Date: 11/19/19

Florida Polytechnic University

Fall 2019 - PHY 2049 - Exam 3

Maximum Points 100

Ans Key

Last Name ______________ First Name ______________ Section 01

Instructions:

The exam consists of two parts. Part I consists of multiple choice/short answer for a total of 50 points. Part II consists of problems which require more complex solutions for a total of 50 points. You must show your work/reasoning to get full credit in Part II. Make sure you supply your answers with the **correct SI units**. Utilize diagrams where appropriate.

NB: The sailing weather was good on Sunday, so I will NOT take points off this exam for too many significant figures. However, don't round too much or too early!

Chapter 31 Formulae:

E= cB	$\vec{S} \equiv \frac{1}{\mu_0} \vec{E} \times \vec{B}$
$\omega = 2\pi f$	$S = c\epsilon_0 E^2$ (instantaneous)
$\lambda f = c$	$I = \frac{c\epsilon_0}{2} E_0^2$ (average)

Part I – Complete all questions. (10 questions: 50 pts)

1. A solenoid is constructed using 1.0 mm wire carefully wound around a 4.0 cm diameter cylinder. The resulting solenoid is 10.0 cm long and will have N = 100 coils. If we drive a current of 25.0 A through the wire, what is the magnitude of the B field 1.0 cm off the central axis of the solenoid?

$$B = \frac{\mu_0 N I}{l} = 4\pi \cdot 10^{-7} \frac{Tm}{A} \cdot \frac{100 \cdot 25A}{0.10m} = \boxed{0.031\ T}$$

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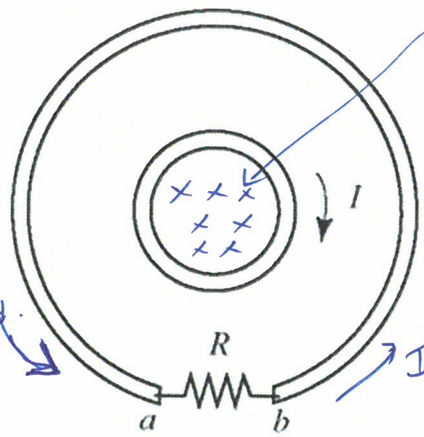
2. In the figure, the inner loop carries a clockwise current I that is increasing. The resistor R is in the outer loop and both loops are in the same plane. The induced current through the resistor R is



B field caused by inner current.

B is increasing.

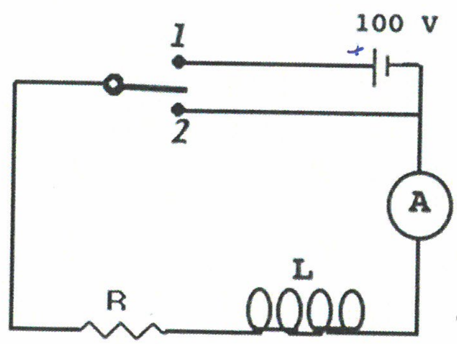
Φ_M in outer loop is increasing.

I induced.

I induced

A) from *a* to *b*.
B) from *b* to *a*.
C) There is no induced current through the resistor.

3. In the following circuit, the switch is held in position 1 for a long time. The switch is rapidly changed to position 2 defining t=0 s. Assuming R = 10 Ω, what can we say about the current I(t) in the circuit?



@ $t = -1$ sec : $I = \frac{100V}{10\Omega} = 10$ Amps

@ $t = 0$ $\quad I(t) = I_0 e^{-t/\tau}$

$I(0) = 10A$

$I(\infty) = 0$ A

A) I(0) = 10 A, I(∞) = 10 A

B) I(0) = 0 A, I(∞) = 10 A

C) I(0) = 10 A, I(∞) = 0 A

D) I(t) = 10 Sin (10t) A

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4. In the circuit shown in the above question, if R = 10. Ω and L = 450. mH what is the time constant of the circuit?

$$\tau = \frac{L}{R} = \frac{450\cdot10^{-3}\,H}{10\,\Omega} = 450\cdot10^{-4}\ \frac{Tm^2}{A}\cdot\frac{A}{V}$$

$$\boxed{\tau = 0.045\,s}$$

$$\frac{\cancel{N}\cdot\cancel{m}^2}{A\cdot\cancel{m}}\cdot\frac{C}{\cancel{N}\cdot\cancel{m}} = \text{seconds}$$

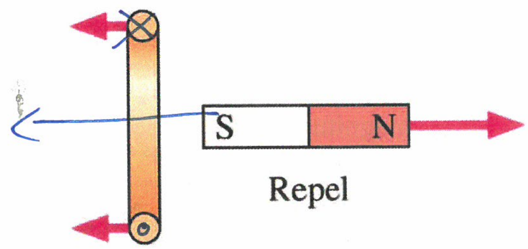
5. What is the current direction in the loop?

