Capacitance

and Capacitors

Capacitance

I. Basic Concepts
- definition
- steady state behavior

II. Capacitor Design
- capacitance vs. geometry
- materials & dielectrics

III. RC Circuits
- dynamic behavior
- charging/discharging

	The student will be able to:	HW:
1	Define and calculate capacitance in terms of voltage and charge and solve related problems.	1 – 3
2	Solve steady-state problems involving series and parallel connections of capacitors and batteries.	4 – 6
3	Solve problems relating capacitance to geometry and dielectrics for parallel plate, cylindrical, and spherical capacitors.	7 – 17
4	Analyze RC circuits in terms of the appropriate differential equation and resulting exponential functions for charge, current, voltage, etc.	18 – 22

Capacitance refers to an electrical device's ability to store or retain charge. Capacitance is defined as the ratio of charge to voltage. This ratio specifies the relative charge capacity of the device.

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

where: C = capacitance
Q = charge
V = potential difference

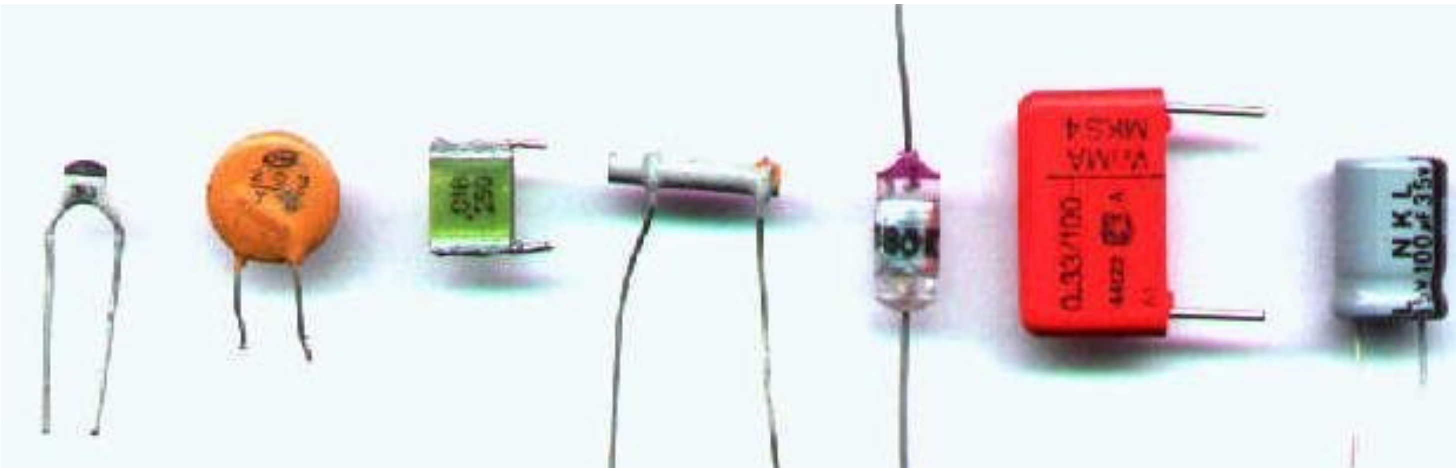
Capacitance – SI Units

1 farad = 1 coulomb per volt

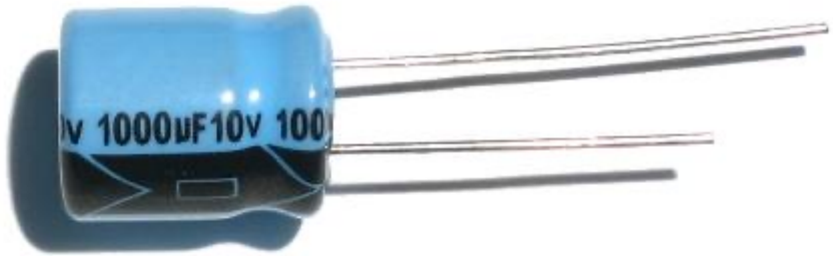
$$1\,\mathrm{F} = 1\,\frac{\mathrm{C}}{\mathrm{V}}$$

Typical capacitors have values in microfarads, nanofarads, or picofarads.

