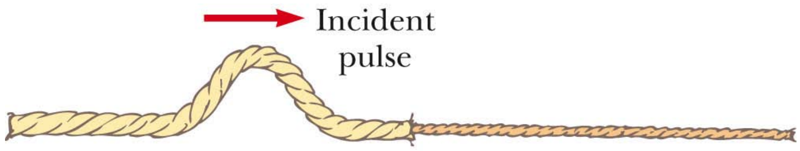
PART I (15 points): True/False

Indicate whether each statement is true or false by circling your answer. No explanation for your choice is required. Each answer is worth 3 points.

1. Consider two barometers that are identical except that one contains a column of fluid of lower density and one contains a column of fluid of higher density. The barometer with the highest column will be the one with the fluid of lowest density.

TRUE or FALSE?

2. The figure below shows an incident pulse traveling along a string of high mass density approaching a boundary that is connected to a string of low mass density.



When the pulse reaches the boundary, a reflected pulse is produced traveling in the opposite direction that is inverted with respect to the incident pulse.

TRUE or FALSE?

3. The frequency of visible light is larger than the frequency of X-rays.

TRUE or FALSE?

4. A camera is initially focused on a distant object. To focus the image of an object close to the camera, the lens must be moved away from the sensor (or film).

TRUE or FALSE?

5. A single slit diffraction pattern is observed. If the slit width is made half as large, then the central bright fringe of the diffraction pattern becomes narrower.

TRUE or FALSE?

PART II (40 points): Multiple choice questions

Only one of the choices given is the correct answer. No explanation for your choice is required. Each multiple choice problem is worth 5 points.

1. A thin rectangular piece of wood floats in a tank of water. You slowly pour oil onto the surface of the water until the height of the oil above the water is twice the height of the piece of wood. If the density of the oil is exactly equal to the density of the wood, which of the following statements is correct?

(a) The wood floats on top of the oil, so it sticks up in the air.

(b) The wood does not change its position.

(c) The wood sinks below the surface of the water.

(d) The wood is half in the water and half in the oil.

(e) The wood floats in the oil just above the water.

2. Increasing the amplitude of the external force acting on a damped mass-and-spring oscillator causes what kind of change in the resonant frequency of the system? (Assume no other changes to the system.)

(a) The frequency increases.

(b) The frequency decreases.

(c) There is no change in the frequency.

(d) The frequency change depends on whether the system is overdamped, underdamped or critically damped.

3. If you blow across the top of an empty soda bottle, a pulse of sound travels down through the air in the bottle. At the moment the pulse reaches the bottom of the bottle, what is the correct description of the displacement of air molecules from their equilibrium positions and the acoustic pressure (i.e., the deviation of the pressure of the air from the normal pressure in the absence of the sound wave) at this point?

(a) The displacement and acoustic pressure are both at a maximum.

(b) The displacement and acoustic pressure are both at a minimum.

(c) The displacement is zero, and the acoustic pressure is a maximum.

(d) The displacement is zero, and the acoustic pressure is a minimum.

4. Two organ pipes, a “closed pipe” of fundamental frequency $f_c = 440$ Hz, which is closed at one end and open at the other end, and an “open pipe” of fundamental frequency $f_o = 660$ Hz, which is open at both ends, produce overtones. Some of the overtone frequencies of the closed pipe are also overtone frequencies of the open pipe. By listing the first five overtone frequencies for each of the two pipes, determine which of the following statements is correct.

(a) The frequency of the third overtone of the closed pipe matches the frequency of the third overtone of the open pipe.

(b) The frequency of the third overtone of the closed pipe matches the frequency of the fourth overtone of the open pipe.

(c) The frequency of the fourth overtone of the closed pipe matches the frequency of the third overtone of the open pipe.

(d) The frequency of the third overtone of the closed pipe matches the frequency of the fifth overtone of the open pipe.

(e) The frequency of the fourth overtone of the closed pipe matches the frequency of the fifth overtone of the open pipe.

5. An image is formed by refraction at a convex spherical surface. The object O is located on the left-hand side of the refracting surface in a medium of index of refraction n_1. The center of curvature of the refracting surface lies on the right-hand side of the refracting surface in a medium of index of refraction n_2, where $n_2 > n_1$. What happens to the image point I when the object point O is moved to the right from very far away to very close to the refracting surface?

