PHY152H1S Practicals Week 5 Presentation

“Capacitance”: What is it???

I have a supercapacitor whose capacitance is 1 Farad. This means

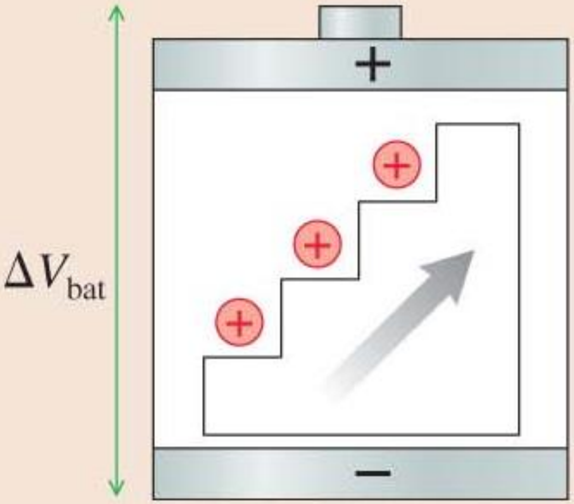
A. a current of 1 Amp flows through it when 1 Volt is applied across it.
B. 1 Coulomb is separated by 1 metre.
C. 1 Joule flows through it in 1 second.
D. it holds 1 Coulomb when 1 Volt is applied across it.
E. it attracts 1 Coulomb of charge with a force of 1 Newton.

The "charge escalator" model of a DC battery.

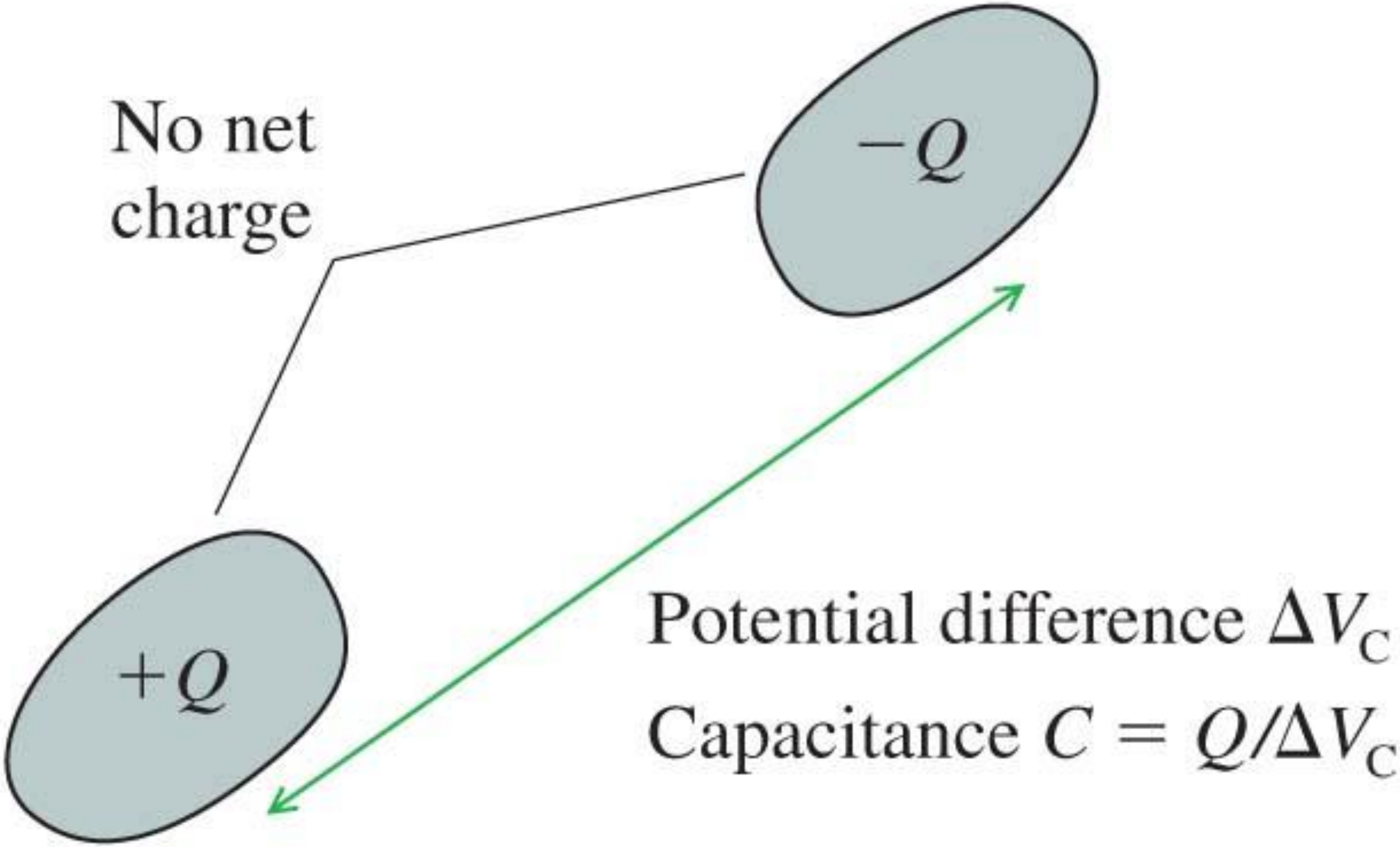
A **battery** is a source of potential. The charge escalator in a battery uses chemical reactions to move charges from the negative terminal to the positive terminal:

$$\Delta V_{\text{bat}} = \mathcal{E}$$

where the emf $\mathcal{E}$ is the work per charge done by the charge escalator.



Any two conducting objects separated by an insulator form a capacitor.



Capacitance and Capacitors

The ratio of the charge Q to the potential difference ΔV_C is called the **capacitance** C:

$$C \equiv \frac{Q}{\Delta V_C} = \frac{\epsilon_0 A}{d} \qquad \text{(parallel-plate capacitor)}$$

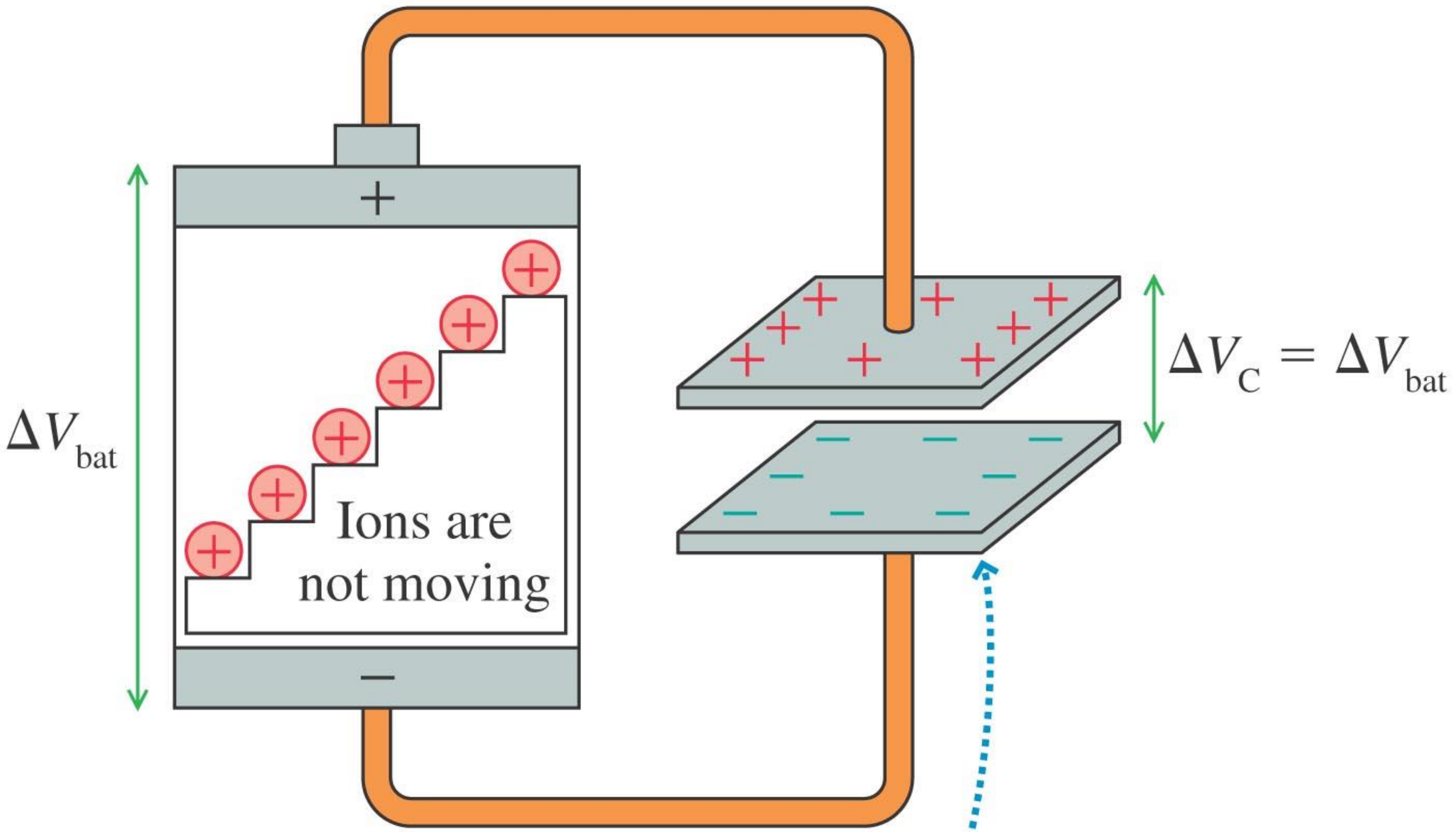
Capacitance is a purely *geometric* property of two electrodes because it depends only on their surface area and spacing. The SI unit of capacitance is the **farad**:

