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Physics 2C, Winter 2020

PRACTICE FINAL EXAM

All students must work independently. You are allowed one page of handwritten notes only; no communication devices (cell phones, etc) permitted. Show all work; no credit will be given for answers with no derivation. Any problem asking for a vector (e.g., force) requires a vector as an answer!

Directions: Work each problem on the exam sheet provided. Put your NAME and PID on EACH sheet (one for each problem) in the space provided. If you don't have enough room on a single side of the page, finish the problem on the back of the page. $15 + 15 + 15 + 10 + 10 + 12 + 10(3) = 107$ points total for this exam.

Please keep in mind the following before you turn in your exam to avoid a 10% penalty:

- Make sure your name and PID are on each sheet in the space provided.
- Turn in all 6 pages. Do not turn in this cover page. If you absolutely could not fit a problem on the front/back of a single sheet, clearly communicate this to the proctor/TA/instructor when you turn in your exam.
- Make sure your pages are in numerical order (page 1, page 2, page 3, etc.)

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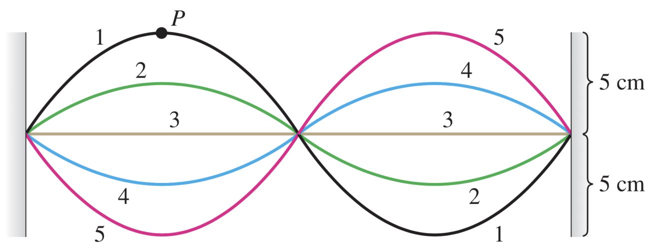
1. (15 points, 5 points each): A string vibrates to produce standing waves. Using a strobe which flashes 200 times per second, five successive pictures are taken one after the other. We see that the maximum displacement occurred for pictures 1 and 5:



The string is 30.0 cm long and has linear mass density 0.100 g/m.

(a) Find the wavelength λ (in m), frequency f (in Hz), period T (in s), and wave speed (in m/s) for the traveling waves on this string.

(b) How fast is point P moving when the string is in position 3?

(c) Draw a history graph of the particle at point P, assuming that picture 3 is where we set $t = 0$. Label both horizontal as well as vertical axes, and provide some values for scale. Include at least $t = 0$ to $t = T$ in your history graph.

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2. (15 points, 5 points each): A plano-concave (diverging) lens is made with a material of index of refraction $n = 1.50$. The curved portion of the lens has radius of curvature of magnitude 100.0 cm.

   (a) What is the focal length of this lens?

   (b) An object is placed in such a location that the magnification has magnitude $|m| = 0.5$. Draw an accurate ray diagram of this situation. How far is the object from the lens?

   (c) Suppose this lens helps someone see better. Is this person far-sighted or near-sighted? What is their near point or far point (whichever is different from that of a person with "normal" vision)? Remember that the "normal" near point is 25 cm and the "normal" far point is ∞.

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3. (15 points, 5 points each): An engine operates via two isochoric and two isothermal processes. The temperature extremes are T_0 and $3T_0$, and the volume extremes are V_0 and $2V_0$. The working substance of the engine is n moles of monoatomic gas.

   (a) Draw this engine on a pV diagram (label the processes and axes, and indicate the direction of the cycle). If the lowest pressure in the cycle is p_0, then what is the highest pressure in the cycle (in terms of p_0)? Label the point with the highest pressure point **1**, and label points **2** through **4** for the next steps in the cycle (so that the cycle is **12341**).

   (b) Which steps (e.g., **12**, **23**, etc.) transfer heat from the surroundings to the gas? For this step (or, for each of these steps), find Q, the heat delivered to the gas, in terms of n, T_0, V_0, and/or any fundamental constants.

   (c) Find the actual efficiency of this engine and compare with the maximum (ideal) efficiency between these two temperature extremes.

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4. (10 points, 5 points each): A linearly-polarized EM wave in vacuum traveling in the $-\hat{\boldsymbol{x}}$ direction has, at $x = 0$ and $t = 0$, the electric field pointing in the $+\hat{\boldsymbol{y}}$ direction with magnitude 4.00×10^4 V/m (this is the amplitude of the electric field wave).

   (a) Find an expression for the magnetic field $\vec{\boldsymbol{B}}(x, t)$. Take $\lambda = 632$ nm.

   (b) Suppose we want to pass this EM wave through a polarizer that will decrease the electric field amplitude to 1.00×10^4 V/m. Find a unit vector in the yz plane that is parallel to the direction we should orient the polarizing filter.

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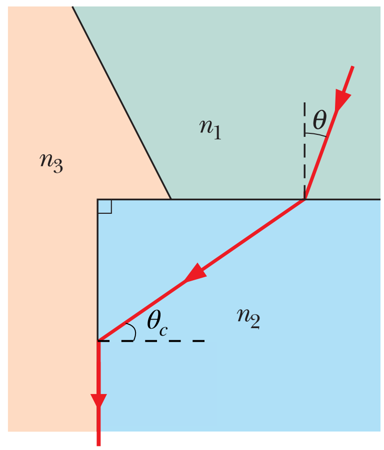
5. (10 points, 5 points each): In the figure below, light initially in material 1 refracts into material 2, crosses that material, and is then incident at the critical angle θ_c on the interface between materials 2 and 3. The indexes of refraction are $n_1 = 1.60$, $n_2 = 1.40$, and $n_3 = 1.20$.



(a) What is angle θ?

(b) If θ is increased, is there refraction of light into material 3? Explain.