(a) The image point I is always to the right of the refracting surface.

(b) The image point I always to the left of the refracting surface.

(c) The image point I is initially to the left of the refracting surface, but ends up to the right of the refracting surface (on the opposite side to O).

(d) The image point I is initially to the right of the refracting surface, but ends up to the left of the refracting surface (on the same side as O).

6. A far-sighted student has a near point of 1.0 m. Calculate the focal length of the glasses needed so the near point will be normal (25 cm).

(a) 72 cm

(b) 20 cm

(c) 33 cm

(d) 1 m

(e) −33 cm

7. A film of thickness t and index of refraction n_1 coats a surface with index of refraction n_2. When $n_1 < n_2$, the condition for destructive interference for reflected monochromatic light of wavelength λ in air (where m is a non-negative integer) is

(a) $t = m\lambda/n_1$

(b) $t = (m + \frac{1}{2})\lambda/n_1$

(c) $2t = m\lambda/n_1$

(d) $2t = (m + \frac{1}{2})\lambda/n_1$

8. Linearly polarized light is to have its axis of polarization rotated by 90° by employing some number of polarizers. In which of the following cases does the final beam have the greatest intensity?

(a) 3 polarizers, where each polarizer rotates the axis of polarization by 30°.

(b) 2 polarizers, where each polarizer rotates the axis of polarization by 45°.

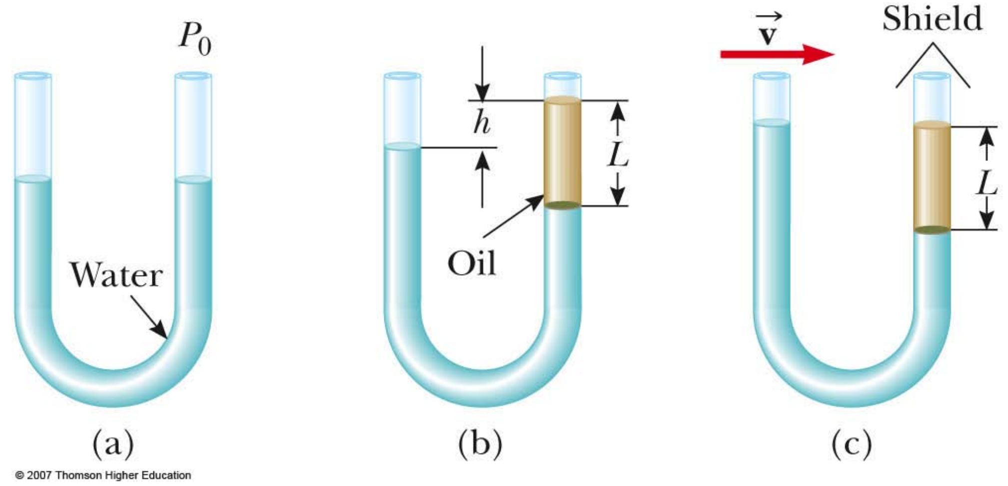
(c) 1 polarizer, which rotates the axis of polarization by 90°.

(d) None of above, since the axis of polarization cannot be rotated in this way.

PART III (120 points): Short problems

To earn full credit on the following problems, you must exhibit the steps that lead to your final result (and will depend on the clarity of your method of solution as well as on your final answer). Each problem is worth 20 points.

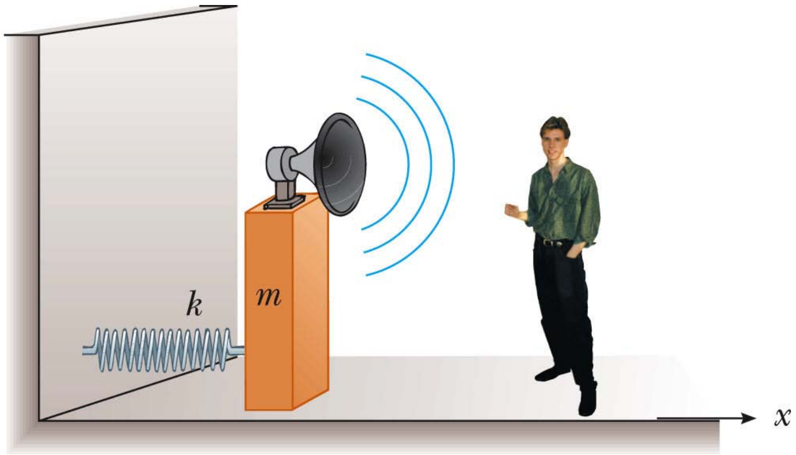
1. A U-tube open at both ends is partially filled with water as shown in figure (a) below. Oil, with a density of 750 kg/m^3 is then poured into the right arm and forms a column $L = 5$ cm high, as shown in (b) below. Notice that the fluid column heights now differ by some amount h. The right arm is then shielded from any air motion while air is blown across the top of the left arm until the two fluids are at the same height, as shown in (c). Assume that the water and oil are at rest (there is no fluid motion within the U-tube). Compute the speed of the air, v being blown across the left arm.



