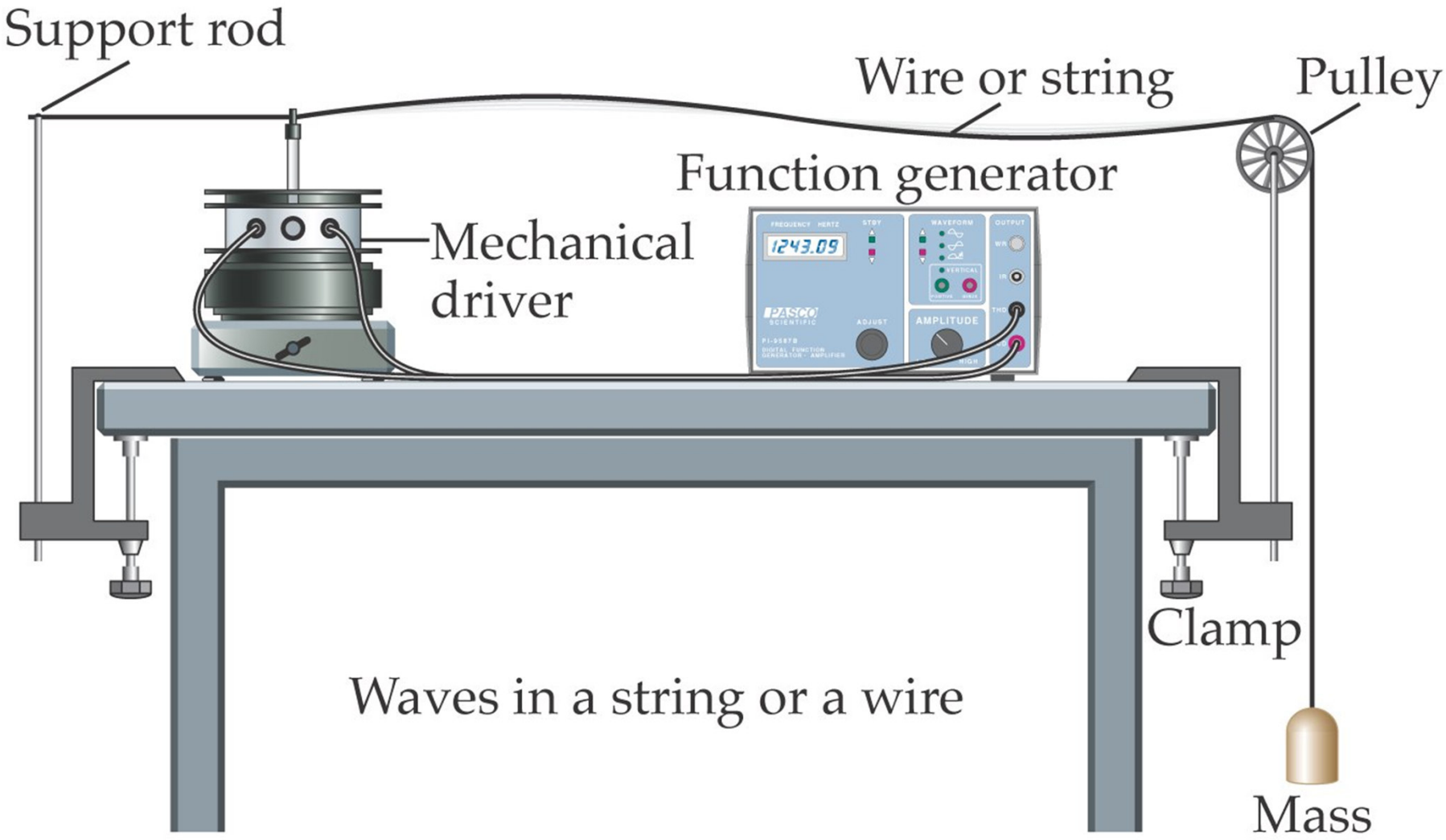
