Class 12: Outline

Hour 1:

Working with Circuits

Expt. 4. Part I: Measuring V, I, R

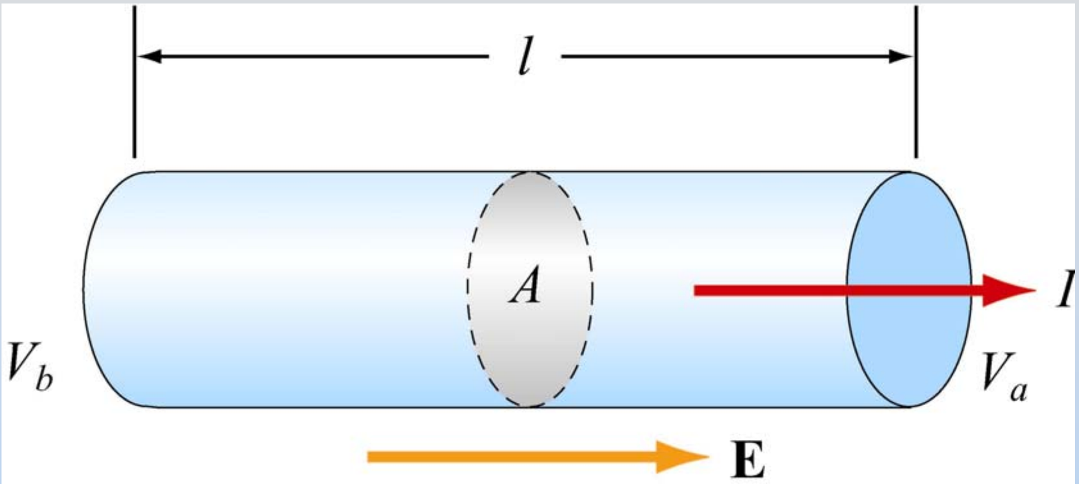
Hour 2:

RC Circuits

Expt. 4. Part II: RC Circuits

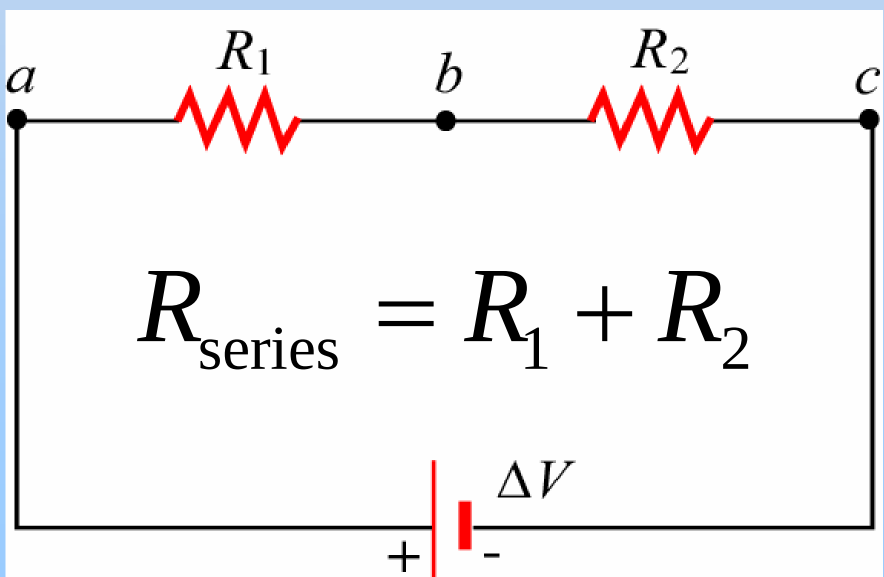
Last Time:
Resistors & Ohm's Law

Resistors & Ohm's Law

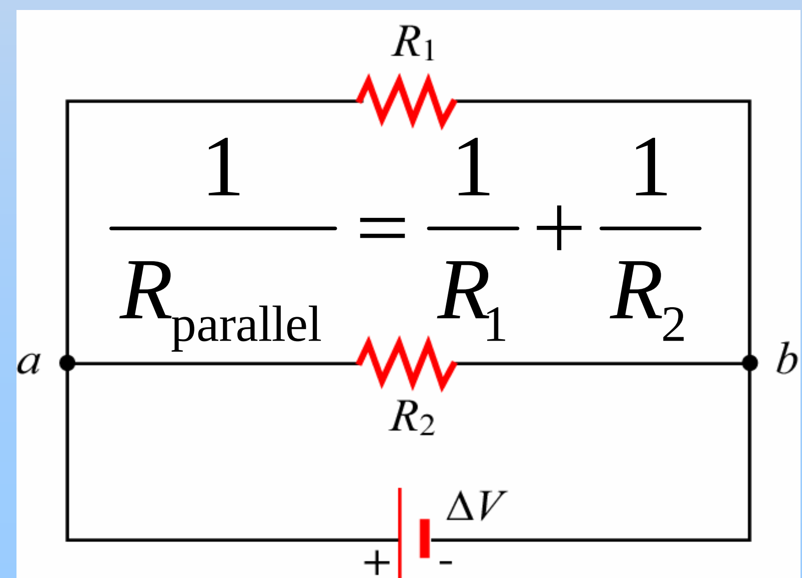


$$R = \frac{\rho \ell}{A}$$

$$\Delta V = IR$$



$$R_{\text{series}} = R_1 + R_2$$

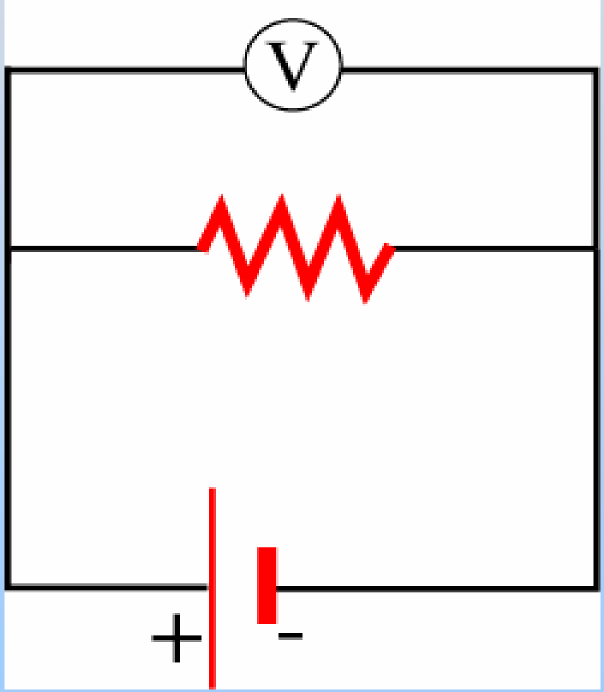


$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Measuring Voltage & Current

Measuring Potential Difference

