PHYS 143 Practice Final

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Time: 120 minutes. Total points: /140

1. /30 2. /20 3. /30 4. /20 5. /20 6. /20

1 Short Conceptual Qs

(It will be helpful to explain your reasoning for each)

1. We have a string created by two strings that are connected at the middle, with different linear mass densities of $\rho_L > \rho_R$. If we have a wave propagating through this system, then $\omega_L(> / = / <)\omega_R$, $\lambda_L(> / = / <)\lambda_R$, $v_L(> / = / <)v_R$.
2. (Ranking) Rank the size of the fundamental frequency for a tube of air with (a) One end open (b) Both ends open (c) Both ends closed.
3. (True/False) Phase velocity is always faster than group velocity.
4. (True/False) If the source is travelling perpendicular to the line of sight with the observer, no Doppler effect is observed.
5. (One sentence explanation) You are at the beach near Lake Michigan on a Sunny day, wearing your Polaroid sunglasses. When you lie down on your side facing the lake, the sunglasses don't work as well - why not?
6. (One sentence explanation) Suppose we put an object in front of a convex lens closer than its focal point. Where does the image form and what is its orientation?
7. If we put a convex lens into water, the magnitude of its focal length would (increase/decrease/stay the same) compared to air.
8. Suppose we do double slit diffraction with a magenta light source, which is a mix of red and blue. Then we will see _____ colour light in the middle of the screen, then the first colour we see away from the center will be _____, then _____. Decreasing the slit distance would make the pattern (more spread out/closer together/the same).
9. The amount of energy required to raise the temperature of a diatomic gas is (higher/lower/the same) as a monotomic gas. Assuming the gases had the same mass and the same temperature, the root mean square velocity of the diatomic gas would be (higher/lower/the same) as a monoatomic gas.
10. (One sentence explanation) Why can't heat flow from cold to hot?

2 EM waves

A particle in vacuum of mass m, charge q is constrained to move without friction in the $\hat{\mathbf{x}}$ direction. The particle is illuminated by a travelling electromagnetic plane wave with B-field:

$$\mathbf{B}_{\text{wave}}(\mathbf{r}, t) = B_0(\hat{\mathbf{y}} + \alpha\hat{\mathbf{z}})\cos(kz - \beta t) \tag{2.1}$$

(a) Calculate α (with justification).

(b) Calculate β (with justification).

(c) What is the electric field of the wave $\mathbf{E}_{\text{wave}}$?

(d) Calculate the acceleration $\mathbf{a}(t)$ of the charge.

3 Wave equations in Plasma and Strings

Charge density fluctuations in electron plasma satisfy a modified wave equation, with:

$$\frac{\partial^2 \rho}{\partial t^2} = c^2 \frac{\partial^2 \rho}{\partial x^2} - \omega_p^2 \rho \tag{3.1}$$

(a) Calculate and sketch the dispersion relation $\omega(k)$ for wave solutions of the form $\rho(x, t) = a\sin(kx - \omega t)$.

(b) Find and sketch the phase/group velocities as a function of k.

(c) Show that the above equation also has a solution $\rho(x, t) = a\cos(\omega t)e^{-\kappa x}$. Find $\kappa(\omega)$ and graph it. What is the physical interpretation of this solution?

Meanwhile, a stiff string has a modified wave equation of the form:

$$\frac{\partial^2 \psi}{\partial t^2} = c^2 \left[\frac{\partial^2 \psi}{\partial x^2} - \alpha\left(\frac{\partial^4 \psi}{\partial x^4}\right)\right] \tag{3.2}$$

(d) Calculate and sketch the dispersion relation $\omega(k)$ in an analogous manner.

(e) Find and the phase/group velocities as a function of k.

(f) The above dispersion relation has implications for piano tuning. Compare ω for standing waves/modes $n = 1$ and $n = 2$ in the cases where $\alpha = 0, \alpha > 0$; what is the effect of α?

