

## Phys 121H Spring 1999 Grades

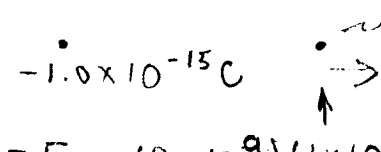
Last 4 digits of Student ID	Final Exam * (out of 200 points)	Total points (Lecture Quiz points count 1/2)	Course Grade
3381	114	442	B+
6828	153	548	A
0289	89	375	C+
6113	132	545	A
4815	77	357	C+
8921	152	542	A
0897	73	299	C
6530	125	413	B
3115	119	421	B
4027	167	551	A
3446	89	427	B
2216	67	310	C
8255	97	424	B
2883	124	455	B+
0947	118	443	B+
6274	88	403	B
7887	149	505	A
0461	156	559	A
1124	97	449	B+
2036	141	494	A
3416	100	366	C+
3820	142	503	A
4061	77	280	C
5459	125	440	B+

\* Average score on Final Exam was 116 out of 200.

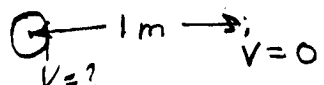
Part I. 100 points. Directions: Mark the answer on both this exam sheet and the Scantron card that most nearly matches the correct answer. No credit will be given unless complete and logical work is shown for numerical answers in the space provided. Each multiple choice question is 5 points.

- I
- II-1
- II-2
- II-3
- II-4

1. An electron is released from rest at a distance of 1 mm from a fixed  $-1 \times 10^{-15} \text{ C}$  charge. The velocity of the electron when it is far from the fixed charge is about:  
 a) 500 m/s    b) 1,200 m/s    c) 1,800 m/s    d) 40,000 m/s    e) 56,000 m/s

$-1.0 \times 10^{-15} \text{ C}$      $\sim 1.6 \times 10^{-19} \text{ C}$   
  
 $V_i = \frac{(9 \times 10^9)(1 \times 10^{-15})}{10^{-3}} = -0.009 \text{ V}$      $V_f = 0$   
 $\frac{1}{2} m v^2 = q \Delta V$      $v = \sqrt{\frac{2 q \Delta V}{m}} = \sqrt{\frac{2(1.6 \times 10^{-19})(9 \times 10^{-3})}{9.1 \times 10^{-31}}} = 56,250 \text{ m/s}$

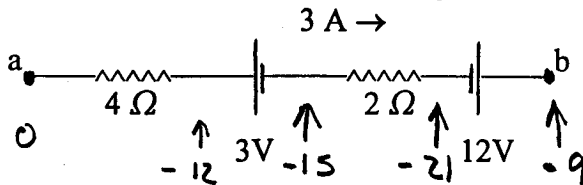
2. A conducting cylinder, radius 1 mm, has a linear charge density of 1 nC/m. If the electric potential 1m from the center of the cylinder is zero, the electric potential on the surface of the cylinder is about:  
 a) 18 V    b) 125 V    c) 300 V    d) 9,000 V    e) 18,000 V

  
 $E = \frac{k 2 \lambda}{r}$      $V = - \int_{1m}^{1mm} \frac{k 2 \lambda}{r} dr = -k 2 \lambda \ln \frac{100}{1}$   
 $V = (9 \times 10^9)(2)(1 \times 10^{-9}) \ln 10^3 = 124.3 \text{ V}$

3. A conducting sphere with radius 10 cm has a uniform charge density of 1.0 nC/m<sup>2</sup> on its surface. The electric field just above the surface of the sphere is about:  
 a) 110 V/m    b) 900 V/m    c) 1800 V/m    d) 18,000 V/m    e) 110,000 V/m

$E = \frac{\sigma}{\epsilon_0} = \frac{1 \times 10^{-9}}{8.85 \times 10^{-12}} = 113 \text{ V/m}$   
 At surface