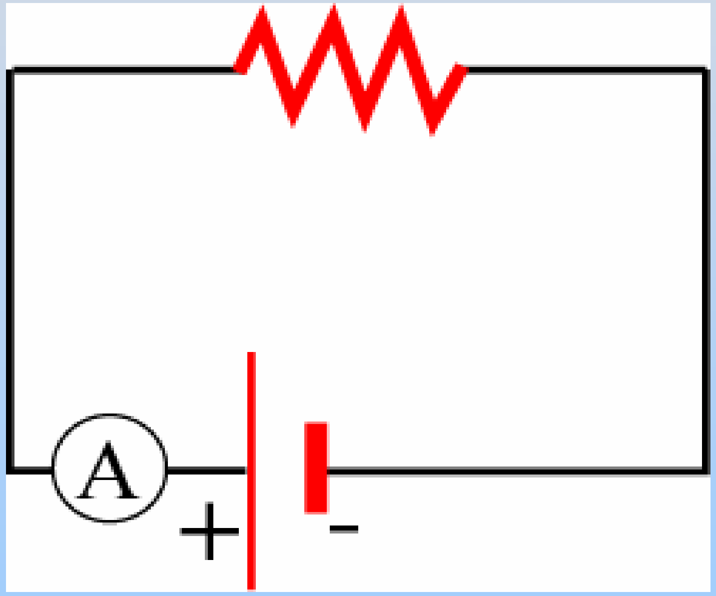
A voltmeter must be hooked in *parallel* across the element you want to measure the potential difference across



Voltmeters have a very large resistance, so that they don't affect the circuit too much

Measuring Current

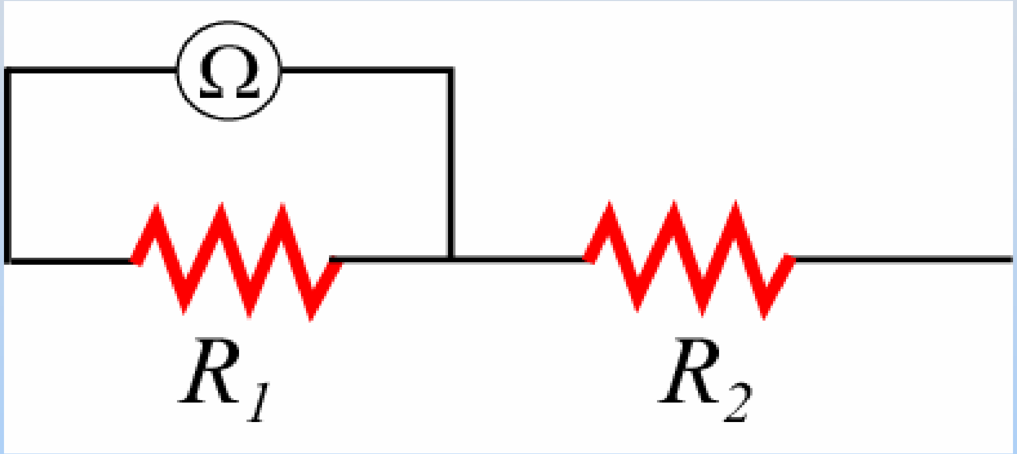
An ammeter must be hooked in *series* with the element you want to measure the current through



