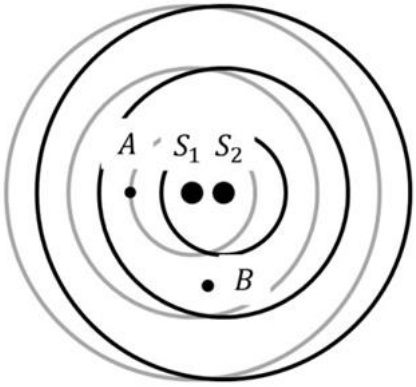
I. [70 points total] 22 Lecture Questions

1. [3 points] System 1 has an object with mass m attached to a spring with a spring constant k. The object in system 1 undergoes simple harmonic motion with maximum displacement A. System 2 has an object with mass $m/2$ attached to a spring with a spring constant $2k$. The object in system 2 undergoes simple harmonic motion with maximum displacement $A/2$. What is the ratio of maximum kinetic energy in system 1 to system 2?
   A. K_1/K_2 = 4
   B. K_1/K_2 = 2
   C. K_1/K_2 = 1
   D. K_1/K_2 = 0.5
   E. K_1/K_2 = 0.25

2. [3 points] As shown, a standing wave on a string is vibrating with a frequency of 400 Hz. The length of the string is 4 m. What is the speed of the wave on this string?
   A. 100 m/s
   B. 200 m/s
   C. 400 m/s
   D. 800 m/s
   E. 1,600 m/s

3. [3 points] Surface waves are generated from two coherent sources, S_1 and S_2, separated by a small distance. The figure shows the crests of the wave from S_1 (gray) and S_2 (black) at an instant. Point A is on the nodal line, and point B is on the antinodal line. Which of the following changes will result in point A being at an antinodal line?
   A. Double the frequency of the wave.
   B. Double the distance between S_1 and S_2
   C. Both A and B
   D. Neither A nor B



4. [3 points] You are standing between two speakers, that both play a constant note with frequency f_S. Both speakers move to the left with speed v_S. The sound from the speakers causes you to hear beats with a beat frequency f_{B1}. You repeat the experiment with the speakers moving with speed $2v_S$. The beat frequency in this case is f_{B2}. Which of the following best describes the relationship between f_{B2} and f_{B1}?

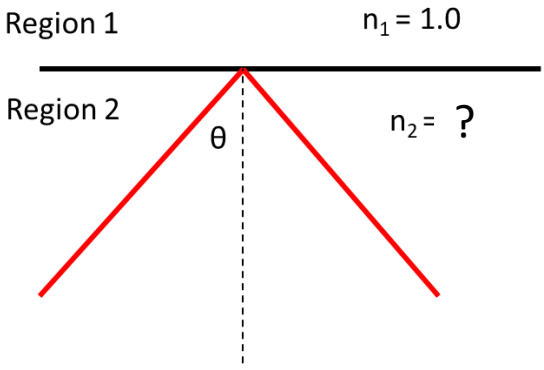
   A. $f_{B2} = 2f_{B1}$
   B. $f_{B2} < 2f_{B1}$
   C. $f_{B2} > 2f_{B1}$
   D. None of the above.

5. [3 points] You measure the intensity level of a screaming child from 5.0 m away to be 72 dB. You move away from the screaming child. You are now 30 m away. What is the intensity level you measure in dB?

   A. 16 dB
   B. 56 dB
   C. 64 dB
   D. 70 dB
   E. None of the above

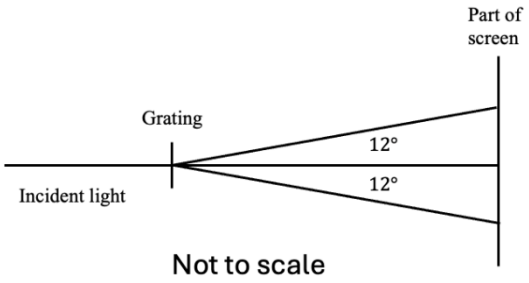
6. [3 points] Light in region 2 is reflected off a boundary with region 1 with index of refraction $n_1 = 1.00$, as shown. The critical angle, θ, for total internal reflection is 50.0 degrees. What is the index of refraction of region 2?

