, the battery produces an equal charge of +q on the right plate of each capacitor and an equal charge of -q on the left plate of each capacitor.

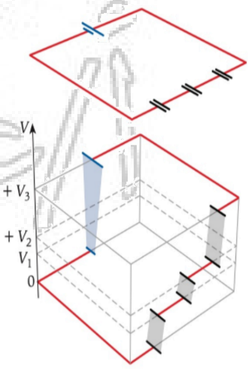


The battery is then connected to the series arrangement of the three capacitors.
*The positive plate of C3 is connected to the positive terminal of the battery and begins to collect positive charge supplied by the battery. This positive charge **induces** a negative charge of equal magnitude onto the other plate of C3.*

The negatively charged plate of C3 is connected to the right plate of C2, which then becomes positively charged because no net charge can accumulate on the isolated section consisting of the left plate of C3 and the right plate of C2. The same will happen to C2 and C1

*charge flows from the battery, charging the positive plate of C3 to a charge of value +q, and inducing a corresponding charge of -q on the negatively charged plate of C1. Therefore, **each capacitor does indeed end up with the same charge.***
The key insight provided by Figure is that the charge on each of the three capacitors is the same. Thus, for the three capacitors in this circuit, we have the sum of the potential drops across all three equal the potential difference supplied by the battery.

The sum of the potential drops across all three equal the potential difference supplied by the battery
The equivalent capacitance can be written as:



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

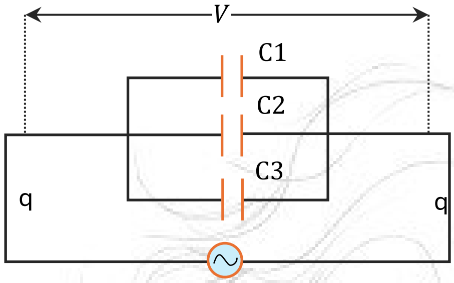
$$\Delta V = \frac{q}{C_{eq}},$$

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

(2)Connection in parallel | **connected in series**

Purpose

◄ *to Get* (*C*) *large capacity.*



If the capacitors are connected in parallel:

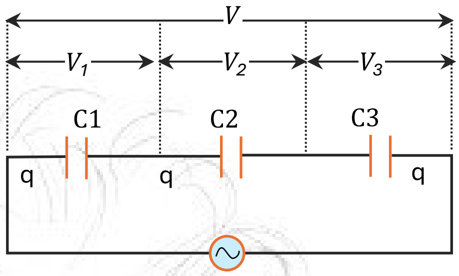
The potential difference is equal, and the charge is divided.

$\because Q_T = Q_1 + Q_2 + Q_3$

$\therefore VC_T = VC_1 + VC_2 + VC_3$

$$C_T = C_1 + C_2 + C_3$$

◄ *to Get* (*C*) *a small capacity.*



If the capacitors are connected in series:

The capacitors are charged with equal charges and the voltage is divided.

$V_T = V_1 + V_2 + V_3$

$\frac{Q_T}{C_T} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

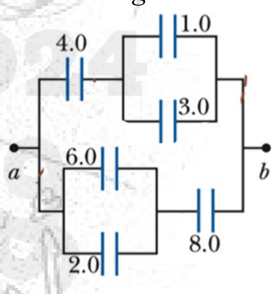
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

If the capacitors are of equal capacitance (C) and number (n)

Parallel: $C_T = n\,C_1$

Series: $C_T = \frac{C_1}{n}$

Find the equivalent capacitance between a and b for the combination of capacitors shown in Figure All capacitances are in microfarads.



a. $C_{eq} = C_1 + C_2 = 4.0\ \mu F$

b. $C_{eq} = C_1 + C_2 = 8.0\ \mu F$

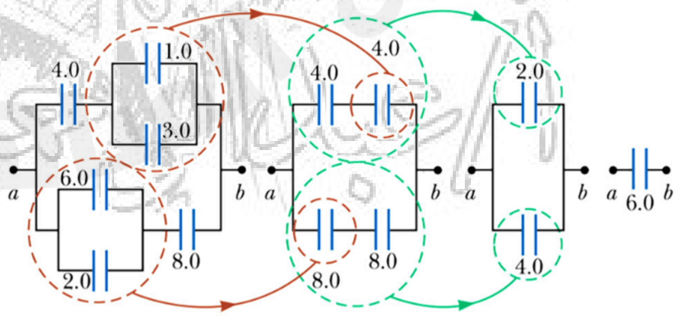
c. $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{4.0\ \mu F} + \frac{1}{4.0\ \mu F} = \frac{1}{2.0\ \mu F}$

$C_{eq} = 2.0\ \mu F$

d. $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{8.0\ \mu F} + \frac{1}{8.0\ \mu F} = \frac{1}{4.0\ \mu F}$

$C_{eq} = 4.0\ \mu F$

e. $C_{eq} = C_1 + C_2 = 6.0\ \mu F$



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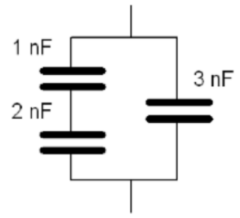
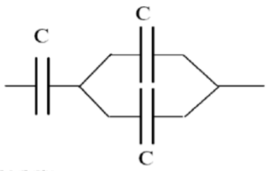
What is the equivalent capacitance for the three capacitors shown below?

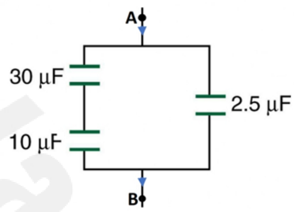
1.



2.



3.



4.