

PHYS 212

Review 2

Exam 2 - 11/1/24-11/4/24

[Queue](#)



Queue sign in

Exam 2 Overview

9/10) Simple Circuits and Kirchhoff's Laws

11) RC Circuits

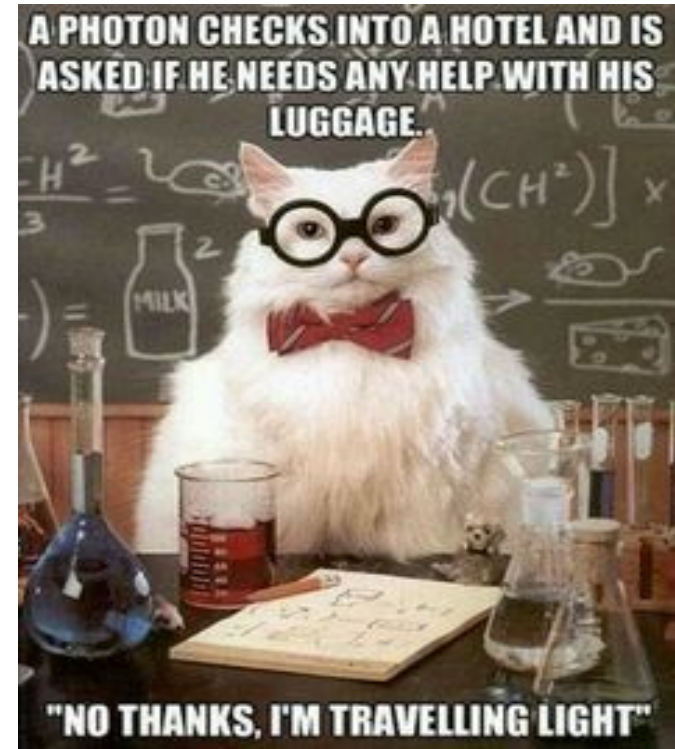
12) Magnetic Force

13) Forces and Magnetic Dipoles

14) Biot-Savart Law

15) Ampere's Law

16) Motional EMF



Current and KCL

Current (I) is the flow of charge per second

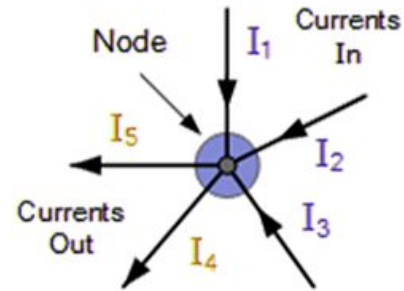
Units: Amperes (A) - Coulombs/second (C/s)

Kirchhoff's Current Law - KCL

- The amount of current going in is equal to the amount of current coming out

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

Currents Entering the Node
Equals
Currents Leaving the Node



$$I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$$

Voltage and KVL

Voltage (V) is the amount of energy per unit charge

- Units: Volts (V) = Joules/Coulomb (J/C)

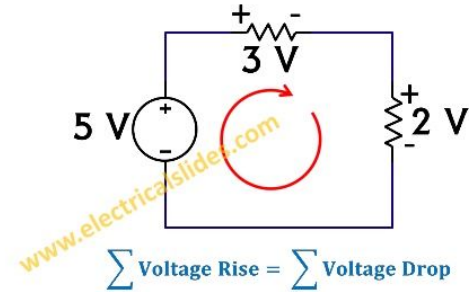
Kirchhoff's Voltage Law - KVL

- The total voltage in a loop is the sum of all the voltage drops and rises
 - Voltage drop - “+” to “-”
 - Voltage rise - “-” to “+”

You can solve all the circuit problems you will see in this course by applying KCL and KVL

Kirchhoff's Voltage Law

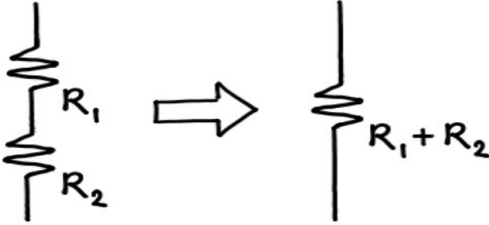
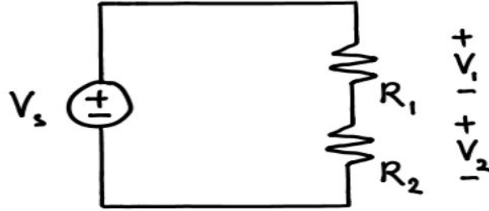
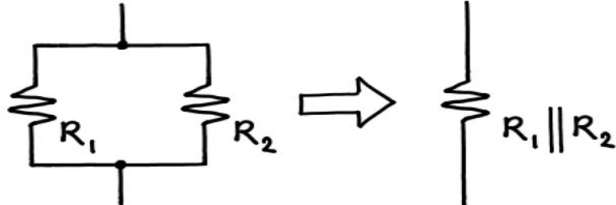
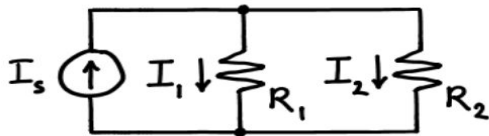
The Sum of Voltage rise across any loop is equal to sum of voltage drops across that loop.



