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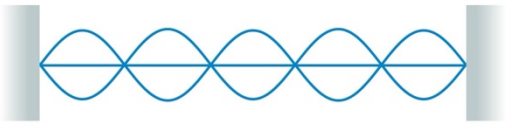
I. Lecture Multiple Choice [60 pts]. **Choose only one answer for each question, circle your answer in this booklet, and fill it out on your bubble sheet.**

Use the following situation to answer the next three questions.

A standing wave of frequency 15 Hz is formed on a uniform string of length $L = 1.3$ m and linear mass density $\mu = 4.2 \times 10^{-3}$kg/m. The standing wave pattern is shown at right.



Consider the following statements about standing waves on a string:

I. The pattern results from the superposition of two in-phase waves traveling in opposite directions.

II. For a standing wave to form on a string with fixed ends, the string's length L must be equal to an integer multiple of half wavelengths, that is, an integer times $\lambda/2$.

III. At a node, the displacement from equilibrium changes from maximum in one direction, goes to zero, then to a maximum in the other direction.

1. [6 pts] Which of the above statement is/are true?

   A. (I) only.
   B. (II) only.
   C. (III) only.
   D. (I) and (II).
   E. (II) and (III).

2. [4 pts] What is the speed of the standing wave?

   A. 7.8 m/s
   B. 39 m/s
   C. 16 m/s
   D. 23 m/s
   E. Zero

3. [4 pts] If we want to double the mode number m, which one of the following, **done on its own** while keeping everything else the same would achieve that?

   A. Doubling the linear mass density of the string.
   B. Doubling the tension in the string.
   C. Quadrupling the tension in the string.
   D. Halving the frequency.
   E. Doubling the frequency.

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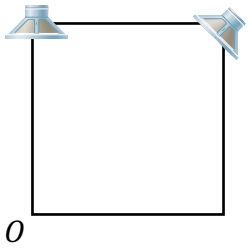
4. [6 pts] Two speakers are located at the corners of a 1.8 m square, as shown. They both produce the same single-frequency tone in phase corresponding to a wavelength λ. An observer at corner O experiences total **destructive interference**, so that they hear no sound at all. What is smallest possible wavelength λ of the sound produced?



   A. 8.7 m

   B. 1.5 m

   C. 4.3 m

   D. 0.74 m

   E. The situation is impossible since the speakers are producing the same wavelength.

5. [5 pts] When a guitar string is sound along with a tuning fork that generates a frequency of 200 Hz, a beat of frequency 4 Hz is heard. Then, when the same string is sounded with a 188 Hz tuning fork, a beat of 8 Hz is heard. What is the frequency of that guitar string?

   A. 180 Hz

   B. 192 Hz

   C. 194 Hz

   D. 196 Hz

   E. 204 Hz

6. [6 pts] The light shining on a diffraction grating has a wavelength of 495 nm (in vacuum). The grating produces a second-order bright fringe whose position is defined by an angle of 9.34°. What is the separation between each two consecutive slits?

   A. 6.1×10^{-6}m

   B. 4.2×10^{-6}m

   C. 3.7×10^{-6}m

   D. 2.2×10^{-6}m

   E. 9.5×10^{-6}m

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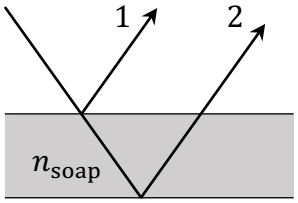
Use the following situation to answer the next two questions.
A thin film of soap of index of refraction $n_{\text{soap}} = 1.33$ and thickness $t = 1.1 \times 10^{-7}\text{m}$ is surrounded by air, as shown. Note: assume normal incidence even though the figure shows it at an angle.



7. [4 pts] Consider a ray of white light incident from air onto the film. This ray is partly reflected back into air (1) and partly transmitted where it goes into the soap then partly reflects and transmits back into air (2). When rays (1) and (2) meet in air:

   A. They both underwent a phase shift due to reflection.
   B. Neither one of them underwent a phase shift due to reflection.
   C. Only ray (1) underwent a phase shift due to reflection.
   D. Only ray (2) underwent a phase shift due to reflection.
   E. The answer would depend on the wavelength of light.

