Physics 25 Practice Problems Chapters 16 and 17

Chapter 16: Waves on Strings

1. A 4.0-meter rope has a mass of 0.7 kg. It is tied at both ends with a tension of 70 N. What is the speed of pulses on this rope?

2. The wave speed on a string is 4.0 m/s. What would be the new wave speed if the tension were increased to a value that is 25 times what it was before?

3. The frequency of a wave on a wire is 40 Hz, and the distance between consecutive "peaks" ("maxima") is 0.15 m. What is the wave speed?

4. The period (T) of oscillation of a string is 0.04 second. If the wave speed is 2.0 m/s, what is the wavelength?

5. If the frequency of the wave on a string is tripled, what happens to the wavelength?

6. If the frequency of a wave on a string is quadruped, what happens to the wave speed?

7. A standing wave on a 1.2-meter string has two anti-nodes. The frequency of the oscillator creating the wave is 40 hertz. What is the wave speed?

8. What is the frequency of a standing wave on a 1.2-meter string that has five anti-nodes (five loops)? The tension in the string is 288 N, and the mass per meter of the string is 2 kg/m.

9. The wave speed on a certain string is unknown, but when its tension is quadrupled, the wave speed is measured to be 10 m/s. What was the original wave speed before the tension was changed?

10. One end of a rope 1.2 meters long is hanging vertically. The top of the rope is being oscillated at small amplitude (small swings) back and forth by hand, and the other end is free to whip back and forth. A standing wave is created with three anti-nodes. The speed of pulses on this rope is 1.92 m/s. What is the frequency at which the hand is oscillating the rope?

Chapter 16 Solutions

1. $v = [70/(0.7/4.0)]^{1/2}$
$= 20$ m/s

2. $v_1 = (T_1/\mu)^{1/2}$
$= 4.0$ m/s
$T_2 = 25\ T_1$
$v_2 = (25T_1/\mu)^{1/2}$
$= 5(T_1/\mu)^{1/2}$
$= 5(4.0)$
$= 20$ m/s

A quicker method is shown at the right.

2. Quicker:

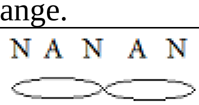
$v = (T/\mu)^{1/2}$
v is directly proportional to the square-root of T, so making the tension 25 times greater makes the speed $\sqrt{25} = 5$ times greater.

3. $\lambda = 0.15$ m
$v = 0.15(40)$
$= 6.0$ m/s

4. $v = \lambda f$
$= \lambda(1/T)$
$\lambda = vT$
$= 2.0(0.04)$
$= 0.08$ m

5.
$\lambda f = v$
$= (T/\mu)^{1/2}$
$=$ constant
If f is tripled, the wave-length becomes one-third of its previous value in order to preserve the product, which cannot change.

6. The speed doesn't change because speed depends only on the string tension and the mass per length, neither of which change. If the frequency of a wave on a string changes, wavelength changes in such a way that the product of the two is always the same. Thus, if frequency is quadrupled, the wavelength is quartered.

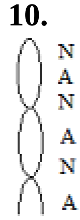
7.


$2(\lambda/2) = 1.2$
$\lambda = 1.2$ m
$v = 1.2(40)$
$= 48$ m/s

8. $T = 288$ N
$\mu = 2$ kg/m
$v = (288/2)^{1/2}$
$= 12$ m/s
5 loops, each $\lambda/2$ wide:
$5(\lambda/2) = 1.2$
$\lambda = 0.48$ m
$0.48f = 12$
$f = 25$ Hz

9. $v_1 = (T_1/\mu)^{1/2}$
$10 = (4T_1/\mu)^{1/2}$
$10 = 2(T_1/\mu)^{1/2}$
$= 2\ v_1$

$2\ v_1 = 10$
$v_1 = 5$ m/s

10.


2.5 loops
$2.5(\lambda/2) = 1.2$
$\lambda = 0.96$ m
$\lambda f = v$
$0.96f = 1.92$
$f = 2$ Hz

Chapter 17 Practice Problems: Sound Waves

1. The distance between consecutive regions of "normal" (N) pressure (P_o) in a sound wave is 0.10 meter. What is the frequency of this wave?

2. Skip this problem.

3. The doctor reports she plans to use 100,000 Hz ultrasound waves to disintegrate a tumor in a patient's kidney. Given that the speed of sound in human tissue is about 1500 m/s, what is the approximate diameter of the tumor, in millimeters?

4. The area of an eardrum is 5.5×10^{-6} m^2. If the sound intensity on the eardrum is 4.0×10^{-6} W/m^2, what is the sound wave power arriving at the eardrum?

5. What is the sound intensity 3.0 meters from a 50-watt spherically-symmetric sound source?

6. The sound intensity at a certain distance from a spherically-symmetric sound source is 6.0×10^{-8} W/m^2. What is the intensity one-third as far from the source?

7. The sound intensity 10 meters from a spherically-symmetric sound source is 1.0 W/m^2. What is the output power of the source?

