PHYS 212
Review 2

[Queue]

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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

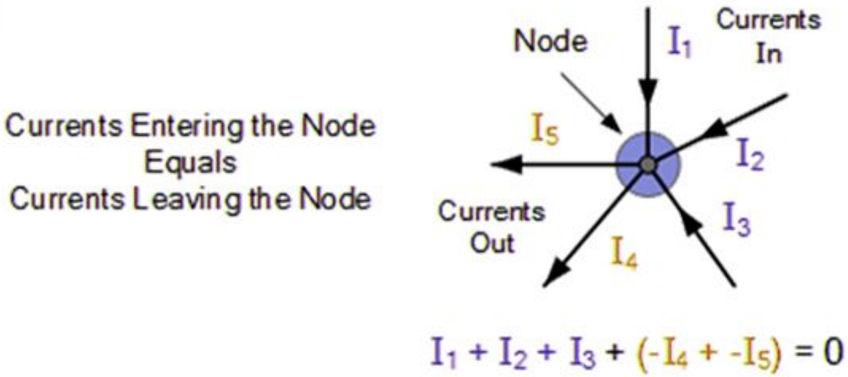
Current (I) is the flow of charge per second

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

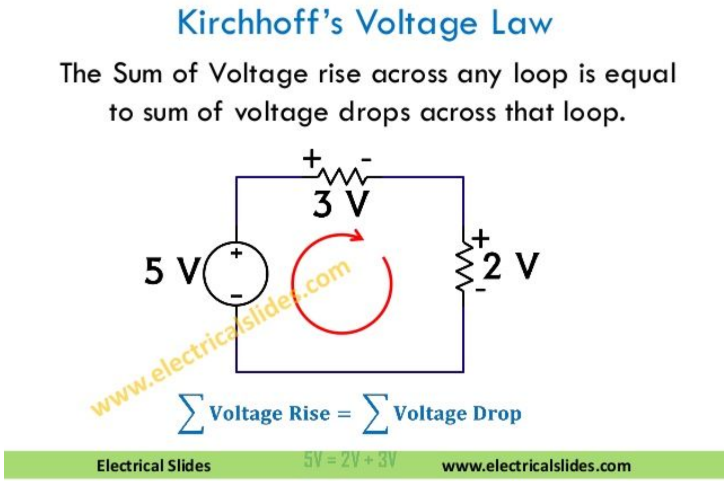
Kirchhoff's Current Law - KCL

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

$$I_{in} = I_{out}$$



Voltage and KVL



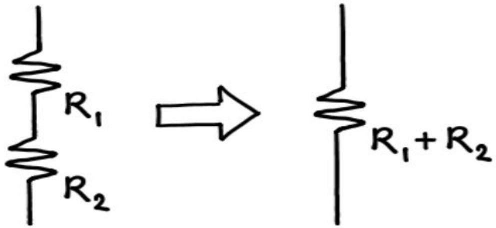
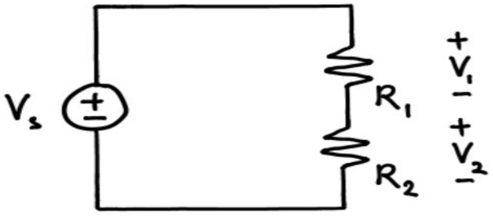
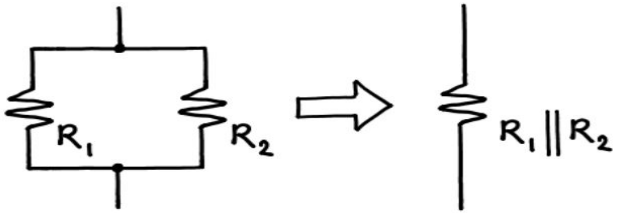
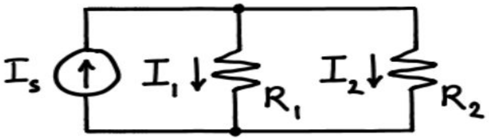
Voltage (V) is the amount of energy per unit charge

- 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

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

Power

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

- Units: Watts (W) = Joules/second (J / s) ==> amount of energy per second
- **$P_{resistor}$ = 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

Time Constant

$$\boxed{\tau = RC}$$

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

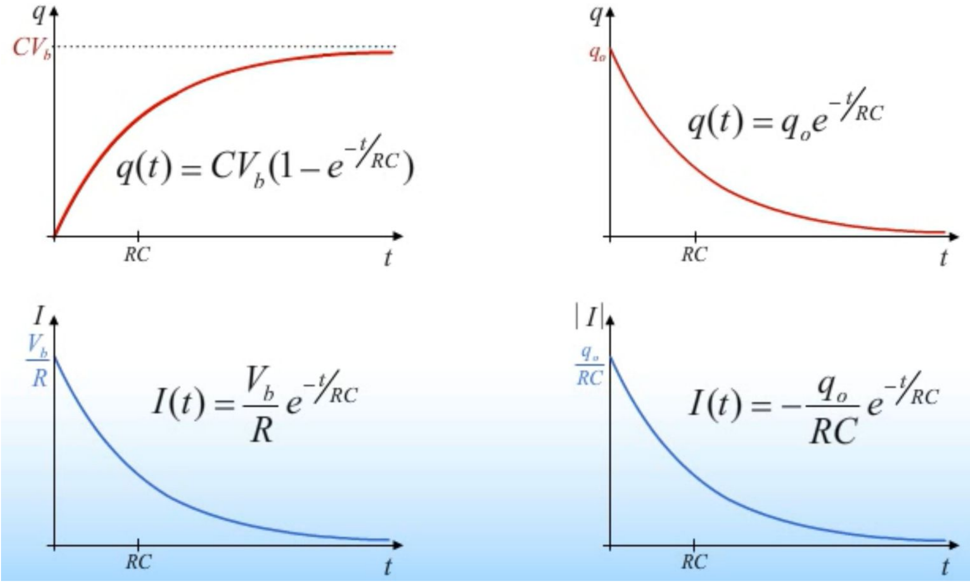
Charging and Discharging Equations

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

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

Charging

Discharging



RC Circuits cont.