8. [4 pts] What is the lowest wavelength that undergoes **<u>constructive</u>** interference between rays (1) and (2)? ($1\text{ nm} = 10^{-9}\text{m}$)

   A. 290 nm
   B. 590 nm
   C. 440 nm
   D. 220 nm
   E. 610 nm

9. [5 pts] In Experiment 1, light of wavelength λ shines onto a mask that has a single thin slit of size a. The pattern is captured on a screen a distance L from the mask. In Experiment 2 we use light of wavelength 1.1λ, a slit of opening $a/3$ and reduce the screen distance to $L/4$. What is the ratio of the width of the central maximum in the second experiment to the width in the first experiment, w_2/w_1?

   A. 1.4
   B. 11
   C. 0.83
   D. 1.2
   E. 0.68

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10. [5 pts] A friend stands 2 m in front of a plane mirror, with you 3 m behind them. What is the distance between you and your friend's image?

    A. 2 m

    B. 3 m

    C. 5 m

    D. 7 m

    E. 10 m

11. [6 pts] The wavelength of a red light in vacuum is 650 nm. When it enters a piece of glass the wavelength is measured to be 430 nm and when it enters a diamond, the wavelength becomes 270 nm. What is the ratio of the speed of light in diamond to that in glass, $v_{\text{diamond}}/v_{\text{glass}}$?

    A. 1.6

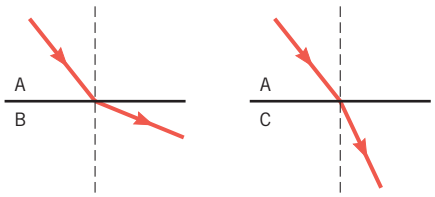
    B. 0.41

    C. 0.63

    D. 1.0

    E. Cannot answer without knowing the frequency.

12. [5 pts] Consider materials A, B and C with indices of refraction n_A, n_B and n_C. In set up 1 material A is placed above B and in set up 2 material A is above material C. Light is incident in from material A on to the other material at the same angle of incidence, as shown. Choose the correct ranking of the indices of refraction of the three materials.



    A. $n_B < n_C < n_A$

    B. $n_A < n_C < n_B$

    C. $n_B < n_A < n_C$

    D. $n_A < n_B < n_C$

    E. $n_C < n_A < n_B$

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II. Lecture Free Response [20 pts] **Show your work for full credit.**

13. [4 pts] Monochromatic light of wavelength 5.4×10^{-7}m passes through two slits separated by a distance 2.5×10^{-6}m. What is the angle of the third maximum θ_3?

14. [4 pts] If a screen is placed a distance of 2.0 m from the slits, how far is the third maximum from the central maximum on the screen?

15. [6 pts] How many bright fringes in total can we see on the screen for this wavelength?

16. [6 pts] What would change in the pattern on the screen if light of a shorter wavelength is used?

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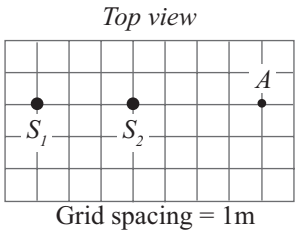
III. Tutorial Free-Response [20 pts]. **Explain your reasoning where stated to get full credit.**
The figure at right shows the top view of a ripple tank where two sources S_1 and S_2 generate circular wavefronts of wavelength λ in phase. (Note: Ignore the change in amplitude of the waves from the point sources as the distance from the point source changes.)



17. [6 pts] If the wavelength used is $\lambda = 1.5$ m, is point *A* a point of maximum constructive interference, maximum destructive interference or neither? Explain briefly.

18. [4 pts] Suppose now the frequency of the two sources is doubled, is point *A* a point of maximum constructive interference, maximum destructive interference or neither? Explain briefly.

19. [6 pts] A light source made up of a point-like bulb and a long filament is placed in front of an opaque mask with an opening shaped like the letter L. On the screen, draw the pattern of light that would form.

20. [4 pts] If we bring the light source a bit closer to the mask, would the pattern on the screen become bigger, smaller, change completely or stay the same? Explain briefly.