A **capacitor** is an electrical device designed specifically to provide a certain amount of capacitance. It consists of two conducting surfaces separated by an insulating material.



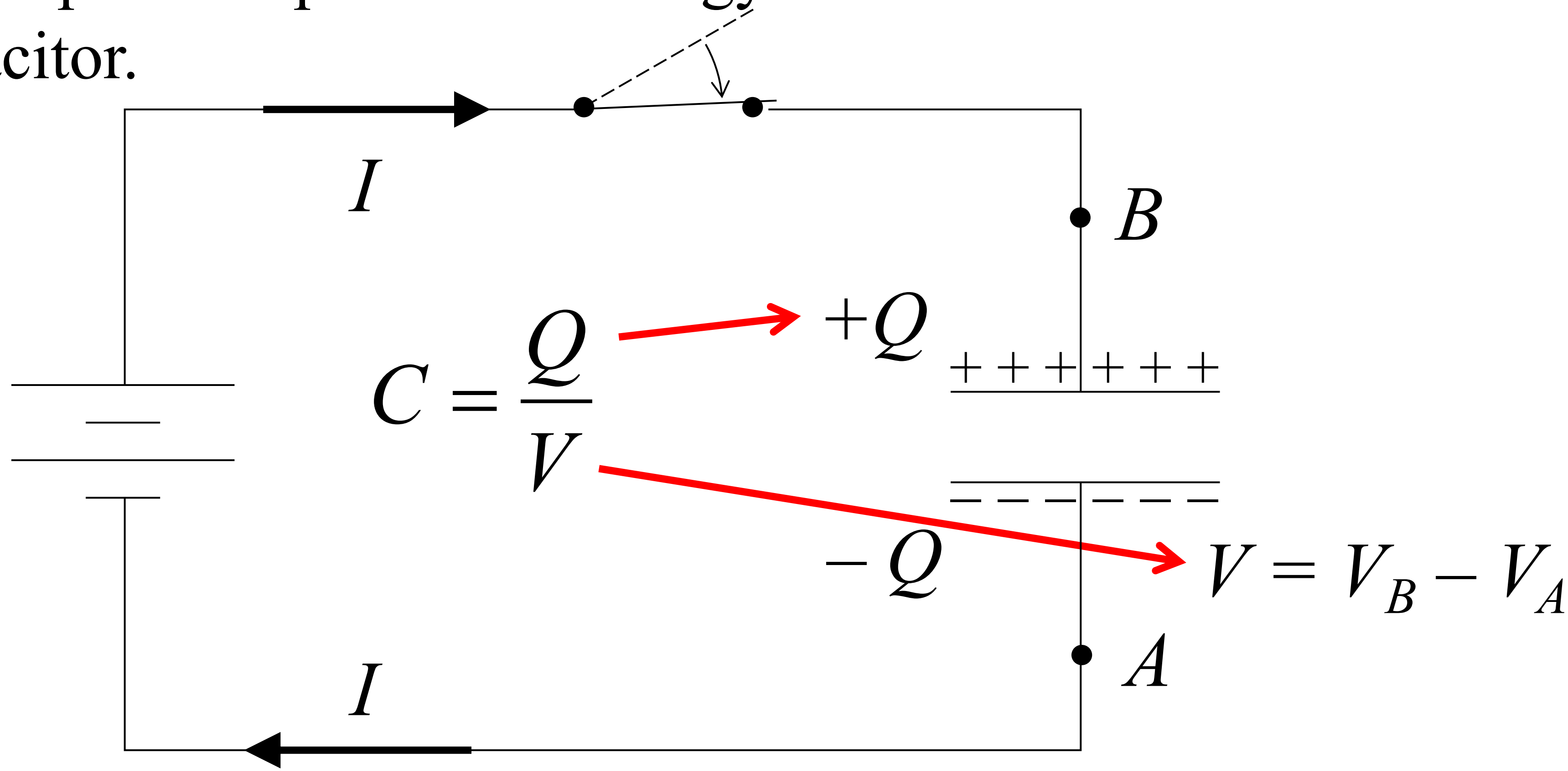
As voltage is applied to the two leads, equal and opposite charges develop on the two conducting surfaces within the capacitor.