Ammeters have a very low resistance, so that they don’t affect the circuit too much

Measuring Resistance

An ohmmeter must be hooked in *parallel* across the element you want to measure the resistance of



Here we are measuring R_1

Ohmmeters apply a voltage and measure the current that flows. They typically won't work if the resistor is powered (connected to a battery)

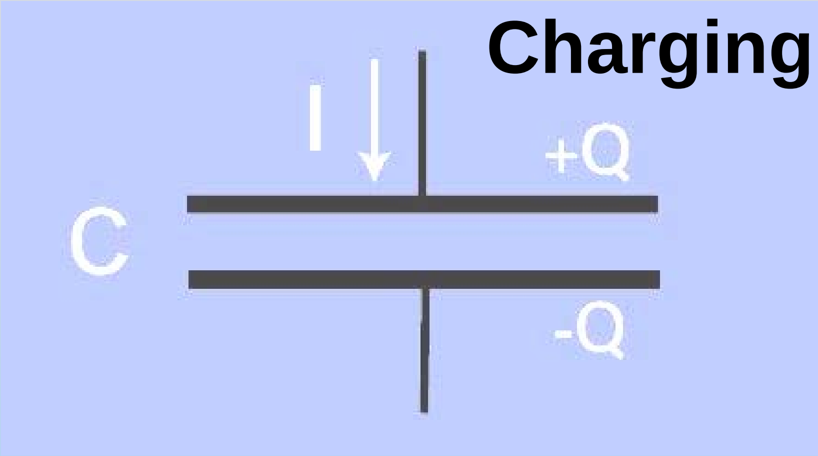
Experiment 4:
Part 1: Measuring V, I & R

RC Circuits

(Dis)Charging a Capacitor

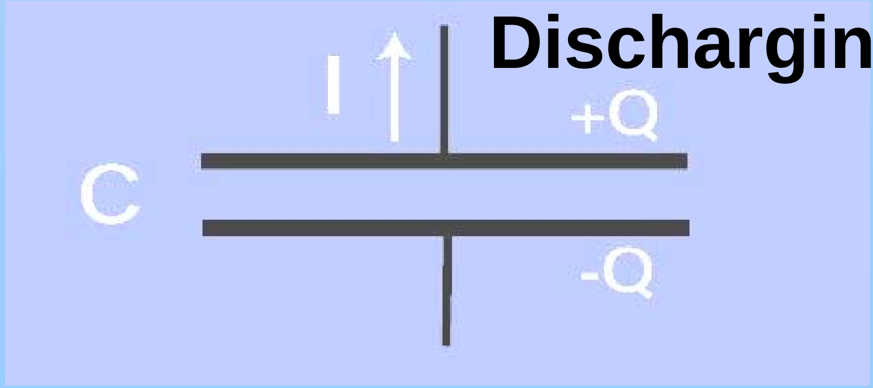
1. When the direction of current flow is toward the positive plate of a capacitor, then