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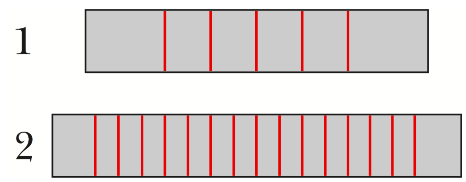
6. (12 points, 4 points each) The figure below gives the interference maxima of two double-slit interference experiments.



(a) Assume the only difference between the two experiments is the wavelength of the monochromatic light incident on the double-slit. If experiment 1 used light of wavelength $\lambda_1 = 560$ nm, what is the wavelength of light λ_2 used in the 2nd experiment?

(b) Assume the only difference between the two experiments is the slit separation. If experiment 1 used a slit width of $d_1 = 80$ μm, what is the slit separation d_2 used in the 2nd experiment?

(c) Assume the only difference between the two experiments is the distance to the screen. If experiment 1 used a distance of $L_1 = 2$ m, what is the distance to the screen L_2 used in the 2nd experiment?

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(30 points, 3 points each): 10 Multiple-choice questions / fill-in-the-blanks on various topics.

Directions for multiple-choice questions: COMPLETELY FILL IN THE SQUARE for the answer. Directions for fill-in-the-blank questions: Your answer should be entirely in the boxed region. Include the number of significant figures ("sig. figs.") requested in the problem.

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7. A lens produces an inverted, enlarged, real image. What can we say about the lens and/or the object location?

   - ☐ The lens is diverging and the object is farther away from the lens than the focal point.
   - ☐ The lens is diverging and the object is closer to lens than the focal point.
   - ☐ The lens is diverging, but we can't tell where the object is relative to the focal point.
   - ☐ The lens is converging and the object is farther away from the lens than the focal point.
   - ☐ The lens is converging and the object is closer to lens than the focal point.

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8. An ideal monoatomic gas expands quasi-statically to twice its volume. If the process is isothermal, the work done by the gas is $W_{\text{by,i}}$. If the process is adiabatic, the work done by the gas is $W_{\text{by,a}}$. Which of the following is true?

   - ☐ $W_{\text{by,i}} = W_{\text{by,a}}$
   - ☐ $0 = W_{\text{by,i}} < W_{\text{by,a}}$
   - ☐ $0 < W_{\text{by,i}} < W_{\text{by,a}}$
   - ☐ $0 = W_{\text{by,a}} < W_{\text{by,i}}$

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9. Unpolarized light passes through two polarizers, the second at an angle 30.0° with respect to the first. The final intensity of the light after it passes through the two polarizers is 9.00 W/m . What would the final intensity be if instead you orient the 2nd polarizer at an angle 60.0° with respect to the first? (3 sig. fig. answer)

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10. An EM wave is traveling in the $-\hat{y}$ direction. At one instant in time and space, the electric field points in the $+\hat{x}$ direction and has magnitude 300 μV/m. What is the magnetic field $\vec{B}$ at this same instant in space and time?

- ☐ $+\hat{z}$ direction, magnitude 1.0×10^{-12} T.
- ☐ $-\hat{z}$ direction, magnitude 1.0×10^{-12} T.
- ☐ $+\hat{z}$ direction, magnitude 9.0×10^{4} T.
- ☐ $-\hat{z}$ direction, magnitude 9.0×10^{4} T.

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11. A camera takes a properly exposed photo with a 3.0-mm-diameter aperture and a shutter time of (1/60) s. What is the appropriate shutter time for a 6.0-mm-diameter aperture?

- ☐ (1/15) s
- ☐ (1/30) s
- ☐ (1/120) s
- ☐ (1/240) s

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12. A block of wood is floating in water. It has density $k\rho_{\mathrm{w}}$, where ρ_{w} is the density of water, and $k < 1$ is a unitless, positive constant. What fraction of the total volume of wood is submerged?

- ☐ k
- ☐ $1 - k$
- ☐ $\frac{k}{k-1}$
- ☐ $\frac{k}{k+1}$

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13. This problem is a continuation of the previous one. When you apply a downward force of magnitude F, the block becomes fully submerged (and is in equilibrium). What is the mass of the block, in terms of F, k, and g?

- ☐ $\frac{F}{kg}$
- ☐ $\frac{kF}{g}$
- ☐ $\frac{(1+k)F}{g}$
- ☐ $\frac{kF}{(1-k)g}$
- ☐ None of the above

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14. On a linear X temperature scale, water freezes at $-325.0°$X and boils at $+275.0°$X. On a linear Y temperature scale, water freezes at $0.00°$Y and boils at $30.00°$Y. A temperature of $50.00°$Y corresponds to what temperature on the X scale?

- ☐ $400.0°$X
- ☐ $675.0°$X
- ☐ $430.0°$X
- ☐ $230.0°$X
- ☐ $505.0°$X

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15. Monochromatic light of wavelength 542 nm is incident on a single, narrow slit. On a screen 0.75 m away, the distance between the 2nd diffraction minimum and the central maximum is 1.50 cm. What is the width of the slit?

- ☐ Less than 20 μm
- ☐ Between 20 μm and 40 μm
- ☐ Between 40 μm and 60 μm
- ☐ Greater than 60 μm

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16. The figure below shows the displacement $y(x = 0, t)$ for a transverse wave on a string. To one significant figure, what is the wave speed given the wavelength is $\lambda = 4$ cm?

- ☐ 1 cm/s
- ☐ 2 cm/s
- ☐ 3 cm/s
- ☐ 4 cm/s
- ☐ 5 cm/s