A) Out at the top, in at the bottom.

B) In at the top, out at the bottom.

C) Either A or B would cause the current loop and the bar magnet to repel each other

N



$\Delta V = -L\frac{dI}{dt}$ 6. Which current is changing more rapidly? The voltage drops are shown for each inductor.

A) Current I_1

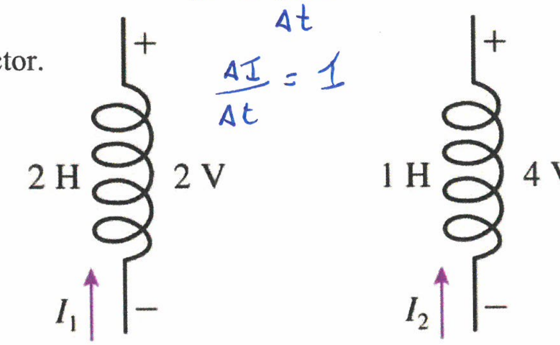
B) Current I_2

C) They are changing at the same rate.

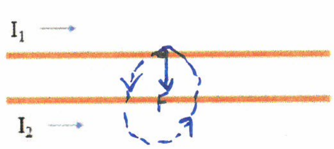
D) Not enough information to tell.

$2 = 2\frac{\Delta I}{\Delta t}$ $\qquad \frac{\Delta I}{\Delta t} = 1$

$4 = 1\frac{\Delta I}{dt}$ $\qquad \frac{\Delta I}{\Delta t} = 4$



7. Two long, straight wires are separated by 1 cm and carry currents as shown in the figure:



$\vec{F} = i\vec{l}\times\vec{B}$

What can we say about the magnitude and direction of the force on the top wire?

A) non-zero, upwards

B) non-zero, downwards

C) non-zero, into the page.

D) force is zero because there is no net charge on wire

Wires are attracted together.

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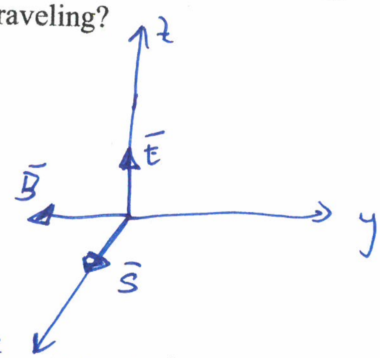
8. If a light wave is traveling at point P with the E field in the **+z** direction and the B field in the **-y** direction (at point P), what direction is the light wave traveling?

$\bar{S} = \frac{1}{\mu_0} \bar{E} \times \bar{B}$



A) +y

B) +x

C) -x

D) -z

9. If a certain electromagnetic wave has an instantaneous intensity of 1.1 W/m², what is the magnitude of the electric field?

$S = c\epsilon_0 E^2$

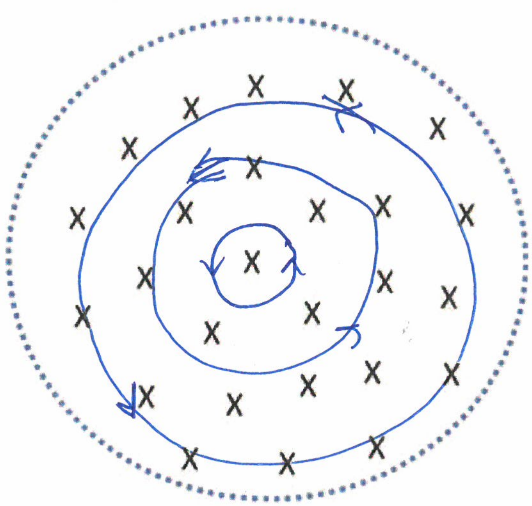
$1.1 \frac{W}{m^2} \cdot \frac{1}{3.0\cdot 10^8 \frac{m}{s}} \cdot \frac{1}{8.85\cdot 10^{-12} \frac{C^2}{Nm^2}} = E^2$

