PHY-112

Principles of Physics-II

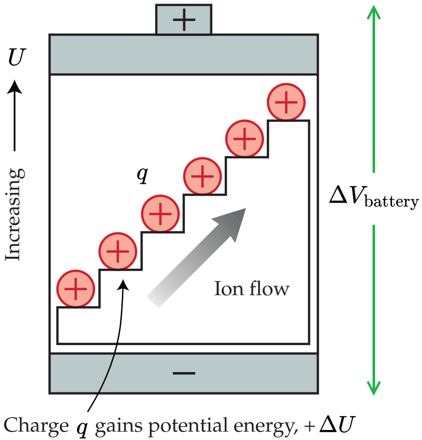
Akiful Islam (AZW)

Spring-24 | Class-12

$$\Delta V = V_{\text{pos}} - V_{\text{neg}} = -\int E_r dr$$

- An electric potential difference is created by separating positive and negative charges.
- A **Battery** does that by using *chemical reactions* to separate charges. The process is called *Electrolysis*.
- It pulls positive and negative charges apart, creating a potential difference between the terminals of the battery.
- When the chemicals are used up, the reactions cease, and the battery is *dead*.

Charge Escalator model of a Battery and its EMF

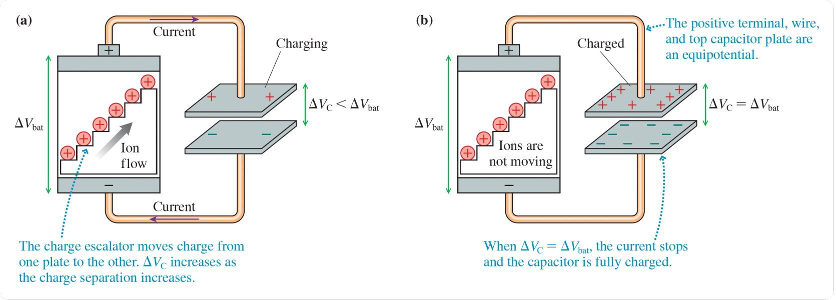


Charge Escalator model of a Battery and its EMF

- The charge escalator lifts positive charges from the negative terminal to the positive terminal. This requires *work*, with the energy being supplied by the chemical reactions.
- The work done per charge is called the Electromotive Force (EMF) of the battery: $\mathcal{E} = \dfrac{W_{\text{chem}}}{q}$.
- The charge separation creates a potential difference $\Delta V_{\text{battery}}$ between the terminals. An ideal battery has $\Delta V_{\text{battery}} = \mathcal{E}$. It is measured in Volt [V] unit.
- **Limitations**: $\Delta V_{\text{battery}} < \mathcal{E}$ if current flows through the battery. The difference is usually small, and a battery can be considered ideal for simplicity.

Capacitance and Capacitors

How to Create a Capacitor?



What is Capacitance of a Capacitor?

$$C = \frac{Q}{\Delta V_C} = \frac{\epsilon_0 E A}{E d} = \frac{\epsilon_0 A}{d}$$

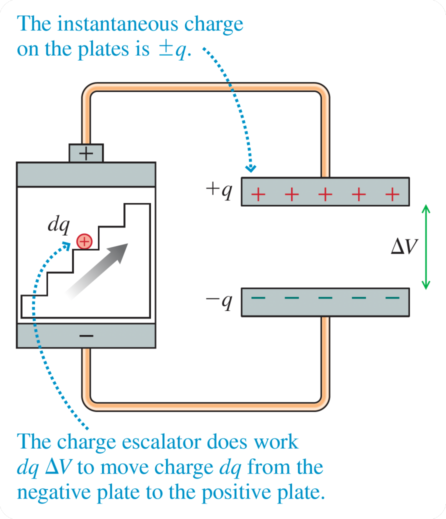
Capacitance of a Capacitor

- measures the capacity of storing energy, not charge.
- is a scalar; measured in $\mathrm{C\,V^{-1}}$, or commonly, **Farad** [F] unit.
- typically μF or nF is used in practice.
- stores energy in the $\vec{E}$-field in between the plates.

Q: The spacing between the plates of a 1.0 mF capacitor is 0.050 mm.

- What is the surface area of the plates?
- How much charge is on the plates if this capacitor is charged to 1.5 V?

The Energy Stored in a Capacitor



The Energy Stored in a Capacitor

$$dU = dq\Delta V_C = dq\frac{q}{C}$$

$$U_C = \int dU = \frac{1}{C}\int_0^Q q dq$$

$$U_C = \frac{Q^2}{2C}$$

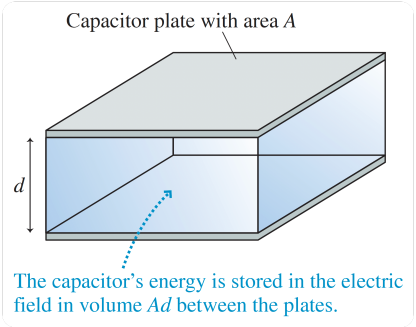
The Energy Stored in a Capacitor

$$U_C = \frac{Q^2}{2C} = \frac{1}{2} Q \Delta V_C = \frac{1}{2} C \Delta V_C^2$$

Testing Concepts (2)

Q: How much energy is stored in a $220\,\mathrm{mF}$ camera-flash capacitor that has been charged to $330\,\mathrm{V}$?

The Energy Stored in a Capacitor



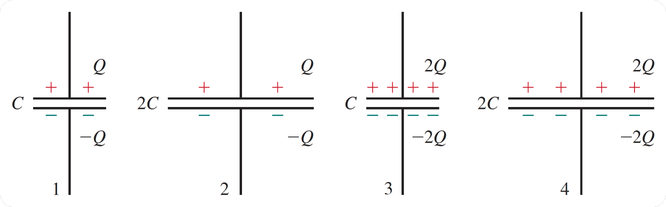
$$U_C = \frac{1}{2} C \Delta V_C^2 = \frac{1}{2} \times \frac{\epsilon_0 A}{d} \times (Ed)^2 = \frac{\epsilon_0}{2} \times (Ad) \times E^2$$

The Energy Density in an Capacitor

$$\text{Energy,} \quad U_C = \frac{1}{2}\epsilon_0 V E^2 \quad [\mathsf{J}]$$

$$\text{Energy Density,} \quad u_C = \frac{U_C}{V} = \frac{1}{2}\epsilon_0 E^2 \quad [\mathsf{J\,m}^{-3}]$$

Q: Of the four capacitors (All four are kept at d separation), rank in order, from largest to smallest,



- the potential differences $(\Delta V_C)_1$ to $(\Delta V_C)_4$
- the maximum storable energies U_1 to U_4