4. A current of 3A is flowing from point a to point b.

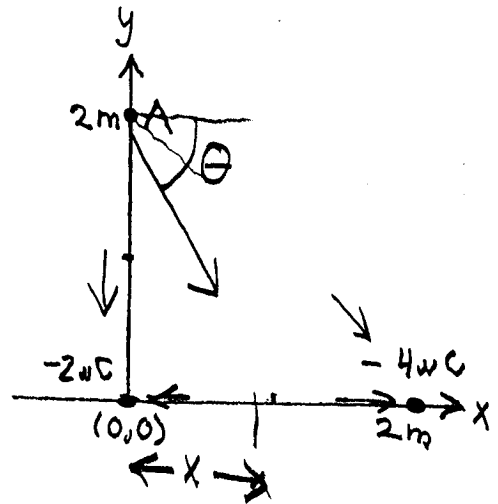


If point a is at zero potential, the potential of point b is:

- a) -3 V    b) -9 V    c) +9 V    d) -21 V    e) +21 V

The following statement applies to problems 5 and 6:

A  $-2\mu\text{C}$  point charge is fixed at the origin and a  $-4\mu\text{C}$  point charge is fixed at  $2\text{m}$  on the  $x$  axis. Point A is located at  $x = 0, y = 2\text{m}$ .



5. The approximate magnitude & direction of the electric field due to these charges at point A is:

- a)  $4,500 \text{ V/m @ } -45^\circ$       b)  $7,700 \text{ V/m @ } -22^\circ$   
 c)  $8,300 \text{ V/m @ } -68^\circ$       d)  $9,000 \text{ V/m @ } -22^\circ$   
 e)  $10,900 \text{ V/m @ } -45^\circ$

$$E_1 = \frac{-9 \times 10^9 \cdot 2 \times 10^{-6}}{2^2} = -4,500 \text{ V/m } \hat{y}$$

$$|E_2| = \frac{9 \times 10^9 \cdot 4 \times 10^{-6}}{8} = 4,500 \text{ V/m}$$

$$E_2 = \frac{1}{\sqrt{2}} 4,500 \hat{x} - \frac{1}{\sqrt{2}} 4,500 \hat{y}$$

$$E = 3181 \hat{x} - 7681 \hat{y}$$

$$|E| = 8,313 \text{ V/m} \quad \theta = \tan^{-1} \frac{-7681}{3181} = -68^\circ$$

6. The approximate location where a charge may be placed such that no force acts on it is:

- a)  $x = +0.17 \text{ m}, y = 0$       b)  $x = +0.50 \text{ m}, y = 0$       c)  $x = +0.83 \text{ m}, y = 0$   
 d)  $x = +1.17 \text{ m}, y = 0$       e) depends on sign of charge

Must be between charges

Find where  $E = 0$

$$\frac{k 2 \mu\text{C}}{x^2} = \frac{k 4 \mu\text{C}}{(2-x)^2}$$

$$\frac{2-x}{x} = \sqrt{2}$$

$$2 = (\sqrt{2} + 1)x, \quad x = \frac{2}{\sqrt{2} + 1}$$

$$x = .83$$

7. Nine identical wires with circular cross section diameter  $d$  and length  $L$  are connected in series. This combination has the same resistance as a single wire of length  $L$  but whose diameter is:

- a)  $3d$       b)  $9d$       c)  $d/3$       d)  $d/9$       e)  $d/81$

$$R = \frac{\rho 9L}{\frac{1}{4}d^2} = \frac{\rho L}{\frac{1}{4}x^2}$$

$$x^2 = \frac{d^2}{9}$$

$$x = \frac{d}{3}$$

8. Two parallel plates separated by a distance  $d$  are connected to a  $6 \text{ V}$  battery.

The charge on the plates is  $12 \text{ nC}$ . The plates are now pulled apart to a distance  $2d$  with the battery still connected. The charge on the plates is now:

- a)  $3 \text{ nC}$       b)  $6 \text{ nC}$       c)  $12 \text{ nC}$   
 d)  $24 \text{ nC}$       e)  $48 \text{ nC}$

$$Q = CV$$

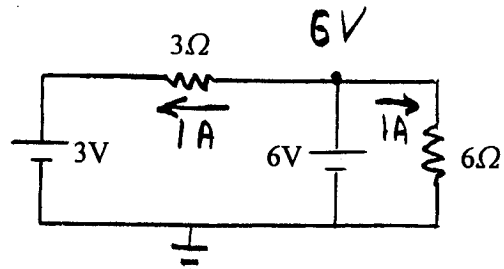
$$C_f \rightarrow \frac{1}{2} C_i$$

$$Q_f \rightarrow \frac{1}{2} Q_i$$

$$Q = 6 \text{ nC}$$

9. In the circuit shown, the 6 V battery:

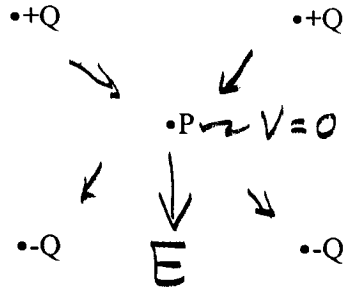
- a) Provides 6 W of power
- b) Absorbs 6 W of Power
- c) Provides 12 W of power**
- d) Absorbs 12 W of Power
- e) Absorbs 24 W of Power



$$P = V \cdot i = 6V \cdot 2A = 12W$$

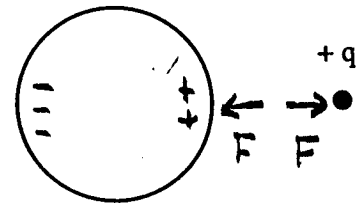
10. Positive charges of +Q and negative charges of -Q are placed on the diagonals of a square. At the point P, at the center of the square:

- a)  $|E| \neq 0; V = 0$
- b)  $|E| = 0; V < 0$
- c)  $|E| = 0; V > 0$
- d)  $|E| \neq 0; V > 0$
- e)  $|E| = 0; V = 0$



11. The figure to the right shows a small electrical charge +q near an uncharged hollow conducting sphere. Which of the following describes the electrical forces acting on the sphere and the small charge.

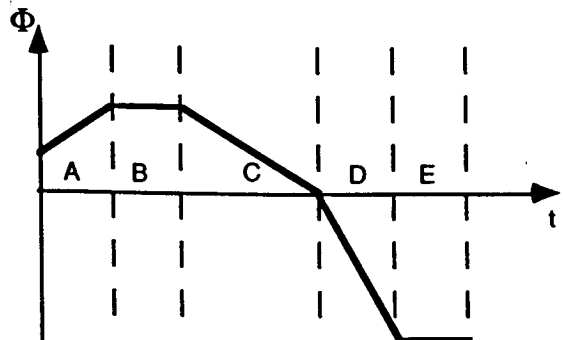
- a) only the small charge experiences a net electrical force.
- b) only the conducting sphere experiences a net electrical force.
- c) both objects experience a net electrical force but the small charge experiences the larger force.
- d) both objects experience net electrical forces that are equal in magnitude.**
- e) there are no electrical forces on either object



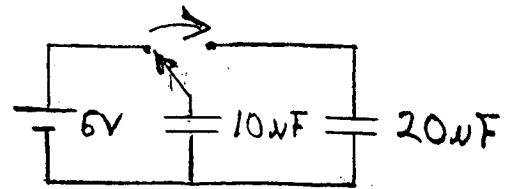
12. The graph of the magnetic flux  $\phi$  through a coil as a function of time is shown at the right. During what time interval does the induced voltage across the output of the coil have the largest magnitude?

- a) A
- b) B
- c) C
- d) D**
- e) E

$\uparrow$   
 $\left| \frac{d\Phi}{dt} \right|$  is largest



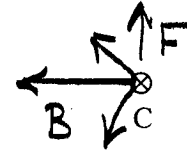
13. A  $10 \mu\text{F}$  capacitor is charged by applying a potential of  $6 \text{ V}$  to it. This capacitor is then disconnected from the battery and connected to a  $20 \mu\text{F}$  capacitor. The voltage across the capacitors is now about:
- a)  $1.0 \text{ V}$       b)  $1.5 \text{ V}$       c)  $2.0 \text{ V}$   
 d)  $3.0 \text{ V}$       e)  $6 \text{ V}$