$\frac{Ws}{m} \cdot \frac{N}{C^2} = \frac{J\cdot \cancel{s}}{\cancel{s}\cdot m} \cdot \frac{N}{C^2} = \frac{N\cancel{m}\cdot N}{\cancel{m}\, C^2} = \frac{N^2}{C^2}$

$E = \sqrt{4.14\cdot 10^2 \; N^2/C^2}$

$\boxed{E = 20.4 \frac{N}{C}}$

10. The diagram below shows the uniform magnetic field inside of an ideal solenoid pointing into the page. The dotted-line is the circumference of the solonoid (there is no B field outside). Take the current I creating the solonoid to be increasing so that the B field magnitude is increasing with time. **Draw** the induced electric field lines for E caused by the changing B field INSIDE THE SOLENOID. Be sure to indicate the direction of the field lines. **(draw at least 3 field lines!)**



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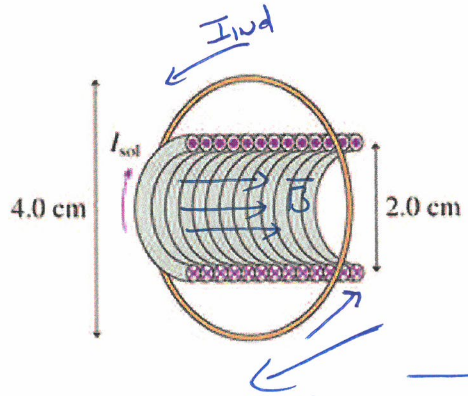
Part II –You must complete each problem in this section. All work must be clearly shown to receive full credit. Give proper SI units with all answers.

Problem II-1: [20 points] A 4.0-cm-diameter loop with resistance 0.12 Ω is arranged around a 2.0-cm-diameter solenoid as shown in the figure. The solenoid is 15.0 cm long and has 100 turns (assume ideal solenoid). The current driving the solenoid is given by I(t) = 1.5 t + 2.5 A (t = seconds). A) Determine the current in the outer loop. B) Looking from the front, is the current in the the outer loop CLOCKWISE or COUNTERCLOCKWISE? C) What would be the current in the outer loop if the axis of the solenoid was tilted 20.0 degrees from its present position (but the solenoid was still entirely passing through the outer loop).



$$B = \frac{\mu_0 N I}{l} = \frac{\mu_0 (100)}{0.15m} \cdot (1.5t + 2.5) A$$

$$B(t) = 8.3776 \cdot 10^{-4} (1.5t + 2.5) \ T$$

chk units: $\frac{T.m}{A} \cdot \frac{1}{m} \cdot A = T$ yes!

$$\Phi_m = \oint \bar{B} \cdot d\bar{A} = B \cdot \oint dA = B(t) \cdot \pi (0.01m)^2 = 2.6319 \cdot 10^{-7} (1.5t + 2.5) \ Tm^2$$

$\cos(0°)$ $\cos(0°)$

$$\mathcal{E} = N \cdot \frac{d\Phi_m}{dt} = (1)\frac{d\Phi_m}{dt} = (2.6319 \cdot 10^{-7})(1.5) \cdot \frac{Tm^2}{s}$$

$$\mathcal{E} = 3.95 \cdot 10^{-7} \text{ Volts}$$

unit chk:

$$\frac{Tm^2}{s} = \frac{N}{A \cdot m} \cdot \frac{m^2}{s} = \frac{Nm}{AS} = \frac{J}{A \cdot S} = \frac{J}{C} = \text{Volt} \checkmark$$

A) $I_{induced} = \frac{\mathcal{E}}{R} = \frac{3.95 \cdot 10^{-7} V}{0.12 \Omega} = \boxed{3.3 \mu A}$

B) COUNTER-CLOCKWISE TO OPPOSE CHANGING FLUX.

