PHYS 1C-2 Spring 2018 – 1st Midterm

[redacted]

- Length: 90 mins.
- Closed book.
- Simple calculators are allowed.
- A formula sheet is allowed.
- Each multiple choice question has only one solution.

Problem 1:	14 /15
Problem 2:	10 /10
Problem 3:	10 /10
Problem 4:	15 /15
Total:	49/50

Problem 1

(1) Consider a solenoid of length L, N windings, and radius b ($L \gg b$). A current I is flowing through the wire. If the radius of the solenoid were doubled, and all other quantities remained the same, the magnetic field inside the solenoid would

A) remain the same.
B) become twice as strong.
C) become four times as strong.
D) become one half as strong.
E) become one fourth as strong.

(2) A current carrying loop of wire lies flat on a table top. When viewed from above, the current moves around the loop in a counterclockwise sense. For points outside the loop, the magnetic field caused by this current

A) circles the loop in a clockwise direction.
B) circles the loop in a counterclockwise direction.
C) points straight up.
D) points straight down.
E) is zero.

(3) Two very long parallel wires are a distance d apart and carry equal currents in opposite directions. The locations where the net magnetic field due to these currents could be zero are:

A) midway between the wires.
B) a distance $d/2$ to the left of the left wire and a distance $d/2$ to the right of the right wire.
C) a distance d to the left of the left wire and a distance d to the right of the right wire.
D) a distance $d/\sqrt{2}$ to the left of the left wire and a distance $d/\sqrt{2}$ to the right of the right wire.
E) The net field cannot be zero.

(4) A circular loop of wire lies in the plane of the paper. An increasing magnetic field points out of the paper. What is the direction of the induced current in the loop?

A) counter-clockwise then clockwise.
B) clockwise then counter-clockwise.
C) clockwise.
D) counter-clockwise.
E) There is no current induced in the loop.

(5) Suppose that you wish to construct a simple ac generator having an output of around 60 V maximum when rotated at 1 Hz. A uniform magnetic field of 1 T is available. If the area of the rotating coil is 1 m^2, how many turns (after rounding) do you need?

A) 1
B) 10
C) 60
D) 100
E) 1000

$\omega = 2\pi\ s^{-1}$ $\quad V = r\omega$

$NB\frac{dA}{dt} = 60V$

$\frac{dA}{dt} = (1m)(2\pi\ m/s) = 2\pi$

$N\,2\pi = 60 \quad N = \frac{60}{2\pi} = 9.55$

(6) A loop of wire sits on the xy plane and a uniform magnetic field is pointing along the z-axis. How can you generate an induced emf on the loop?

A) move it along the x-axis.
B) move it along the z-axis.
C) oscillate it back and forth along the x-axis.
D) oscillate it back and forth along the z-axis.
E) rotate it about the x-axis.

(7) Which of the following statement about Ampere's law is true?

A) Ampere's law is the same as the Gauss's law for magnetism.
B) Ampere's law is valid only for symmetric current systems such as lines and cylinders.
C) If there is no current inside an Amperian loop, the magnetic field must be zero everywhere on that loop.
D) Only current encircled by an Amperian loop can produce a magnetic field on that loop.
E) Zero magnetic field along the entire Amperian loop means no current is enclosed.

(8) A resistor and an inductor are connected in series to an ideal battery having a voltage V_0. At the moment contact is made with the battery, the voltage across the resistor and the voltage across the inductor, respectively, are

A) 0 and 0.
B) V_0 and V_0.
C) 0 and V_0.
D) V_0 and 0.
E) $V_0/2$ and $V_0/2$.

(9) Which of the following statement about inductors is correct?

A) When it is connected in a circuit, an inductor always resists having current flow through it.
B) An inductor always resists any change in the current through it.
C) Inductors store energy by building up charges.
D) When an inductor and a resistor are connected in series with a battery, the current in the circuit is zero in one time constant.
E) When an inductor and a resistor are connected in series with a battery, the current in the circuit is zero after a very long time.

(10) In an LC circuit containing a 1 H ideal inductor and a 2 F capacitor, the maximum charge on the capacitor is 3 C during the oscillations. What is the maximum current through the inductor during the oscillations?

A) 1 A.
B) 2 A.
C) 3 A.
D) $\sqrt{2}/3$ A.
E) $3/\sqrt{2}$ A.

$$\cancel{\tfrac{1}{2}}\frac{1}{C}Q^2 = \cancel{\tfrac{1}{2}}LI^2$$

$$I = \frac{Q}{\sqrt{LC}} = \frac{3C}{\sqrt{2}\,s}$$

(11) Which of the following circuit, when connected with an ideal battery, will have zero current at infinite time?

A) R circuit.
B) RL circuit.
C) LC circuit.
D) RCL circuit.
E) None of the above.

(12) When an AC RCL series circuit is at resonance, which of the following statement is accurate?

A) The impedance has its maximum value.
B) The reactance of the inductor is zero.
C) The reactance of the capacitor is zero.
D) The reactance due to the inductor and capacitor has its maximum value.
E) The current amplitude is a maximum.

(13) In an AC RCL series circuit, the frequency at which the circuit is at resonance is f. If you double the resistance, the inductance, the capacitance, and the voltage amplitude of the ac source, what is the new resonance frequency?

A) $4f$.
B) $2f$.
C) f.
D) $f/2$.
E) $f/4$.

(14) In an AC RCL series circuit, which of the following does not depend on the frequency of the source?

A) Resonance frequency.
B) Impedance.
C) Phase angle of the voltage relative to the current.
D) Power.
E) None of the above.