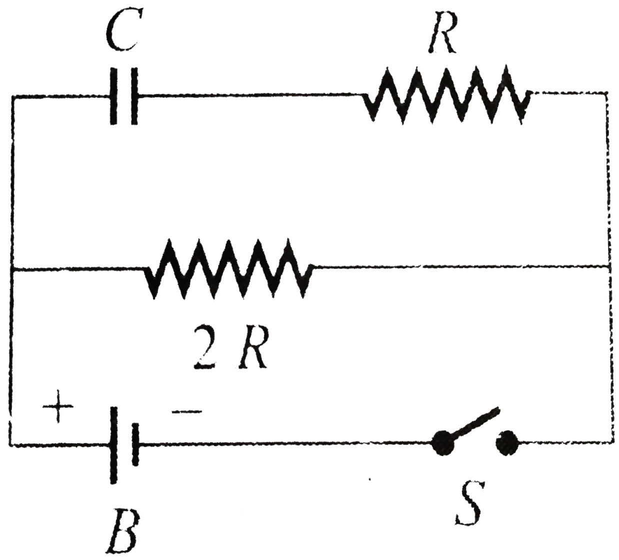
Charging

t = 0 → capacitor acts like a wire (short circuit)

- V = 0 V, but there is a current

t = ∞ → no current thru capacitor (open circuit)

- I = 0 A, but there is a voltage



Discharging

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

t = ∞ → capacitor acts like a wire (all the charge is dissipated aka gone)

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

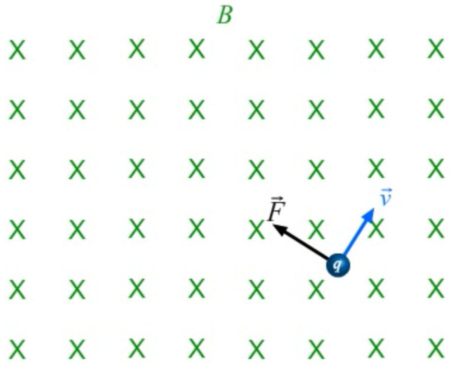
- Curl your fingers along the direction in which the current is flowing, your thumb gives you the direction of the magnetic dipole

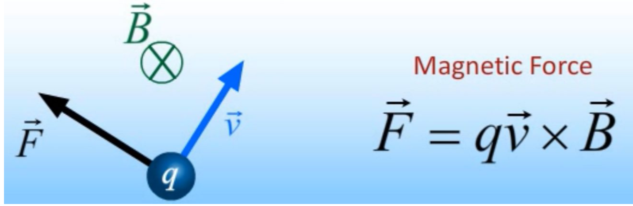
3rd RHR - Magnetic Fields

- 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"

Magnetic Force on Charges

- $F_m = qv \times B$
  - we know that **F = ma**
  - and for these problems $\mathbf{a = a_c = v^2/r}$
  - If we substitute in for F we get $\mathbf{mv^2/r = qv \times B}$
  - We use this to solve for any missing variable





Right-Hand Rule (1st RHR)

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

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

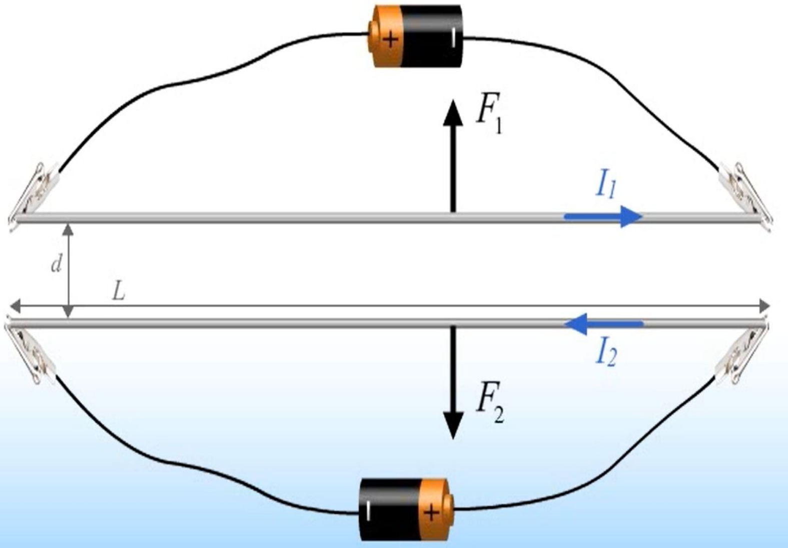
Forces on Current Wires and Loops

$F_{wire} = I\ L \times B$ (1st RHR)

- The force around an entire loop of current is always zero (assuming 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

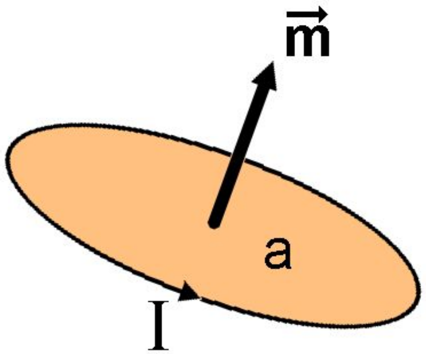
Currents traveling in opposite directions - repel



