I. [70 points total] 21 Lecture Questions

1. [3 points] A mass on a spring executes simple harmonic motion with displacement $D(t) = 3\sin(2t)$ with t measured in seconds and the displacement measured in meters. What is the period of this motion?
   A. 1 second
   B. π seconds
   C. 2 seconds
   D. 3 seconds
   E. 3π seconds

2. [3 points] A string of length 3.0 m is fixed on one end and driven at a frequency of 50 Hertz on the other end, forming a standing wave with nodes at *x* = 0.0 m, 1.5 m, and 3.0 m. Now suppose we increase the frequency to 150 Hertz, and a new standing wave is formed. What is the smallest value of *x* for which there is a node at *x* in this new standing wave?
   A. 0.5 m
   B. 1.5 m
   C. 0.7 m
   D. 0.3 m
   E. 1.0 m

3. [3 points] Two coherent in-phase point sources separated by 10 cm generate waves on the surface of water. The wave speed is 1.0 m/s. What is the minimum frequency for there to be a nodal line?
   A. 20 Hertz
   B. 15 Hertz
   C. 10 Hertz
   D. 1 Hertz
   E. 5 Hertz

4. [3 points] An ambulance moving at a constant speed passes directly by a stationary observer. When it's approaching the observer (head on), the observer hears a frequency of 854 Hz; when it's moving directly away, the observer hears a frequency of 700 Hz. How fast is the ambulance moving? The speed of sound in air is 343 m/s.
   A. 11 m/s
   B. 23 m/s
   C. 34 m/s
   D. 45 m/s
   E. 56 m/s

5. [3 points] A buzzer emits 1.26×10^{-7} W of power, equally in all directions. How far away do you have to be from the buzzer in order for it to be barely audible? (Note: barely audible means 0 dB).
   A. 25 m
   B. 50 m
   C. 75 m
   D. 100 m
   E. 200 m

6. [3 points] Glass with index of refraction 1.5 is coated with a transparent plastic film with index of refraction 1.3; outside is air. Using ray optics, compute the critical angle (to the normal) for a ray incoming from the glass to totally internally reflect from the plastic / air interface.
   A. 0.43 rad
   B. 0.63 rad
   C. 0.55 rad
   D. 0.83 rad
   E. 0.73 rad

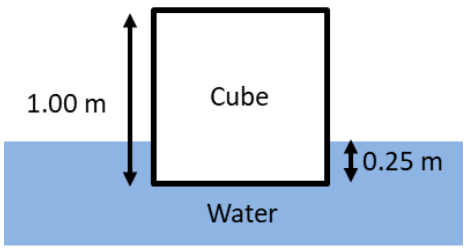
7. [3 points] An object is 10 cm in front of a concave (converging) mirror with a radius of curvature of 40 cm. The image is:
   A. real and upright
   B. real and inverted
   C. virtual and upright
   D. virtual and inverted
   E. infinitely far away

8. [3 points] Blue light with wavelength 470 nm passes through a diffraction grating with slits 10000 nm apart, and generates an interference pattern on a screen, with a distance of 1.00 m between the central maximum and the first principal maximum. Now suppose you instead take red light of wavelength 700nm, and replace the diffraction grating with one whose slits are 20000 nm apart, but keep the screen at the same distance. What is the new distance between the central maximum and the first principal maximum?
   A. 0.23 m
   B. 0.43 m
   C. 0.74 m
   D. 1.24 m
   E. 1.38 m

9. [3 points] Light is normally incident on an air gap interface of thickness t between two pieces of glass. Compute the smallest value of $t > 0$ for which this interface preferentially transmits blue light of wavelength 470 nm.
   A. 235 nm
   B. 325 nm
   C. 470 nm
   D. 940 nm
   E. 1410 nm