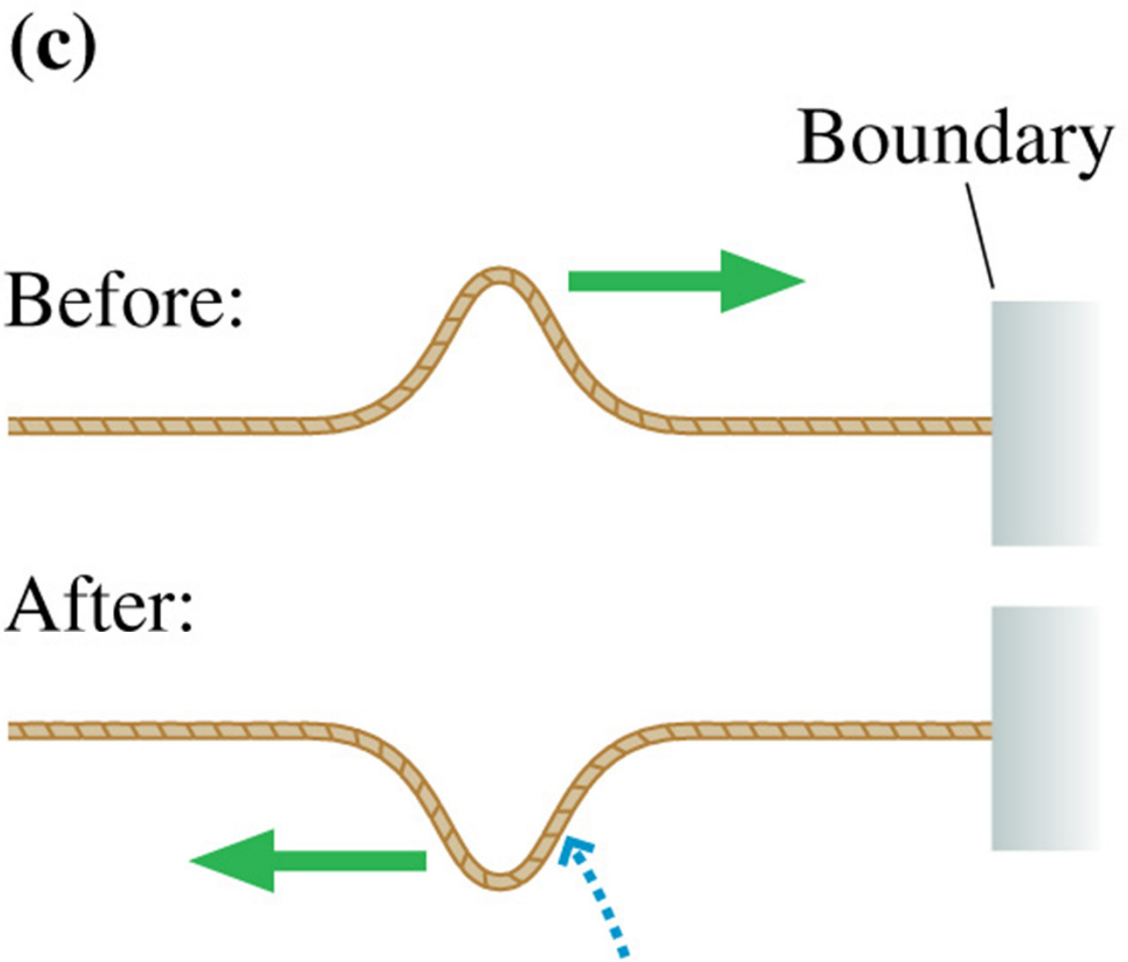
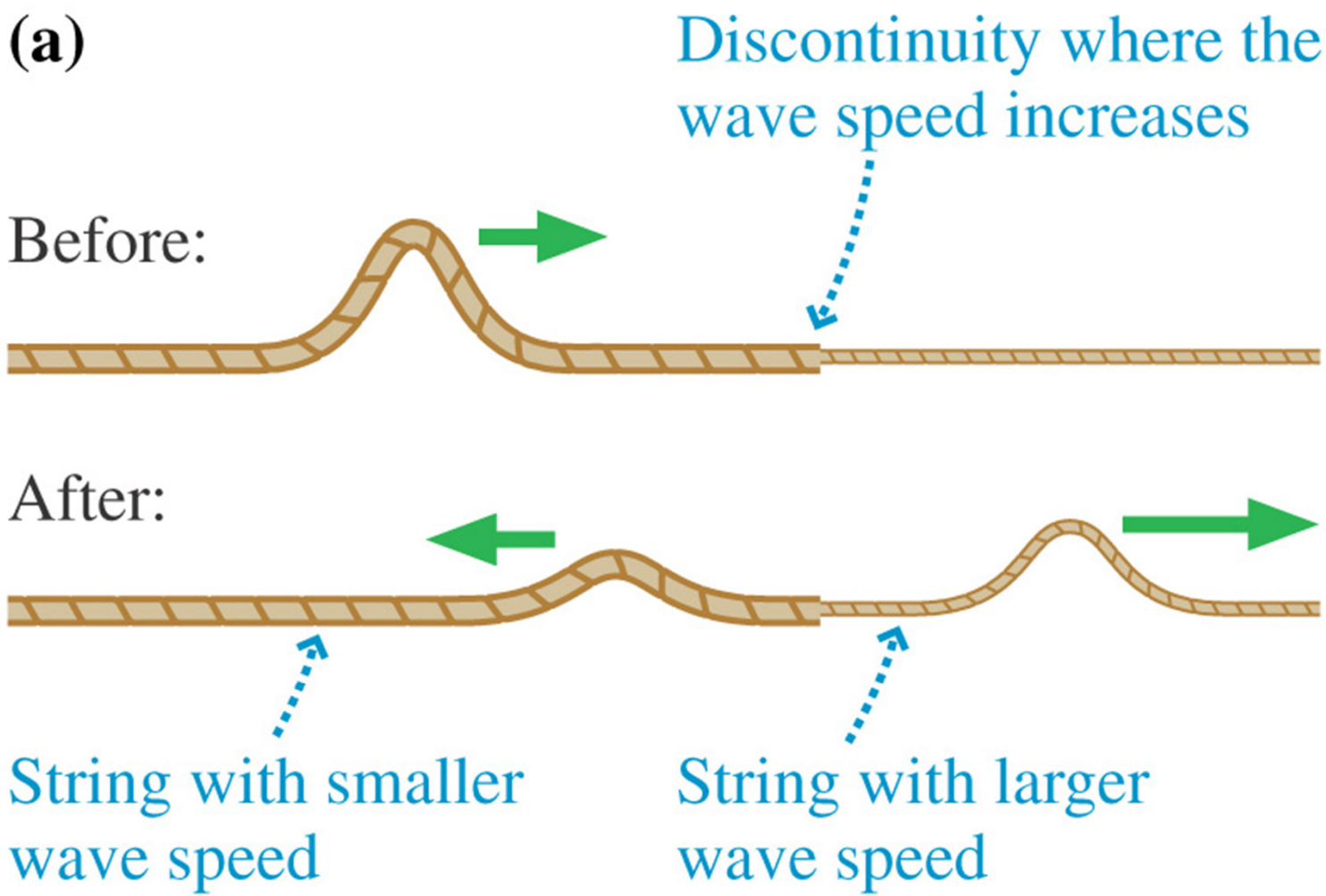
