Solutions to HW30, Chapters 17, 39

NOTE! The problems in masteringphysics.com had their numbers altered slightly for each individual student. The solutions below use the same numbers as those used in the book for that problem!

17.22. Model: Interference occurs according to the difference between the phases $(\Delta\phi)$ of the two waves.

Solve: (a) A separation of 20 cm between the speakers leads to maximum intensity on the *x*-axis, but a separation of 60 cm leads to zero intensity. That is, the waves are in phase when $(\Delta x)_1 = 20\text{ cm}$ but out of phase when $(\Delta x)_2 = 60\text{ cm}$. Thus,

$$(\Delta x)_2 - (\Delta x)_1 = \frac{\lambda}{2} \quad\Rightarrow\quad \lambda = 2(60\text{ cm} - 20\text{ cm}) = 80\text{ cm}$$

(b) If the distance between the speakers continues to increase, the intensity will again be a maximum when the separation between the speakers that produced a maximum has increased by one wavelength. That is, when the separation between the speakers is $20\text{ cm} + 80\text{ cm} = 100\text{ cm}$.

17.24. Visualize: Examine just one side of the headphones, since it works the same on both sides.

Solve: To produce maximum destructive interference the delayed wave needs to be π rad out of phase with the incoming wave; this corresponds to ½ of a period.

$$\Delta t = \frac{T}{2} = \frac{1}{2f} = \frac{1}{2(110\text{ Hz})} = 0.45\text{ ms}$$

Assess: Since *v* does not appear the answer is independent of it; we are glad noise-canceling headphones do not need to be readjusted every time the temperature (and therefore the speed) changes. We also did not need to know the distance (1.8 m) to the buzzing sound. 4.5 ms is doable with modern electronics.

17.28. Solve: (a) The circular wave fronts emitted by the two sources indicate the sources are out of phase. This is because the wave fronts of each source have not moved the same distance from their sources.

(b) Let us label the top source as 1 and the bottom source as 2. Because the wave front closest to source 2 has moved only half of a wavelength, whereas the wave front of source 1 has moved one wavelength, the phase difference between the sources is $\Delta\phi_0 = \pi$. For the point *P*, $r_1 = 2\lambda$ and $r_2 = 3\lambda$. The phase difference is

$$\Delta\phi = \frac{2\pi\Delta r}{\lambda} + \Delta\phi_0 = \frac{2\pi(3\lambda - 2\lambda)}{\lambda} + \pi = 3\pi$$

This corresponds to destructive interference.

For the point *Q*, $r_1 = 3\lambda$ and $r_2 = \frac{3}{2}\lambda$. The phase difference is

$$\Delta\phi = \frac{2\pi\left(\frac{3}{2}\lambda\right)}{\lambda} + \pi = 4\pi$$

This corresponds to constructive interference.

For the point *R*, $r_1 = \frac{5}{2}\lambda$ and $r_2 = 3\lambda$. The phase difference is

$$\Delta\phi = \frac{2\pi\left(\frac{1}{2}\lambda\right)}{\lambda} + \pi = 2\pi$$

This corresponds to constructive interference.

	r_1	r_2	Δr	C/D
P	2λ	3λ	λ	D
Q	3λ	$\frac{3}{2}\lambda$	$\frac{3}{2}\lambda$	C
R	$\frac{5}{2}\lambda$	3λ	$\frac{1}{2}\lambda$	C

Assess: Note that it is not r_1 or r_2 that matters, but the difference Δr between them.

17.32. Solve: The beat frequency is

$$f_{beat} = f_1 - f_2 \quad \Rightarrow \quad 3 \text{ Hz} = f_1 - 200 \text{ Hz} \quad \Rightarrow \quad f_1 = 203 \text{ Hz}$$

f_1 is larger than f_2 because the increased tension increases the wave speed and hence the frequency.

17.34. Solve: The beat frequency is the difference of the two gong frequencies: 155 Hz – 151 Hz = 4.0 Hz. The number of beats heard in 2.5 s is $(4.0 \text{ Hz})(2.5 \text{ s}) = (4.0 \text{ beats/s})(2.5 \text{ s}) = 10 \text{ beats}$.

Assess: This would give a vibrating quality to the music.

17.35. Solve: The beat frequency is

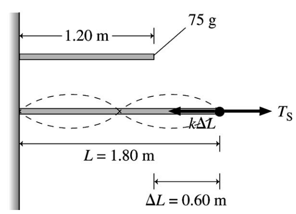
$$f_{beat} = f_1 - f_2 = 100 \text{ MHz}$$

where we have used the fact that the $\lambda_1 < \lambda_2$ so $f_1 > f_2$. The frequency of emitter 1 is $f_1 = c/\lambda_1$, where $\lambda_1 = 1.250 \times 10^{-2}$ m. The wavelength of emitter 2 is

$$\lambda_2 = c/f_2 = \frac{c}{f_1 - 100 \text{ MHz}} = \frac{c}{c/\lambda_1 - 100 \text{ MHz}} = \frac{(3.00 \times 10^8 \text{ m/s})}{(3.00 \times 10^8 \text{ m/s})/(1.250 \times 10^{-2} \text{ m}) - 100 \text{ MHz}} = 1.26 \text{ cm}.$$

17.44. Model: The stretched bungee cord that forms a standing wave with two antinodes is vibrating at the second harmonic frequency.