8. The sound intensity at a certain point is 4.0×10^{-8} W/m^2. What is the decibel level there?

9. What sound intensity corresponds to a decibel level of 50 dB?

10. The decibel level at a certain point is 90 dB. (a) What will be the approximate new decibel level if the sound intensity at that point is reduced to $1/16^{th}$ of its previous value? (b) What if it were quadrupled?

11. A dog kennel consists of forty cages in a circular array, each one occupied by a barking dog; each dog is barking with the same power. The decibel level at the center is 80 dB. How many dogs would have to stop barking in order that the new decibel level at the center become about 71 dB?

12. Skip this problem.

13. A siren broadcasting 3000 Hz sound is racing at 30 m/s toward an automobile traveling at 45 m/s toward the siren. What frequency does the driver of the automobile hear?

14. A police car moving at 35 m/s and emitting 2400 Hz sound is chasing an automobile attempting to escape the police. The driver of the automobile hears 2200 Hz sound. What is the automobile's speed?

15. A standing sound wave exists in a tube that is open at one end, closed at the other end. Sound waves of 400-Hz frequency create a standing wave in the tube with five anti-nodes. What is the length of the tube?

16. What is the frequency of the standing sound wave resonating with two anti-nodes in a 2.2-meter tube that is open at both ends?

Solutions for Chapter 17

<table>
<tr>
<td>1. The distance between consecutive normals (N) of a sound wave is $\lambda/2$, so

$\lambda/2 = 0.10$

$\lambda = 0.20$ m
f = 340/0.20
= 1700 Hz</td>
<td>2. Skip this problem</td>
<td>3. $\lambda = 1500/100{,}000$
= 0.015 m
= 15 mm
Tumor diameter = 15 mm</td>
</tr>
<tr>
<td>4. $4.0 \times 10^{-6} = P/5.5\times10^{-6}$
$P = 2.2 \times 10^{-11}$ W</td>
<td rowspan="2">6. $I_1 = P/4\pi r_1^2$
$= 6.0 \times 10^{-8}$ W/m^2
$I_2 = P/4\pi(r_1/3)^2$
$= 9\,(P/4\pi r_1^2)$
$= 9\,I_1$
$= 9\,(6.0 \times 10^{-8})$
$= 54 \times 10^{-8}$ W/m^2

Faster: I depends inversely as the square of r, so reducing r to one-third raises I to nine times its previous intensity.</td>
<td>7. $P/4\pi(10)^2 = 1.0$
P = 1257 W</td>
</tr>
<tr>
<td>5. $I = 50/4\pi(3)^2$
$= 0.44$ W/m^2</td>
<td>8. $\beta = 10 \log (I/I_o)$
$= 10 \log(4 \times 10^{-8}/1 \times 10^{-12})$
= 46 dB</td>
</tr>
<tr>
<td>9. $I = I_o\,(10^{\beta/10})$
$= 1 \times 10^{-12}\,(10^{50/10})$
$= 1.0 \times 10^{-7}$ W/m^2</td>
<td>10.
(a) 1/16 = (½)(½)(½)(½)
4 halvings
$\Delta\beta = 4\,(-3)$
= -12
$\beta = 90 - 12$
= 78 dB
(b) A quadrupling is the same as two doublings, each doubling adding 3 dB:
$\Delta\beta = 3 + 3$
= 6 dB
$\beta = 90 + 6$
= 96 dB</td>
<td>11. $\Delta\beta = -9$ dB
-3 -3 -3: three halvings
40→20→10→5
40 - 5 = 35

Thirty-five dogs must stop barking.</td>
</tr>
</table>

12. Skip this problem	

13.
$f_o = f_s (340 \pm v_o)/ (340 \pm v_s)$

The observer is moving toward the source, so we choose the sign for the observer that would make the ratio larger: we therefore make the *numerator* larger by using the positive sign.

The source is moving toward the observer, so we choose the sign that would make the ratio larger: we therefore make the *denominator* smaller by using the negative sign.

$f = 3000(340+45)/(340-30)$
$= 3726$ Hz

14. $f_o = f_s (340 \pm v_o) / (340 \pm v_s)$

Observer is moving away from the source, so we use sign in the numerator that will make the ratio smaller. We therefore choose the negative sign.

The source is moving toward the observer, so we choose the sign that will make the ratio larger. We therefore make the denominator smaller by using the negative sign.

Let x = car speed

$2200 = 2400 (340 - x)/(340 - 35)$
$x = 60.42$ m/s

15.	**16.**
$\lambda = 340/400$ $= 0.85$ m $\lambda/4 = (0.85/4)$ m $= 0.2125$ m Five A's in the sequence below: A-N-A-N-A-N-A-N-A-N There are nine AN or NA widths, each width being a quarter-wavelength long: L = 9 (0.2125) = 1.91 m	ANA $AN + NA = \lambda/4 + \lambda/4$ $2(\lambda/4) = 2.2$ $\lambda = 4.4$ m $f = v/\lambda$ $= 340/\lambda$ $= 340/4.4$ $= 77$ Hz