Electrical Slides

5V = 2V + 3V

www.electricalslides.com

Name	Diagram	Formulas
Series Resistors		Equivalent resistance = $R_1 + R_2$
Voltage Divider		$V_1 = \frac{R_1}{R_1 + R_2} V_s \quad V_2 = \frac{R_2}{R_1 + R_2} V_s$
Parallel Resistors		Equivalent resistance = $R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2}$
Current Divider		$I_1 = \frac{R_2}{R_1 + R_2} I_s \quad I_2 = \frac{R_1}{R_1 + R_2} I_s$

Power

Power is the amount of energy per second being delivered/absorbed

- Units: Watts (W) = Joules/second (J / s) ==> amount of energy per second
- $P_{\text{resistor}} = IV = V^2/R = I^2R$ (These last 2 equations are for resistors **ONLY**)

The sign (“+” or “-”) is very important when it comes to power **(Not on your test)**

- Negative power means that circuit element is delivering energy to the circuit (sources, capacitors, inductors)
- Positive power means that the circuit element is absorbing energy from the circuit (resistors, capacitors, inductors)

RC Circuits

τ - tau is the time constant which affects the rate of growth/decay

Time Constant

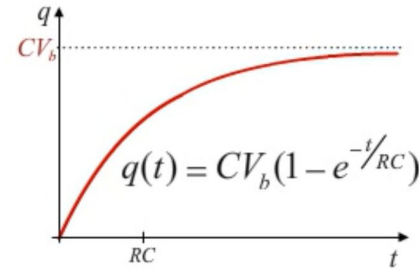
$$\tau = RC$$

Charging and Discharging Equations

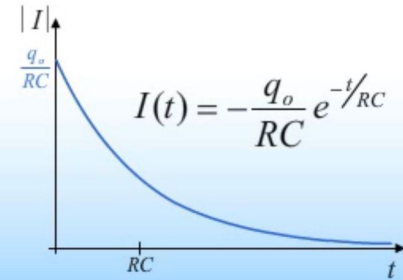
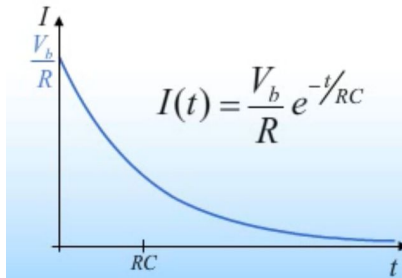
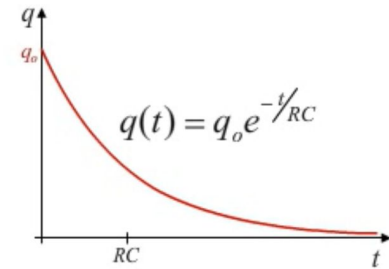
$$Q(t) = Q(\infty) \left(1 - e^{-t/\tau} \right)$$

$$Q(t) = Q(0) e^{-t/\tau}$$

Charging



Discharging



RC Circuits cont.

Charging

$t = 0 \rightarrow$ capacitor acts like a wire (short circuit)

- $V = 0$ V, but there is a current

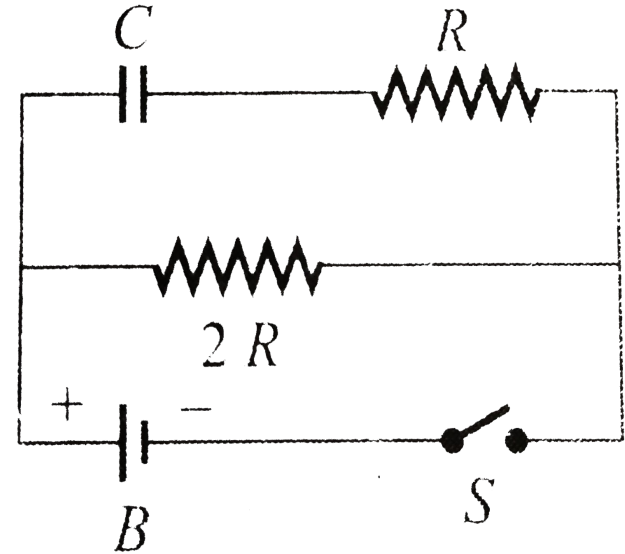
$t = \infty \rightarrow$ no current thru capacitor (open circuit)

- $I = 0$ A, but there is a voltage

Discharging

$t = 0 \rightarrow$ capacitor acts like a battery ($C = Q/V$ where V is found when charging up)

$t = \infty \rightarrow$ capacitor acts like a wire (all the charge is dissipated aka gone)



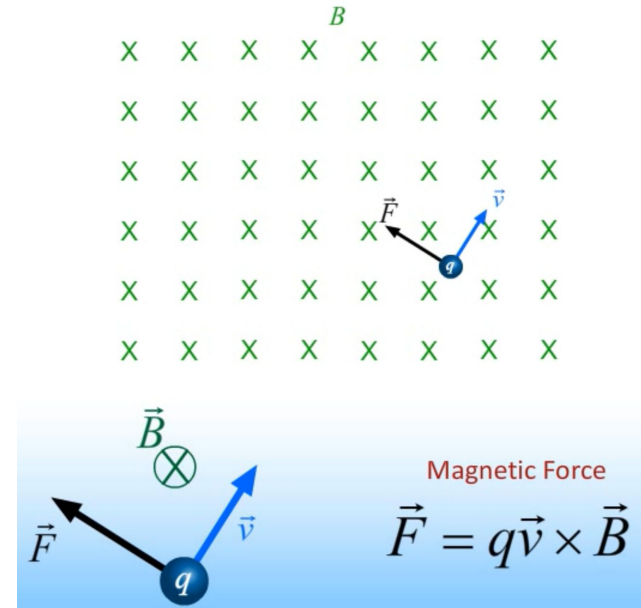
Magnetic Force on Charges

- $\mathbf{F}_m = q\mathbf{v} \times \mathbf{B}$
 - we know that $\mathbf{F} = m\mathbf{a}$
 - and for these problems $\mathbf{a} = \mathbf{a}_c = \mathbf{v}^2/r$
 - If we substitute in for F we get $m\mathbf{v}^2/r = q\mathbf{v} \times \mathbf{B}$
 - We use this to solve for any missing variable

Right-Hand Rule (1st RHR)

- Point fingers or hand along the direction of \mathbf{v}
- Curl fingers in the direction of \mathbf{B}
- Thumb points in the direction of the force*