$$I = +\frac{dQ}{dt}$$

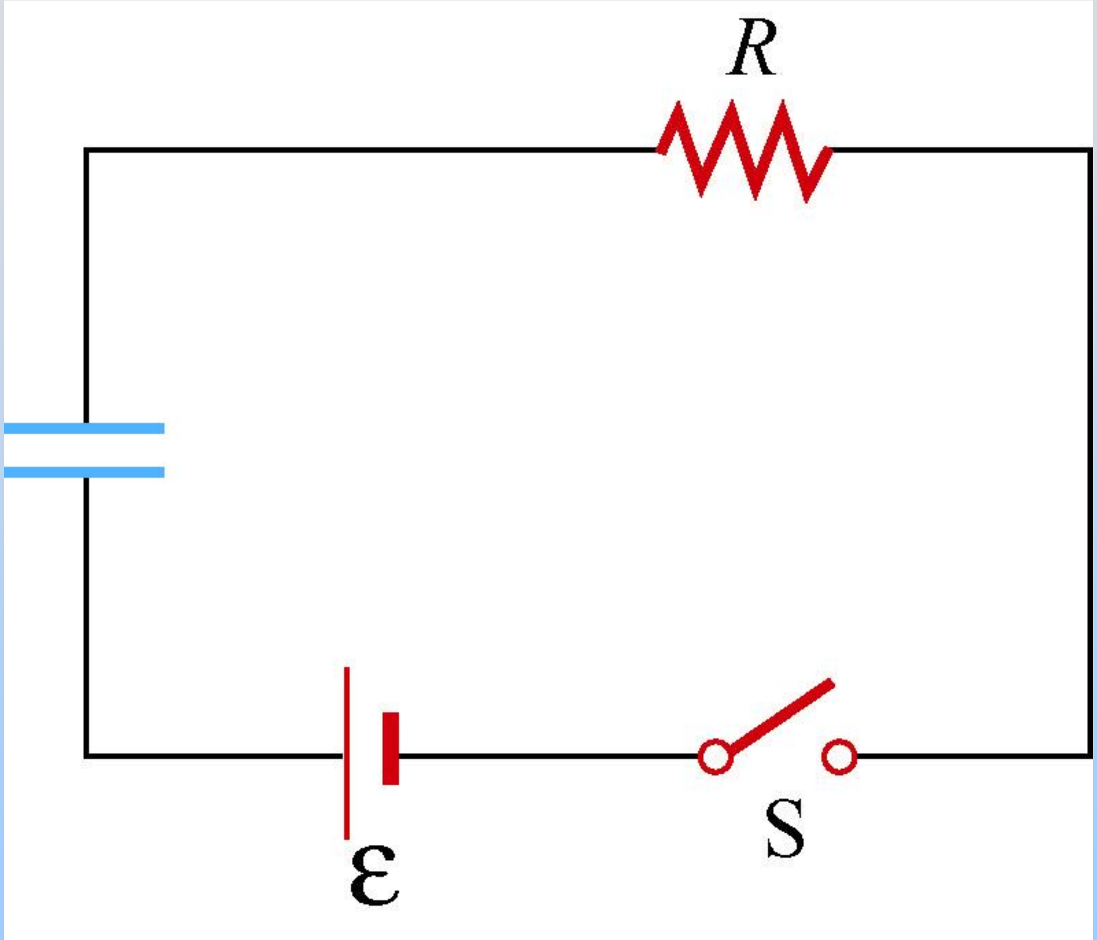


2. When the direction of current flow is away from the positive plate of a capacitor, then

$$I = -\frac{dQ}{dt}$$

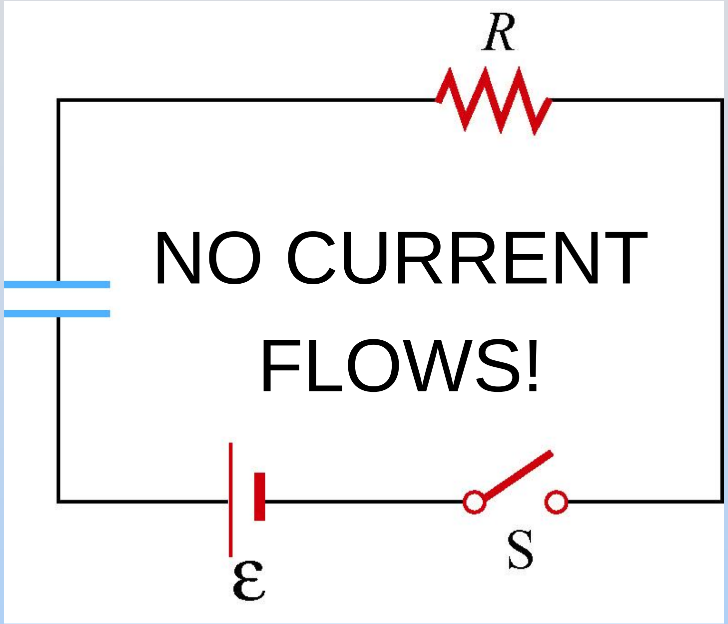


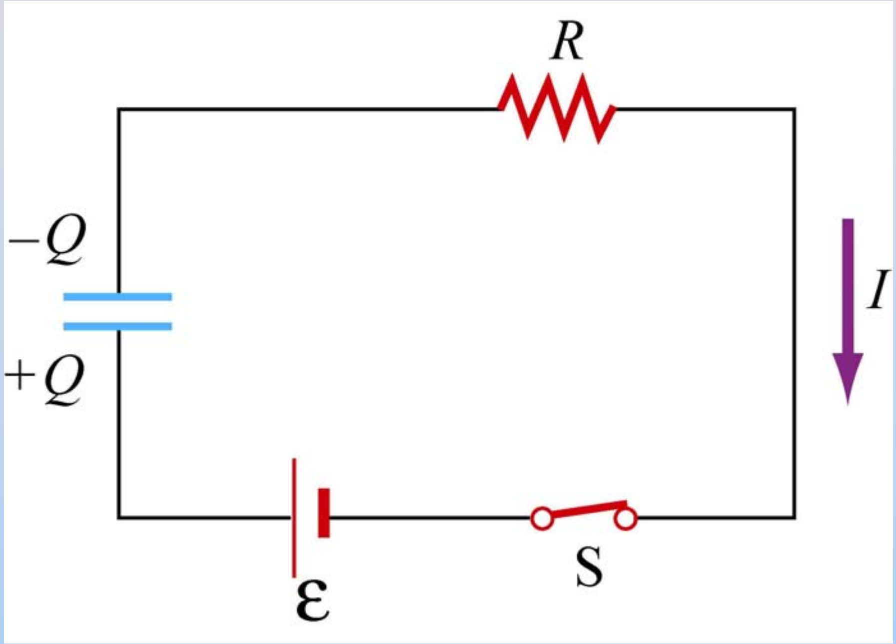
Charging A Capacitor



What happens when we close switch S?

