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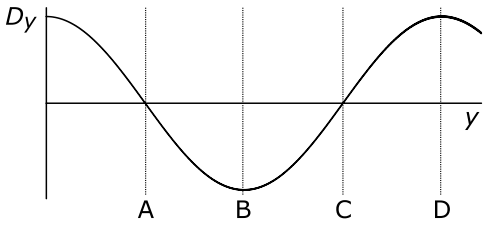
I. [70 points total] 21 Lecture Questions

1. [3 points] A mass on a frictionless surface is attached to a horizontal spring with spring constant $k = 2\ \mathrm{N/m}$. The spring is compressed by $x = 0.1\ \mathrm{m}$ and released from rest. By how much will the velocity of the mass change as it passes through $x = 0$, if it is instead compressed by $x = 0.2\ \mathrm{m}$ before being released?
   A. Increase by a factor of 2
   B. Decrease by a factor of 2
   C. Increase by a factor of 4
   D. Increase by a factor of $\sqrt{2}$
   E. It will remain the same.

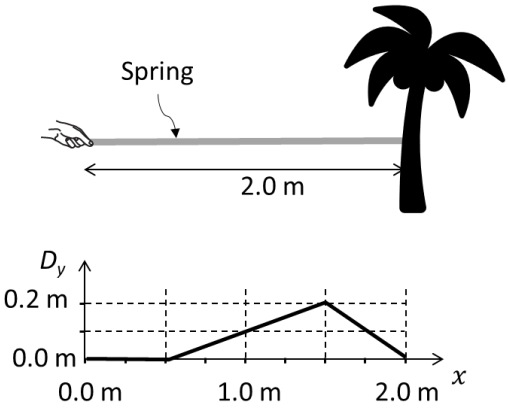
2. [3 points] A simple pendulum is released from rest and undergoes oscillations of frequency $3.0\ \mathrm{s^{-1}}$. The length of the string is decreased by a factor of 4.0. What is the new frequency of oscillations?
   A. Not enough information
   B. $1.5\ \mathrm{s^{-1}}$
   C. $3.0\ \mathrm{s^{-1}}$
   D. $6.0\ \mathrm{s^{-1}}$
   E. $12.0\ \mathrm{s^{-1}}$

3. [4 points] The figure shows the displacement of air molecules in a sound wave as a function of position at a moment in time. At the instant shown, where is the pressure of the air a maximum?



   A. Point A
   B. Point B
   C. Point C
   D. Point D
   E. Points A and C

4. [3 points] You attach the right end of a spring firmly to a tree located at $x = 2.0$ m. At $t = 0.0$ s you start moving the left end of the spring to create a pulse. At $t = 8.0$ s the start of the pulse has just reached the tree and the figure below right shows the wavefunction at that time. At $t = 8.0$ s what is the vertical velocity of the spring element located at $x = 1.0$ m?

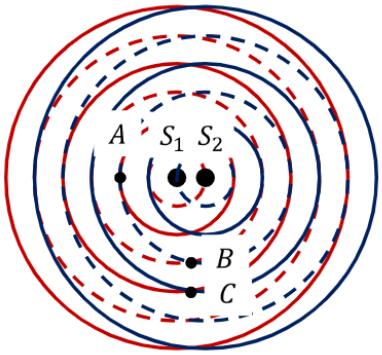


   A. -0.025 m/s
   B. -0.05 m/s
   C. 0.05 m/s
   D. 0.025 m/s
   E. 0.25 m/s

5. [4 points] You are tuning a guitar to middle C. A tuning fork with resonant frequency $f = 261.63$ Hz (C) is struck, and when you pluck the guitar string, you hear a beat frequency of 2.60Hz. By how much should you change the tension of the string? Select one answer below.

   A. Increase by 1%
   B. Decrease by 1%
   C. Increase by 2%
   D. Decrease by 2%
   E. C or D

6. [3 points] Consider the following set up, illustrated at right. Surface waves are generated from two coherent sources, S1 and S2, separated by a small distance. The figure shows the crests (solid) and troughs (dashed) of the waves from S1 and S2 at an instant t. Select all of the true statements about the system at a time $t + T$ later, where T is the period of the waves.