Magnetic Moment

Find the magnetic moment $\mu = NIA$

- Where N is the number of loops (typically 1)
- I in the current in the wire
- A is the Area in the loop



Use the right hand rule to find direction of the moment

Torques and Energy on Current Loops

Remember sin(θ) goes with cross products and cos(θ) goes with dot products

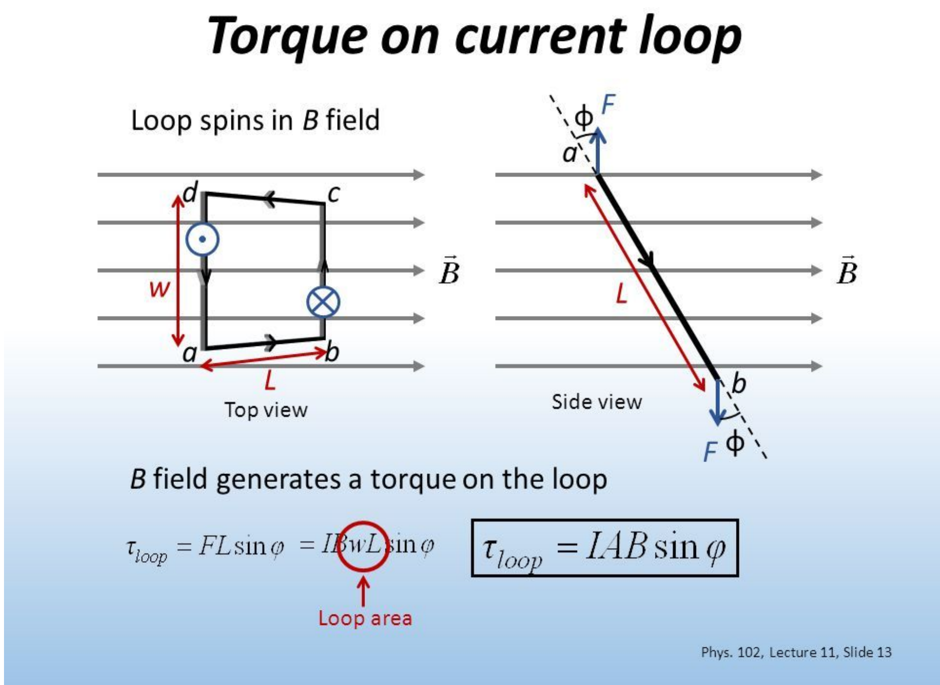
Magnetic Dipole: **μ = n * I * A (2nd RHR)**

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

Torque: **τ = μ x B = |μ||B|sin(θ) (1st RHR)**

Potential Energy: **U = -μ · B = -|μ||B|cos(θ)**

Work: **W = -U**



Torques and Energy Cont.

Remember sin(θ) goes with cross products and cos(θ) goes with dot products

Torque: $\boldsymbol{\tau}$ **= µ x B = |µ||B|sin(θ)**

Max when sin(θ) = 1 → θ = 90 → when µ and B are perpendicular

Potential Energy: **U = -µ · B = -|µ||B|cos(θ)**

Min when cos(θ) = 1 → θ = 0° → when µ and B are parallel in the same direction

Max when cos(θ) = -1 → θ = 180° → µ and B are parallel in opposite directions

Work: **W = -U**

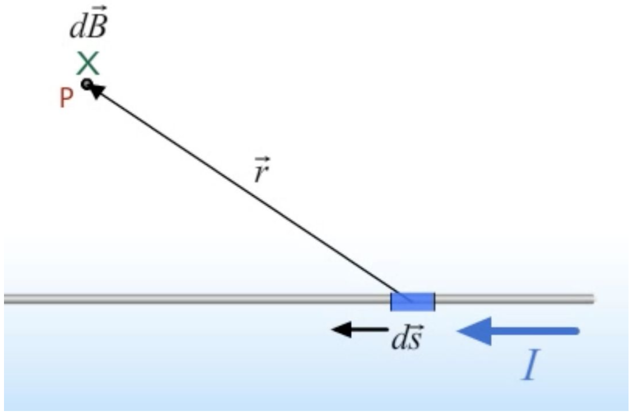
Biot-Savart Law

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)**

Most general case, integrate dB to find the total magnetic field at a point

-

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l} \times \hat{r}}{r^2}$$



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**

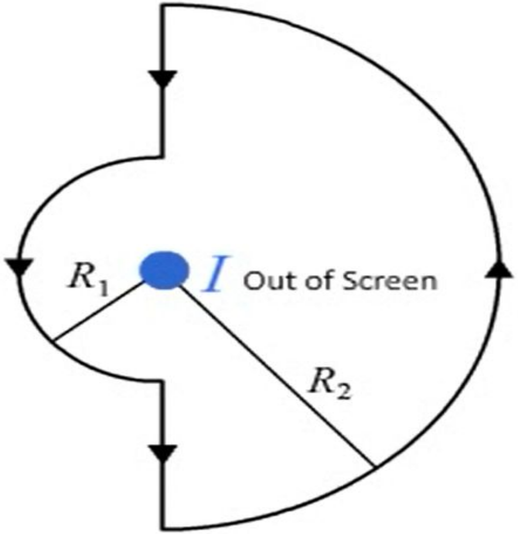
Current density: J = I / A

Units: (A/m^2)

