Lecture 4

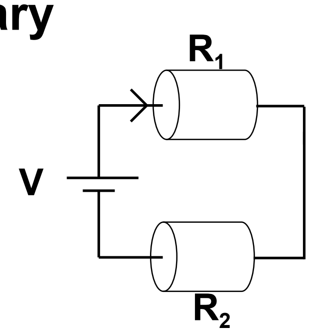
Physics 1402: Lecture 11
Today's Agenda

- **Announcements:**
  - **Lectures posted on: www.phys.uconn.edu/~rcote/**
  - **HW assignments, solutions etc.**
- **Homework #4:**
  - **On Masterphysics : due next Friday at 8:00 AM**
  - **Go to masteringphysics.com**

Summary

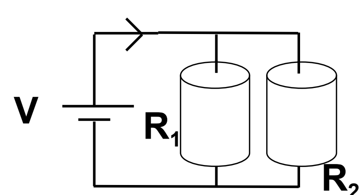
- **Resistors in series**
  - **the current is the same in both R_1 and R_2**
  - **the voltage drops add**

$$R = R_1 + R_2$$



- **Resistors in parallel**
  - **the voltage drop is the same in both R_1 and R_2**
  - **the currents add**

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$



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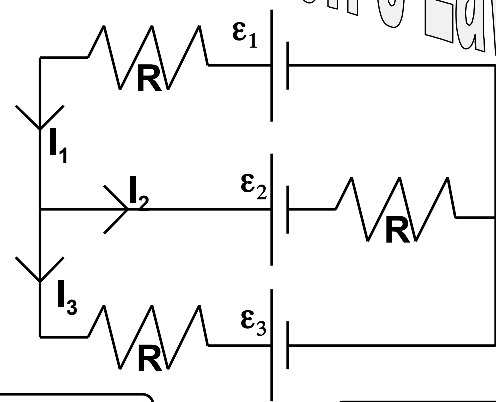
Kirchoff's Laws



$$\sum_{\text{loop}} V_n = 0$$

$$I_{\text{in}} = \sum I_{\text{out}}$$

Kirchoff's First Rule

"Loop Rule" or "Kirchoff's Voltage Law (KVL)"

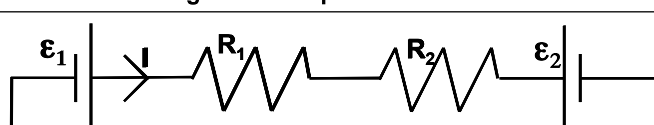
"When any closed circuit loop is traversed, the algebraic sum of the changes in potential must equal zero."

KVL: $$\sum_{\text{loop}} V_n = 0$$

- **This is just a restatement of what you already know: that the potential difference is independent of path!**
- **RULES OF THE ROAD:**

We will follow the convention that voltage gains enter with a + sign and voltage drops enter with a - sign in this equation.

Move clockwise around circuit:



$\varepsilon_1 \quad - IR_1 \quad - IR_2 \quad - \varepsilon_2 = 0$

Kirchoff's Second Rule

"Junction Rule" or "Kirchoff's Current Law (KCL)"

- **In deriving the formula for the equivalent resistance of 2 resistors in parallel, we applied Kirchoff's Second Rule (the junction rule).**

  "At any junction point in a circuit where the current can divide (also called a node), the sum of the currents into the node must equal the sum of the currents out of the node."

  $$I_{\text{in}} = \sum I_{\text{out}}$$

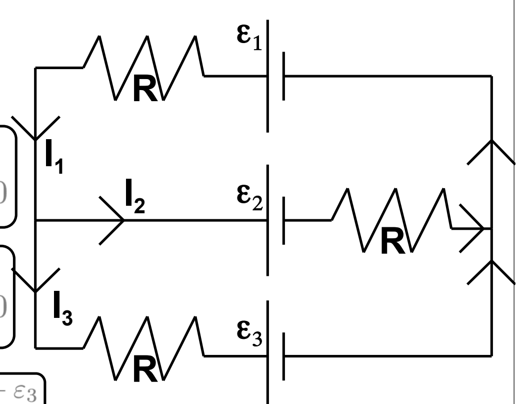
- **This is just a statement of the conservation of charge at any given node.**

