SOLUTIONS

Name:______________________________

Student ID #:______________________________

Signature:______________________________

Physics 1C *Practice* Midterm #2

- By signing above, you agree to the statement below "Academic Integrity – A Bruin's Code of Conduct".
- This exam contains four workout problems, each 10 points, for a total of 40 points. Remember to write down each step of your calculation, and explain your answers. You have 50 minutes to complete this exam.
- Close your exam when time is up, and show your student ID when handing it in.
- Detailed exam rules:
  - By signing above, you agree to the statement below "Academic Integrity – A Bruin's Code of Conduct".
  - You can use any type of calculator that does not have internet capability. Silence and put away your cell phones, tablets, and laptops.
  - Quote numerical answers with 3 significant figures, e.g. 0.262 or 3.72×10^3. Always specify the units, and quote final answers in SI units unless otherwise directed.
  - The last page of the exam is an equation sheet that may be torn off.
  - Fit all relevant calculations on the front of the pages. If you run out of room, use the front of the blank page before the equation sheet, and indicate "Problem <n> continued:" to help us in grading.
- If you have questions during the exam, raise your hand. If you are not seated near the end of a row, you may need to come to the aisle or down to the front of the room to ask them.

Academic Integrity - A Bruin's Code of Conduct:

As a student and member of the UCLA community, you are expected to demonstrate integrity in all of your academic endeavors. When accusations of academic dishonesty occur, the Office of the Dean of Students investigates and adjudicates suspected violations of this student code. Unacceptable behavior includes cheating, fabrication or falsification, plagiarism, multiple submissions without instructor permission, using unauthorized study aids, facilitating academic misconduct, coercion regarding grading or evaluation of coursework, or collaboration not authorized by the instructor. Please review our campus' policy on academic integrity in the UCLA Student Conduct Code: https://deanofstudents.ucla.edu/individual-student-code .

If you engage in these types of unacceptable behaviors in our course, then you will receive a zero as your score for that assignment. If you are caught cheating on an exam, then you will receive a score of zero for the entire exam. These allegations will be referred to the Office of the Dean of Students and can lead to formal disciplinary proceedings. Being found responsible for violations of academic integrity can result in disciplinary actions such as the loss of course credit for an entire term, suspension for several terms, or dismissal from the University. Such negative marks on your academic record may become a major obstacle to admission to graduate, medical, or professional school.

By submitting my assignments and exams for grading in this course, I acknowledge the above-mentioned terms of the UCLA Student Code of Conduct, declare that my work will be solely my own, and that I will not communicate with anyone other than the instructor and proctors in any way during the exams.

Problem 1 (10 pts): A circuit contains two elements in series, but it is not known which of L, R, or C they are. The circuit is connected to U.S. house wiring, i.e. AC power that is 120 volts RMS and 60 Hz. The current in the circuit has RMS magnitude 3.90 A, and the phase of the current is behind the voltage by 30.0°.

a) (2 pts) What are the two elements of the circuit? Explain how you figured that out.
b) (6 pts) What values of inductance, resistance, and/or capacitance do they have?
c) (2 pts) How much power is used by the circuit?

a) CIVIL mnemonic. Look at this
I is after V in inductor - there must be an inductor L.
There must be R because if it was LC, the phase angle would be 90°. So $\boxed{LR}$

b) $Z = \frac{V_{rms}}{I_{rms}} = \frac{120}{3.90}\,\Omega = 30.8\,\Omega$

$\cos\phi = \frac{R}{Z}$ so $R = Z\cos\phi = 30.8 \cdot \cos(30^\circ)\,\Omega = \boxed{26.7\,\Omega}$

Then $Z^2 = R^2 + X_L^2 \Rightarrow X_L = \sqrt{Z^2 - R^2} = 15.4\,\Omega = \omega L = 2\pi f \cdot L$

so $L = \frac{X_L}{2\pi f} = \frac{15.4}{2\pi \cdot 60}\,H = \boxed{0.041\,H}$

c) $P = I_{rms} V_{rms} \cos\phi = 3.90 \cdot 120 \cdot \cos(30^\circ)\,W$

$\boxed{P = 405\,W}$

(Also $P = I_{rms}^2 R = (3.90)^2 (26.7)\,W = 406\,W$
same answer)