   A. Point A will have a minimum magnitude displacement.
   B. Point A will have neither a minimum or maximum magnitude displacement.
   C. Point B will have a minimum magnitude displacement.
   D. Point B will have a maximum magnitude displacement.
   E. Point C will have a maximum magnitude displacement.

7. [4 points] A U-tube with both sides open to the atmosphere is filled with water with mass density $\rho = 1000$ kg/m^3 (figure a). Oil, with mass density $\rho = 717$ kg/m^3, is added to the left side, as in figure b. How much higher is the equilibrium height of the oil than the equilibrium height of the water, when the heights are measured with respect to the oil-water interface?

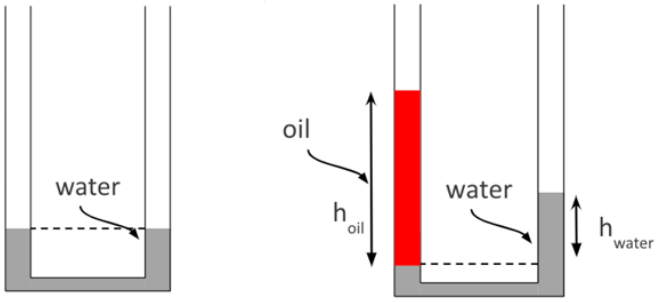


Figure (a) Figure (b)

A. Not enough information
B. 39% higher
C. 95% higher
D. 139% higher
E. 195% higher

8. [3 points] Initially a toy boat with a rock on board floats in a small tub of water. You remove the rock from the boat and place it in the water, where it sinks to the bottom of the tub. What happens to the water level in the tub?

A. It rises.
B. It falls.
C. It stays the same.
D. Not enough information

9. [3 points] Water flows horizontally at velocity v through a cylindrical pipe of cross-sectional diameter d_1. The pipe is then split into two equal segments, each with cross-sectional diameter d_2 and the velocity in each segment is measured to be $2v$. What can you conclude about the ratio of the diameters of the pipes?
   A. $d_2/\,d_1 = 1$
   B. $d_2/\,d_1 = 1/2$
   C. $d_2/\,d_1 = 1/4$
   D. $d_2/\,d_1 = 1/\sqrt{2}$
   E. Not enough information

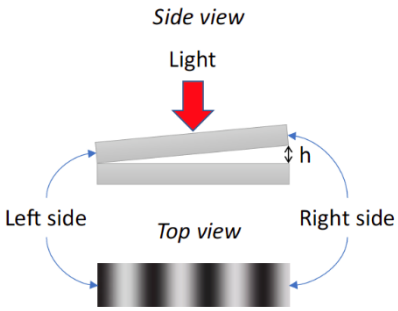
10. [3 points] A beam of light in glass travels with a speed of 0.50 *c* and hits an interface with air. What is the minimum angle relative to the normal vector at the surface between the glass and the air at which no light is transmitted into the air?
   A. 45°
   B. 35°
   C. 30°
   D. 50°
   E. 60°

11. [4 points] Two **converging** lenses, 1 and 2, are separated by 150 mm, with lens 1 on the left. The focal length of lens 1 is 100 mm and that of lens 2 is 200 mm. An object is placed 50 mm to the left of lens 1. How far from lens 2 should a screen be placed if the image formed by the two lenses is to be focused on the screen?
   A. 1000 mm
   B. 500 mm
   C. 300 mm
   D. 150 mm
   E. 450 mm

12. [4 points] A **<u>diverging mirror</u>** has a magnitude of focal length 700 mm. An object is located 350mm in front of the mirror. What is the magnification of the image formed?
    A. 0.33
    B. 0.5
    C. 0.67
    D. 0.9
    E. 1