NOTE: The density of air is 1.29 kg/m^3. The density of water is 1000 kg/m^3 (but you knew that, right?). Due to the presence of the shield shown in figure (c), the velocity of the air across the top of the right arm is zero. To solve this problem it is *not* necessary to determine the height h shown in (b).

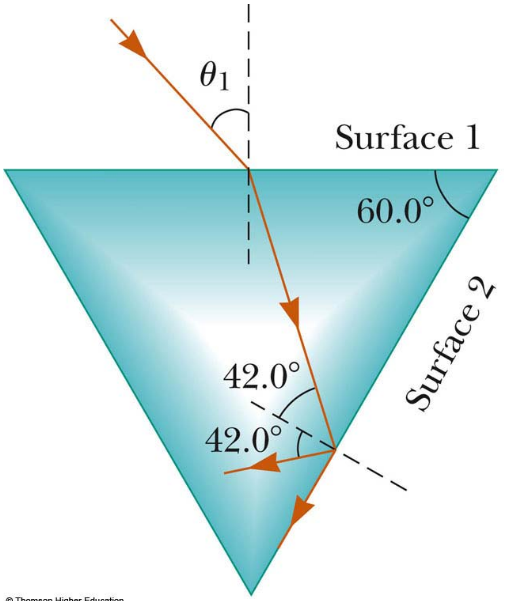
2. A block with a speaker bolted to it is connected to a spring with a spring constant $k = 20$ N/m, as shown in the figure below. The total mass of the block and speaker is $m = 5$ kg, and the amplitude of this unit's motion is 0.5 m.

(a) The speaker emits sound waves of frequency 440 Hz. Determine the highest and lowest frequency heard by the person to the right of the speaker (shown in the figure at the top of the next page). Take the speed of sound to be 343 m/s.



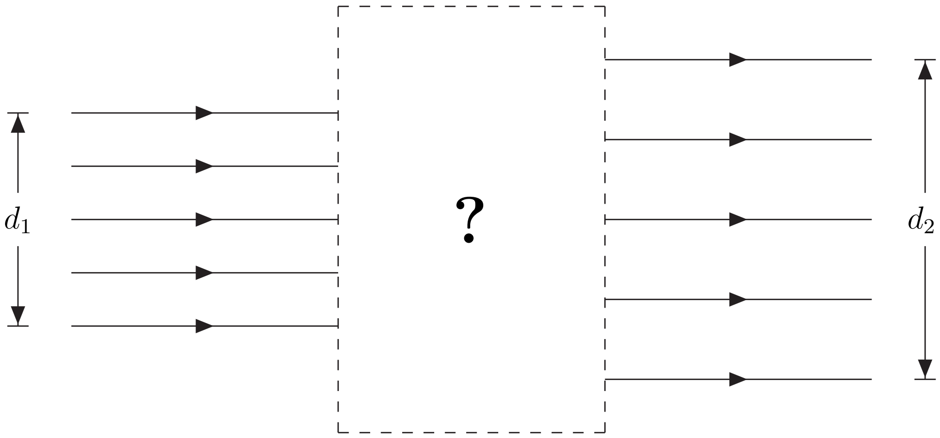
(b) If the maximum sound level heard by the observer is 60 dB when he is closest to the speaker, 1 m away, what is the minimum sound level heard by the observer?

3. A light beam (shown in the figure below) is incident on a triangular glass object. The angle of incidence at surface 1 is denoted by θ_1. The light beam then strikes surface 2 at the critical angle for total internal reflection. This angle is observed to be 42°. Compute the angle of incidence θ_1.