*This works for positive charges, flip your thumb 180° for a negative charge



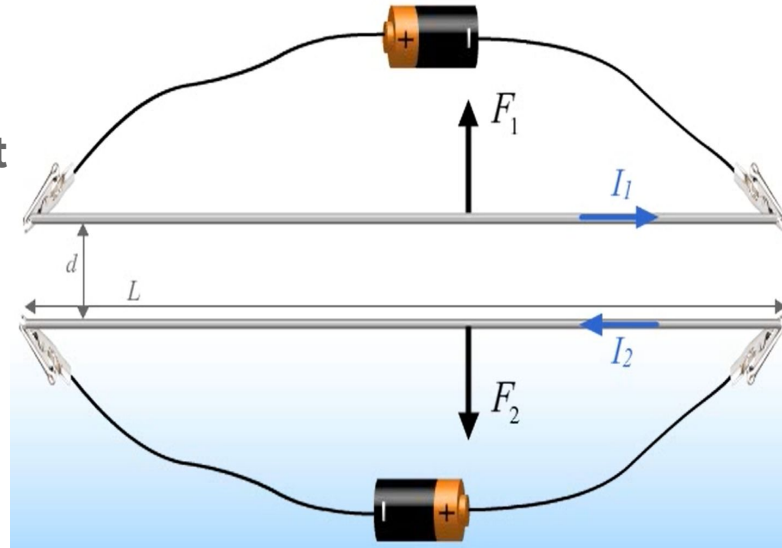
Forces on Current Wires and Loops

$$\mathbf{F}_{\text{wire}} = I \mathbf{L} \times \mathbf{B} \text{ (1st RHR)}$$

- The force around an entire loop of current is always zero (assuming \mathbf{B} is constant) but be careful because it may not be zero at a segment of the loop

Currents traveling in the same direction - attract

Currents traveling in opposite directions - repel



Torques and Energy on Current Loops

Remember $\sin(\theta)$ goes with cross products and $\cos(\theta)$ goes with dot products

Magnetic Dipole: $\mu = n * I * A$ (2nd RHR)

- n = # of turns
- I = current through loop
- A = area of the loop

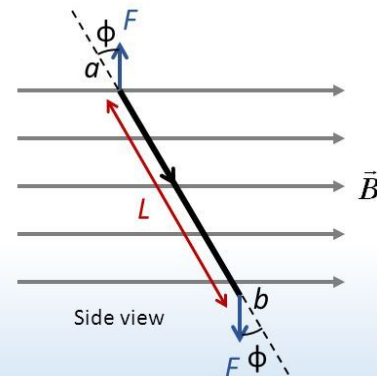
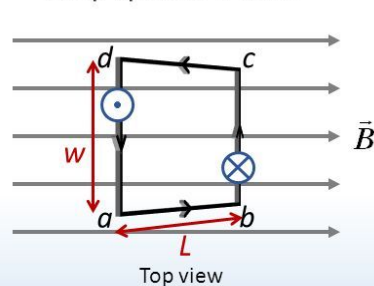
Torque: $\tau = \mu \times B = |\mu||B|\sin(\theta)$ (1st RHR)

Potential Energy: $U = -\mu \cdot B = -|\mu||B|\cos(\theta)$

Work: $W = -U$

Torque on current loop

Loop spins in B field



B field generates a torque on the loop

$$\tau_{loop} = FL \sin \phi = IBwL \sin \phi$$

↑
Loop area

$$\tau_{loop} = IAB \sin \phi$$

Torques and Energy Cont.

Remember $\sin(\theta)$ goes with cross products and $\cos(\theta)$ goes with dot products

Torque: $\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B} = |\boldsymbol{\mu}| |\mathbf{B}| \sin(\theta)$

Max when $\sin(\theta) = 1 \rightarrow \theta = 90^\circ \rightarrow$ when $\boldsymbol{\mu}$ and \mathbf{B} are perpendicular

Potential Energy: $\mathbf{U} = -\boldsymbol{\mu} \cdot \mathbf{B} = -|\boldsymbol{\mu}| |\mathbf{B}| \cos(\theta)$

Min when $\cos(\theta) = 1 \rightarrow \theta = 0^\circ \rightarrow$ when $\boldsymbol{\mu}$ and \mathbf{B} are parallel in the same direction

Max when $\cos(\theta) = -1 \rightarrow \theta = 180^\circ \rightarrow \boldsymbol{\mu}$ and \mathbf{B} are parallel in opposite directions

Work: $\mathbf{W} = -\mathbf{U}$

Biot-Savart Law

By using the Biot-Savart Law, we were able to derive the equation for the **magnetic field produced by a current carrying wire (in orange)**

Direction of B is always tangent to the circle (3rd RHR)

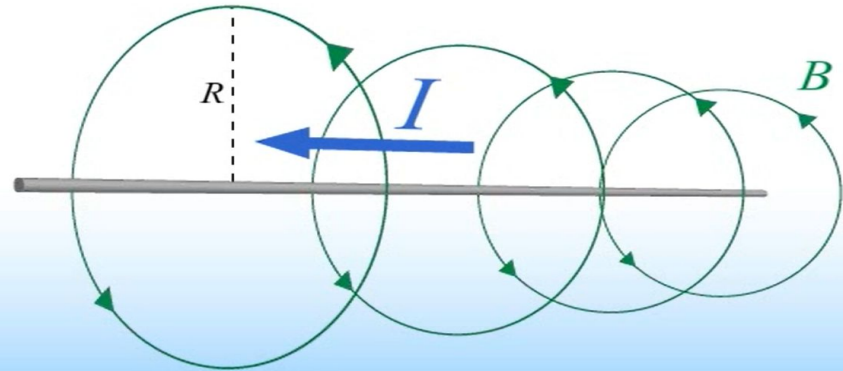
(Not used often, painful to integrate)

$$B = \frac{\mu_0 I}{2\pi R}$$

Right Hand Rule

1. Place thumb in direction of I
2. Fingers curl in direction of B

$$B_z = \frac{\mu_0 I R^2}{2(z^2 + R^2)^{3/2}}$$



Right-Hand Rules (3 Total)

1st RHR - Cross Products

- Place your fingers along the first vector, curl your fingers in the direction of the second vector, your thumb gives you the direction of the force, torque, etc.