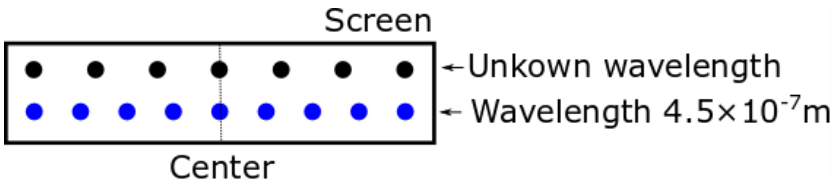
13. [3 points] If the headlights on a car are separated by 1.3 m, what is the furthest distance down the road the car can be located for an eye to resolve the headlights if the angular resolution of the eye is 5.0×10^{-4} rad, and the person has excellent vision?
    A. 5.0 km
    B. 1.3 km
    C. 2.6 km
    D. 0.65 km
    E. 4.8 km

14. [4 points] Monochromatic light shines down on a piece of glass that has a slight angle to horizontal that rests with the left side on a flat piece of glass and the right side raised by $h = 8.2 \times 10^{-7}\ m$, as shown at right. There is a small air gap between the pieces of glass. The image below shows the reflected light over the entire surface of the glass. What is the wavelength of the light?



    A. 4.7×10^{-7} m
    B. 6.6×10^{-7}m
    C. 1.1×10^{-6} m
    D. 1.6×10^{-6} m
    E. 3.3×10^{-6} m

15. [4 points] Two different light sources are incident on a double slit with unknown spacing between slits. One light source has a wavelength of 4.50×10^{-7} m and the other has an unknown wavelength. The interference patterns cast on a screen a long distance away are shown below.



What is the unknown wavelength?

A. 3.4×10^{-7} m
B. 3.6×10^{-7} m
C. 5.6×10^{-7} m
D. 6.0×10^{-7} m
E. More information is required.

16. [3 points] A monatomic ideal gas is in a fixed-volume flask. You increase the root-mean-square speed of the gas particles by a factor of 2. By what factor does the gas pressure change?

A. 2
B. 4
C. $\sqrt{2}$
D. 8
E. Pressure does not change.

17. [3 points] A fixed amount of ideal gas is held in a rigid container that expands negligibly when heated. At 20.0 °C the gas pressure is p. What temperature does the gas need to reach to have a gas pressure of $2p$?

A. 40 °C
B. 80 °C
C. 313 °C
D. 293 °C
E. Insufficient information to determine

18. [3 points] During an adiabatic process, an ideal gas does 25 J of work on its environment. What is the change in the internal (thermal) energy of the gas during this process?
    A. -25 J
    B. 25 J
    C. -50 J
    D. 50 J
    E. Cannot be determined

19. [3 points] A sample of an ideal gas with $\gamma = 1.4$, initially has a volume of 1.00 L and a pressure of 100 Pa. If the gas expands isentropically to 1.15 L, what is the final pressure?
    A. 87 Pa
    B. 100 Pa
    C. 82.2 Pa
    D. 90 Pa
    E. 115 Pa

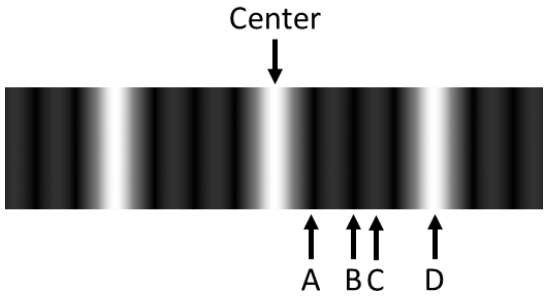
20. [3 points] A steady device in each cycle converts 140 J of heat is transferred into a reservoir at 340 K. Calculate the entropy change for the environment.
    A. 2.51 J/K
    B. 0.412 J/K
    C. 5.03 J/K
    D. 0.207 J/K
    E. Insufficient information to determine

21. [3 points] A heat engine that operates on a Carnot cycle has an efficiency of 0.5 when its low-temperature reservoir is at 10°C. By how many degrees Celsius must you increase the temperature of the high-temperature reservoir to increase the efficiency to 0.6 if you continue to use the same low-temperature reservoir?
    A. 3°C
    B. 5°C
    C. 94°C
    D. 125°C
    E. 142°C