   A. $n_2 = 1.56$
   B. $n_2 = 1.31$
   C. $n_2 = 1.00$
   D. $n_2 = 0.77$
   E. $n_2 = 0.64$

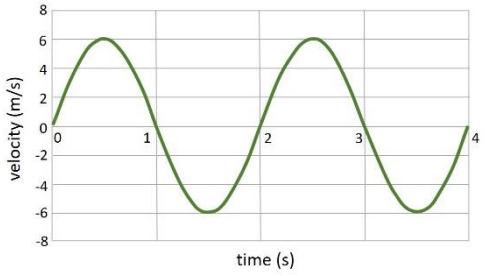


7. [3 points] An object is put in front of a diverging lens. The object distance is 5.0 cm, and the absolute value of the focal length of the lens is 10 cm. Which of the following statements is true about the image?
   A. The image is real, and the image distance is 10 cm.
   B. The image is virtual, and the image distance is 10 cm.
   C. The image is real, and the image distance is 3.3 cm.
   D. The image is virtual, and the image distance is 3.3 cm.

8. [3 points] You shine monochromatic light with a wavelength $480\ \text{nm}$ at a diffraction grating with an unknown spacing between the slits. You observe a pattern on a distant screen and notice that the $m = 1$ maximum is $12.0°$ away from the center of the pattern, as shown. At what angle is the highest order maximum that can be seen on the screen? Assume the screen is large enough that all maxima are visible.
   A. $\theta = 24.6°$
   B. $\theta = 56.3°$
   C. θ is very slightly less than $90.0°$
   D. θ is exactly $90.0°$.
   E. None of the above.

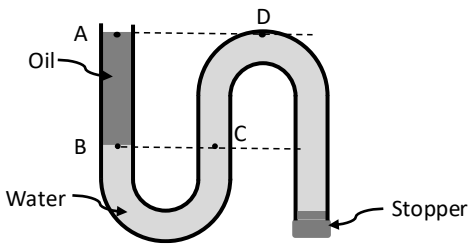


9. [3 points] The figure shows the velocity-versus-time graph for an object in simple harmonic motion. What is the maximum positive acceleration of the particle?
   A. 6.2 m/s^2
   B. 12 m/s^2
   C. 8.8 m/s^2
   D. 10 m/s^2
   E. 19 m/s^2



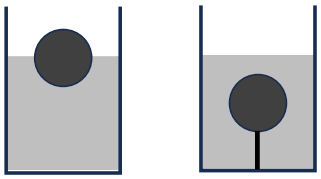
10. [3 points] You have two lasers. Laser 1 is labeled $560\ \text{nm}$; laser 2 is missing its label. If you shine laser 1 on a metal surface, the maximum kinetic energy of the ejected electrons is found to be $2.20 \times 10^{-19}\text{J}$. If you shine laser 2 on the same metal surface, the maximum kinetic energy of the ejected electrons is found to be $2.40 \times 10^{-19}\text{J}$. What is the wavelength of laser 2?
    A. $\lambda_2 = 530\ \text{nm}$
    B. $\lambda_2 = 1892\ \text{nm}$
    C. $\lambda_2 = 611\ \text{nm}$
    D. $\lambda_2 = 334\ \text{nm}$
    E. There is not enough information.

11. [3 points] A bent tube with a stopper at one end is filled with water and oil as shown at right. 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 comparison of the pressures at these points? Note that the density of oil is less than that of water. Select <u>all</u> that apply.