I - Current

A - Area

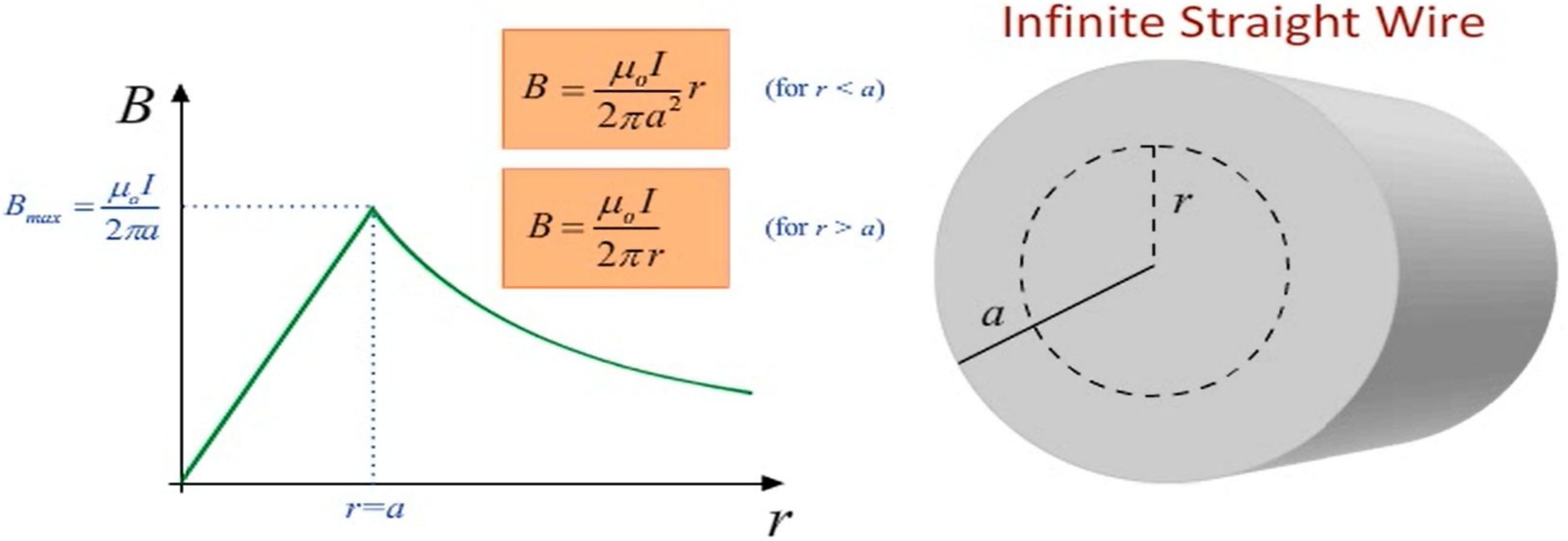
$$\oint_{loop} \vec{B}\cdot d\vec{l} = \mu_o I_{enclosed}$$



Ampere's Law Cont.

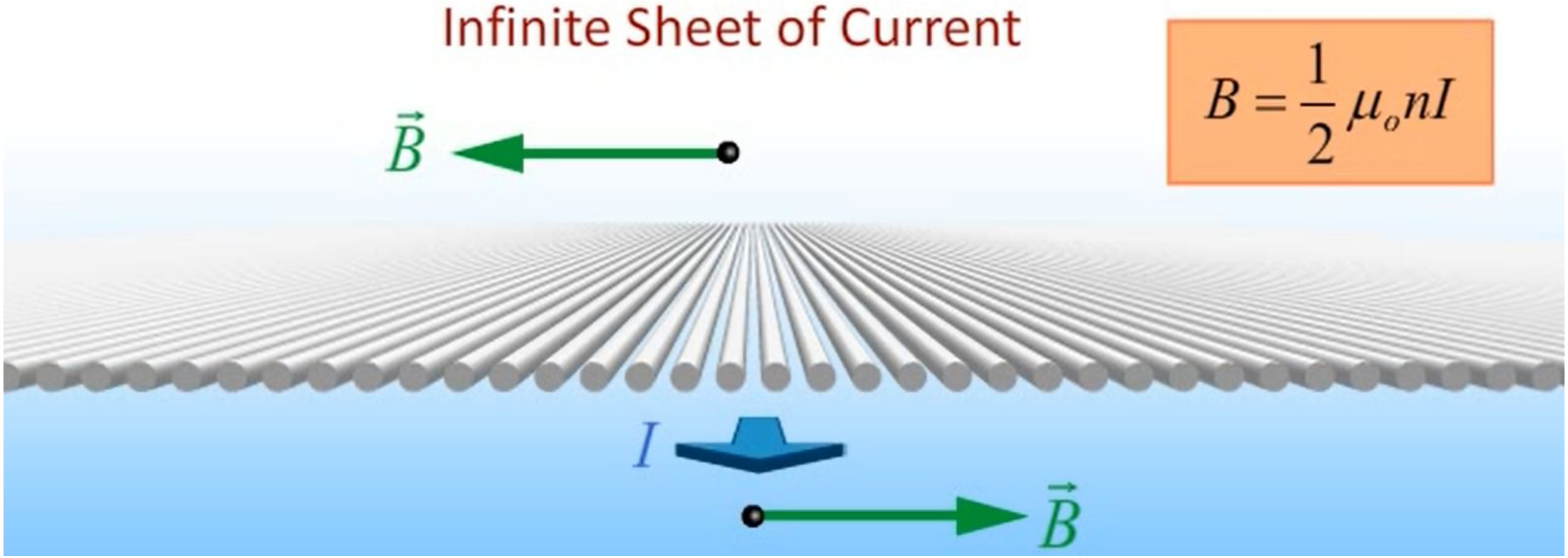
Magnetic field equations inside and outside a current-carrying wire

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



Ampere's Law Cont.

