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

\[ R = \frac{\rho l}{A} \]

\[ \Delta V = IR \]

\[ R_{\text{series}} = R_1 + R_2 \]

\[ \frac{1}{R_{\text{parallel}}} = \frac{1}{R_1} + \frac{1}{R_2} \]
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.

![Diagram showing ohmmeter hooked in parallel across R1 and R2](image)

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

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

\[ \int_{Q_0}^{Q} \frac{dQ}{Q - C \varepsilon} = -\int_{0}^{t} \frac{dt}{RC} \]

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

NO CURRENT FLOWS!

\[ \frac{dq}{dt} = 0 \]

\[ q = -Q \]

\[ q = +Q \]

\[ I = -\frac{dq}{dt} \]

\[ \sum \Delta V_i = \frac{q}{C} - IR = 0 \]
Discharging A Capacitor

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

\[ Q(t) = Q_0 e^{-t/RC} \]
General Comment: RC

All Quantities Either:

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

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

\(\tau\) can be obtained from differential equation (prefactor on \(d/dt\)) e.g. \(\tau = RC\)
Exponential Decay

Very common curve in physics/nature

How do you measure $\tau$?

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 $\tau$

\[ \text{Value}(t) = \text{Value}_0 e^{-t/\tau} \]
Demonstrations: RC Time Constants
Experiment 4:  
Part II:  RC Circuits
PRS Question:
Multiloop circuit with Capacitor in One Loop