2nd RHR - Magnetic Dipole

- Curl your fingers along the direction in which the current is flowing, your thumb gives you the direction of the magnetic dipole

3rd RHR - Magnetic Fields

- Place your thumb along the direction of current, curl your fingers to give you the direction of the “circular path”, B is tangent to the “circular path”

Ampere's Law

Think of it as the 2D version of Gauss's Law, but for magnetic fields now

By convention for line integrals, **traversing a closed loop counter-clockwise (CCW) is positive and traversing it clockwise (CW) is negative**

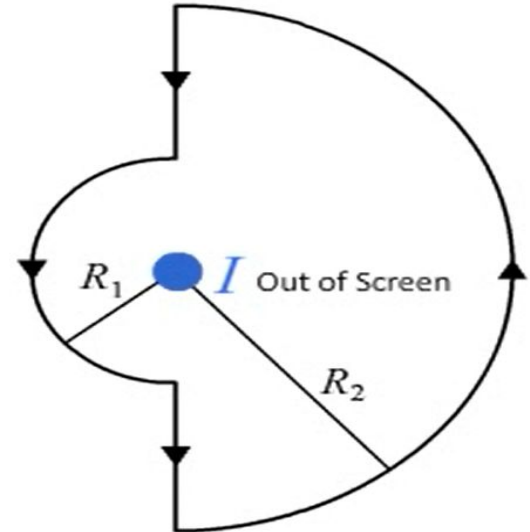
Current density: $J = I / A$

Units: (A/m²)

I - Current

A - Area

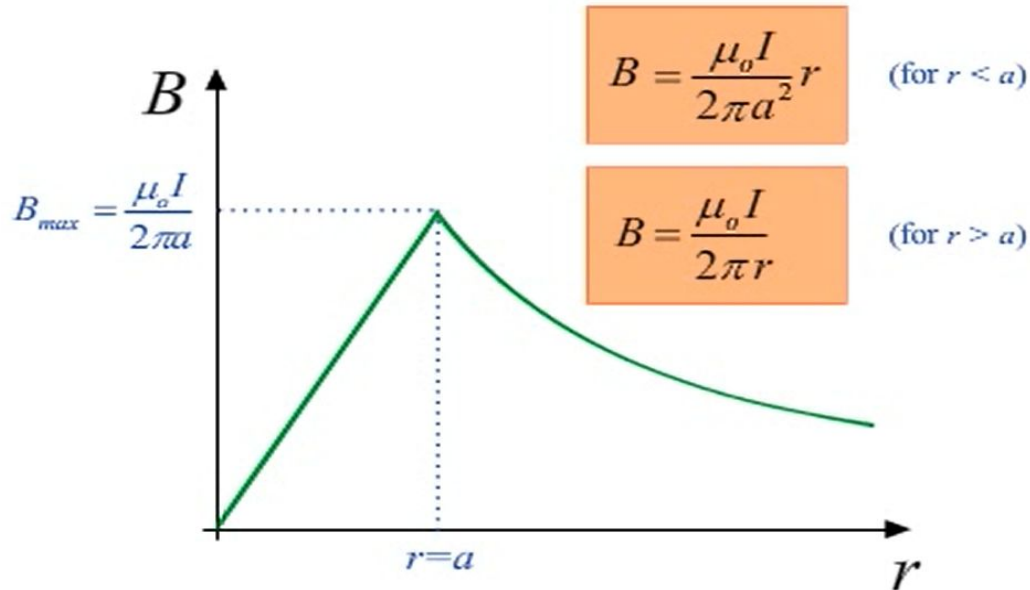
$$\oint_{\text{loop}} \vec{B} \cdot d\vec{l} = \mu_o I_{\text{enclosed}}$$



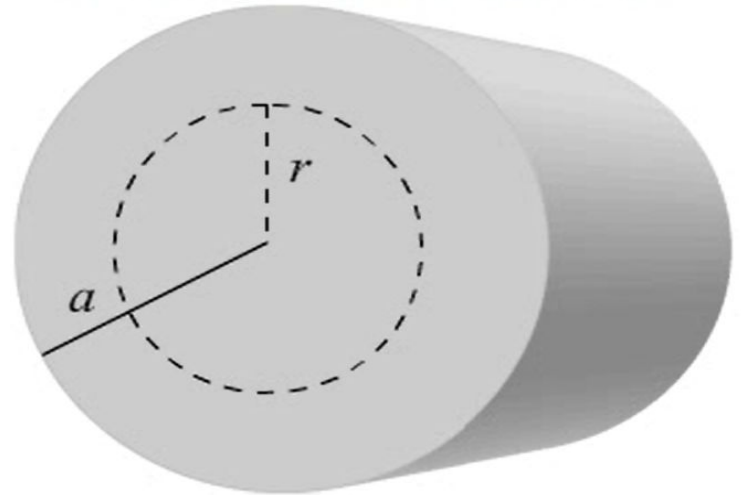
Ampere's Law Cont.