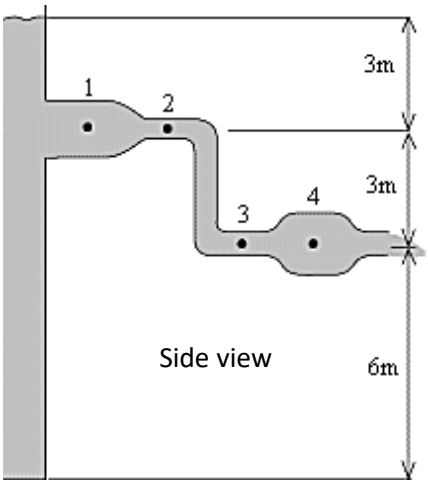
10. [3 points] X-rays of wavelength 2.0 nm have just enough energy to knock an electron out of a certain metal. Suppose now that we irradiate this metal with x-rays of wavelength 1.0 nm. What is the wavelength of the fastest electrons that are knocked out of the metal?
   A. 0.012 nm
   B. 0.035 nm
   C. 0.049 nm
   D. 0.12 nm
   E. 0.53 nm

11. [3 points] A cube with a side length of 1.00 m floats in water with 0.25 m submerged as shown. What is the mass of the cube? Note that the density of water is 1000 kg/m^3.



A. 250 kg
B. 750 kg
C. 1000 kg
D. 2500 kg
E. 7400 kg

12. [4 points] A non-viscous ideal fluid is discharged from the tank in the manner shown at right. The flow is laminar, and the narrow pipe has one ninth the cross-sectional area of the wide pipe. At point 1 the fluid is flowing with a speed of 0.7 m/s. Compare the pressure at points 1 and 3.



A. $p_1 < p_3$
B. $p_3 < p_1$
C. $p_1 = p_3$
D. Not enough information is given to answer.

13. [3 points] A 23 kg object is undergoing lightly damped harmonic oscillations. If the total energy drops to 1/6th its original value in 2.1 s, what is the value of the time constant for damping, τ?

A. 1.2 s
B. 0.17 s
C. 3.1 s
D. 0.58 s
E. 2.1 s

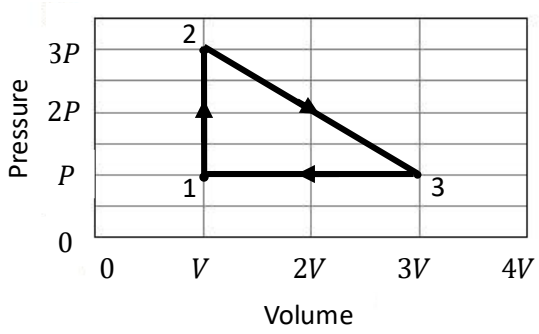
14. [4 points] Two identical insulating rigid tanks A and B contain different monatomic gasses. The number of particles in tank A is greater than that in tank B. The temperatures of the two gases are equal. Which of the following statements is/are correct? Select all that apply.
    A. The rms speed of the gas particles in tank A must be equal to that in tank B.
    B. The mass of the gas in tank A must be greater than that in tank B.
    C. The thermal energy of the gas in tank A must be greater than that in tank B.
    D. The average kinetic energy of the gas particle in tank A must be equal to that in tank B.
    E. None of the above is correct.

15. [4 points] beam of monochromatic light with a wavelength of 650 nm passes through a diffraction grating with slits 2500 nm apart. How many spots are observed on a large screen placed a small distance in front of the diffraction grating?
    A. 1
    B. 3
    C. 5
    D. 6
    E. 7

16. [4 points] A rigid container contains *N* particles of an ideal gas at room temperature, $20°C$, and at pressure *P*. Suppose you want to use the same container to create a condition where the pressure inside the container is *P*/2. Which of the following changes could you make? Select all that apply.
    A. Decrease the temperature to $10°C$ but keep the same number of particles.
    B. Decrease the temperature to $5°C$ and increase the number of particles to 2*N*.
    C. Keep the same temperature and decrease the number of particles to *N*/2.
    D. Keep the same temperature and number of particles but use another ideal gas with half the particle mass as the original gas.
    E. None of the above changes will work.