$60 \mu\text{C}$  on  $10 \mu\text{F}$  capacitor

$$V_{\text{on cap.}} = \frac{60 \mu\text{C}}{30 \mu\text{F}} = 2 \text{ V}$$

↑  $C_1 + C_2$



14. Wires A and B carry currents of equal magnitudes in the same direction as shown. Wire C is placed above and equidistant from Wires A and B. Wire C carries a current into the page. The direction of the force acting on Wire C is:
- a) zero      b) ↑      c) ←  
 d) →      e) ↓

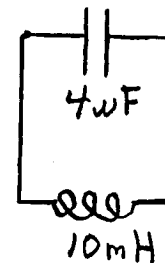


15. An electron is moving with a speed of  $1 \times 10^7 \text{ m/s}$  perpendicular to a magnetic field of  $6 \text{ mT}$ . The radius of the orbit of the electron is approximately: (use  $m_e = 9.1 \times 10^{-31} \text{ kg}$ )
- a)  $10 \text{ m}$       b)  $1 \text{ m}$       c)  $10 \text{ cm}$       d)  $1 \text{ cm}$       e)  $1 \text{ mm}$

$$\frac{mv^2}{r} = qvB$$

$$r = \frac{mv}{qB} = \frac{(9.1 \times 10^{-31})(1 \times 10^7)}{(1.6 \times 10^{-19})(6 \times 10^{-3})} = .94 \text{ cm}$$

16. In the oscillating LC circuit shown,  $L = 10 \text{ mH}$  and  $C = 4 \mu\text{F}$ . The maximum voltage across the capacitor is  $6 \text{ V}$ . If the current is zero and increasing at  $t=0$ , the time when the current first reaches  $50 \text{ mA}$  is approximately:



- a)  $8 \mu\text{s}$       b)  $32 \mu\text{s}$       c)  $86 \mu\text{s}$       d)  $230 \mu\text{s}$       e)  $310 \mu\text{s}$

1<sup>st</sup> Find  $i_{\text{max}}$ :  $i_{\text{max}} = Q_{\text{max}} \omega = V_{\text{max}} \frac{C}{\sqrt{LC}} = V_{\text{max}} \sqrt{\frac{C}{L}}$

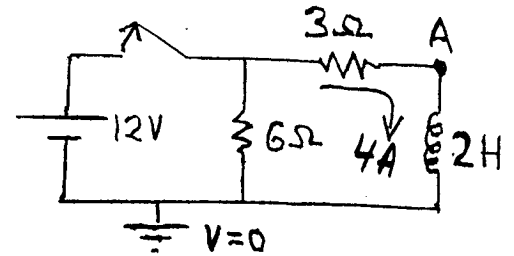
2<sup>nd</sup> Find  $\omega$ :  $\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4 \times 10^{-6} \times 1 \times 10^{-2}}} = 120 \text{ mA}$

$$\omega = 5000 \text{ rad/sec}$$

$$i = I_{\text{max}} \sin \omega t \quad 50 \text{ mA} = 120 \text{ mA} \sin 5000 t$$

$$t = \frac{1}{5000} \sin^{-1} \frac{50}{120} = 86 \mu\text{s}$$

17. In the circuit shown at the right, the switch has been closed a long time and then suddenly opened. At the instant the switch is reopened the voltage at point A relative to ground is:

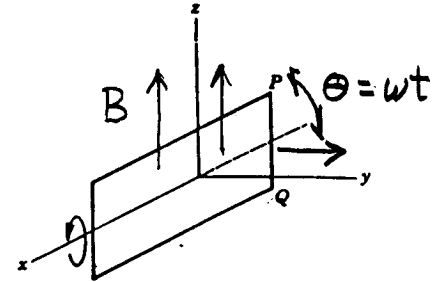


- a) -36V    b) -12V    c) zero    d) +12V    e) +36V

$$V = 4A \cdot 9\Omega = 36V$$

↑  
must be -

18. A single turn wire loop with area  $0.20 \text{ m}^2$  is rotating at an angular frequency of  $300 \text{ rad/s}$  in a magnetic field of  $0.05 \text{ T}$ . When the magnetic field is pointed in the plane of the loop (as shown), the EMF generated in the loop is about:



(Hint: Derive the expression for EMF in this case)

