Physics 5B Practice Problems Solutions

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1 Multiple Choice Section

1. The figure below shows two identical speakers that are connected to the same amplifier, but Speaker B is wired backwards such that it oscillates 180 out of phase with respect to Speaker A. If the speakers emit the same sound intensity, and if the wavelength of the sound waves is 2 m, then the point P is

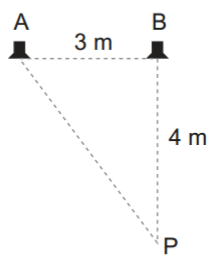


Figure 1: This figure is courtesy of Professor Robert Johnson.

   A. a point of maximum sound intensity.
   B. a point of negative sound intensity.
   C. a point of zero sound intensity.
   D. a point of minimum sound intensity.

2. The wavelength of visible light is closest to
   A. 1 centimeter $10^{-2}m$
   B. 1 Angstrom $10^{-10}m$
   C. 1 micron $10^{-6}m$
   D. 1 nanometer $10^{-9}m$
   E. 1 femtometer $10^{-15}m$

3. The lowest tone to resonate in an organ pipe open at both ends is 200 Hz. What is the frequency of the first overtone that resonates in the same pipe?
   A. 200 Hz
   B. 300 Hz
   C. 400 Hz
   D. 600 Hz
   E. 100 Hz

4. A speaker is radiating sound uniformly in all directions, with no obstructions present anywhere around it. At a distance of 5 m the sound intensity level is 90 dB. Which of the following is the sound intensity level at a distance of 500 m?

   A. 70 dB

   B. 60 dB

   C. 50 dB

   D. 40 dB

5. The figure represents the instantaneous shape of a transverse wave traveling from left to right. At this instant in time, the segment of string at point P has

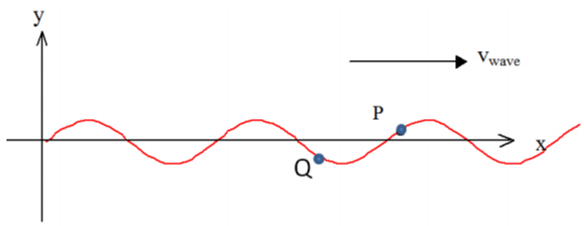


Figure 2: This figure is courtesy of Professor Robert Johnson.

   A. $v_y < 0$ **and** $a_y < 0$

   B. $v_y > 0$ and $a_y < 0$

   C. $v_y < 0$ and $a_y > 0$

   D. $v_y > 0$ and $a_y > 0$

2 Free Response

6. A cylindrical telescoping pipe is closed at one end and located in a room filled with an unknown gas. An audio speaker located outside the pipe near the open end emits a tone of 2000 Hz. The length of the pipe is slowly reduced until a loud resonance is heard. The pipe is then slowly reduced in length again, by 0.25 m, whereupon a second loud resonance is heard. What is the speed of sound in the pipe?

   A. We know that the pipes length is reduced by 0.25m between two successive resonances (modes). So all we need to determine is the difference in two anti-nodes (points of maximum displacement of gas molecules)in terms of its wavelength.

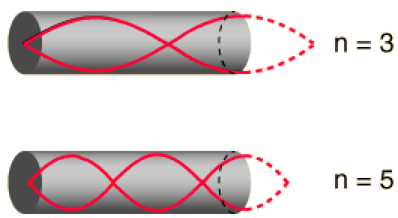


Figure 3: This shows the length difference between two successive anti-nodes. Specifically $n = 3$ and $n = 5$ (Only odd modes for closed pipes!). It may be different lengths for different modes but in terms of wavelength its constant.

From the figure its easy to see that the difference is just

$$\Delta\ell = \frac{\lambda}{2}$$

Since we know $\Delta\ell$ we can easily solve for λ,

$$\lambda = 2\Delta\ell = 2(0.25m) = 0.50m$$

The speed of sound is then just

$$v = f\lambda = 2000Hz \cdot 0.50m = 1000\frac{m}{s}$$

What is (approximately) the shortest length that this pipe can have for it to resonate at 2000 Hz?

   A. The fundamental frequency (or overtones) in a closed pipe is when the displacement of air molecules is zero at the closed end and maximum at the open end. For the shortest possible length this would correspond to a sine wave starting at zero at the closed end and reaching its first maximum at the other end of the pipe (the open end). Therefore, one fourth of the spatial period could fit into the entire length of the pipe.