Magnetic field equations inside and outside a current-carrying wire

Memorize inside equation (#1), it will save you time from deriving it on the exam



Infinite Straight Wire

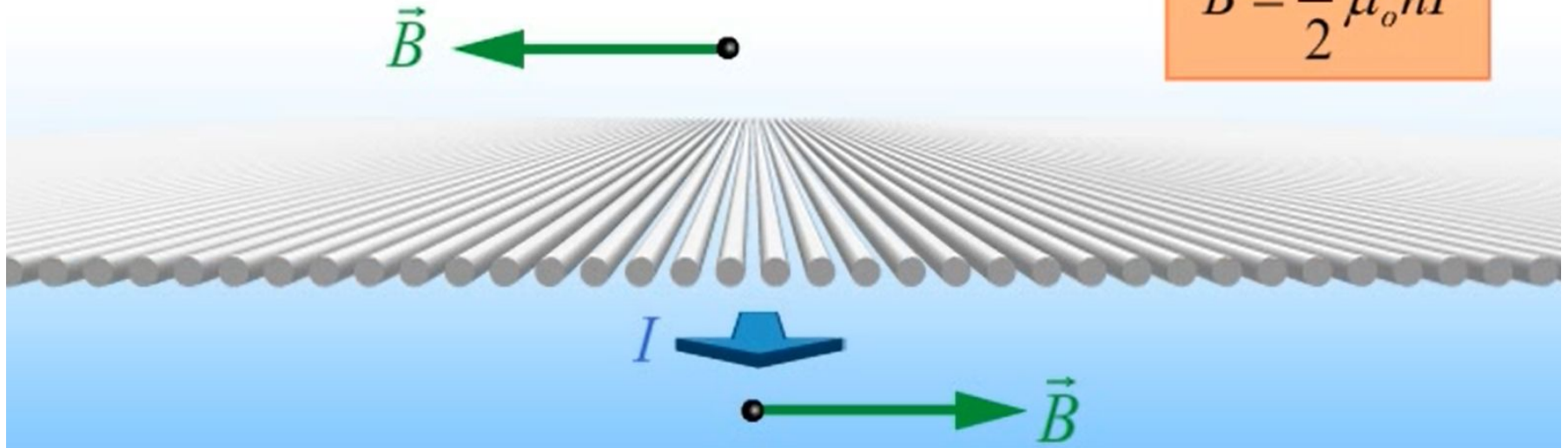


Ampere's Law Cont.

Magnetic field equation for an infinite sheet of current

Infinite Sheet of Current

$$B = \frac{1}{2} \mu_0 n I$$



Motional EMF

Potential difference = Voltage = Electromagnetic Force (EMF)

$$\mathcal{E} = vBL$$

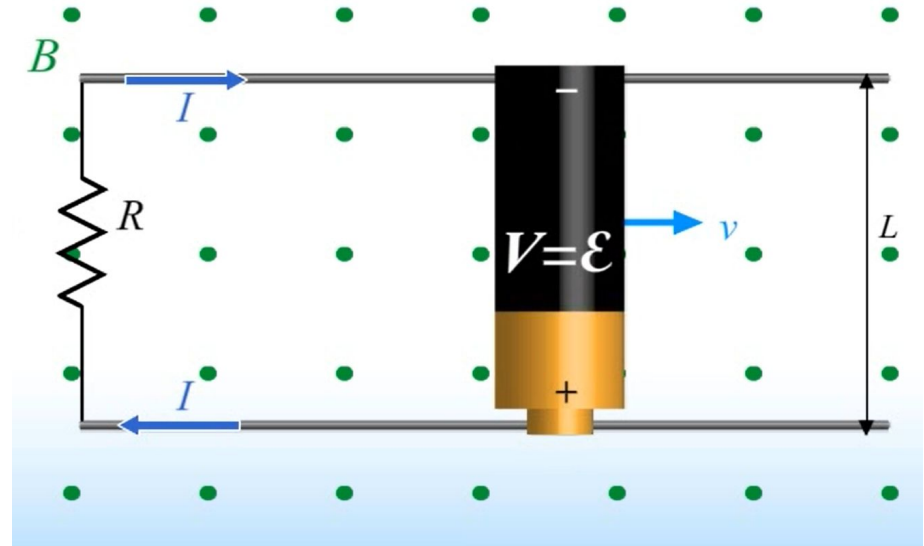
v - velocity

B - magnetic field

L - length of the loop

To find direction of current: 1st RHR

- RHR wrt the magnet: $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$
- Your thumb gives you the direction of the current



Faraday's Law

$$\mathcal{E}_{\text{induced}} = -\frac{d\Phi_B}{dt}$$

Main Idea: A changing magnetic flux creates an electric field

The induced EMF (voltage) always opposes the change in magnetic flux

The induced EMF gets **multiplied by N turns** if the loop has N turns in it

3 ways to change the magnetic flux

- Making the area of the loop smaller or larger
- Moving the loop around in a constant magnetic field
- Having a time-varying magnetic field (i.e. B is not constant with time)

Faraday's Law cont.

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

Steps for solving Faraday's Law problems (2 types)

Type 1: (Usually given B as a function of time or on a graph)

$$\mathcal{E}_{\text{induced}} = -\frac{d\Phi_B}{dt}$$

- 1) Find the magnetic flux ($\mathbf{B} \cdot \mathbf{A}$)
- 2) Solve for the induced EMF by take the negative derivative of the magnetic flux with respect to time (**-d/dt of the magnetic flux**)

Type 2: (Usually a picture with one or “N” conducting loops)

- 1) **Determine the change in magnetic flux, B_{induced} will always point in the opposite direction** to the change in magnetic flux
- 2) **Use the 3rd RHR:** Point your fingers in the direction of B_{induced} and curl your fingers to give you the direction of the induced current