II. [15 points total] 4 Lab Questions

22. [4 points] In a lab, a team measured a force acting on a surface, F, and the area of the surface, A. The team reports the pressure acting on the surface due to this force to be $p = \frac{F}{A} = 17.8 \pm 0.5\ \mathrm{N/m^2}$. If the team measured the force to be $F = 32.51 \pm 0.05$ N, which of the following values with their uncertainties is consistent with their measurement of the area, A?
    A. $1.826 \pm 0.002\ \mathrm{m^2}$
    B. $1.83 \pm 0.05\ \mathrm{m^2}$
    C. $1.83 \pm 0.03\ \mathrm{m^2}$
    D. $1.8 \pm 0.2\ \mathrm{m^2}$
    E. $1.8 \pm 0.5\ \mathrm{m^2}$

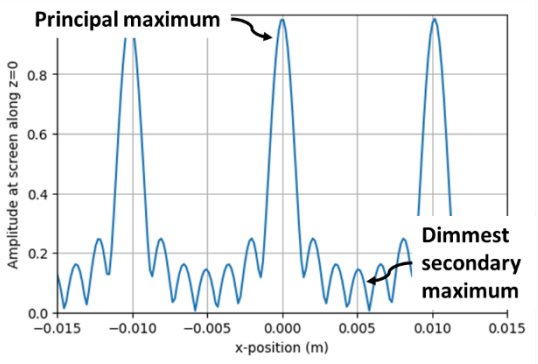
23. [4 points] A monochromatic beam of light is incident on a mask containing four equally spaced slits. Each slit is very narrow and may be treated as a point source. The interference pattern observed on a distant screen is shown in the image upper right. Which points on the interference pattern could have the phasor diagram (phasors added head to tail) shown at bottom right? Note that points A and B are at minima, point C is at a secondary maximum, and point D is at a maximum.



    A. Point A
    B. Point B
    C. Point C
    D. Point D
    E. None of these points

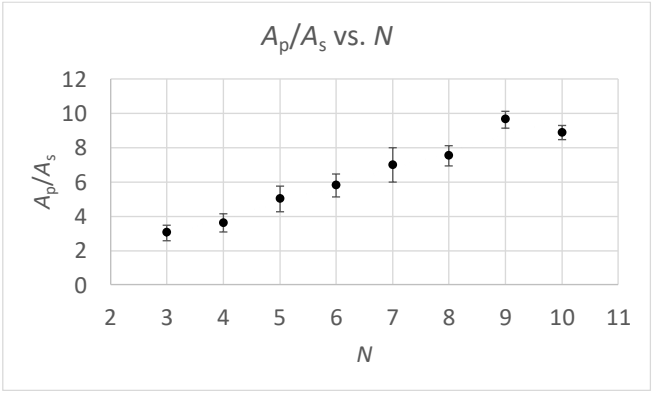
Use the following scenario for the next two questions.

In a simulated multi-slit interference experiment, a lab team decided to measure the ratio of the amplitude at the principal maximum, A_p, over the amplitude at the dimmest secondary maximum, A_s, as the number of slits, N, are increased.



24. [3 points] In this experiment, which of the following statements is/are correct? Select <u>all</u> that apply.
    A. N is a dependent variable.
    B. N is a control variable.
    C. N is an independent variable.
    D. A_s is a control variable.
    E. A_p is a control variable.

25. [4 points] The graph below shows the result. The straight dotted line is the best-fit line. Which of the following statements can you conclude from this graph? Select <u>all</u> that apply.

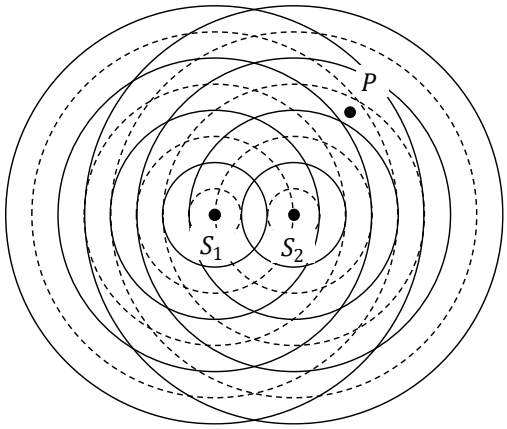


    A. The best-fit line is a good fit.
    B. The best-fit line is <u>not</u> a good fit.
    C. A_p/A_s vs. N is consistent with a linear relationship.
    D. A_p/A_s vs. N is <u>not</u> consistent with a linear relationship.
    E. A_p/A_s vs. N <u>must</u> be a linear relationship.