$$\ell = \frac{\lambda}{4} = \frac{0.50m}{4} = 0.125m$$

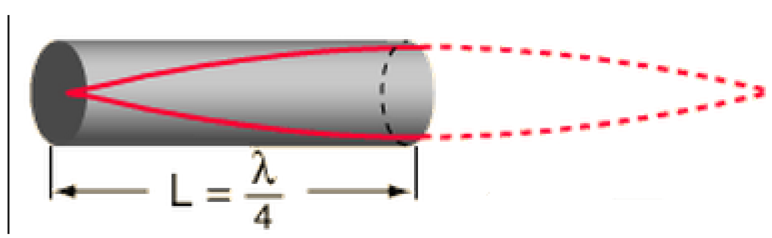
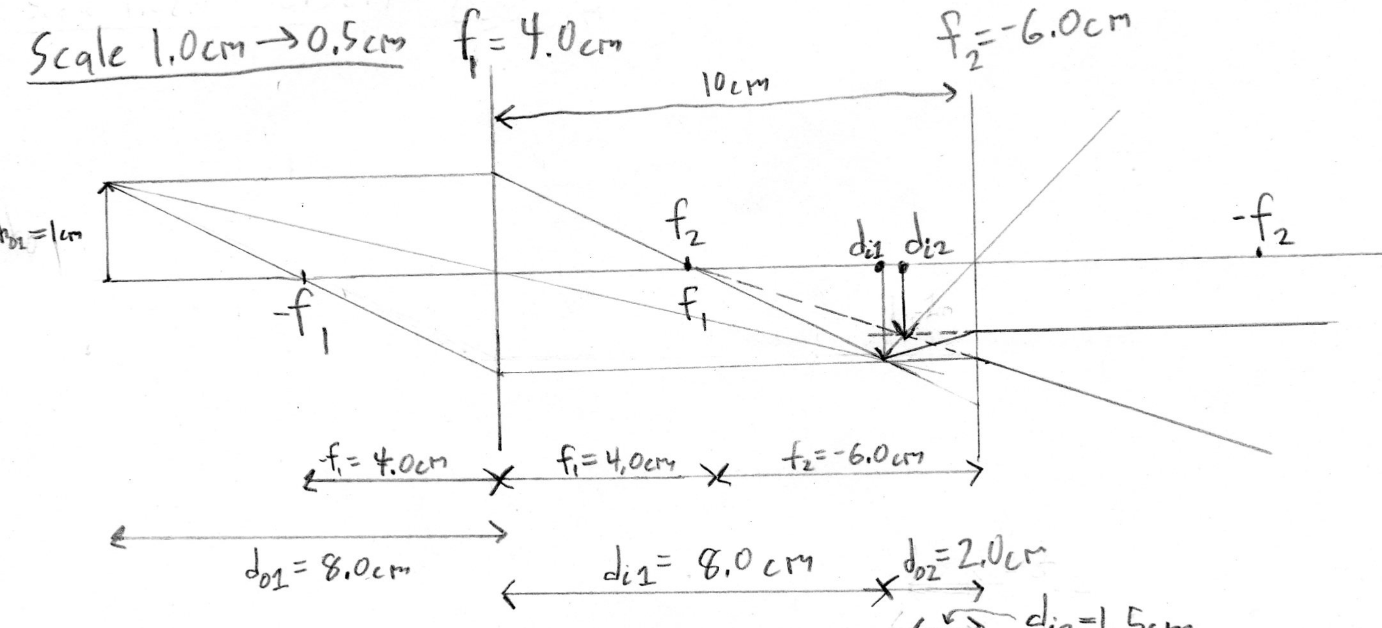


Figure 4: This shows one fourth a wavelength in the pipe (solid line) and another fourth (totaling half a wavelength) outside of the pipe(dashed line).

7. A diverging lens with focal length $f_1 = -6.0$ cm is placed 10 cm behind a converging lens of focal length $f_1 = 4.0$ cm. A 2 cm tall object is placed 8.0 cm in front of the converging lens. Draw the principal rays to locate final image and verify mathematically. Is the final image virtual or real? Is it upright or inverted?



A. We treat each lens independently. Hence, we will treat the image formed by the first lens as the object of the second lens. First lens obtain a generic equation for the image distance.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \longrightarrow d_i = \frac{d_o f}{d_o - f}$$

For the first lens we will get the image distance as

$$d_{i1} = \frac{d_{o1} f_1}{d_{o1} - f_1} = \frac{(4cm)(8cm)}{8.0cm - 4.0cm} = 8.0cm$$

Now use this image as the second lens object, $d_{o2} = 10.0cm - d_{i1} = 2.0cm$.

$$d_{i2} = \frac{d_{o2} f_2}{d_{o2} - f_2} = \frac{(2.0cm)(-6.0cm)}{2cm - (-6.0cm)} = -1.5cm$$

B. For object placed at $4.0cm$ **we get**

$$d_i = d_i = \frac{d_o f}{d_o - f} = \frac{d_o f}{4.0cm - 4.0cm} = \frac{d_o f}{0} = \infty$$

The image forms at an infinite distance away from the mirror! But don't fret this just means the rays that come from the converging lens are all parallel. Consequently, the object just forms at the focal point of the diverging lens.

$$d_{i2} = f_2 = -6.0cm \quad \text{from} \quad \text{lens} \quad 2$$