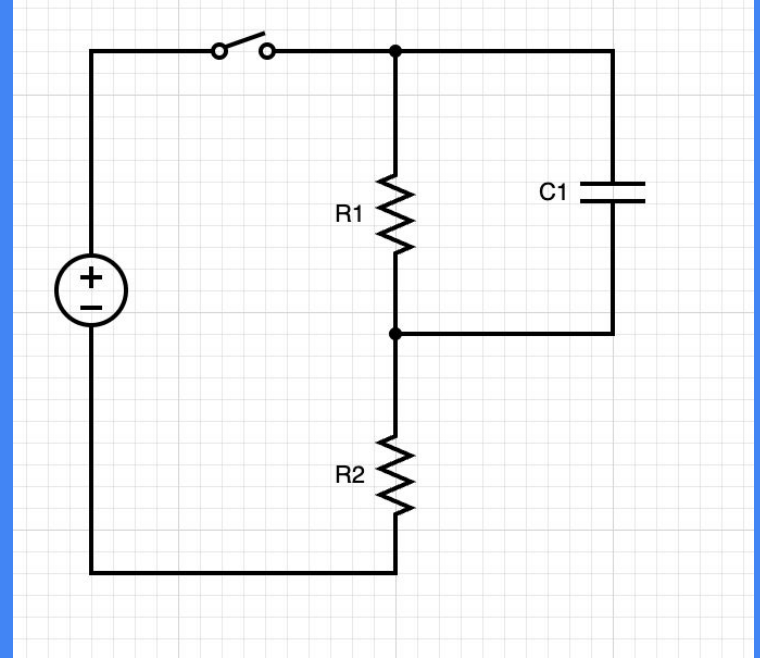
Question Time!



Question 1

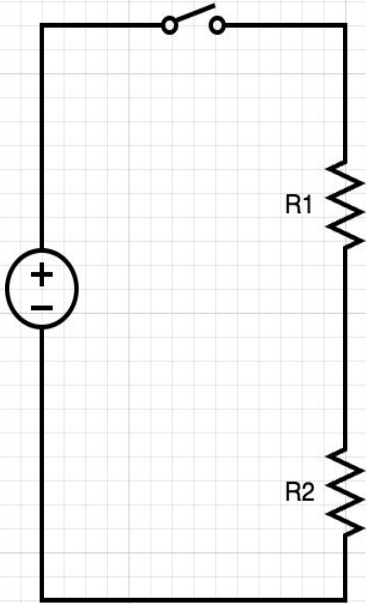
This Question is Based of
the Following Circuit

Draw the Following Circuit

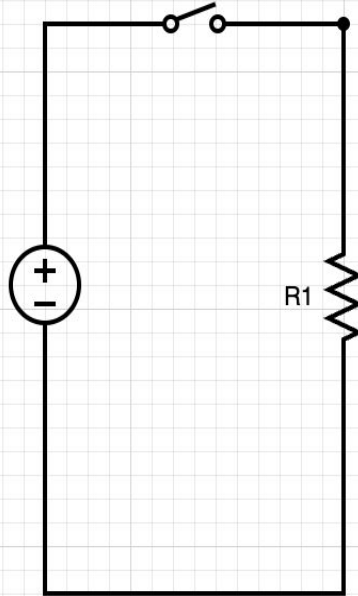


Where Would Current Flow at $t=0$

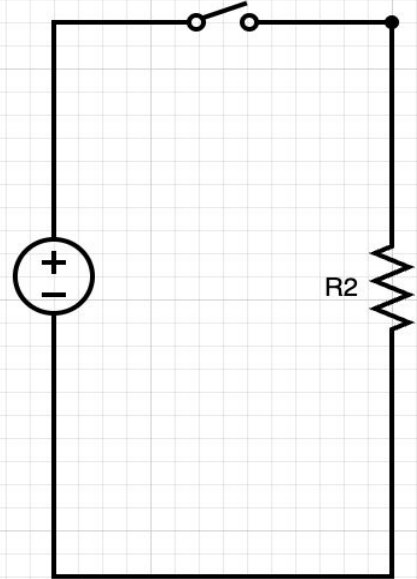
A



B



C

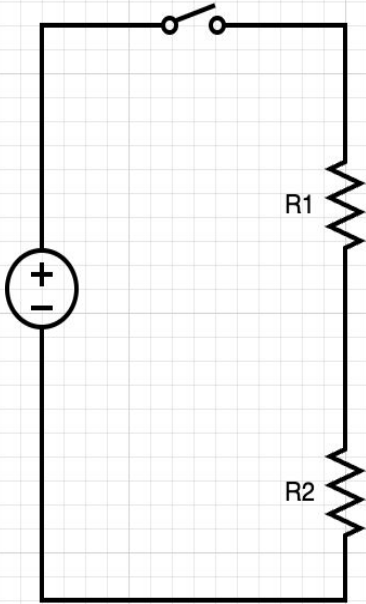


Correct: C

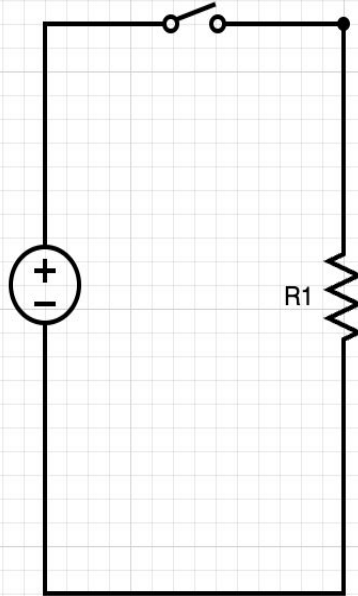
No current flows through R1 as the capacitor acts like a short