1 farad = 1 F = 1 C/V.

The charge on the capacitor plates is directly proportional to the potential difference between the plates.

$$Q = C\Delta V_C \qquad \text{(charge on a capacitor)}$$

Equilibrium in a simple circuit with a battery and a parallel plate capacitor:

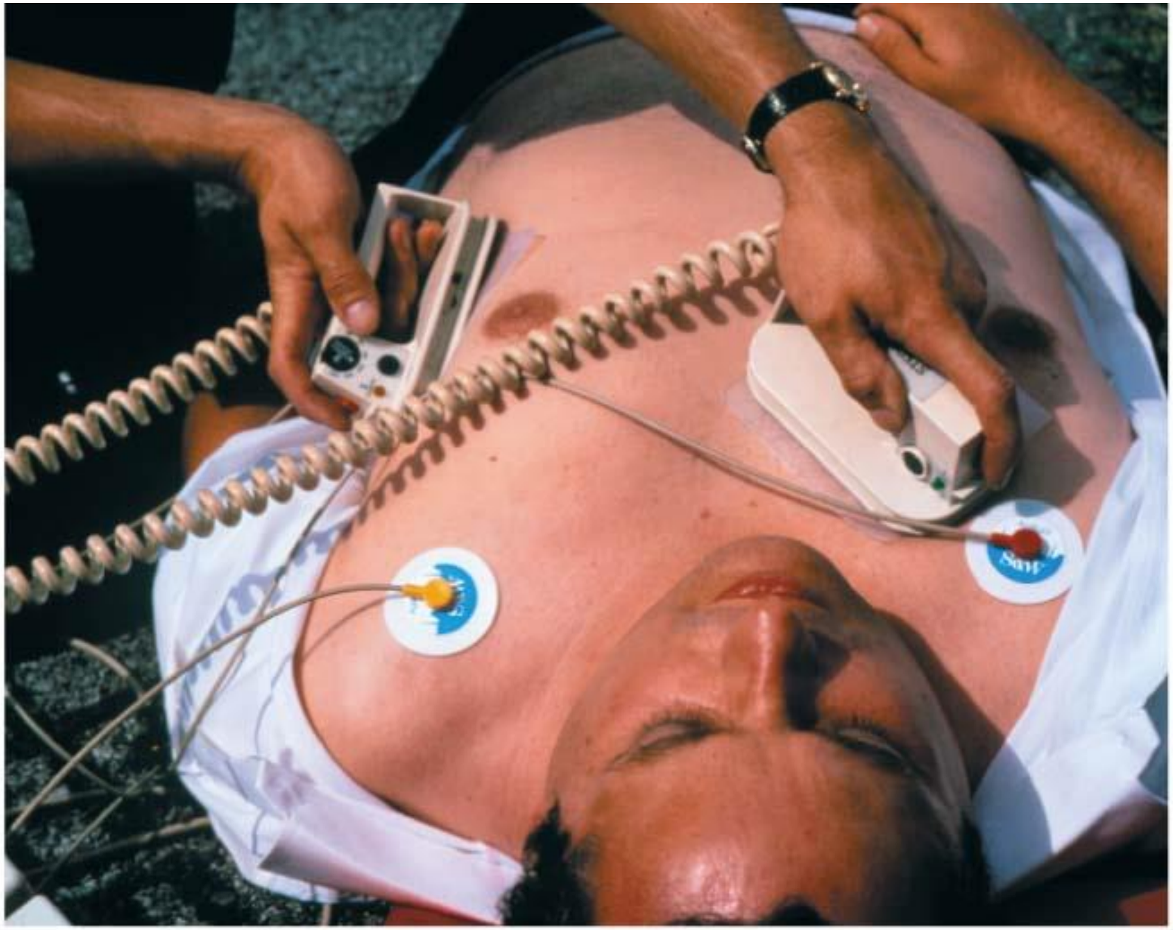


When $\Delta V_C = \Delta V_{bat}$, the current stops and the capacitor is fully charged.

The Energy Stored in a Capacitor

- Capacitors are important elements in electric circuits because of their ability to store energy.
- The charge on the two plates is $\pm Q$ and this charge separation establishes a potential difference $\Delta V = Q/C$ between the two electrodes.
- In terms of the capacitor's potential difference, the potential energy stored in a capacitor is

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



