Solutions

PHYSICS 202 Exam 2
Spring 2007

Do NOT open out the exam until instructed to do so!

Name: ___________________________ UIN: ______________________

Signature: ________________________ E-mail: ______________________

Section Number: ____________ (5 points off for a wrong sec. #)

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<td>525</td>
<td>T 2:20-5:10pm</td>
<td>Milan Poudel</td>
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<td>526</td>
<td>T 3:55-6:45pm</td>
<td>Morgan Priolo</td>
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<td>527</td>
<td>T 5:30-8:20pm</td>
<td>Dan Xie</td>
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- You have the full class period to complete the exam.
- Formulae are provided on a separate colored sheet. You may NOT use any other formula sheet.
- When calculating numerical values, be sure to keep track of units.
- You may use this exam or come up front for scratch paper.
- Be sure to put a box around your final answers and clearly indicate your work to your grader.
- Clearly erase any unwanted marks. No credit will be given if we can’t figure out which answer you are choosing, or which answer you want us to consider.
- Partial credit can be given only if your work is clearly explained and labeled.
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Problem 1 (15 points):
In PHYS 202 class, you saw an example of electromagnetic induction in the case where a rectangular wire loop is moving at a constant speed in a uniform magnetic field. See the figure. The magnetic field is directed out of the page. Your task is to fill the table below on the magnitude of the magnetic flux (\(\Phi_B\)) in the loop, the magnitude of the rate change of the flux (\(\Delta\Phi_B/\Delta t\)), and the current (\(I\)) in terms of \(R\), \(\ell\), \(a\), \(v\), and/or \(B\), or put zero if the magnitude is zero. Also write c.w. (\(\leftarrow\)) or c.c.w. (\(\leftarrow\)) for the direction of the current. [You don’t need to write down the direction if \(I = 0\).]

A rectangular wire loop, moving at a constant speed \(v\) in a uniform magnetic field.
Problem 2 (25 points):
The figure shows a circuit that you design in PHYS 202 lab. You are about to measure the currents. Predict the current through each resistor, before the measurements. [Hint: Write down a set of equations using Kirchhoff's junction and loop rules. Indicate clearly the loop(s) for the loop rule.]

Junction Rule: \[ I_1 + I_3 = I_2 \]  
Loop Rule: \[ 92.0 \text{ V} - (40.0 \Omega) I_1 - (210.0 \Omega) I_2 + 55.0 \text{ V} = 0 \) (Loop X)

\[ 57.0 \text{ V} - (35.0 \Omega) I_3 - (210.0 \Omega) I_2 + 55.0 \text{ V} = 0 \) (Loop Y)

\[ 2 \Rightarrow I_1 = \frac{92.0 + 5}{140.0} - \frac{210.0}{140.0} I_2 \quad \therefore I_1 = 1.05 - 1.5 I_2 \]

\[ 3 \Rightarrow I_3 = \frac{57.0 + 55.0}{35.0} - \frac{210.0}{35.0} I_2 \quad \therefore I_3 = 3.2 - 6.0 I_2 \]

\[ 4, 5 \text{ into } 1 \Rightarrow (1.05 - 1.5 I_2) + (3.2 - 6.0 I_2) = I_2 \]

\[ \therefore I_2 = \boxed{0.5 \text{ A}} \]

\[ 2 \Rightarrow I_1 = \boxed{0.3 \text{ A}} \]

\[ 3 \Rightarrow I_3 = \boxed{0.2 \text{ A}} \]

15 pts Does the student identify 3 equations correctly using Kirchhoff's rules?

10 pts Does the student solve 3 equations correctly?
Problem 3 (25 points):
In PHYS 202 lecture, you learned the magnetic field is produced by a current. So, in the lab, you prepare two simplest current configurations: (i) a very long, straight wire carrying a current of \( I_1 = 10.0 \, \text{A} \) of current and (ii) a circular ring of radius \( R = 4.50 \, \text{cm} \) carrying a current of \( I_2 = 12.0 \, \text{A} \). The distance between the straight wire and the center of the ring is \( D = 10.0 \, \text{cm} \). The pre-lab assignments are:

(a) (10 pts) Find the direction of the magnetic field due to \( I_2 \) at the center of the ring;

(b) (10 pts) Find the direction of \( I_1 \) to have a maximum magnitude of the magnetic field due to \( I_1 \) and \( I_2 \) at the center of the ring;