17. [4 points] An ideal monatomic gas with 1.0×10^{23} particles and $C_V = 12.5\,\mathrm{J/(mol \cdot K)}$ is in a chamber with a plunger on top. While an external force pushes on the plunger, the chamber is heated by a flame. If 50 J of work is done on the gas by the plunger, and 30 J of heat is transferred to the gas by the flame, what is the change in the temperature of the gas?
    A. +15 K
    B. +22 K
    C. +39 K
    D. +58 K
    E. +97 K

18. [4 points] An ideal gas undergoes the process 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. Determine the work done on the gas during the process.



    A. $-4PV$
    B. $-2PV$
    C. $+2PV$
    D. $+4PV$
    E. $+6PV$

19. [3 points] The temperature of an ice block with a mass of 0.30 kg is raised from -5.0 °C to -1.0 °C. How much energy is transferred to it? Note that the specific heat capacity of ice is 2090 J/K·kg.
    A. 0.63 kJ
    B. 2.5 kJ
    C. 3.1 kJ
    D. 3.8 kJ
    E. 8.4 kJ

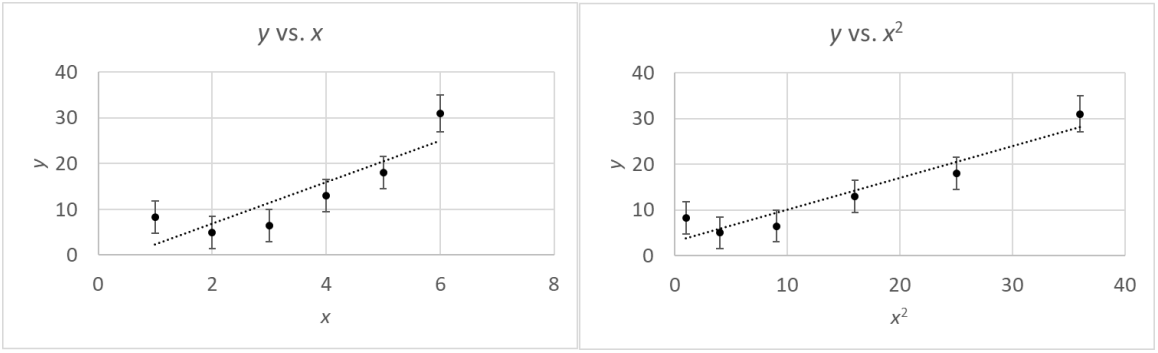
20. [4 points] What is the entropy change for the environment when 140 J of heat is transferred to a thermal reservoir with a temperature of 340 K.
    A. 0.21 J/K
    B. 0.41 J/K
    C. 2.5 J/K
    D. 5.0 J/K
    E. 0 J/K

21. [3 points] A heat engine that operates on a Carnot cycle has an efficiency of 0.50 when its low temperature reservoir is at 10 °C. If you continue to use the same low-temperature reservoir, by how much must you increase the temperature of the high-temperature reservoir to increase the efficiency to 0.60?
    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 weight of an object, w, and its vertical displacement, Δy. The team reported the change in gravitational potential energy of the object-earth system to be, $\Delta U = w \cdot \Delta y = 20 \pm 2$ J. If the team measured the weight to be $w = 5.0 \pm 0.1$ kg, which of the following values with their uncertainties is consistent with their measurement of Δy according to the rule for handling uncertainty that we use in PHYS 123?
    A. 4.00 ± 0.08 m
    B. 4.00 ± 0.31 m
    C. 4.0 ± 0.31 m
    D. 4.0 ± 0.4 m
    E. 4 ± 0.5 m

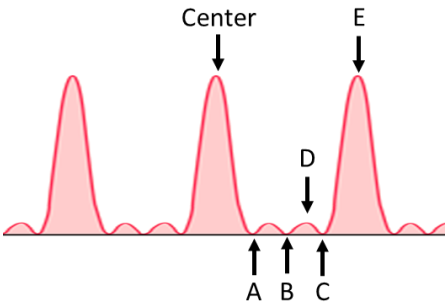
23. [4 points] Suppose that the graphs below show the data you obtained for values of *x* and *y*. The left graph shows *y* vs. *x*, and the right graph shows *y* vs. x^2. Each graph has a linear best-fit line.