Where Would Current Flow at $t=\infty$

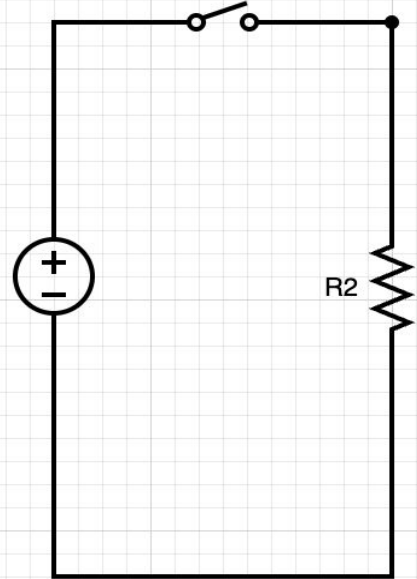
A



B



C



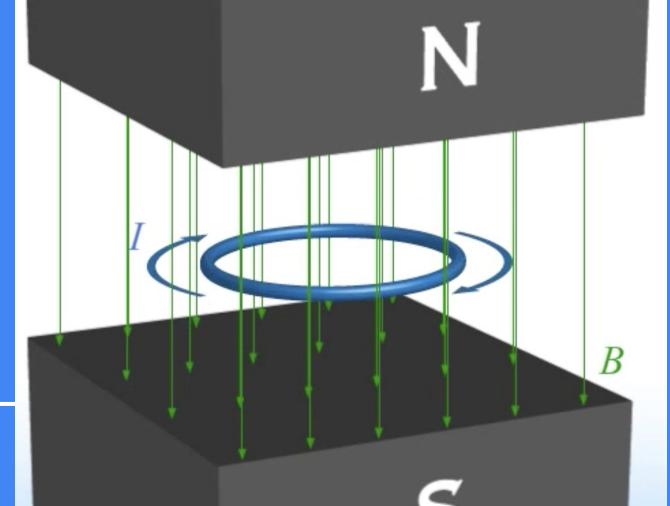
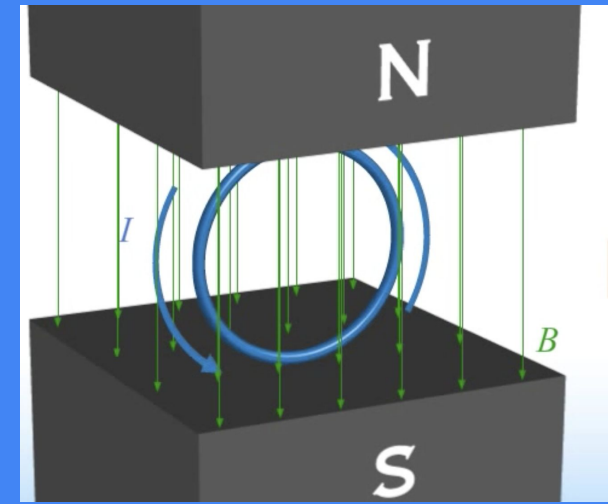
Correct: A

No current flows through the capacitor
after a long time

Question 2a

Initial condition is seen above. You then rotate the loop into the final condition seen below.

What is the work done by you?



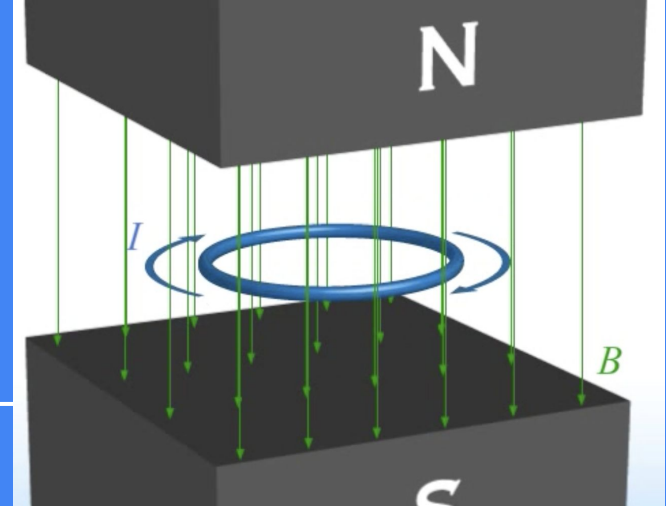
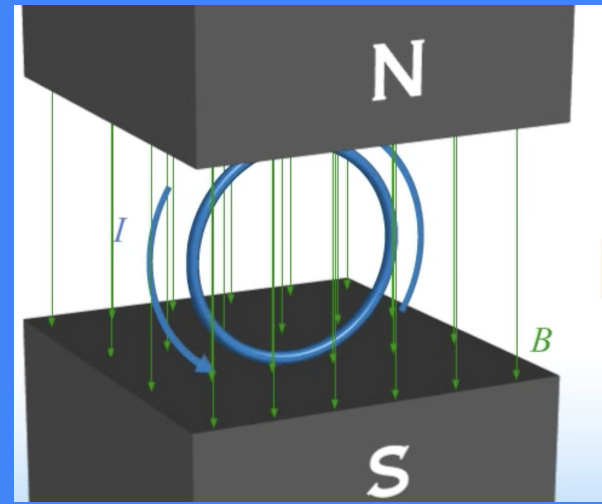
**The work done by you is
NEGATIVE.**

The loop has a lower potential energy,
meaning you took away energy.

Question 2b

Initial condition is seen above. You then rotate the loop into the final condition seen below.

What is the work done by the magnetic field.



The work done by the B-field is POSITIVE.

Work = Force x Distance

$$W = F.d$$

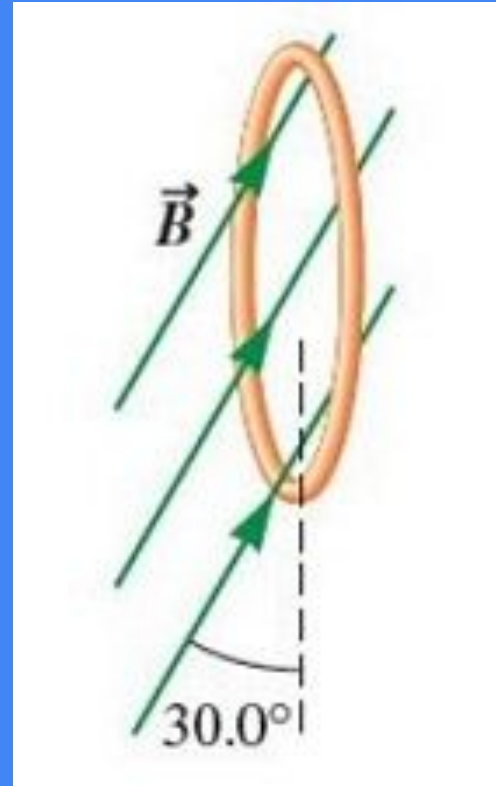
The Force and Distance are in the same direction, giving positive work.