Magnetic field equation for an infinite sheet of current



Motional EMF

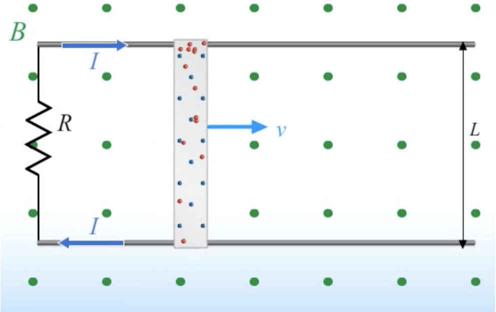
Potential difference = Voltage = Electromagnetic Force (EMF)

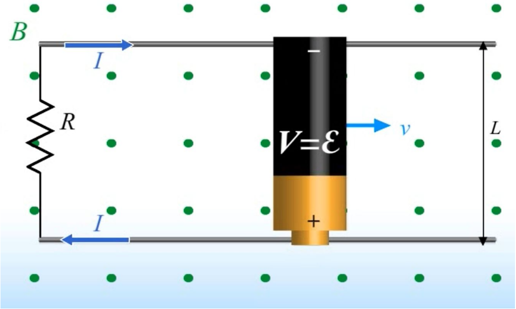
$$\mathcal{E} = vBL$$

v - velocity

B - magnetic field

L - length of the loop





To find direction of current: 1st RHR

- RHR wrt the magnet: **F = qv x B**
- **Your thumb gives you the direction of the current**

Faraday's Law

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

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.

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

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

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

<u>**Type 1:**</u> (Usually given B as a function of time or on a graph)

1) Find the magnetic flux **(B · 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)**

<u>**Type 2:**</u> (Usually a picture with one or "N" conducting loops)

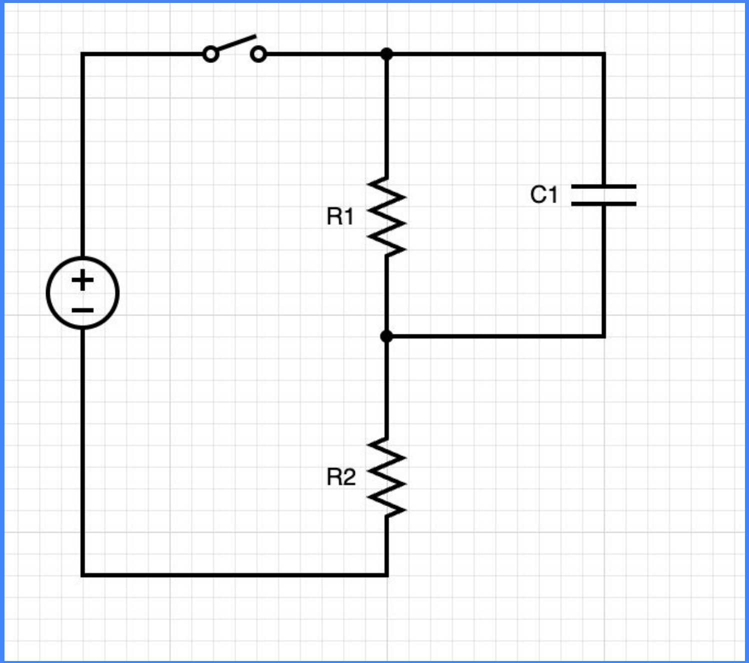
1) **Determine the change in magnetic flux, $B_{induced}$ will always point in the opposite direction** to the change in magnetic flux
2) **Use the 3rd RHR:** Point your fingers in the direction of $B_{induced}$ and curl your fingers to give you the direction of the induced current

Question Time!

Question 1

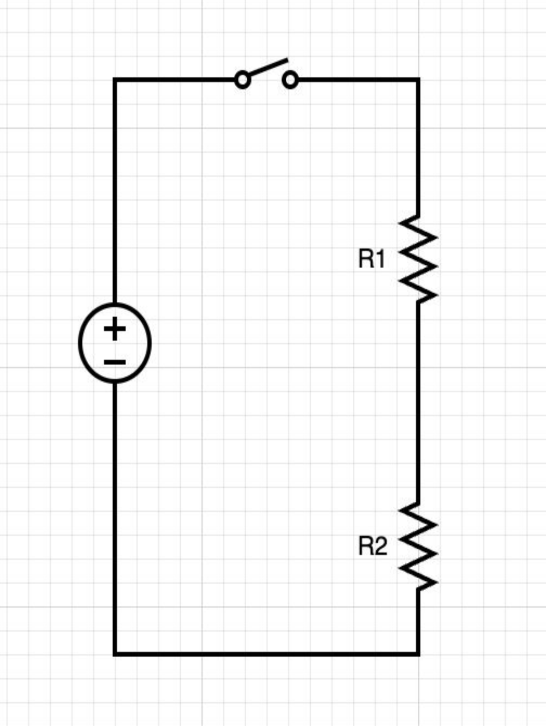
This Question is Based of the Following Circuit