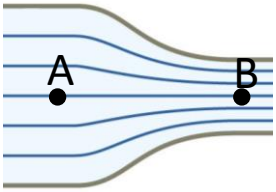


    A. $p_\text{A} = p_\text{D}$
    B. $p_\text{A} > p_\text{D}$
    C. $p_\text{B} = p_\text{C}$
    D. $p_\text{B} < p_\text{C}$
    E. $p_\text{C} > p_\text{D}$

12. [3 points] A hollow glass sphere of volume $V = 500\ \text{ml}$ floats at rest exactly half submerged in a fluid with density $0.9\ \text{kg/l}$. The sphere is then fully submerged and tied by a string to the bottom of the tank, as shown. What is the tension in the string?
    A. $T = 2.2\ N$
    B. $T = 4.4\ N$
    C. $T = 1.1\ N$
    D. There is not enough information.



13. [3 points] A non-viscous liquid has laminar flow from left to right through the pipe shown. At point A, the pressure of the fluid is 5×10^5 Pa, and the speed of the fluid is 10 m/s. At point B, the pressure is 3.5×10^5 Pa. The density of the fluid is 1000 kg/m^3. What is the speed of the fluid at point B?



A. 10 m/s
B. 12 m/s
C. 16 m/s
D. 20 m/s
E. 40 m/s

14. [3 points] A system can be found in any one of six macrostates, as shown in the table. What is the probability of finding it in macrostate C?

Macrostate	A	B	C	D	E	F
Number of microstates	1	3	5	7	9	7

A. $Pr = 5$
B. $Pr = 0.16$
C. $Pr = 0.083$
D. $Pr = 0.031$
E. There is not enough information.

15. [3 points] You are looking down at a thin layer of oil on the surface of a block of glass. You shine a red light straight down at a point where the thickness of the oil is the minimum thickness at which you see minimal reflected light. The refractive index of the oil is 1.5 and the refractive index of the glass is 1.6. Which of the following statements are correct?

i. There is no phase shift for light reflected from the air-oil interface.
ii. If the glass had an index of refraction of 1.4 instead, then you would see maximal reflected light.
iii. If the thickness of the oil were doubled, then you would see maximal reflected light.

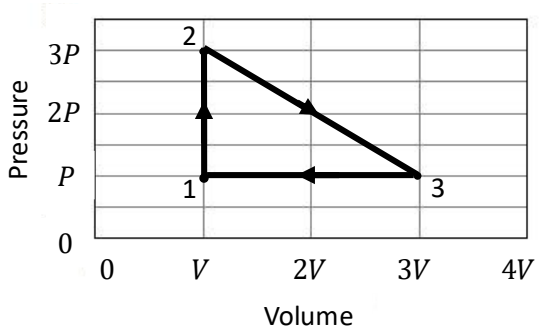
A. i. only
B. ii. Only
C. iii. Only
D. i. and ii.
E. ii. and iii.

16. [3 points] A laser beam with a wavelength λ is incident normal to a mask with a single slit of width a cut in it. After passing through the slit, the light from the laser strikes a screen 2.0 m away from the mask. Consider the point on the screen where you observe the third diffraction minimum away from the central bright spot. How much farther has light traveled to this point from one side of the slit compared to light from the other side of the slit?
    A. 1.5λ
    B. 3λ
    C. a
    D. $1.5a$
    E. $3a$

17. [4 points] Suppose that *N* particles of an ideal gas are in a container that can keep the pressure of the gas constant. Initially the gas is at room temperature, $20°\text{C}$, and its volume is *V*. Which of the following single changes, if any, would raise the temperature of the gas to $40°\text{C}$? Select all that apply.
    A. Increase the volume of the gas to 2*V*.
    B. Decrease the volume of the gas to *V*/2.
    C. Increase the number of the particles to 2*N*.
    D. Decrease the number of the particles to *N*/2.
    E. None of the above changes will work.