Problem 2 (10 pts): A laser produces a beam of light along the +z-axis in air ($n = 1.000$) that is polarized so that the electric field only has components in the y-direction. The average power in the laser beam is 30.0 mW. The wavelength of the light is 570 nm. The beam is round and its diameter is 0.600 mm. Assume that the electric field is at a maximum along the +y direction at the origin at $t = 0$.

a) (2 pts) What is the frequency f of the laser light?
b) (3 pts) What is the intensity I of the laser beam?
c) (4 pts) What is the maximum value of magnetic field B_{max} within the beam?
d) (1 pt) What is the direction of the magnetic field within the laser beam at the origin at $t = 0$?

a) $c = f\lambda$ so $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}}{570\times10^{-9}}$ Hz $= \boxed{5.263\times10^{14}\text{ Hz}}$

b) $I = \frac{P}{\text{Area}}$ where P is given and area $A = \pi\left(\frac{d}{2}\right)^2$

$A = \pi\left(\frac{0.600\times10^{-3}}{2}\right)^2 m^2 = 2.83\times10^{-7} m^2$

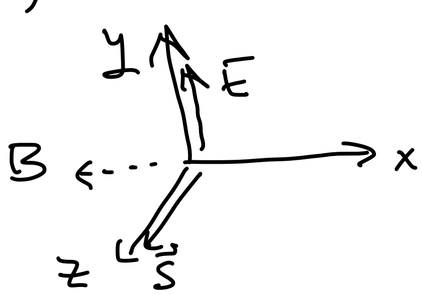
$I = \frac{30\times10^{-3}}{2.83\times10^{-7}}$ W/m² $= \boxed{1.06\times10^{5}\text{ W/m}^2}$

c) $B = E/c$ and $I = \frac{1}{2}\epsilon_0 c E_{max}^2 \Rightarrow E_{max} = \sqrt{\frac{2I}{\epsilon_0 c}}$

$E_{max} = \sqrt{\frac{2\cdot1.06\times10^{5}}{8.85\times10^{-12}\cdot3\times10^{8}}}$ N/C $= 8940$ N/C

$B_{max} = E_{max}/c = \frac{8940}{3\times10^{8}}$ T $= \boxed{2.98\times10^{-5}\text{ T}}$

d) $\vec{E}\times\vec{B}$ is the direction of beam $\vec{S}$



By right-hand rule we see

$\vec{B}$ is in $\boxed{-x\text{-direction} \quad (-\hat{i})}$

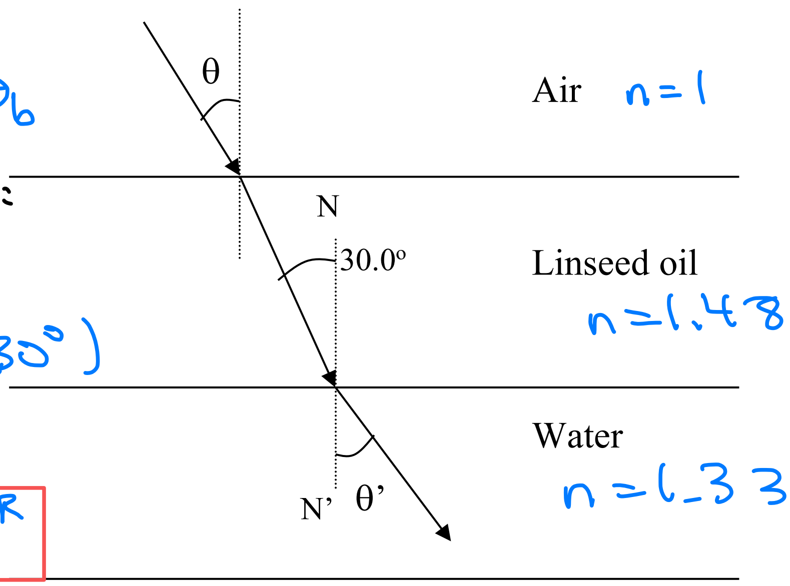
Problem 3 (10 pts): The light beam shown below makes an angle of 30.0° with the normal line NN' in the linseed oil. The index of refraction of linseed oil is 1.48 and that for water is 1.33.