Draw the Following Circuit

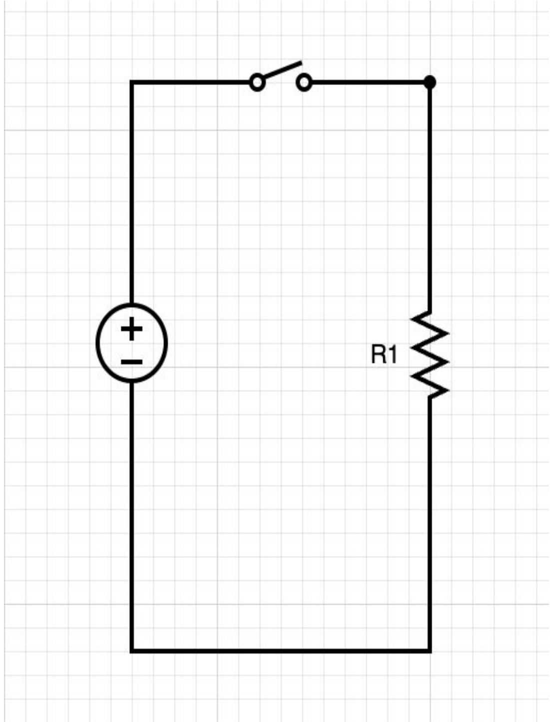


Where Would Current Flow at t=0

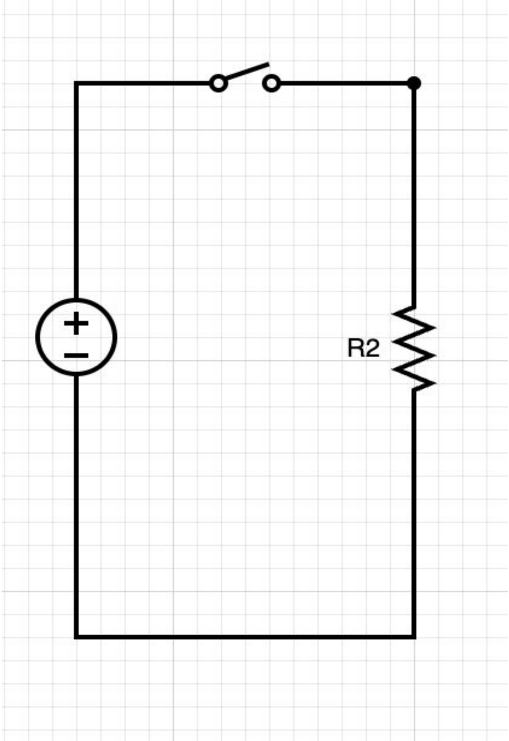
A



B



C

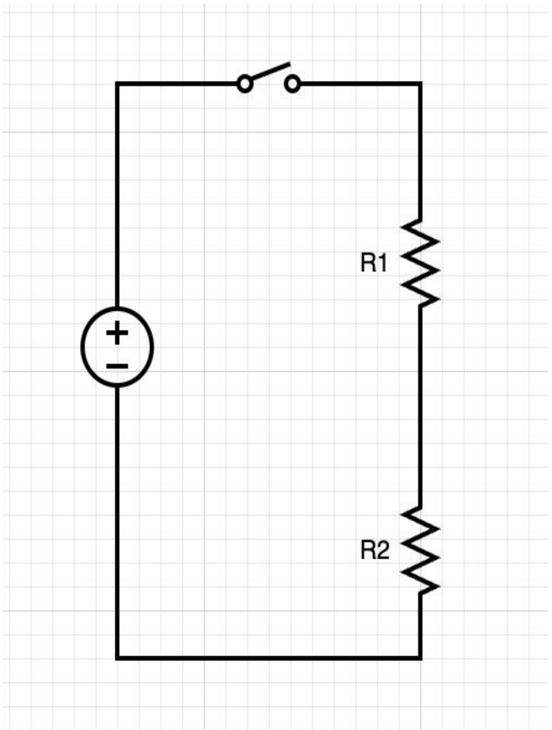


Correct: C

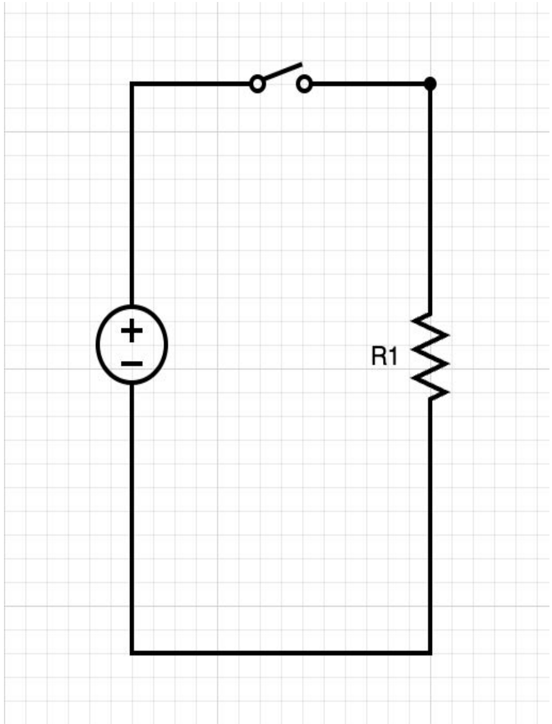
No current flows through R1 as the capacitor acts like a short