18. [4 points] An ideal monatomic gas with 1.0×10^{23} particles is in a chamber with a plunger on top. While an external force pushes on the plunger, the chamber is heated by a flame. While 35 J of heat is transferred to the gas by the flame, the temperature of the gas increased by 45 K. What is the work done on the gas by the plunger?
    A. 3.9 J
    B. 27 J
    C. 58 J
    D. 93 J
    E. 130 J

19. [4 points] An ideal gas undergoes the processes represented in the diagram at right, where the gas is in state 1 when the process begins and again in state 1 at the finish. Compare the absolute values of the work done on the gas for each process, $|W_{1\to2}|$, $|W_{2\to3}|$, and $|W_{3\to1}|$, and for the whole cycle, $|W_{\text{whole}}|$.



A. $|W_{2\to3}| > |W_{3\to1}| = |W_{\text{whole}}| > |W_{1\to2}|$
B. $|W_{\text{whole}}| > |W_{2\to3}| > |W_{3\to1}| > |W_{1\to2}|$
C. $|W_{\text{whole}}| > |W_{2\to3}| > |W_{1\to2}| > |W_{3\to1}|$
D. $|W_{2\to3}| > |W_{3\to1}| > |W_{1\to2}| = |W_{\text{whole}}|$
E. $|W_{2\to3}| > |W_{3\to1}| > |W_{1\to2}| > |W_{\text{whole}}|$

20. [3 points] How much energy needs to be added to an ice block with a mass of 1.20 kg at a temperature of -15.0 °C to turn it into liquid water at 5.0 °C? Note that the specific heat capacity of ice is 2090 J/K·kg, that of liquid water is 4181 J/K·kg, and the specific transformation energy for melting for water is 3.34×10^5 J/kg.

A. 62.7 kJ
B. 401 kJ
C. 426 kJ
D. 438 kJ
E. 464 kJ

Consider the following scenario for the next two questions.

Consider a heat engine that operates between two constant-temperature reservoirs at 840 K and at 310 K. For each cycle, 420 J of heat is transferred from the high-temperature reservoir to the engine.

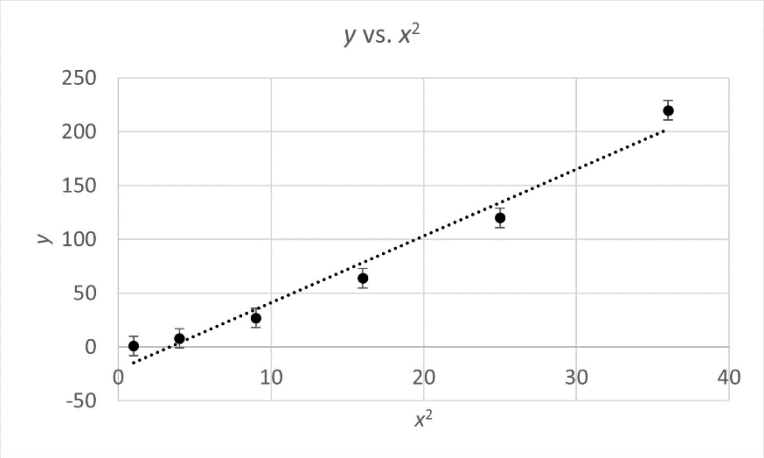
21. [4 points] What is the change in entropy of the high-temperature reservoir each cycle of the heat engine?
    A. $+0.50\,\mathrm{J/K}$
    B. $-0.50\,\mathrm{J/K}$
    C. $+0.86\,\mathrm{J/K}$
    D. $-0.86\,\mathrm{J/K}$
    E. $-0.80\,\mathrm{J/K}$

22. [3 points] If the engine is operating at the highest efficiency allowed by the second law of thermodynamics, how much heat is transferred to the low-temperature reservoir from the engine in each cycle?
    A. 155 J
    B. 265 J
    C. 666 J
    D. 718 J
    E. 1140 J