NOTE: Do not assume that the medium outside the glass is air. Nevertheless, you have enough information to solve the problem.

4. In many applications, it is necessary to expand the diameter of a beam of parallel rays of light. This change can be made by using a converging lens and a diverging lens in combination. Suppose you have a converging thin lens of focal length 21 cm and a diverging thin lens of focal length -12 cm. Let d_1 be the diameter of the incoming beam of parallel rays, as shown in the figure below. Arrange the two lenses (inside the dashed box area shown below) so that the light beam that emerges is still composed of parallel rays with a beam diameter of d_2 such that $d_2 > d_1$.



(a) Through which lens does the incoming beam first pass?

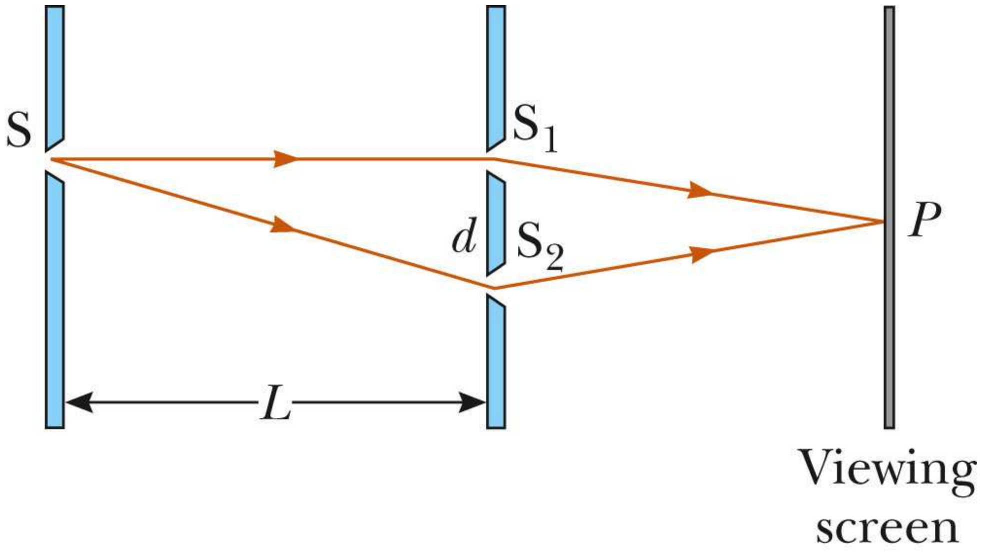
(b) What is the distance between the two lenses?

(c) Compute the ratio d_2/d_1 by which the diameter of the beam has been increased.

HINT: Draw a ray diagram to make sure that your answer makes sense. In particular, the ray diagram will help you answer part (c).

5. Monochromatic light of wavelength 600 nm passes through a very narrow slit S and then strikes a screen that contains two parallel slits S_1 and S_2 as shown in the figure at the top of the next page. Slits S and S_1 are located at the same vertical height and are separated by a distance of $L = 1.2$ m. The slit S_2 lies a distance d below the slit S_1. The light is detected at a point P on a second screen that is equidistant from S_1 and S_2. When either slit S_1 or S_2 is separately open, equal light intensities are measured at the point P. When both slits are simultaneously open, the intensity is three times larger.

NOTE: In this problem, we will ignore *all* single-slit diffraction effects.



(a) Determine the value of the phase difference (in radians) of the two waves that interfere at the point P. (If you find more than one possible value, choose the smallest allowed positive phase angle.)

(b) What is the minimum difference in path lengths of the two light waves that interfere at point P.

(c) *EXTRA CREDIT:* What is the minimum possible value for the slit separation d?

6. The *resolving power* of a microscope is defined by RP$= f\theta$, where f is the focal length of the objective lens and θ is the minimal angular separation of two resolvable objects according to Rayleigh's criterion.

Yellow light of wavelength 589 nm is used to view an object under a microscope. The diameter of the objective lens is 5 mm and its focal length is 9 mm.

(a) Compute the resolving power of the microscope.

(b) Suppose water (with an index of refraction $n = 4/3$) fills the space between the object and the objective lens. How is the resolving power of the microscope changed?