4 Diffraction

A monochromatic beam is incident on N slits, which results in a intensity pattern as a function of angle on a screen some distance away as shown in the figure below. Each slit has a width D and the distance between the centers of the slits is d. The distance between the screen and the slits is very large. The following pattern is observed:

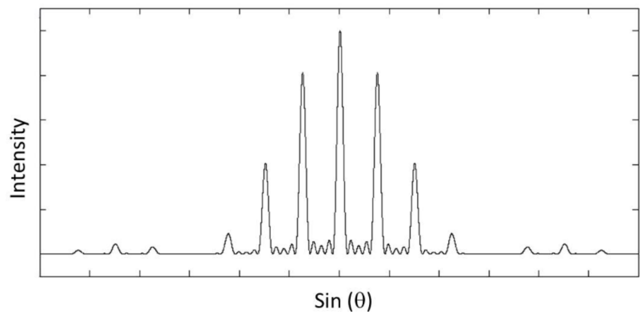


Figure 5: Interference pattern due to N slits.

From the pattern, deduce the following (and explain your reasoning):

(a) The number of slits N on which the beam is incident.

(b) The ratio d/D.

(c) Now suppose we take $D \to 0$, while the intensity of the monochromatic beam is increased so that the intensity of the central maximum is unchanged. On top of the plot (showing he original intensity pattern in dashed lines) on the next page, draw the resulting intensity pattern.

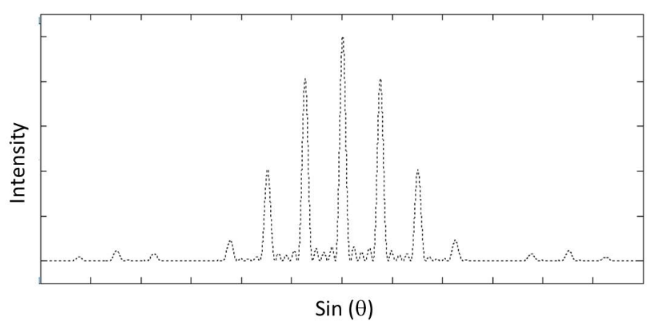
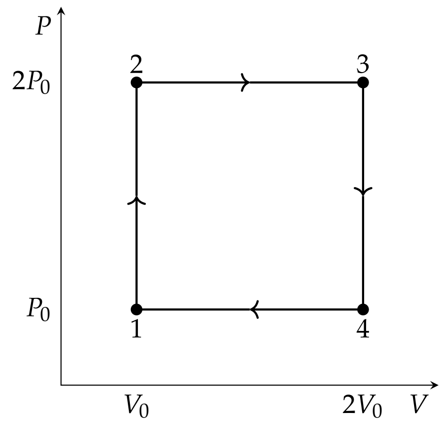


Figure 6: Plot the resulting intensity pattern as $D \to 0$.

5 Heat Engines

Consider the following heat engine, where the work medium can be assumed to be a monoatomic gas.



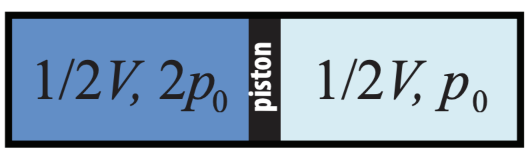
(a) What is the work done in one cycle?

(b) What is the heat that flows in/out of the gas at each step?

(c) What is the efficiency of the engine?

6 Entropy

Consider an ideal monoatomic gas in a cylinder with a movable piston in the middle, separating the cylinder into two parts. The cylinder itself is an isolated system, and the two gas volumes in the cylinder are closed systems. They can exchange heat and work with one another, but no particles.



In the initial configuration, $V_L^{\mathrm{i}} = V_R^{\mathrm{i}} = V/2$. The gas pressure in the left part of the container is twice the right part, $p_R^{\mathrm{i}} = p_0, p_L^{\mathrm{i}} = 2p_0$. The temperature in both parts is T.

(a) What is the equilibrium position of the piston? What are the temperatures when the final position is reached?

(b) What is the change in entropy during the equilibriation process?

(c) Show that the entropy in the final configuration is a maximum as V_L^{f} is varied. Does this make sense?