Where Would Current Flow at t=∞

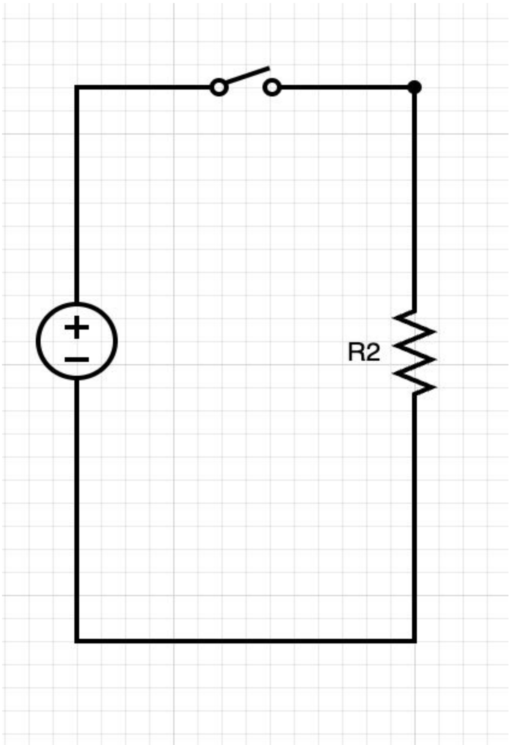
A



B



C



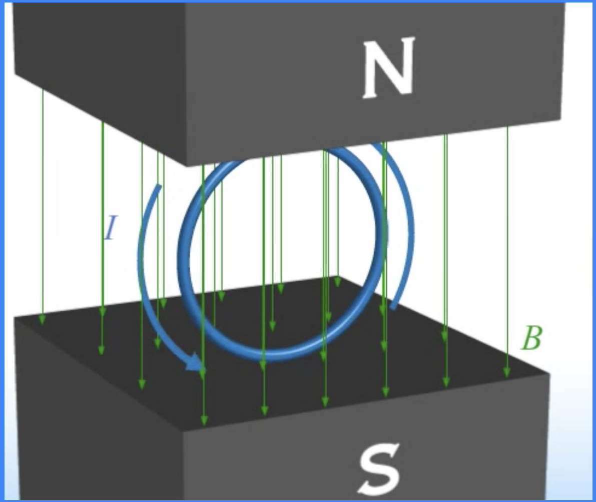
Correct: A

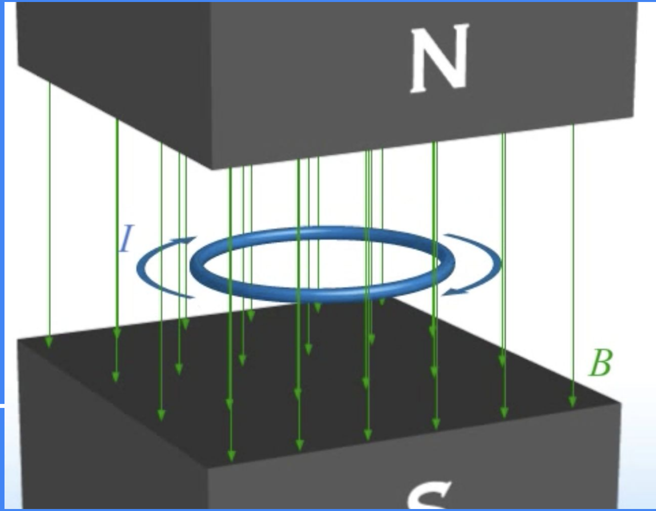
No current flows through the capacitor after a long time

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?





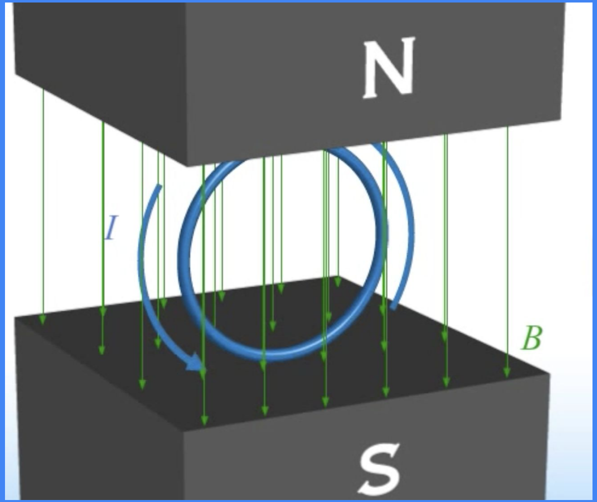
The work done by you is NEGATIVE.

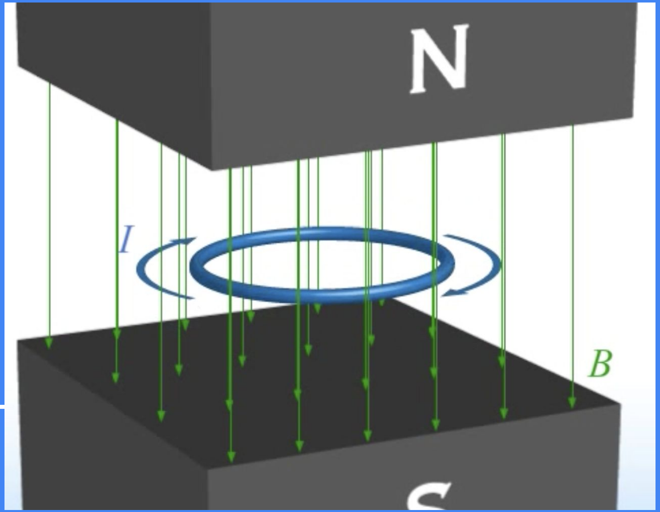
The loop has a lower potential energy, meaning you took away energy.

