PHYSICS 202 Exam 3
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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- 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.
| Problem 1   | (25) |
| Problem 2   | (25) |
| Problem 3   | (25) |
| Problem 4   | (25) |
| Problem 5   | (10) |
| Problem 6   |     |
| Problem 7   |     |
| TOTAL       | (110)|
Problem 1 (25 points):
In a PHYS 202 lab, you study a RLC circuit with a ac voltage of the form
\( e(t) = E_{\text{max}} \cos(\omega t + \phi) \) and its instantaneous circuit current is \( I(t) = I_{\text{max}} \cos(\omega t) \). Assume \( E_{\text{max}} = 150 \text{ Volts}, \omega = 377 \text{ rad/sec}, R = 250 \Omega, C = 3.5 \mu\text{F} \) and \( L = 0.6 \text{ H} \). The angle \( \phi \) is the phase angle of the source voltage with respect to the current in the circuit, and can be positive or negative value. You have to answer 5 questions before the measurement.

(a) (5 pts) What is the impedance of the circuit?
(b) (5 pts) What is the current amplitude?
(c) (5 pts) What are the voltage amplitudes across the resistor, across the capacitor, and across the inductor?
(d) (5 pts) Does the source voltage lag or lead the current?
(e) (4 pts) Construct the phase diagram at \( t = T_{\text{period}}/8 \).

(a) \[ Z = \sqrt{R^2 + \left( X_L - X_C \right)^2} = \sqrt{250^2 + \left( \frac{1}{\omega C} \right)^2} = 587.5 \Omega \]

(b) \[ I_{\text{max}} = \frac{V_{\text{max}}}{Z} \]

\[ I_{\text{max}} = \frac{150}{587.5} = 0.255 \text{ A} \]

(c) \[ V_{\text{R}} = I_{\text{max}} R = (0.255)(250) = 63.8 \text{ V} \]
\[ V_{\text{L}} = I_{\text{max}} X_L = (0.255)(226.2) = 57.7 \text{ V} \]
\[ V_{\text{C}} = I_{\text{max}} X_C = (0.255)(757.9) = 193.3 \text{ V} \]

(d) \[ \phi = \tan^{-1} \left( \frac{X_L - X_C}{R} \right) = -64.8^\circ \text{ Lag} \]

(e) \[ t = T/8 \Rightarrow \omega t = 45^\circ \]
\[ \tan \phi = \frac{V_{C}^{\text{max}} - V_{L}^{\text{max}}}{V_{R}^{\text{max}}} \]

\[ = \frac{X_{L} - X_{C}}{R} \]

\[ V_{R}^{\text{max}} \]

\[ \sqrt{(V_{R}^{\text{max}})^2 + (V_{L}^{\text{max}} - V_{C}^{\text{max}})^2} \]
\[ t = \frac{T}{8} \]
\[ 45^\circ \text{ in } \omega t \]

\[ \sqrt{(V_R^{\max})^2 + (V_L^{\max} - V_C^{\max})^2} \]

\[ = E^{\max} = 150 \, V \]
Problem 2 (25 points):

You are a member of Project "PHYS202 Exam3" team in National Aggie Spacecraft Agency (NASA) and doing research on the concept of solar sailing. A solar sailing craft uses a large, low-mass sail and the energy and momentum of sunlight for propulsion. Your primary responsibility is to finalize the following specifications of the spacecraft:

(a) (10 pts) Should the material for sail be absorptive or reflective? Why?

(b) (10 pts) What is the minimum size of a sail to propel the spacecraft against the sun's gravitational force if the spacecraft is placed at a distance of $1.5 \times 10^{11}$ m from the sun? Express your result in square kilometers. Assume the mass of the spacecraft is 10,000 kg and the total power output of the sun is $3.9 \times 10^{26}$ W. Ignore the gravitation forces from all other planets.

(c) (5 pts) Explain why your answer to part (b) is independent of the distance from the sun.