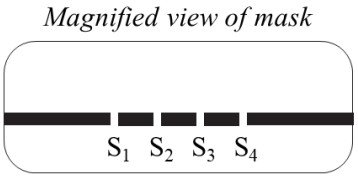


Suppose that you are testing two models below, where *m* and *b* are arbitrary constants.
Model 1: $y = mx + b$
Model 2: $y = mx^2 + b$

Based on these graphs, what can you conclude? Select all that apply.
    A. The data supports Model 1.
    B. The data supports Model 2.
    C. The data does not support either Model 1 or Model 2.
    D. We do not have enough information to conclude anything.

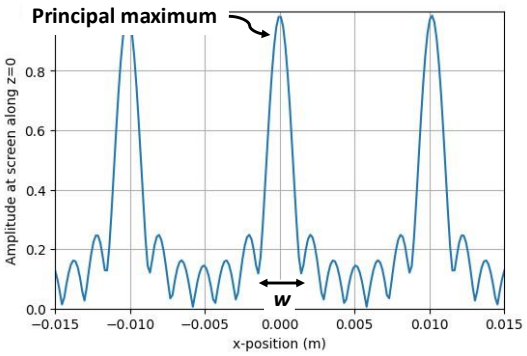
24. [4 points] A monochromatic beam of light is incident on a mask containing four equally spaced slits, and the interference pattern is observed on a distant screen. The intensity as a function of position on the screen is shown in the image at top right. Each slit, S_1 through S_4, as shown in the bottom figure is very narrow and may be treated as a point source. At a point on the screen, the phase difference between the light from adjacent slit is $\frac{3\pi}{2}$. To which of the points on the screen shown in the top figure does this point correspond?





A. Point A: the first minimum to the right of the central maximum
B. Point B: the second minimum to the right of the central maximum
C. Point C: the third minimum to the right of the central maximum
D. Point D: the second secondary maximum to the right of the central maximum
E. Point E: the first principal maximum to the right of the central maximum

25. [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*. In this experiment, which of the following statements is/are correct? Select all that apply.

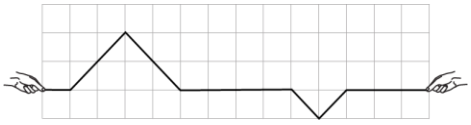


A. *N* is a dependent variable.
B. *N* is a control variable.
C. *N* is an independent variable.
D. *w* is an independent variable.
E. *w* is a dependent variable.

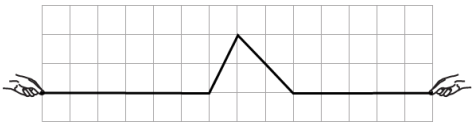
[15 points total] 5 Tutorial Questions

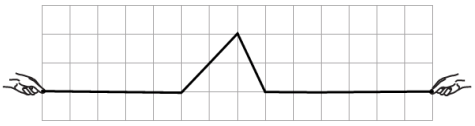
26. [3 points] A block of mass *m* on a horizontal frictionless surface is attached to a horizontal spring with spring constant *k*. The block is pulled some horizontal distance from the equilibrium position and released such that it oscillates with simple harmonic motion. Now the spring is replaced with a spring with **twice the spring constant**, and the block is replaced with a block with **half the mass**; everything else in the setup is unchanged (i.e. the block is released from the same position relative to the equilibrium position). Consider a system consisting of the block and the spring. Which of the following statements are correct for the new situation compared to the initial situation? Select all that apply
    A. The maximum kinetic energy decreases.
    B. The maximum potential energy increases.
    C. The total energy increases.
    D. The total energy remains the same.
    E. None of the above