Junction Example

Junction:
$I_1 = I_2 + I_3$

Outside loop:
$\varepsilon_1 - \varepsilon_3 - I_1 R - I_3 R = 0$

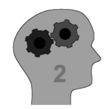
Top loop:
$\varepsilon_1 - I_1 R - \varepsilon_2 - I_2 R = 0$



$$I_1 = \frac{2\varepsilon_1 - \varepsilon_2 - \varepsilon_3}{3R}$$

$$I_2 = \frac{\varepsilon_1 + \varepsilon_3 - 2\varepsilon_2}{3R}$$

$$I_3 = \frac{\varepsilon_1 + \varepsilon_2 - 2\varepsilon_3}{3R}$$

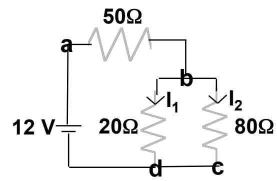


Lecture 4

Chapter 11, ACT 1

- **Consider the circuit shown:**
  - **What is the relation between $V_a - V_d$ and $V_a - V_c$?**

2A



(a) $(V_a - V_d) < (V_a - V_c)$
(b) $(V_a - V_d) = (V_a - V_c)$
(c) $(V_a - V_d) > (V_a - V_c)$

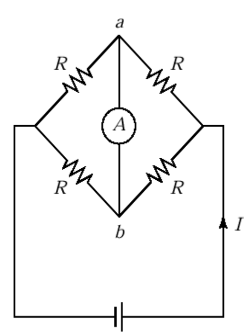
2B

– **What is the relation between I_1 and I_2?**

(a) $I_1 < I_2$ **(b)** $I_1 = I_2$ **(c)** $I_1 > I_2$

Chapter 11, ACT 2

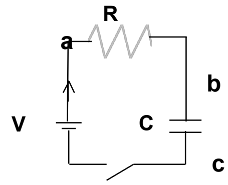
- An ammeter *A* is connected between points *a* and *b* in the circuit below, in which the four resistors are identical. The current through the ammeter is



A) I B) I/2 C) I/4 D) I/8 E) 0

Lecture 4

RC Circuits



- Consider the circuit shown:
  - What will happen when we close the switch ?
  - Add the voltage drops going around the circuit, starting at point a.

IR + Q/C – V = 0

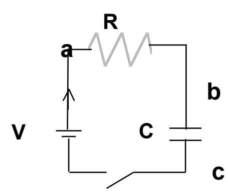
  - In this case neither I nor Q are known or constant. But they are related,

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

$$\Longrightarrow \quad \frac{dQ}{dt}R + \frac{Q}{C} = V$$

•This is a simple, linear differential equation.

RC Circuits



- We do a little bit of algebra and separate dq and dt.

$$\frac{dQ}{dt} = \frac{Q - CV}{RC}$$

$$\frac{dQ}{Q - CV} = \frac{dt}{RC}$$

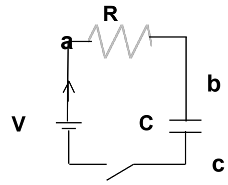
$$\int_{Q_1}^{Q_2} \frac{dQ}{Q - CV} = \frac{1}{RC}\int_{t_1}^{t_2} dt$$

$$\ln\left(\frac{Q_2 - CV}{Q_1 - CV}\right) = -\frac{t_2 - t_1}{RC}$$

RC Circuits

- **Case 1: Charging**

$Q_1 = 0$, $Q_2 = Q$ and $t_1 = 0$, $t_2 = t$

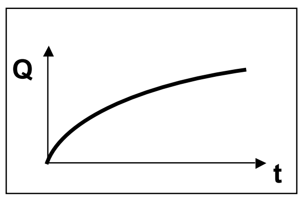


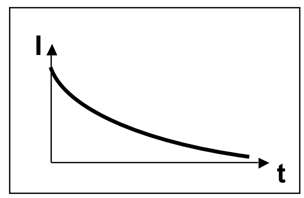
$$\ln\left(\frac{Q_2 - CV}{-CV}\right) = -\frac{t}{RC}$$