(a) The material should be totally reflective, so that the radiation force is maximized.

$$ F_{rad} = \left( \frac{2 \frac{I}{c}}{A} \right) A $$

(b) $ F_{rad} = F_{grav} $ \hspace{1cm} \leftarrow \hspace{1cm} \text{Sun's Power over} \hspace{1cm} 4\pi r^2 = I $

\[ \frac{2 \frac{I}{c}}{A} = G \frac{mM_{sun}}{r^2} \]

\[ A = \frac{G mM_{sun}}{r^2} \times \frac{4\pi r^2}{2 \text{(Sun's Power)}} \]

\[ A = 6.42 \times 10^6 \text{ m}^2 = 6.4 \text{ km}^2 \]

(c) $ A $ is expressed independently of " $ r $ " in Eq. 1.

This is because $ I \propto \frac{1}{r^2} \rightarrow F_{rad} \propto \frac{1}{r^2}$ and " $ \frac{1}{r^2} $ " dependence in $ F_{grav} $ is cancelled each other.
Problem 3 (25 points):
In a science lab, you are testing three ideal polarizing filters. An incident beam of unpolarized light of intensity \( I_0 \) phases through a series of ideal polarizing filters with their polarizing directions tuned to various angles.

(a) (15 pts) What is the light intensity (in terms of \( I_0 \)) at point A, B, and C?

(b) (5 pts) What will be the light intensity at point C, if we remove the middle filter?

(c) (5 pts) What is your choice of the filters to block the incident light completely?

\[
(a) \quad I_A = \frac{1}{2} I_0 \\
I_B = \frac{I_A \left( \cos \phi \right)^2}{\text{Malus's Law}} = \frac{1}{2} I_0 \left( \cos 60^\circ \right)^2 = 0.125 I_0 \\
I_C = I_B \left( \cos 30^\circ \right)^2 = (0.125 I_0) \left( \cos 30^\circ \right)^2 = 0.0938 I_0
\]

\[
(b) \quad I_C = I_A \left( \cos 90^\circ \right)^2 = 0
\]

(c) Filters A and C.
Problem 4 (25 points):
In a PHYS 202 lecture, you worked on two problems similar to ones that you are seeing here.

(a) (15 pts) The light beam strikes surface 2 at the critical angle. Find the angle at incidence $\theta_1$.

(b) (10 pts) Red helium-neon laser light of wavelength 632 nm in vacuum strikes a flat block of a transparent substance at an angle of incidence of $37^\circ$, and the transmitted ray is refracted at an angle of $25^\circ$. Calculate the speed of light in the transparent material.

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad - (1) \]
\[ \uparrow \quad \uparrow \]
\[ 1.0 \quad 1.5 \]
\[ n_2 \sin \phi_2 = n_3 \sin 90^\circ \quad - (2) \]
\[ \uparrow \quad \uparrow \]
\[ 1.5 \quad 1.0 \]
\[ \theta_2 = 70^\circ - \phi_2 \quad - (3) \]

\(\phi_2 = \sin^{-1} \left( \frac{n_3}{n_1} \right) = 41.81^\circ\)

\(\theta_2 = 28.19^\circ\)

\(\theta_1 = \sin^{-1} \left( n_2 \sin \theta_2 \right) = 45.12^\circ\)

Note: All are surrounded by Air ($n=1.00$).

\((b)\) \quad n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
\[ \uparrow \quad \uparrow \]
\[ 37^\circ \quad 25^\circ \]

\(\theta_2 = \frac{c}{n_2} \]
\[ = \frac{2.99 \times 10^8}{2.11 \times 10^8} m/s \]
Problem 5 (10 points):
I bought a loop antenna and attached to my TV set. I thought the best signal quality would be obtained when the plane of the loop is perpendicular to the direction between the TV set and the TV station. But, I found it was not. It was when the plane of the loop is parallel to the direction. Since you are taking PHYS 202, I asked why. You gave me a memo to explain the reason with an illustration in the attachment (see the figure). However, I lost your memo. Sorry, but could you explain again?

\[ \Phi_B^{(1)} = B \cdot \frac{A}{a \cdot b} \]

\[ \frac{\Delta \Phi_B^{(1)}}{\Delta t} = \left( \frac{\Delta B}{\Delta t} \right) (a \cdot b) \]

\[ \Phi_B^{(2)} = B \cdot \frac{A}{a \cdot b} \cos 90^\circ \]

\[ \frac{\Delta \Phi_B^{(2)}}{\Delta t} = \left( \frac{\Delta B}{\Delta t} \right) (a \cdot b) (0.174) \]

The electromotive force in the loop antenna is maximized when \( \vec{B} \) is perpendicular to the loop plane.