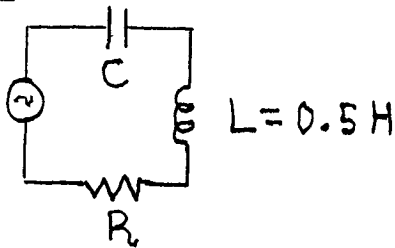
- a) 0 V    b) 3 mV    c) 30 mV    d) 300 mV    e) 3.0 V

$$\Phi = B \cdot A \cos \omega t$$

↙ in this case  $\omega t = \pi/2$

$$\frac{d\Phi}{dt} = B \cdot A \omega \sin \omega t = (0.05)(0.2)(300) = 3 \text{ V}$$

$\mathcal{E}_{\max} = 10 \text{ V}$   
 $f = 60 \text{ Hz}$



The circuit to the left applies to questions 19 & 20:

A  $60 \text{ Hz}$  AC source with  $\mathcal{E}_{\max} = 10 \text{ V}$  is applied to this circuit, resulting in a maximum current of  $50 \text{ mA}$ .

The phase shift  $\phi = -\pi/4$  radians. The inductance is  $L = 0.5 \text{ H}$

19. The resistance of the circuit is:

- a)  $71 \Omega$     b)  $100 \Omega$     c)  $141 \Omega$     d)  $173 \Omega$     e)  $200 \Omega$

$$Z = \frac{\mathcal{E}}{I} = \frac{10}{.05} = 200 \Omega$$

$$R = Z \cos \phi = 200 \cos \pi/4 = 141 \Omega$$

20. The capacitance is about:

- a)  $8 \mu\text{F}$     b)  $16 \mu\text{F}$     c)  $26 \mu\text{F}$     d)  $56 \mu\text{F}$     e)  $67 \mu\text{F}$

$$\tan^{-\pi/4} = \frac{X_L - X_C}{R}$$

$$-R = X_L - X_C$$

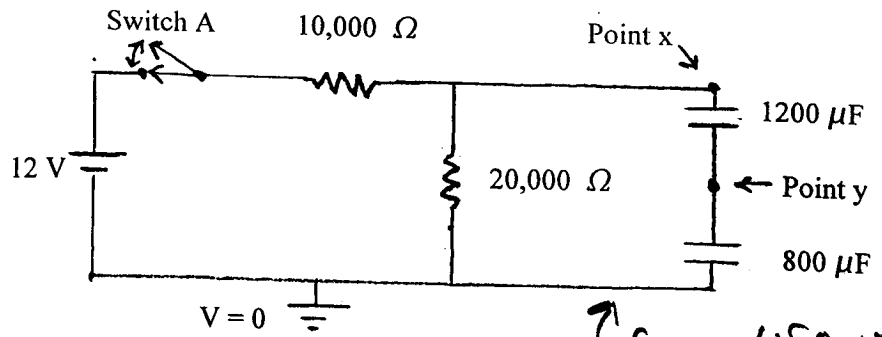
$$X_L = (377)(0.5) = 188 \Omega$$

$$X_C = X_L + R = 188 + 141 = 330 \Omega$$

$$C = \frac{1}{X_C \omega} = \frac{1}{(330)(377)} = 8 \mu\text{F}$$

Part II workout problems: Show your work

1. (25 pts)



Switch A has been closed a long time.

(7 pts) a) What is the potential at point x and point y

No current flows through capacitors.

$$V(\text{Point x}) = 12V \cdot \frac{20,000}{30,000} = 8V$$

$$Q_{800} = 8V \cdot C_{eq} = 8V(480\mu F)$$

$$V(\text{Point y}) = \frac{Q_{800}}{800\mu F} = \frac{V_x C_{eq}}{800} = \frac{8V(480\mu F)}{800\mu F} = 4.8V$$

Switch A is now opened.