electrolytic
capacitor

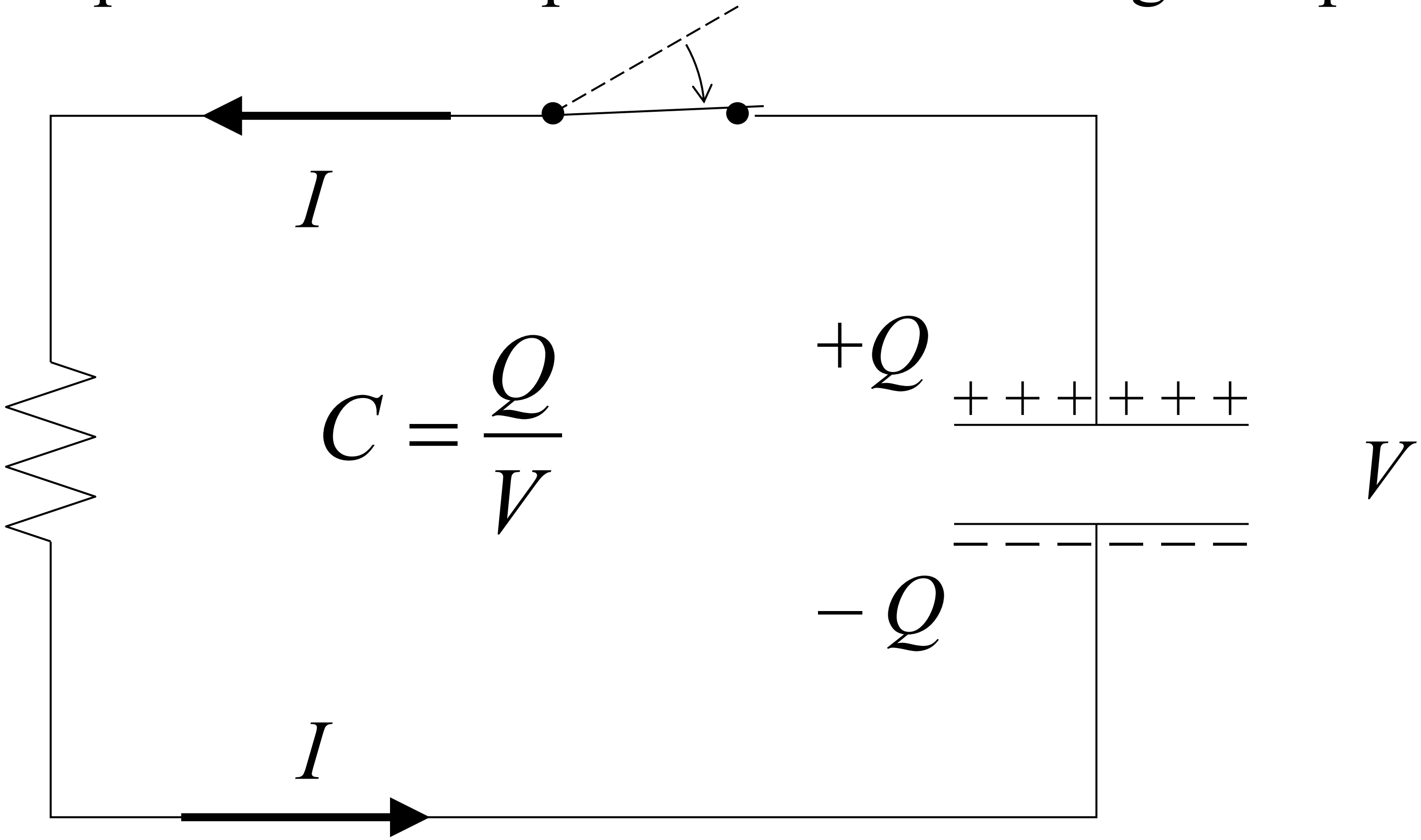
parallel plate
capacitor

When switch is closed equal current flows on both sides of the capacitor causing equal and opposite charge of amount Q to develop on the plates and energy to transfer from cell to capacitor.