C) Flux is multiplied by $\cos(20°)$

$\therefore \mathcal{E} = \mathcal{E}_{above} \cdot \cos(20°)$

$I = I_{above} \cdot \cos 20° = \boxed{3.1 \mu A}$

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Problem II-2: [20 points] You build an LC oscillator circuit using a capacitor with C = 1.5 μF in series with an inductor. A) What inductor size is needed so the circuit oscillates at a a frequency of 1001 kHz? B) If we constructed this inductor from a 1.0 cm diameter solenoid with length 10.0 cm, how many turns would we need? (round to neared whole number of turns) C) If the maximum charge on the oscillating capacitor is 1.23 μC, what is the formula for Q(t) on the capacitor? D) What is the maximum voltage drop accross the inductor?

$f = 1001 \cdot 10^3$ Hz

$\omega = 2\pi f = 6.289 \cdot 10^6$ radians/s

$\omega_{LC}^2 = \frac{1}{LC} \Rightarrow L = \frac{1}{\omega^2 C} = \frac{1}{\left(6.289 \cdot 10^6 \frac{\text{rad}}{s}\right)^2 \cdot 1.5 \times 10^{-6} F}$

$L = 1.686 \cdot 10^{-8}$ H

$\boxed{\text{A} \quad L = 1.7 \cdot 10^{-8}\ H}$

unit chk:

$\frac{1}{F/s^2} = \frac{s^2}{F} = \frac{s^2 V}{C} = \frac{s^2\, Nm}{C \cdot C}$!

same.

$H = \frac{Tm^2}{A} = \frac{Tm^2 s}{C} = \frac{N}{A \cdot m} \cdot \frac{m^2 \cdot s}{C} = \frac{Nm\, s}{C \cdot C}$

B $L = \frac{\Phi_m}{I} = \frac{N \cdot B\left(\pi (0.005m)^2\right)}{I}$

$= \frac{N \pi (0.005m)^2}{I} \cdot \frac{\mu_0 N I}{l}$ } Notice! I's cancel! N is squared!

$L = \frac{N^2 \mu_0 \pi (0.005m)^2}{0.1m} \Rightarrow N^2 = \frac{0.10m\left(1.686 \cdot 10^{-8} H\right)}{\mu_0 \pi (0.005m)^2} = 17.08$

$N = \sqrt{17.08} = 4$ TURNS!

C $Q(t) = Q_0 \sin(\omega t)$

$Q_0 = 1.23 \cdot 10^{-6} C$

$\omega = 6.289 \cdot 10^6$ rad/s

PART D: $Q = CV$ $\quad V = \frac{Q}{C} = \frac{1.23 \cdot 10^{-6} C}{1.5 \cdot 10^{-6} \frac{C}{V}} = 0.82 V$

this maximum voltage on the capacitor will be the same maximum as the inductor.

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you can also find from $\Delta V = -L \frac{dI}{dt}$

$$\frac{dI}{dt} = \frac{d}{dt}\left[\frac{d}{dt} Q(t)\right]$$

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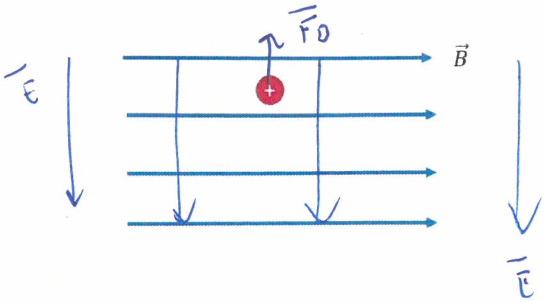
Problem II-4: An proton is moving out of the page towards your face in a uniform magnetic field as shown in the figure below. B = 0.55 T and the velocity of the proton is 1.1 x 10^3 m/s. You would like the proton to continue to move in a straight line so you apply an external electric field. What is the magnitude and direction of the electric field you must apply?



E field must point down to oppose force

$$\boxed{F_B = qv \times B = qvB\sin 90^\circ = 9.68 \cdot 10^{-17}\ N}$$

$$F_E = q \cdot E = q\,v \cdot B \cdot \cancel{\sin 90^\circ}$$

$$E = v \cdot B = \left(1.1 \cdot 10^3\ \frac{m}{s}\right)\left(0.55\ T\right)$$

7/7 magnitude
3/3 direct

$$\boxed{E = 6.05 \cdot 10^2\ \frac{N}{C}}$$

units $\frac{m \cdot T}{s} = \frac{\cancel{m}}{s} \cdot \frac{N}{A \cdot \cancel{m}} = \frac{N}{\cancel{s}} \cdot \frac{\cancel{s}}{C} = \frac{N}{C}$