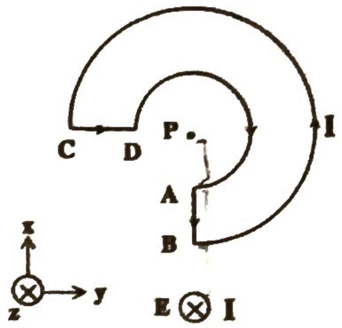
(15) An ideal transformer consists of a 500-turn primary coil and a 2000-turn secondary coil. If the current in the secondary is 3 A, what is the current in the primary?

A) 3/4 A.
B) 4/3 A.
C) 12 A.
D) 24 A.
E) 48 A.

+10

Problem 2

In the figure below, find the magnetic field at point P using the xyz vector coordinate. The system contains two parts: an $ABCD$ loop on the xy plane and an infinitely long wire at E along the z-axis, both carrying current I. Both the arcs BC and DA give an angle of 270°. The wire at E has a current flowing along the z-axis. The distances PA, AB and BE are all equal to a. Express your answer in the form of $\vec{B} = B_x\hat{x} + B_y\hat{y} + B_z\hat{z}$.



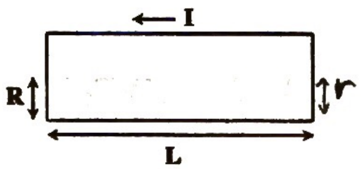
$\frac{3}{4}\left(\frac{\mu_0 I}{2a} - \frac{\mu_0 I}{4a}\right)\hat{z}$

$+ \frac{\mu_0 I}{2\pi 3a}\hat{y}$

$$\boxed{\vec{B} = 0\hat{x} + \frac{\mu_0 I}{6\pi a}\hat{y} + \frac{3\mu_0 I}{16a}\hat{z}}$$

Problem 3

A current I passes through a cylindrical wire of radius R and length L. A 2D projection of the setup is shown below. (a) For a constant current I, find the magnetic field inside the wire and the magnetic flux through the shaded rectangular region. (b) Now the current is slowly increasing $I(t) = at$. Find the induced emf ε through the shaded region. If a current can be induced along the perimeter of the shaded region, does it flow clockwise or anticlockwise?



a) $2\pi r B = \mu_0 I \frac{r^2}{R^2}$

$\boxed{B = \frac{\mu_0 I r}{2\pi R^2}}$ 3

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$\Phi_B = \int_0^R \frac{\mu_0 I r}{2\pi R^2} L\,dr = \frac{\mu_0 I L}{2\pi R^2} \int_0^R r\,dr = \frac{\mu_0 I L}{2\pi R^2}\left(\frac{1}{2}R^2\right) = \boxed{\frac{\mu_0 I L}{4\pi}}$

b) $\frac{dI}{dt} = a \quad -\frac{d\Phi_B}{dt} = \mathcal{E} = \boxed{-\frac{\mu_0 L}{4\pi} a}$ 2

Clockwise

2

Problem 4

A resistor R, a capacitor C and an inductor L are all connected in parallel with an ac source with fixed $V(t) = V_0 \cos \omega t$. (a) In terms of V, what is the potential differences across the resistor (V_R), the capacitor (V_C) and the inductor (V_L)? (b) What are the corresponding current amplitudes, i.e. I_R, I_C and I_L? Are I_L and I_C leading or lagging I_R? (c) Use a vector diagram to represent the relations among I_R, I_C, I_L and the total current I through the source. (d) Express the amplitude of I in terms of R, C, L, V_0 and ω. (e) At what frequencies (ω) is I maximized? Sketch $I(\omega)$ vs ω.

a) $V_R = V \quad V_C = V \quad V_L = V$ 1

$C = \frac{Q}{V} \quad Q = CV \quad \frac{dQ}{dt} = C\frac{dV}{dt}$

b) $\boxed{I_R = \frac{V}{R}}$ $\boxed{I_C = C\frac{dV}{dt} = -\omega C V_0 \sin \omega t = \omega C V_0 \cos(\omega t + \frac{\pi}{2})}$

$V_L = L\frac{dI}{dt} \quad \frac{dI}{dt} = \frac{1}{L}V_L \quad I = \frac{1}{L}\int V_L$

$\boxed{I_L = \frac{1}{L}\int V = \frac{1}{\omega L}V_0 \sin \omega t = \frac{1}{\omega L}V_0 \cos(\omega t - \frac{\pi}{2})}$

current amplitudes

$$\boxed{\begin{aligned} |I_R| &= \frac{V_0}{R} \\ |I_C| &= \omega C V_0 \\ |I_L| &= \frac{1}{\omega L}V_0 \end{aligned}}$$

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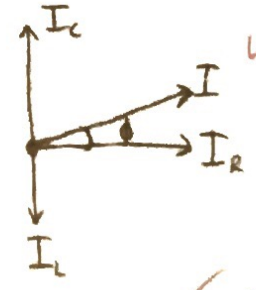
I_C is leading

I_L is lagging

c)



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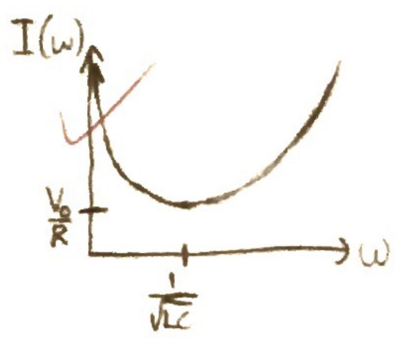
e) I is maximized when $\omega \to 0$ and $\omega \to \infty$ 3



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d) $|I| = V_0\sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2}$