Question 3

A stationary loop ($r = 2\text{m}$) has a magnetic field pass through it from a 30° angle.

The magnitude of the B-field follows the following function:

$$B(t) = 4t - 20$$

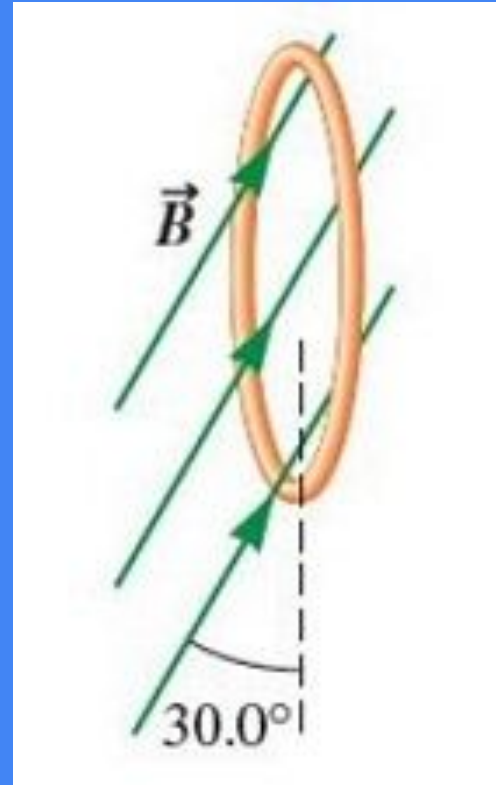


Question 3a

$R = 2\text{m}$, 30° angle, $B(t) = 4t - 20$

What is expression for the magnetic flux?

- a. $\Phi_B = (4\pi)(4t - 20)$
- b. $\Phi_B = (2\pi)(4t - 20)$
- c. $\Phi_B = (4\pi)(4)$
- d. $\Phi_B = (2\pi)(4)$



Correct: B

$$\Phi_B = B \cdot \text{Area}, B = (4t-20) \cdot \sin(30), \sin(30) = 0.5$$

$$A = \pi r^2 = \pi(2)^2 = 4\pi$$

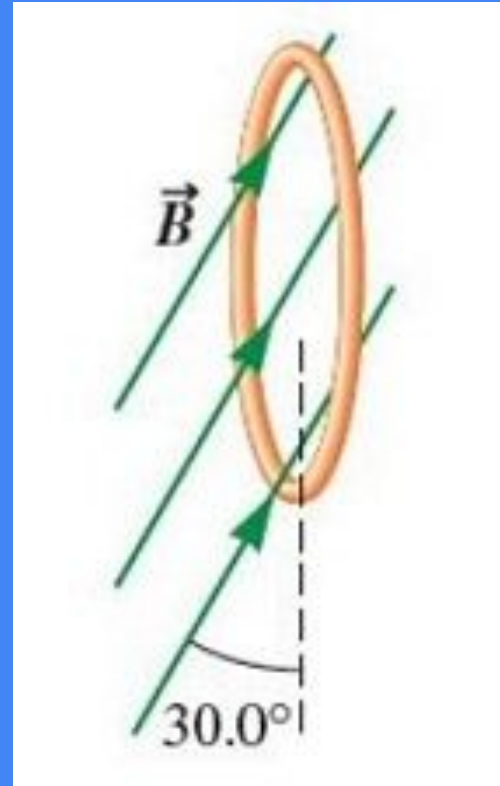
$$\Phi_B = B \cdot \text{Area} = (4t-20)(0.5)(4\pi) = (2\pi)(4t - 20)$$

Question 3b

$R = 2\text{m}$, 30° angle, $B(t) = 4t - 20$

What is expression for the motional EMF?

- a. $\text{EMF} = -8\pi \cos(30)$
- b. $\text{EMF} = 8\pi \cos(30)$
- c. $\text{EMF} = -8\pi$
- d. $\text{EMF} = 8\pi$



Correct: C

Differentiate the Flux and multiply by (-1)

$$\Phi_B = (2\pi)(4t - 20) = 8\pi t - 40\pi$$

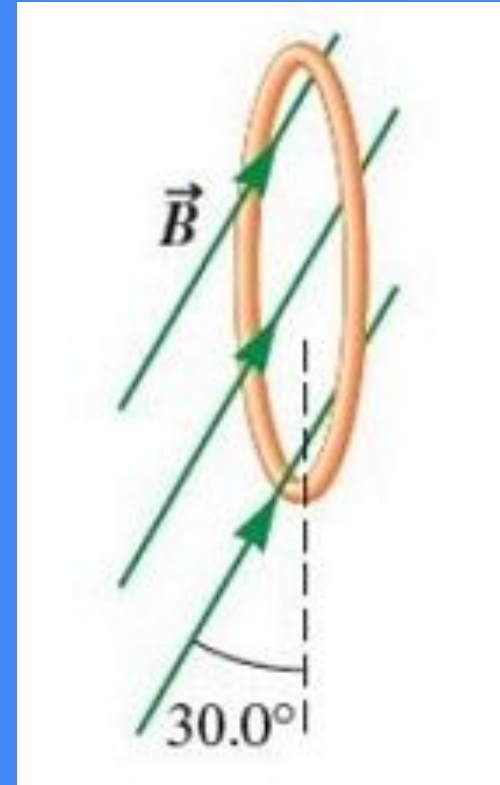
$$\text{EMF} = -d/dt (8\pi t - 40\pi) = -1 \cdot 8\pi = -8\pi$$

Question 3c

What is the direction of the current generated on the loop?

Assume magnetic field is slightly into the page

- a. Clockwise
- b. Counter-Clockwise



Correct: A

Negative EMF would typically result in clockwise current, but since the B field is into the page, the current is clockwise.

Don't forget to sign in to the queue