(4 pts) b) What is the current through the 20,000 Ohm resistor the instant the switch is opened?

$$i = \frac{8V}{20,000\Omega} = .4mA$$

$$C_{eq} = 480\mu F$$

$$V(\text{Point x}) = 8V$$

$$V(\text{Point y}) = 4.8V$$

(9 pts) c) Find the following 5 seconds after the switch has been opened:

i) The potential at point x.    ii) The potential at point y.    iii) The current flowing through the 20,000 Ohm resistor.

$$\tau = RC = (20,000)(480\mu F) = 9.6 \text{ sec}$$

$$V_x = 8 e^{-5/9.6} = 4.75V$$

$$V_y = \frac{Q}{800\mu F} = \frac{V_x C_{eq}}{800} = \frac{(4.75)(480)}{800} = 2.85V$$

$$i = \frac{V_x}{20,000} = \frac{4.75}{20,000} = .24mA$$

$$V(\text{Point x}) = 4.75V$$

$$V(\text{Point y}) = 2.85V$$

$$i = .24mA$$

(5 pts) d) At what time after the switch is opened will the potential at Point y = 1.0V?

(Hint: Use your answers to part a) to get started)

$$V_y = \frac{V_x (480\mu F)}{800\mu F} \quad V_x = \frac{800\mu F}{480\mu F} V_y = 1.667V$$

$$\text{So when } V_x = 1V \quad V_y = 1.667V$$

$$V_y = 8 e^{-t/\tau}$$

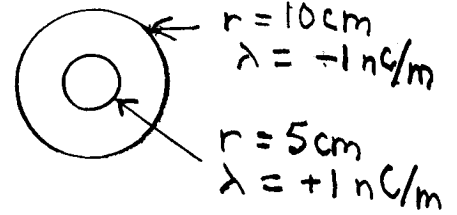
$$\frac{1.667}{8} = e^{-t/9.6s}$$

$$t = -9.6 \left( \ln\left(\frac{1.667}{8}\right) \right) = 15.05 \text{ sec}$$

2. (25 points) Two long thin concentric conducting pipes have linear charge densities and radii as follows:

Inner pipe: radius of 5 cm and net charge of 1 nC/m.

Outer pipe: radius of 10 cm and net charge of -1 nC/m



(5 pts) a) What is the surface charge density of the inner pipe?

$$\sigma = \frac{Q}{A} = \frac{Q}{2\pi r l} = \frac{\lambda}{2\pi r}$$

$$= \frac{1 \times 10^{-9}}{2\pi (5 \times 10^{-2})} = 3.2 \text{ nC/m}^2 \quad \sigma = 3.2 \text{ nC/m}^2$$

(4 pts) b) What is the electric field just above the outer surface of the inner pipe?

$$E = \frac{\sigma}{\epsilon_0} = \frac{3.2 \times 10^{-9} \text{ nC/m}^2}{8.85 \times 10^{-12}} = 362 \text{ V/m}$$

$$E = 362 \text{ V/m}$$

(4 pts) c) What is the electric field just above the outer surface of the outside pipe?

$$E = 0 \quad \text{because } 0 \text{ charge enclosed}$$

$$E = 0$$

(8 pts) d) What is the potential difference between the pipes?

Which pipe has the larger potential?

$$E = \frac{2k\lambda}{r}$$

$$\Delta V = -\int E \cdot ds = -\int \frac{2k\lambda}{r} dr = -2k\lambda \int_{5\text{cm}}^{10\text{cm}} \frac{dr}{r}$$

$$V_{\text{OUT}} - V_{\text{IN}} = -2(9 \times 10^9)(1 \times 10^{-9}) \ln \frac{10}{5} = -12.5 \text{ V}$$

$$\Delta V = 12.5 \text{ V}$$

Larger potential: inside

(4 pts) e) What is the capacitance per meter of the pipes?

$$C/l = \frac{Q/l}{V} = \frac{1 \times 10^{-9} \text{ C/m}}{12.5 \text{ V}} = 80 \text{ pF/m}$$

$$C = 80 \text{ pF/m}$$

3. (25 points) A 200 turn solenoid with a radius of 5 cm has an internal resistance of  $5\Omega$ .  
The instant the solenoid is connected to a 12 V DC source the current increases at a rate of 50 A/s in the solenoid.