a) (7 pts) Determine the angles θ and θ'.
b) (3 pts) How close is the angle θ to the angle for which the light reflected from the air-linseed oil interface (ray not shown) will be totally polarized?

a) Apply

$n_a \sin\theta_a = n_b \sin\theta_b$

at each interface:



$1.0 \sin\theta = 1.48 \sin(30°)$

$\sin\theta = 0.74$

$\boxed{\theta = 47° = 0.833^R}$

and

$1.48 \sin(30°) = 1.33 \sin\theta'$

$\sin\theta' = 0.556$

$\boxed{\theta' = 33.8° = 0.59^R}$

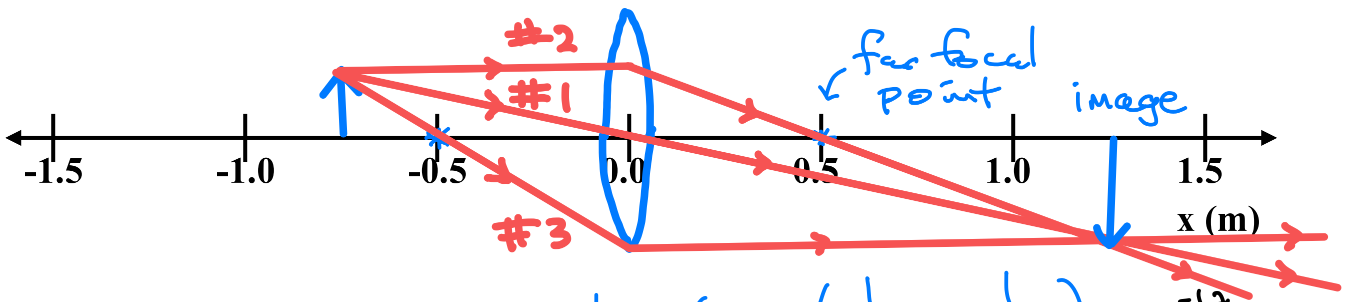
b) Brewster's angle $\tan\theta_p = \frac{n_b}{n_a} = \frac{1.48}{1.00} = 1.48$

$\theta_p = 55.9° = 0.977^R$

$\Delta\theta = \theta_p - \theta = 55.9° - 47° = \boxed{8.9° = 0.155^R}$

Problem 4 (10 pts): An upright object 20 cm high is placed 75 cm to the left of a bi-convex lens (i.e. thickest in the middle). Each surface has a radius of curvature 40 cm, and the refractive index of the lens is 1.4. The lens is placed at $x = 0$.

a) (6 pts) How far from the lens is the image located? Is this image upright or inverted? What is the size of this image?
b) (4 pts) Using a simple arrow to denote the object, draw a ray diagram with at least two rays to verify that the image is consistent with your answers in part a). Explain the choice of each ray in a sentence.



a) First, find f from $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$, with positive R_1, negative R_2

$$\frac{1}{f} = (1.4-1)\left(\frac{1}{40cm} + \frac{1}{40cm}\right) \Rightarrow f = 50\,cm$$

Then solve $\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$ for image distance

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{50cm} - \frac{1}{75cm} \Rightarrow \boxed{s' = 150\,cm}$$

Inverted or not from magnification

$M = \frac{-s'}{s} = \frac{-150}{75} = -2$ negative means $\boxed{\text{inverted}}$,

Size $h' = |M\,h| = 2 \cdot 20cm = \boxed{40\,cm}$

b) any 2 OK

Ray #1 is easiest: thru center of lens ⇒ undeflected
Ray #2 parallel to optic axis, bent to pass thru focal point – on far side since f positive.
Ray #3 more difficult: pointed at near focal point, will emerge from lens parallel to optic axis.

Rays appear to diverge from location of image.