(c) (5 pts) Predict the maximum magnitude of the magnetic field at the center of the ring due to the combination of wires.

\[ \begin{align*}
\mathbf{B}_1 &= \frac{\mu_0 I_1}{2\pi D} \mathbf{\times}, \quad \mathbf{B}_2 = \frac{\mu_0 I_2}{2R} \mathbf{\times} \\
\therefore |\mathbf{B}_{I_1+I_2}| = |\mathbf{B}_1| + |\mathbf{B}_2| &= \frac{\mu_0}{2} \left( \frac{I_1}{\pi D} + \frac{I_2}{R} \right) \\
&= \frac{4\pi \times 10^{-7} \, \text{Tm/A}}{2} \left[ \frac{10.0 \, \text{A}}{\pi (0.10 \, \text{m})} + \frac{12.0 \, \text{A}}{(0.0450 \, \text{m})} \right] \\
\text{Partial credits} &= 1.88 \times 10^{-4} \, \text{T}
\end{align*} \]

- 2 pts \( \mathbf{B}_{I_1+I_2} = \mathbf{B}_1 + \mathbf{B}_2 \) \( \left\downarrow \text{Does the student know this?}\right. \\
- 1 pt \mathbf{B}_1 = \frac{\mu_0 I_1}{2\pi D} \mathbf{\times} \quad \left\downarrow \text{Does the student use the correct formula?}\right. \\
- 1 pt \mathbf{B}_2 = \frac{\mu_0 I_2}{2R} \mathbf{\times} \\
- 1 pt \quad |\mathbf{B}_{I_1+I_2}| = 1.88 \times 10^{-4} \, \text{T} \)
Problem 4 (25 points):
Your assignment in a PHYS 202 lab is to characterize the motion of a rectangular circuit shown in the figure. The rectangular loop is hinged along the \( y \) axis. It carries a 15.0 A current and is located in a uniform 1.20 T magnetic field oriented in the +x direction.
(a) (15 pts) Make a clear sketch showing the direction of the force that the magnetic field exerts on each segment of the circuit.
(b) (10 pts) Of four forces you drew in part (a), decide which one(s) exerts a torque about the hinge. Then calculate the magnitude of only the force(s) that exerts this torque.

(b) Torque around \( y \) axis

\[ \text{Force to rotate the rectangular circuit about \( y \) axis} \]

\[ |F_3| = I l B \sin \phi = 1.44 \text{ N} \]

\[ \text{Angle between } I \text{ and } B = 90^\circ \]
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Problem 5 (10 points):
In a PHYS 202 lab, you are assigned to calculate the time response of the circuit ($\varepsilon = 100 \, \text{V}$, $R_1 = 10 \, \Omega$, $R_2 = 30 \, \Omega$, and $L = 2.0 \, \text{H}$) before its measurements. See the figure. Find
(a) (5 pts) the current through each of the resistor just after the switch (S) is closed;
(b) (3 pts) the current through each resistor after S has been closed a long time;
(c) (2 pts) the current through $R_1$ right after S is re-opened in part (b).

Redraw

Loop Rule

Loop 1 : $\varepsilon = I_1 R_1$ ------- (1)
Loop 2 : $\varepsilon = I_2 R_2 + L \frac{\Delta I_2}{\Delta t}$ ------- (2)

(1) $I_1 = \frac{\varepsilon}{R_1} = \frac{100 \, \text{V}}{10 \, \Omega} = 10.0 \, \text{A} \quad \text{(no time dependence)}$

(2) $I_2(t) = \frac{\varepsilon}{R_2} \left[ 1 - e^{-\frac{(R_2/L)t}{1}} \right]$

\[\begin{align*}
  t = 0 & \rightarrow I_2 = 0 \\
  t = \infty & \rightarrow I_2 = \frac{\varepsilon}{R_2} = \frac{100 \, \text{V}}{30 \, \Omega} = 3.33 \, \text{A}
\end{align*}\]

Answers

(a) $I_1 = \boxed{10.0 \, \text{A}}$ \hspace{1cm} $I_2 = \boxed{0}$

(b) $I_1 = \boxed{10.0 \, \text{A}}$ \hspace{1cm} $I_2 = \boxed{3.33 \, \text{A}}$

(c) Right after S is reopened, L tries to maintain the current (3.33 A).