(4 pts) a) Find the inductance of the solenoid.

$$\mathcal{E}_L = -L \frac{di}{dt}$$

$$L = \frac{\mathcal{E}_L}{\frac{di}{dt}} = \frac{12V}{50A/s} = .24H$$

$$L = .24H$$

(4 pts) b) Find the magnetic flux in the solenoid after the DC source is connected a long time

$$\Phi = \frac{Li}{N} = \frac{(.24H)(2.4A)}{200} = 2.88 \text{ mWb}$$

$$i = \frac{12V}{5\Omega} = 2.4A$$

$$\Phi = 2.88 \text{ mWb}$$

The solenoid is now connected to a current source that increases the current at a uniform rate of 10 A/s.

(6 pts) c) What is the rate of change of the magnetic field inside the solenoid?

$$B = \frac{\Phi}{A} = \frac{Li}{N \cdot A}$$

$$\frac{dB}{dt} = \frac{L}{NA} \frac{di}{dt} = \frac{.24H}{(200)(\pi(.05)^2)} \cdot 10A/s = 1.52 T/s$$

$$dB/dt = 1.52 T/s$$

(7 pts) d) A small ring, radius 1cm, with  $.01\Omega$  resistance is placed inside the solenoid with its plane perpendicular to the magnetic field. When the current is increasing at 10 A/s in the solenoid, what is the current flowing in the ring?

$$i = \frac{1}{R} A \frac{dB}{dt} = \frac{\pi(.01)^2}{.01} \cdot 1.52 = 47.8 \text{ mA}$$

$$i = 47.8 \text{ mA}$$

(4 pts) e) What is the mutual inductance between the solenoid and the ring?

$$\mathcal{E}_R = .01\Omega (47.8 \text{ mA}) = 477 \mu V$$

$$\mathcal{E}_R = M \frac{di_s}{dt} \quad M = \frac{\mathcal{E}_R}{\frac{di_s}{dt}} = \frac{477 \mu V}{10 A/s} = 47.7 \mu H$$

4. (25 pts) A coil (with both resistance and inductance) is connected to a 60 Hz AC EMF generator with 6 V (RMS) output. At this frequency the RMS current is 50 mA. When the frequency is increased to 120 Hz (at the same voltage) the RMS current drops to 40 mA.

- (5 pts) a) What is the impedance of the coil at 60 Hz and 120 Hz?

$$Z_{60} = \frac{E}{i} = \frac{6}{50 \times 10^{-3}} = 120 \Omega$$

$$Z_{120} = \frac{6}{40 \times 10^{-3}} = 150 \Omega$$

$$Z_{60} = 120 \Omega$$

$$Z_{120} = 150 \Omega$$

- (10 pts) b) What is the inductance and resistance of the coil?

$$Z^2 = R^2 + (\omega L)^2$$

$$\omega = 377 \text{ rad/s @ } 60 \text{ Hz}$$

$$(120)^2 = R^2 + \omega^2 L^2$$

$$(150)^2 = R^2 + 4\omega^2 L^2$$

$$L^2 = \frac{1}{3\omega^2} [(150)^2 - (120)^2]$$

$$L = .138 \text{ H}$$

$$L = \frac{1}{\sqrt{3}} \frac{1}{377} \sqrt{(150)^2 - (120)^2} = .138 \text{ H}$$

$$X_L = \omega L = 52 \Omega \text{ at } 60 \text{ Hz}$$

$$R = \sqrt{Z^2 - X_L^2} = \sqrt{(120)^2 - (52)^2} = 108 \Omega \quad R = 108 \Omega$$

- (5 pts) c) What is the phase shift (in degrees) of the current relative to the EMF source at 60 Hz?

Is the current leading or lagging the EMF source?

Current lags inductive circuit

$$\phi_{60} = \tan^{-1} \frac{X_L}{R} = \tan^{-1} \frac{52 \Omega}{108 \Omega} = 25.7^\circ$$

$$\phi = 25.7^\circ$$

- (5 pts) d) What capacitance connected in series with the coil will put the current in phase with the EMF at 60 Hz?

$$\text{Want } X_C = X_L = 52 \Omega$$

$$X_C = \frac{1}{\omega C} = 52 \Omega$$

$$C = \frac{1}{(377)(52)} = 51 \mu\text{F}$$

$$C = 51 \mu\text{F}$$