A defibrillator, which can restore a normal heartbeat, discharges a capacitor through the patient's chest.

RC Circuits

- Consider a charged capacitor, an open switch, and a resistor all hooked in series. This is an *RC* Circuit.
- The capacitor has charge Q_0 and potential difference $\Delta V_C = Q_0/C$.
- There is no current, so the potential difference across the resistor is zero.
- At $t = 0$ the switch closes and the capacitor begins to discharge through the resistor.
- The capacitor charge as a function of time is

$$Q = Q_0 e^{-t/\tau}$$

where the time constant τ is

$$\tau = RC$$

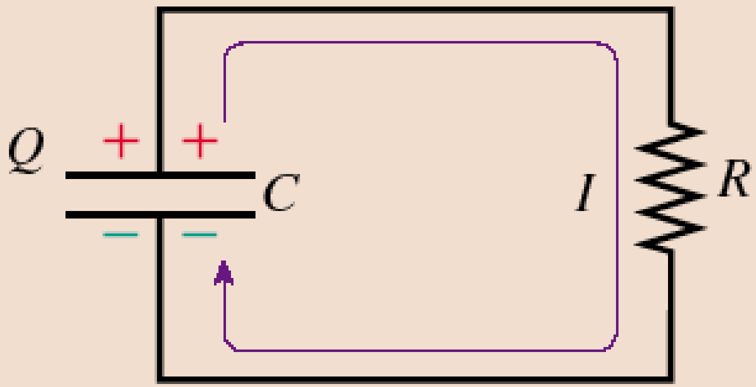
RC circuits

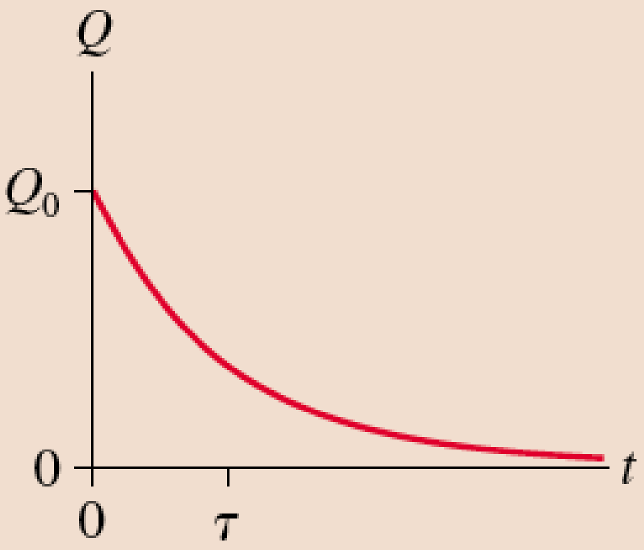
The discharge of a capacitor through a resistor satisfies:

$$Q = Q_0 e^{-t/\tau}$$

$$I = -\frac{dQ}{dt} = \frac{Q_0}{\tau} e^{-t/\tau} = I_0 e^{-t/\tau}$$

where $\tau = RC$ is the **time constant.**





1 Ohm × 1 Farad = 1 second.