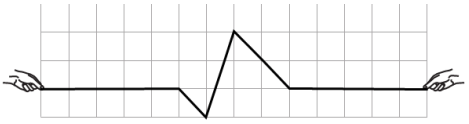
27. [3 points] Two students hold either end of a stretched spring. At time t = 0 s, both students start generating a pulse at their end of the spring. The shape of the spring at time t = 5 s, before the pulses have reached each other, is shown below.

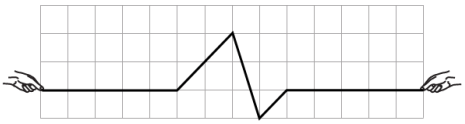


Which of the following shows the shape of the spring at t = 9 s (4 s after the image above)? A

A. 

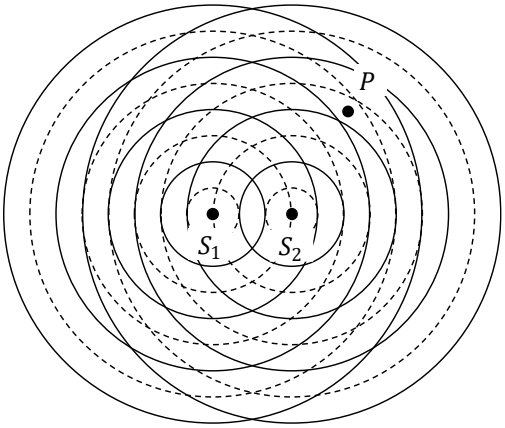
B. 

C. 

D. 

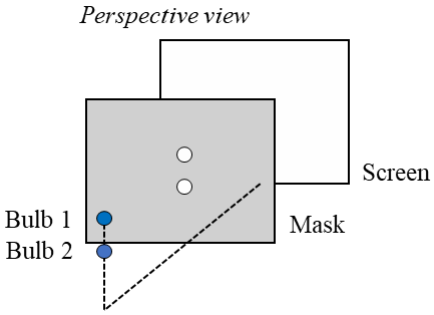
E. This situation is not possible.

28. [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. Which of the following statements is/are correct regarding the point labeled by *P*? Select all that apply.

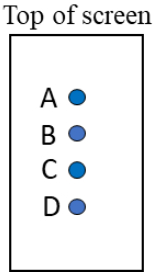


A. At $t = 0$, point *P* is a location of constructive interference.
B. At $t = 0$, point *P* is a location of destructive interference.
C. At $t = 0$, point *P* is a location of neither constructive nor destructive interference.
D. A quarter of a period after $t = 0$, point *P* is a location of constructive interference.
E. A quarter of a period after $t = 0$, point *P* is a location of destructive interference.

29. [3 points] Consider the following two cases.
Case 1: A mask with two medium sized holes directly above each other is placed in front of a screen. Two 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.
Case 2: Case 2 is identical to Case 1 except Bulb 2 is removed.

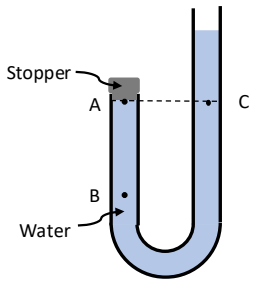


In Case 1, you see the pattern on the screen as shown at right. The images of the bulbs are labeled as A through D. In Case 2, which image or images disappear? Select all that apply.



A. Image A
B. Image B
C. Image C
D. Image D
E. None of the images disappear.

30. [3 points] A U-shaped tube filled with water is closed on the left end as shown at right. The right side of the tube is taller, and the water surface level is higher than the stopper. Positions A and C are at the same height. Which of the following is the correct ranking of the pressures at these points? Select <u>all</u> that apply.



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