II. [15 points total] 4 Lab Questions

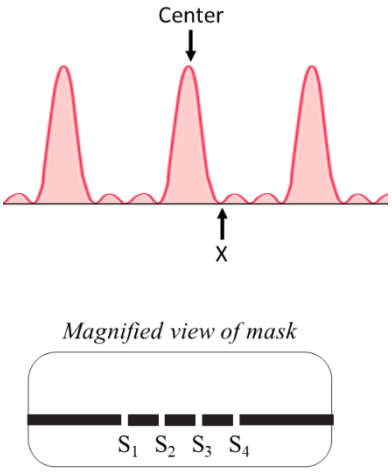
23. [4 points] In a lab, a team measured the mass of an object to be $m = 5.00 \pm 0.01$ kg, and its volume to be $V = 0.35 \pm 0.01$ L. Based on these measurements, which of the following values with their uncertainties is consistent with the best estimate of the density of this object ($\rho = m/V$) according to the rule for handling uncertainty that we use in PHYS 123?
    A. 14.3 ± 0.41 kg/L
    B. 14.29 ± 0.02 kg/L
    C. 14.29 ± 0.03 kg/L
    D. 14.29 ± 0.44 kg/L
    E. 14.3 ± 0.4 kg/L

24. [4 points] Suppose that a team of students are trying to develop a mathematical model relating variables *x* and *y*. They obtain data and plot *y* vs. x^2 to try to produce a linearized graph with a linear best-fit line as shown below.



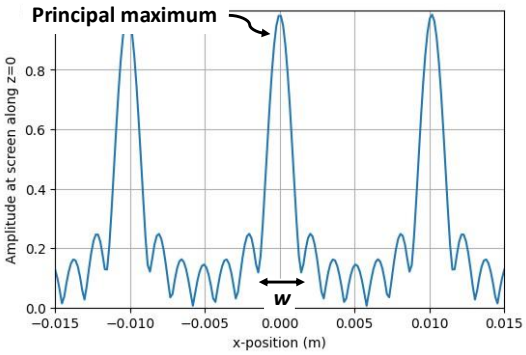
Which of the following statements is correct based on the graph? Select all that apply.
    A. The team properly linearized the graph.
    B. The team should try plotting another graph, such as *y* vs. x^3.
    C. The team should try plotting another graph, such as *y* vs. *x*.
    D. The team can conclude how *x* and *y* are mathematically related from the best-fit line of this graph.

25. [4 points] A monochromatic beam of light is incident on a mask containing four equally spaced slits, and the interference pattern is observed on a distant screen. The intensity as a function of position on the screen is shown in the image at top right. Each slit, S_1 through S_4, as shown in the bottom figure is very narrow and may be treated as a point source. Point X on the screen is the first minimum to the right of the central maximum. What is the phase difference between the light from adjacent slits arriving at Point X?



A. 0
B. $\pi/3$
C. $\pi/2$
D. π
E. $3\pi/2$

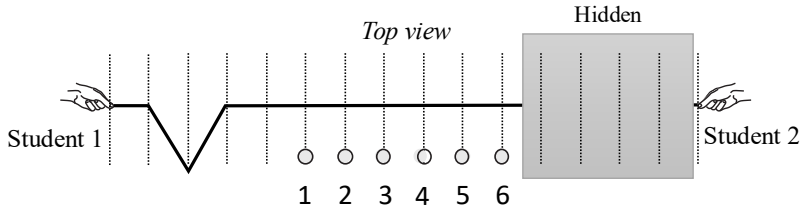
26. [3 points] In a simulated multi-slit interference experiment, a lab team decided to measure the width of the central principal maximum, *w*, as they increased the number of slits, *N*. They kept the wavelength of the light, λ, the width of the slits, *a*, and the screen distance, *y*, constant. Which of the following variables is the dependent variable in this experiment?