III. **[15 points total] 5 Tutorial Questions**

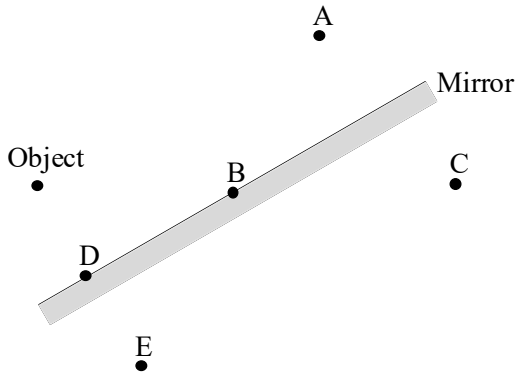
26. [3 points] A block of mass m on a horizontal frictionless surface is attached to a horizontal spring with spring constant k. The block is pulled some horizontal distance, d, from the equilibrium position and released such that it oscillates with simple harmonic motion. Suppose that you are making one change to this setup while all the other aspects of the setup remain the same. Which of the following single changes would cause the total energy of the spring-block system to double? Select all that apply.
    A. Increase the initial displacement from the equilibrium position to $2d$.
    B. Increase the initial displacement from the equilibrium position to $\sqrt{2}d$.
    C. Increase the mass of the block to $2m$.
    D. Increase the spring constant to $2k$.
    E. None of the above

27. [3 points] Consider two point-sources (S1 and S2) oscillating up and down with an identical harmonic motion on a water surface producing a circular wave pattern. The diagram shows the wavefronts at $t = 0$ where the solid lines represent the crests, and the dashed lines represent the troughs. Is position P a point of complete constructive interference, complete destructive interference, or half-way between constructive and destructive interference at $t = T/4$, where T is the period of the waves.

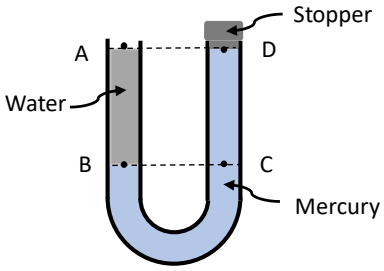


    A. Constructive interference
    B. Destructive interference
    C. Half-way between constructive and destructive interference
    D. The answer depends on the frequency of the waves.

28. [3 points] An object is placed in front of a plane mirror as shown at right. Which of the positions, labeled A through E, is the image of the object formed? E

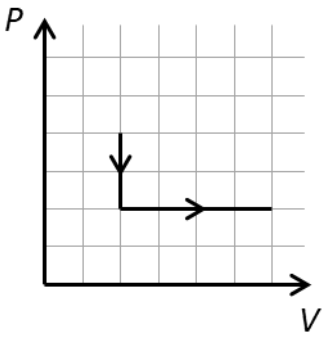


29. A U-tube closed on one end with a stopper is partially filled with mercury. Water is then poured on top of the mercury on the left side of the tube. The surface of the water is at the same level as the stopper and open to the air as shown. Positions A and D are at the same height, and positions B and C are at the same height. Which of the following is the correct ranking of the pressures at these points? Note that the density of mercury is higher than that of water.



A. $p_B = p_C > p_A = p_D$
B. $p_B = p_C > p_A > p_D$
C. $p_B = p_C > p_D > p_A$
D. $p_A > p_B > p_C > p_D$
E. $p_D > p_C > p_B > p_A$

30. For the process represented in the PV diagram at right, which of the following statements are correct? Choose <u>all</u> that apply.



A. The internal energy of the gas increases.
B. The work done on the gas is positive.
C. The heat transferred to the gas is negative.
D. The temperature of the gas increases.
E. None of the above is correct.