Visualize:



Solve: Because the vibrating cord has two antinodes, $\lambda_2 = L = 1.80$ m. The wave speed on the cord is

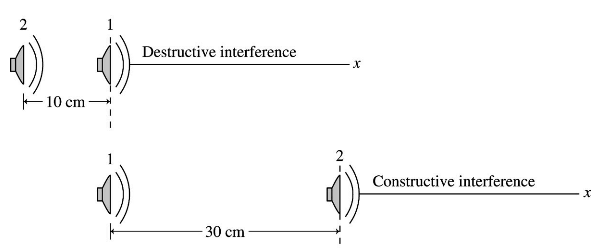
$$v_{cord} = f\lambda = (20 \text{ Hz})(1.80 \text{ m}) = 36 \text{ m/s}$$

The linear density of the cord is $v_{cord} = \sqrt{T_S/\mu}$. The tension T_S in the cord is equal to $k\Delta L$, where k is the bungee's spring constant and ΔL is the 0.60 m the bungee has been stretched. The linear density has to be calculated at the stretched length of 1.8 m where it is now vibrating. Thus,

$$v_{cord} = \sqrt{\frac{T_S}{\mu}} = \sqrt{\frac{k\Delta L}{m/L}} \Rightarrow k = \frac{mv_{cord}^2}{L\Delta L} = \frac{(0.075 \text{ kg})(36 \text{ m/s})^2}{(1.80 \text{ m})(0.60 \text{ m})} = 90 \text{ N/m}$$

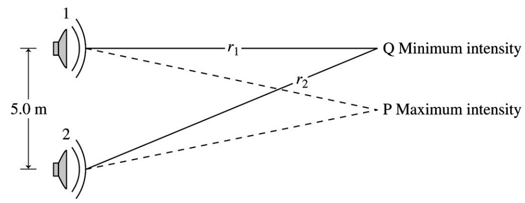
17.61. Model: Constructive or destructive interference occurs according to the phases of the two waves.

Visualize:



Solve: (a) To go from destructive to constructive interference requires moving the speaker $\Delta x = \frac{1}{2}\lambda$, which is equivalent to a phase change of π rad. Since $\Delta x = 40$ cm, we find $\lambda = 80$ cm.

17.69. Model: The changing sound intensity is due to the interference of two overlapped sound waves.
Visualize: The listener moving relative to the speakers changes the phase difference between the waves.



Solve: Initially when you are at *P*, equidistant from the speakers, you hear a sound of maximum intensity. This implies that the two speakers are in phase $(\Delta\phi_0 = 0)$. However, upon moving to *Q* you hear a minimum of sound intensity, which implies that the path length difference from the two speakers to *Q* is $\lambda/2$. Thus,

$$\tfrac{1}{2}\lambda = \Delta r = r_2 - r_1 = \sqrt{(r_1)^2 + (5.0\text{ m})^2} - r_1 = \sqrt{(12.0\text{ m})^2 + (5.0\text{ m})^2} - 12.0\text{ m} = 1.0\text{ m}$$

$$\lambda = 2.0\text{ m} \quad \Rightarrow \quad f = \frac{v}{\lambda} = \frac{340\text{ m/s}}{2.0\text{ m}} = 170\text{ Hz}$$

39.24. Model: Protons are subject to the Heisenberg uncertainty principle.
Solve: We know the proton is somewhere within the nucleus, so the uncertainty in our knowledge of its position is at most $\Delta x = L = 4.0$ fm. With a finite Δx, the uncertainty Δp_x is given by the uncertainty principle:

$$\Delta p_x = m\Delta v_x = \frac{h/2}{\Delta x} \Rightarrow \Delta v_x = \frac{h}{2mL} = \frac{6.63\times10^{-34}\text{ Js}}{2(1.67\times10^{-27}\text{ kg})(4.0\times10^{-15}\text{ m})} = 5.0\times10^{7}\text{ m/s}$$

Because the average velocity is zero, the best we can say is that the proton's velocity is somewhere in the range -2.5×10^7 m/s to 2.5×10^7 m/s. Thus, the smallest range of speeds is 0 to 2.5×10^7 m/s.

39.25. Solve: The uncertainty in velocity is $\Delta v_x = 3.58\times10^5\text{ m/s} - 3.48\times10^5\text{ m/s} = 1.0\times10^4\text{ m/s}.$ Using the uncertainty principle (Equation 39.28), the minimum uncertainty in position is

$$\Delta x \approx \frac{h}{2\Delta p_x} = \frac{h}{2m_e\Delta v_x} = \frac{6.63\times10^{-34}\text{ J}\cdot\text{s}}{2(9.11\times10^{-31}\text{ kg})(1.0\times10^4\text{ m/s})} = 3.6\times10^{-8}\text{ m} = 36\text{ nm}$$

Assess: This is a few dozen atomic diameters.