At all times the ratio of charge Q to voltage V is constant and equal to the particular capacitance C, which depends on the characteristics of the capacitor design and materials.

When connected to a resistance the capacitor acts as a source of energy, potential, and current. The current depletes charge from both plates of the capacitor and its voltage drops.



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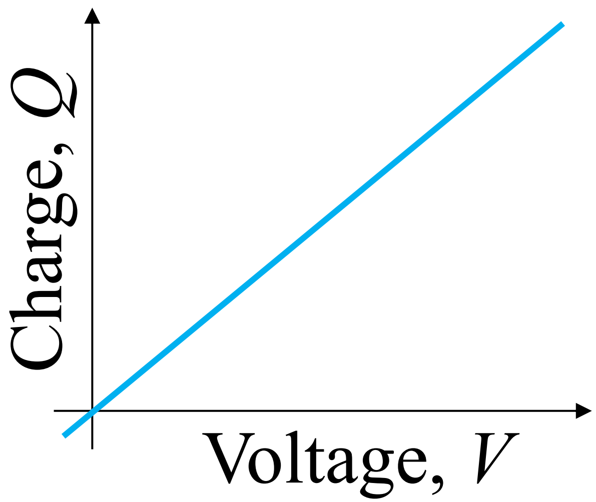
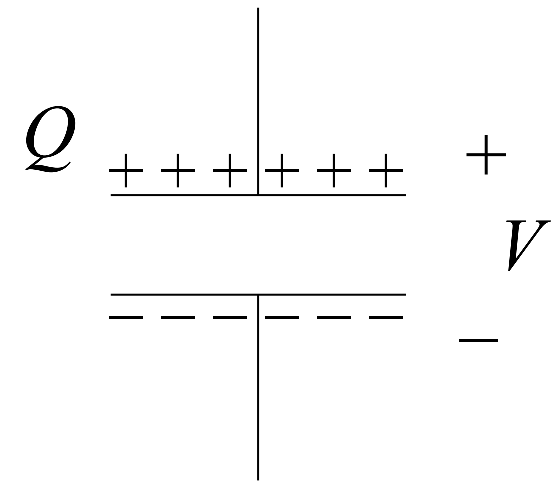
Behavior of a Capacitor in a Circuit





- The ratio $Q/V = C$ remains constant at all times!
- "Charging" a capacitor, the value of Q increases until the increased voltage prevents further current.
- "Discharging" a capacitor, the value of Q decreases until the decreased voltage is insufficient to cause any further current.

The energy stored in a capacitor depends on the amount of charge stored and the potential difference across the two terminals.

$$U = \frac{1}{2} C V^2$$

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

where: U = potential energy
C = capacitance
Q = charge
V = potential difference

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Behavior of Capacitors in Circuits: Charging

- If the charge amount is zero then voltage across a capacitor must be zero also – charge can "readily" flow to and from the plates.
- As plates become oppositely charged, it is as if a "current passes through" a capacitor (in spite of the gap inside).
- As charge builds up, so does the voltage and potential energy, and forces oppose the addition of more charge to the plates and current decreases.
- At some point, depending on the circuit, a voltage is reached that prevents further charge buildup and current drops to zero – a state of equilibrium.

Behavior of Capacitors in Circuits: Discharging

- A charged capacitor is a source of electric potential and energy and can drive current through a circuit somewhat like a battery.
- Unlike a battery, the voltage does not have any tendency to remain constant as current flows.
- As charge decreases so does the voltage and potential energy, and the forces causing the discharge lessen, decreasing the current.
- Discharge will continue until a new equilibrium voltage is reached, at which point forces tending to send charge into the capacitor are balanced with forces tending to send charge out.

The effective of equivalent capacitance of multiple connected capacitors:

parallel

$$C_{eq} = C_1 + C_2 + C_3 + \ldots$$

series

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