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

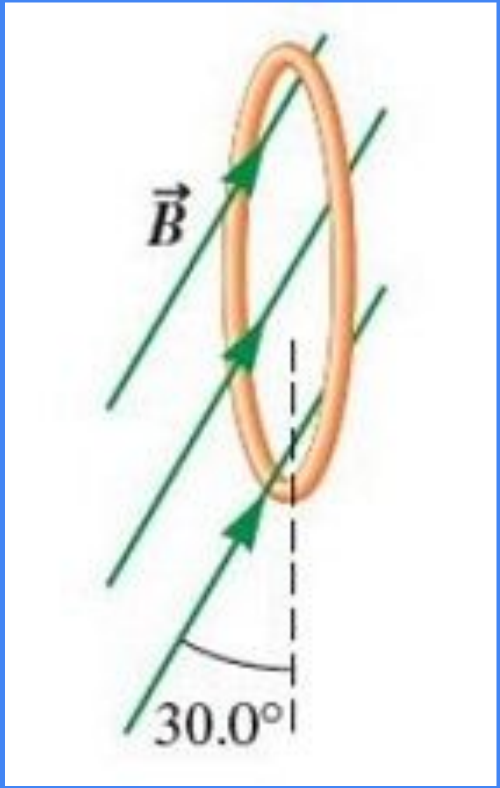
$$W = F.d$$

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

Question 3

A stationary loop (r = 2m) 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
In the direction of green arrow

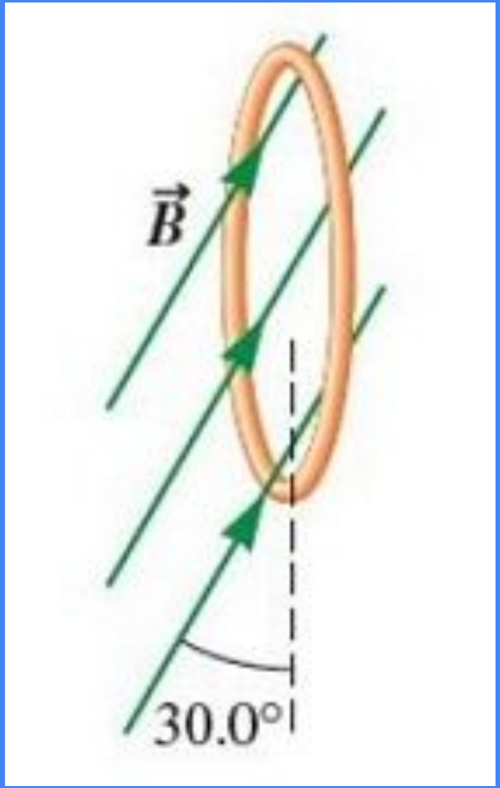


Question 3a

R = 2m, 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

Φ_B = B*Area, B = (4t-20)*sin(30), sin(30) = 0.5

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

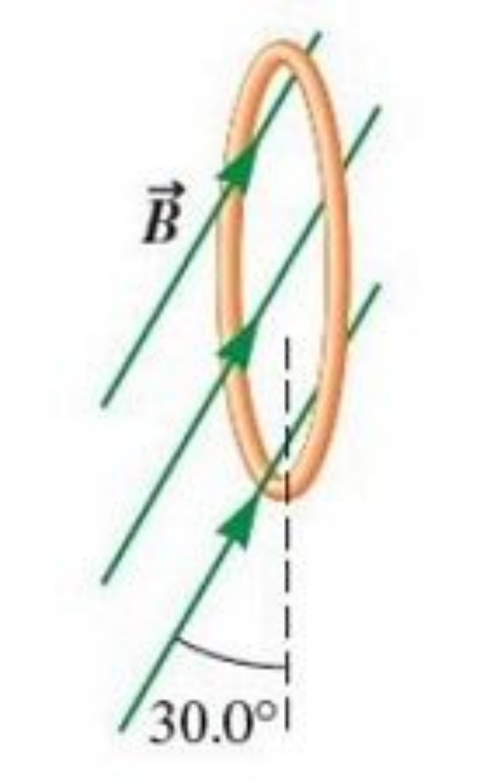
Φ_B = B*Area = (4t-20)(0.5)(4π) = (2π)(4t - 20)

Question 3b

R = 2m, 30° angle, B(t) = 4t - 20

What is expression for the motional EMF?

a. EMF = -8π*cos(30)
b. EMF = 8π*cos(30)
c. EMF = -8π
d. EMF = 8π



Correct: C

Differentiate the Flux and multiply by (-1)

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

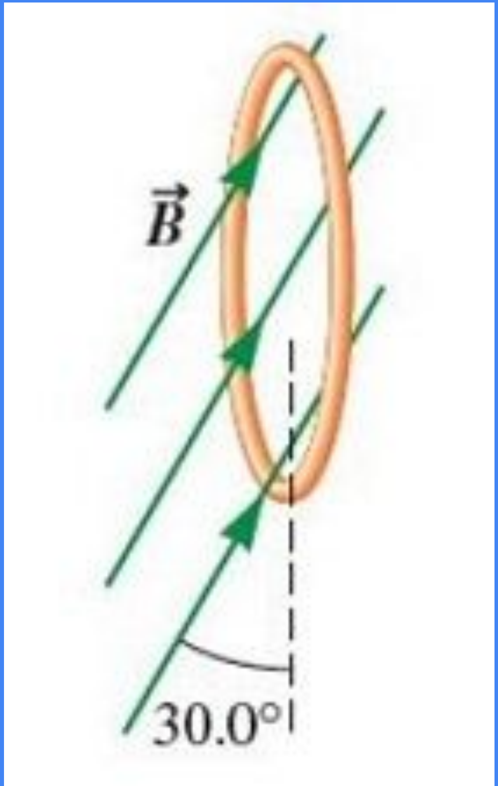
EMF = $-d/dt\ (8\pi t - 40\pi) = -1*8\pi = -8\pi$

Question 3c

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

Assume the green arrow points in the positive direction

a. Clockwise
b. Counter-Clockwise



Correct: B

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

Don't forget to sign in to the queue