Charging A Capacitor

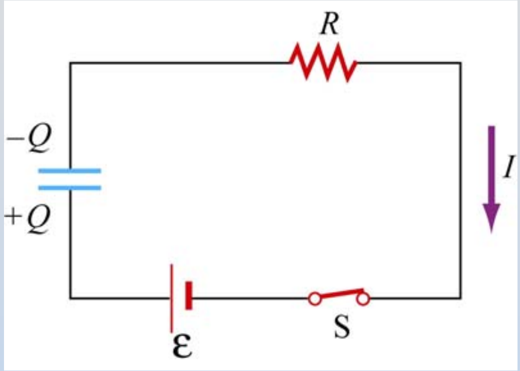




1. Arbitrarily assign direction of current
2. Kirchhoff (walk in direction of current):

$$\sum_i \Delta V_i = \varepsilon - \frac{Q}{C} - IR = 0$$

Charging A Capacitor



$$\varepsilon - \frac{Q}{C} = \frac{dQ}{dt}R \Rightarrow \frac{dQ}{Q - C\varepsilon} = -\frac{dt}{RC}$$

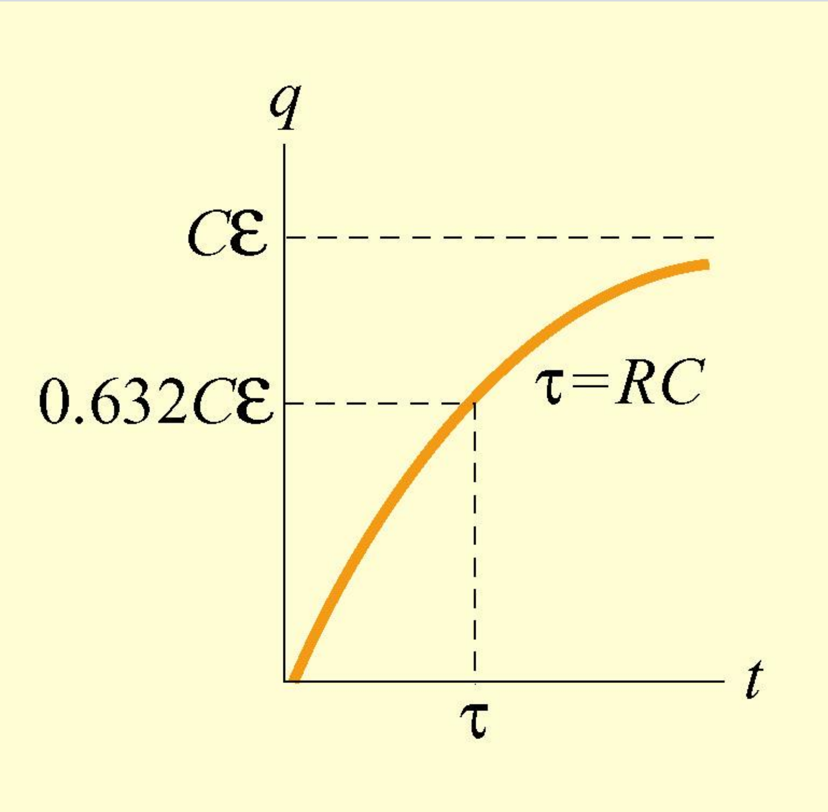
$$\int_0^Q \frac{dQ}{Q - C\varepsilon} = -\int_0^t \frac{dt}{RC}$$

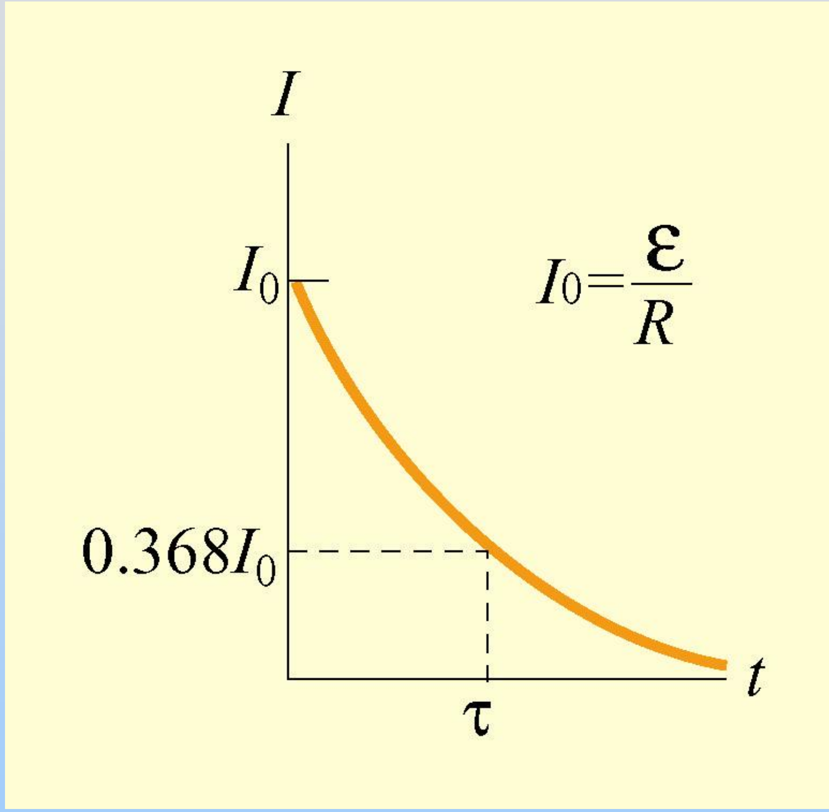
A solution to this differential equation is:

$$Q(t) = C\varepsilon\left(1 - e^{-t/RC}\right)$$

RC is the time constant, and has units of seconds

Charging A Capacitor



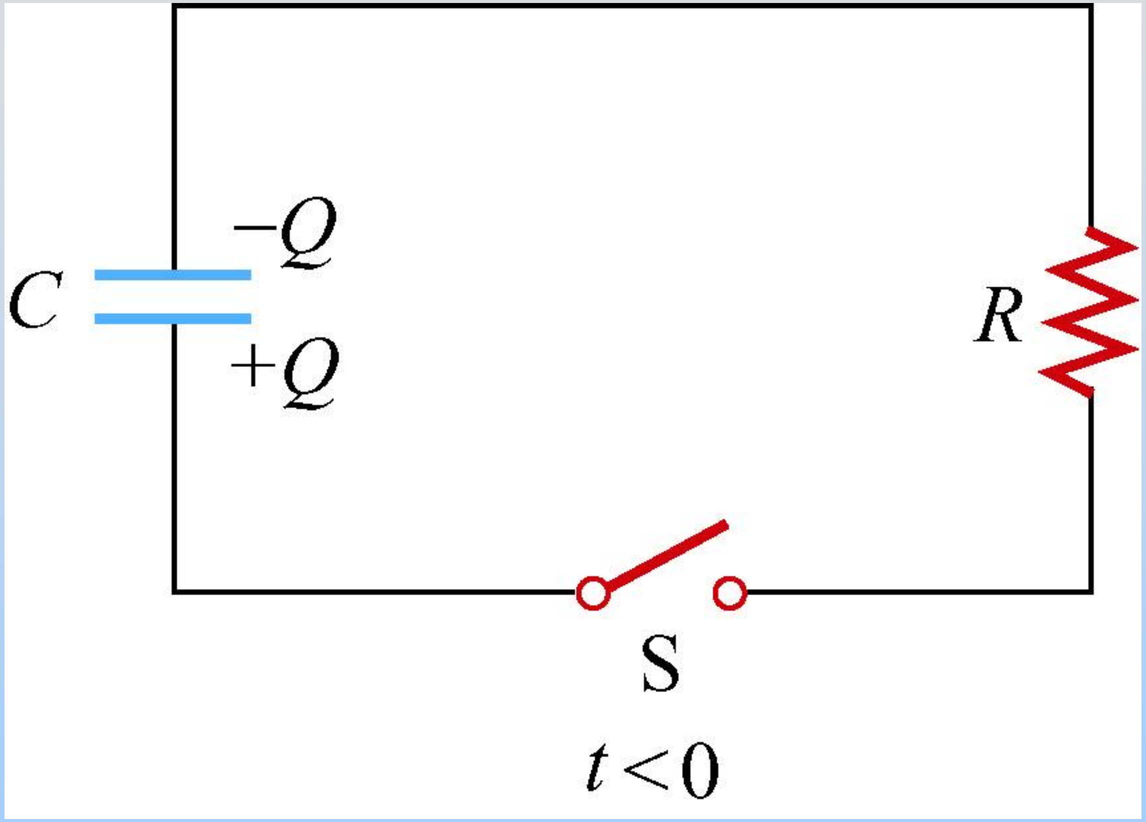


$$Q = C\mathcal{E}\left(1 - e^{-t/RC}\right)$$

$$I = \frac{dQ}{dt} = \frac{\mathcal{E}}{R}e^{-t/RC}$$

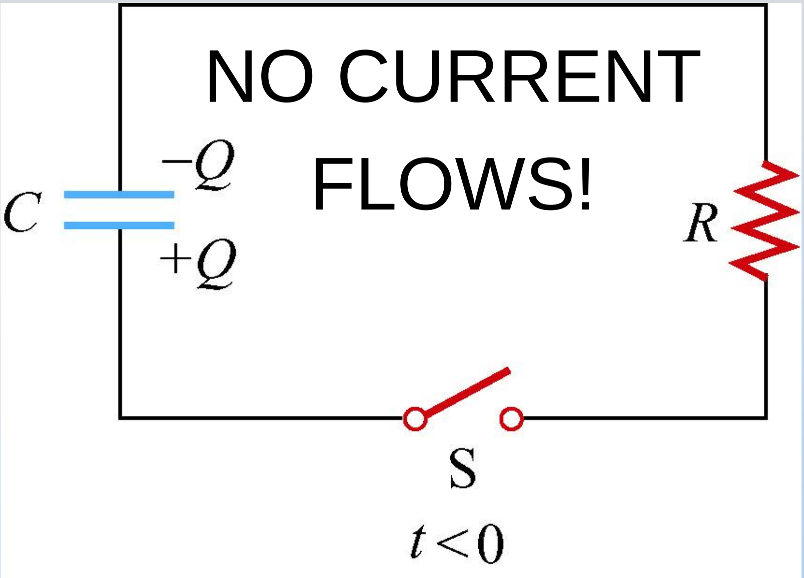
PRS Questions:
Charging a Capacitor

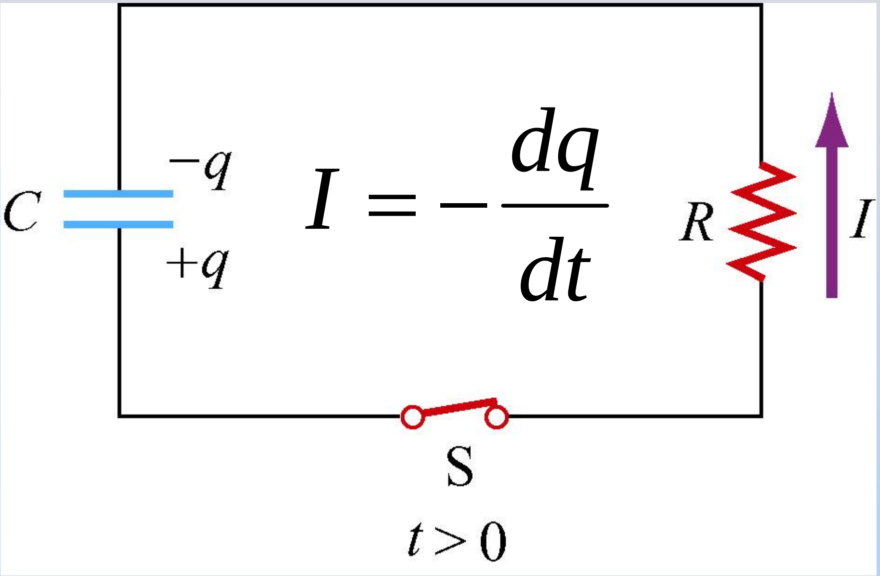
Discharging A Capacitor



What happens when we close switch S?