A. *w*
B. *N*
C. λ
D. *a*
E. *y*

III. [15 points total] 4 Tutorial Questions

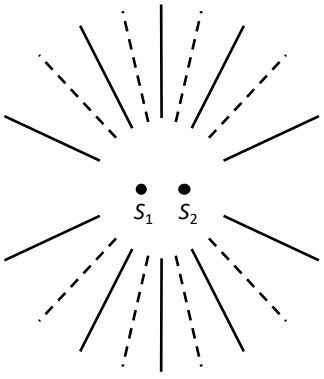
27. [4 points] Two students hold either end of a stretched spring. There are six cups placed on one side of the spring. Both students generate a pulse similar in shape, but the pulses are not necessarily generated at the same time or have the same orientation. The shape of the spring before the pulses have reached each other, is shown below (note that any pulse student 2 may have generated is hidden in the image).



If <u>all cups **except** cup 5</u> are knocked over (ignoring reflection of pulses after pulses reaching the opposite student), was student 2's pulse generated *before*, *after*, or *the same time* as student 1's? Was student 2's pulse in the *same* orientation as student 1's pulse, or is it in the *opposite* orientation? Select <u>all</u> that apply.

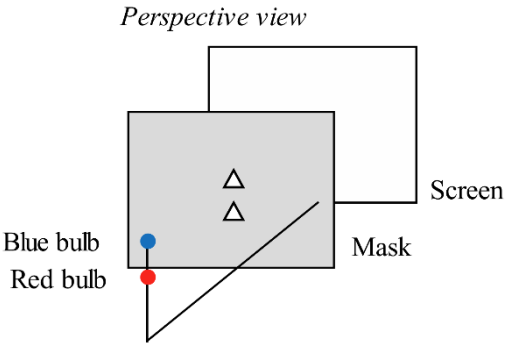
A. Student 2's pulse was generated *before* student 1's.
B. Student 2's pulse was generated *after* student 1's.
C. Student 2's pulse was generated *the same time* as student 1's.
D. Student 2's pulse was in the *same* orientation as student 1's pulse.
E. Student 2's pulse was in the *opposite* orientation as student 1's pulse.

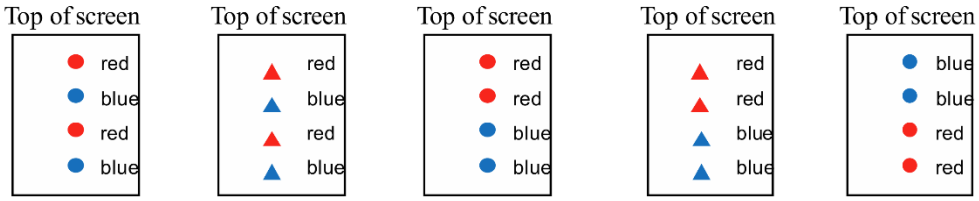
28. [3 points] Two point-sources (S_1 and S_2) separated by a distance d generate periodic waves by tapping the surface of the water. Both sources produce waves with wavelength λ. The diagram at right shows the interference pattern created: **antinodal lines** are represented by **solid lines,** and *nodal lines* are represented by *dashed lines*. What is d in terms of λ?



A. $1.5\lambda < d < 2\lambda$
B. $d = 2\lambda$
C. $2\lambda < d < 2.5\lambda$
D. $d = 2.5\lambda$
E. $2.5\lambda < d < 3\lambda$

29. [4 points] A mask with two medium sized triangular holes directly above each other is placed in front of a screen. Two small bulbs are placed in front of the mask at the same heights as the holes, as shown at right. The holes are large enough that you can ignore diffraction. Which of the following diagrams corresponds to what you would see on the screen? B





30. [4 points] An ideal monatomic gas begins in an initial state, i, then undergoes a process with a final state f as shown. Which of the following choices about the absolute values of the change in the thermal energy of the gas, $|\Delta E_{\text{th}}|$, work done on the gas, $|W|$, and heat transferred to the gas, $|Q|$, during this process is correct? Select <u>all</u> that apply.

A. $|W| > |Q|$
B. $|W| < |Q|$
C. $|\Delta E_{\text{th}}| > |Q|$
D. $|\Delta E_{\text{th}}| < |Q|$
E. None of the above is correct.