Midterm 2 constants:

$\epsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{Nm^2}$

$\mu_0 = 4\pi \times 10^{-7}\ Wb/A \cdot m$

$e = 1.6 \times 10^{-19}\ C$

$c = 3.00 \times 10^8\ m/s$

Midterm 2 equations:

$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$, $\overrightarrow{dF} = I\overrightarrow{dl} \times \vec{B}$

$\oiint \vec{B} \cdot \overrightarrow{dA} = 0$

$R = {mv}/{|q|B}$

$\vec{\mu} \equiv I\vec{A}$, $\vec{\tau} = \vec{\mu} \times \vec{B}$, $U = -\vec{\mu} \cdot \vec{B}$

$\vec{B} = \frac{\mu_0 q \vec{v} \times \hat{r}}{4\pi r^2}$, $\overrightarrow{dB} = \frac{\mu_0 I \overrightarrow{dl} \times \hat{r}}{4\pi r^2}$

$\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 I_{enc} + \mu_0 \epsilon_0 \frac{d}{dt} \iint \vec{E} \cdot \overrightarrow{dA}$

$\vec{B} = \frac{\mu_0 I}{2\pi r} \hat{\phi}$, $\frac{F}{L} = \frac{\mu_0 I I'}{2\pi r}$

$B = \frac{\mu_0 N I}{2\pi r}$, $B = \mu_0 n I$, $n \equiv N/L$

$\mu = K_m \cdot \mu_0$, $\chi_m = K_m - 1$

$\mathcal{E} = -\frac{d}{dt}\Phi_B = -\frac{d}{dt}\iint \vec{B} \cdot \overrightarrow{dA}$

$\mathcal{E} = \oint (\vec{v} \times \vec{B}) \cdot \overrightarrow{dl}$

$\mathcal{E} = NBA\omega \cdot sin\omega t$

$\mathcal{E} = -L\frac{di}{dt}$, $L = \frac{N\Phi_B}{i}$

$U = \frac{1}{2}LI^2$, $u \equiv \frac{U}{Vol.} = \frac{B^2}{2\mu_0}$

$\tau = \frac{L}{R}$

$\omega = \sqrt{\frac{1}{LC}}$, $\omega' = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$ and $\tau = \frac{2L}{R}$

$V_{rms} = \frac{V_0}{\sqrt{2}}$, $I_{rms} = \frac{I_0}{\sqrt{2}}$

$\langle P \rangle = \frac{V_{rms}^2}{R} = I_{rms}^2 R = I_{rms} V_{rms}$ (resistive)

$V_R = IR, V_L = IX_L, V_C = IX_C$, $X_L = \omega L$, $X_C = {1}/{\omega C}$

$V = IZ$, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$\tan\phi = \frac{X_L - X_C}{R}$, $cos\phi = \frac{R}{Z}$

$\langle P \rangle = I_{rms} V_{rms} cos\phi$

$\frac{I_1}{I_2} = \frac{\mathcal{E}_2}{\mathcal{E}_1} = \frac{N_2}{N_1}$

$k\lambda = 2\pi$, $v = f\lambda = \omega/k$

$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$, $B = E/c$

$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$, $I = S_{av} = \frac{1}{2}\epsilon_0 c E_{max}^2$

$\frac{1}{A}\frac{dp}{dt} = \frac{S}{c}$, $p_{rad} = \frac{(1-2)I}{c}$

$\frac{c}{v} \equiv n = \frac{\sqrt{\epsilon\mu}}{\sqrt{\epsilon_0 \mu_0}}$, $\lambda = \frac{\lambda_0}{n}$

$\theta_r = \theta_a$ or $n_a sin\theta_a = n_b sin\theta_b$

$I = I_{max}\cos^2\phi$

$tan\theta_p = \frac{n_b}{n_a}$

$I_{scat} \propto \lambda^{-4}$

$P \equiv \frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$

$M \equiv \frac{y'}{y} = -\frac{s'}{s}$

Or $M \equiv \frac{\theta'}{\theta} = \frac{25\ cm}{f}$ or $M = \frac{-f_1}{f_2}$ or $M = \frac{-25\ cm \cdot s_1'}{f_1 f_2}$

f-number $\equiv \frac{f}{D}$

$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$