Discharging A Capacitor





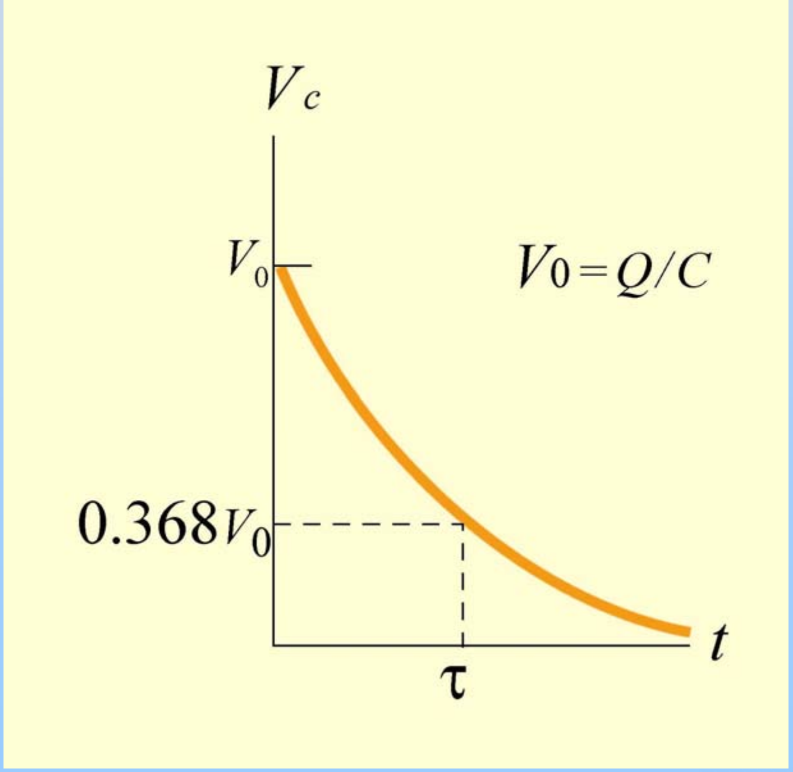
$$I = -\frac{dq}{dt}$$

$$\sum_i \Delta V_i = \frac{q}{C} - IR = 0$$

Discharging A Capacitor

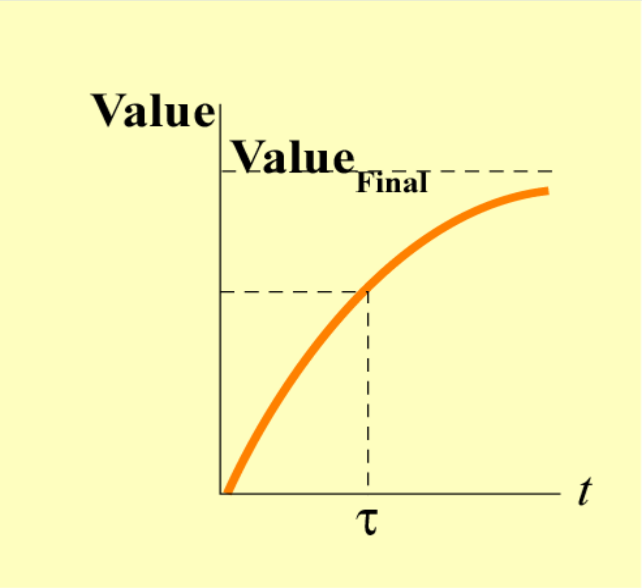
$$\frac{dq}{dt}+\frac{q}{RC}=0 \Rightarrow \int_{Q_0}^{Q}\frac{dq}{q}=-\int_{0}^{t}\frac{dt}{RC}$$

$$\boxed{Q(t)=Q_o e^{-t/RC}}$$

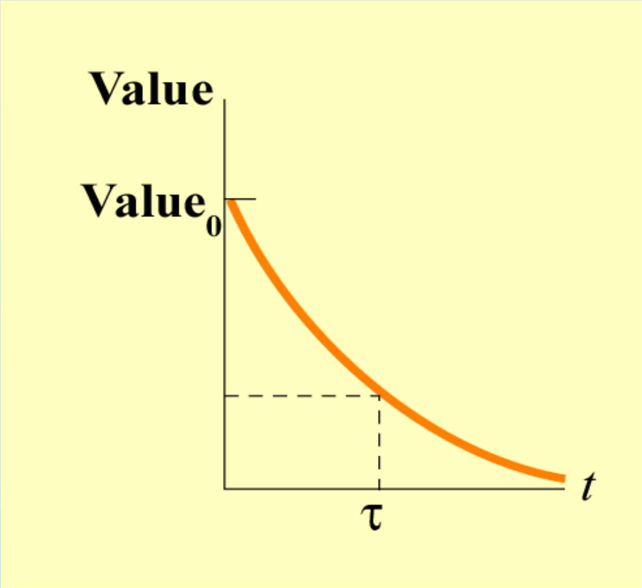


General Comment: RC

All Quantities Either:



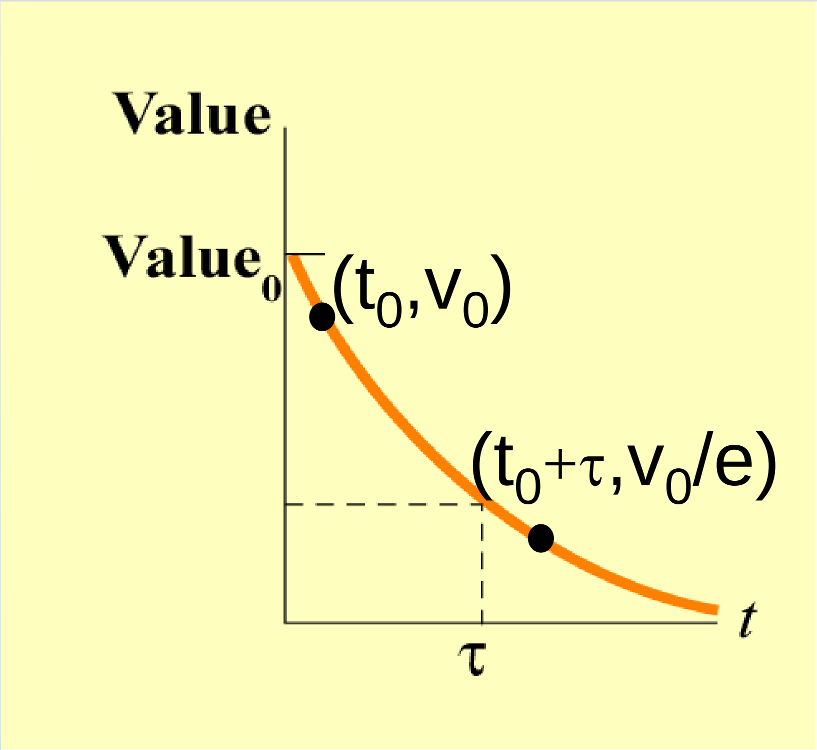
$$\text{Value}(t) = \text{Value}_{\text{Final}}\left(1 - e^{-t/\tau}\right)$$



$$\text{Value}(t) = \text{Value}_0 e^{-t/\tau}$$

τ can be obtained from differential equation (prefactor on d/dt) e.g. τ = RC

Exponential Decay



$$\text{Value}(t) = \text{Value}_0 e^{-t/\tau}$$

Very common curve in physics/nature

How do you measure τ?

1) Fit curve (make sure you exclude data at both ends)

2) a) Pick a point
   b) Find point with y value down by e
   c) Time difference is τ

Demonstrations: RC Time Constants

Experiment 4:
Part II: RC Circuits

PRS Question: Multiloop circuit with Capacitor in One Loop