•To get Current, I = dQ/dt

$$Q = CV(1 - e^{-t/RC}) = Q_{\max}(1 - e^{-t/RC})$$

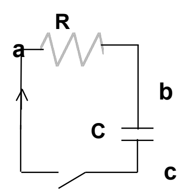
$$I = \frac{V}{R}e^{-t/RC}$$





RC Circuits

- **Case 2: Discharging**
- **To discharge the capacitor we have to take the battery out of the circuit**



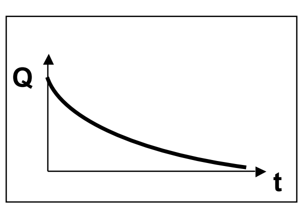
$$\frac{dQ}{dt}R + \frac{Q}{C} = 0$$

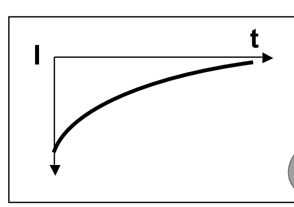
$$\ln\left(\frac{Q}{Q_0}\right) = -\frac{t}{RC}$$

$$Q = Q_0 e^{-t/RC}$$

•To get Current, I = dQ/dt

$$I = -\frac{Q_0}{RC}e^{-t/RC}$$





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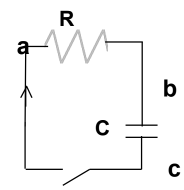
Chapter 11, ACT 3

- Consider the simple circuit shown here. Initially the switch is open and the capacitor is charged to a potential V_O. Immediately after the switch is closed, what is the current ?



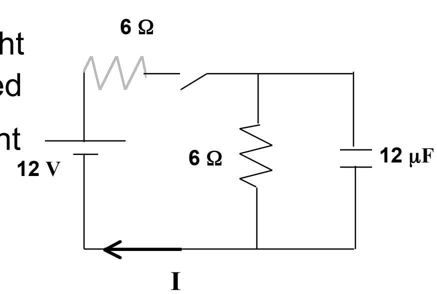
A) $I = V_O/R$ B) $I = 0$ C) $I = RC$ D) $I = V_O/R \exp(-1/RC)$

Chapter 11, ACT 4

Consider the circuit at right after the switch is closed

i) What is the initial current I?

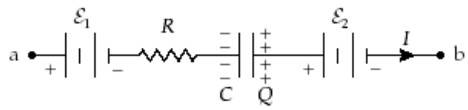
A) 0 B) 1 A C) 2 A
D) 3 A E) 4 A



ii) What is the current I after 2 minutes?

A) 0 B) 1 A C) 2 A
D) 3 A E) 4 A

Lecture 11, ACT 5



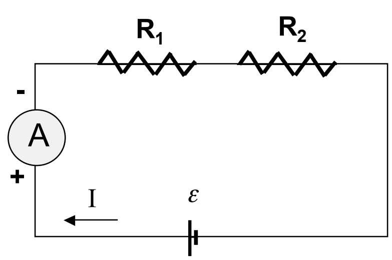
If R = 3.0 kΩ, C = 6.0 nF, $\mathcal{E}_1$ = 10.0 V, Q = 18 nC, $\mathcal{E}_2$ = 6.0 V, and I = 5.0 mA, what is the potential difference $V_b - V_a$?

a. –13 V
b. +28 V
c. +13 V
d. –28 V
e. +2.0V

Electrical Instruments

The Ammeter

The device that measures current is called an *ammeter*.

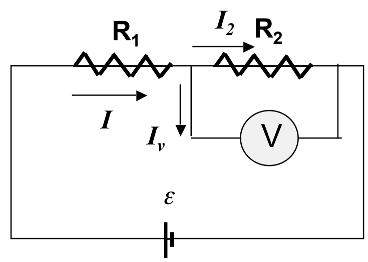


Ideally, an ammeter should have zero resistance so that the measured current is not altered.

Electrical Instruments

The Voltmeter

The device that measures potential difference is called a *voltmeter*.



An ideal voltmeter should have infinite resistance so that no current passes through it.

Problem Solution Method:

Five Steps:

1) Focus the Problem
   - draw a picture – what are we asking for?
2) Describe the physics
   - what physics ideas are applicable
   - what are the relevant variables known and unknown
3) Plan the solution
   - what are the relevant physics equations
4) Execute the plan
   - solve in terms of variables
   - solve in terms of numbers
5) Evaluate the answer
   - are the dimensions and units correct?
   - do the numbers make sense?