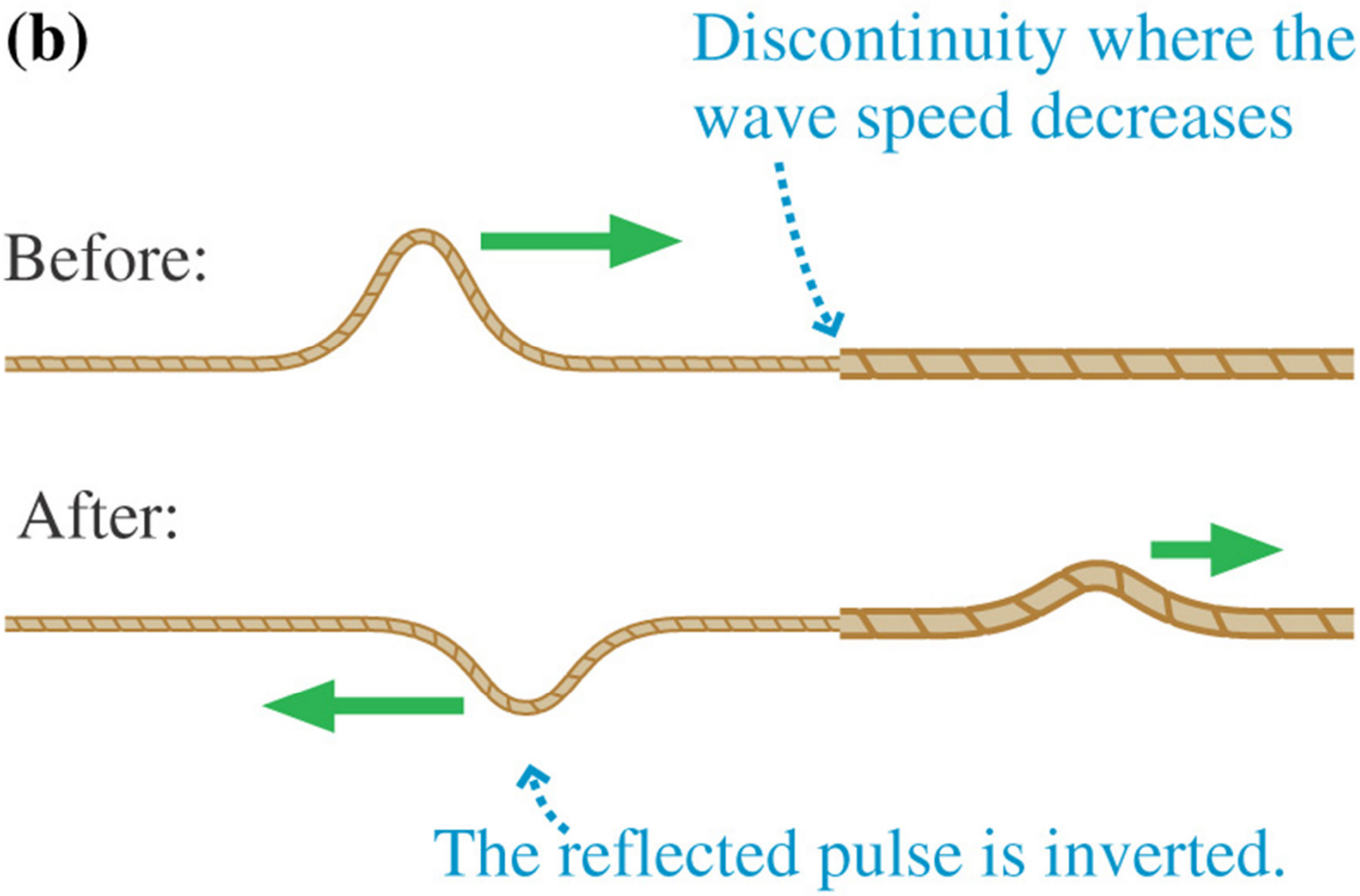
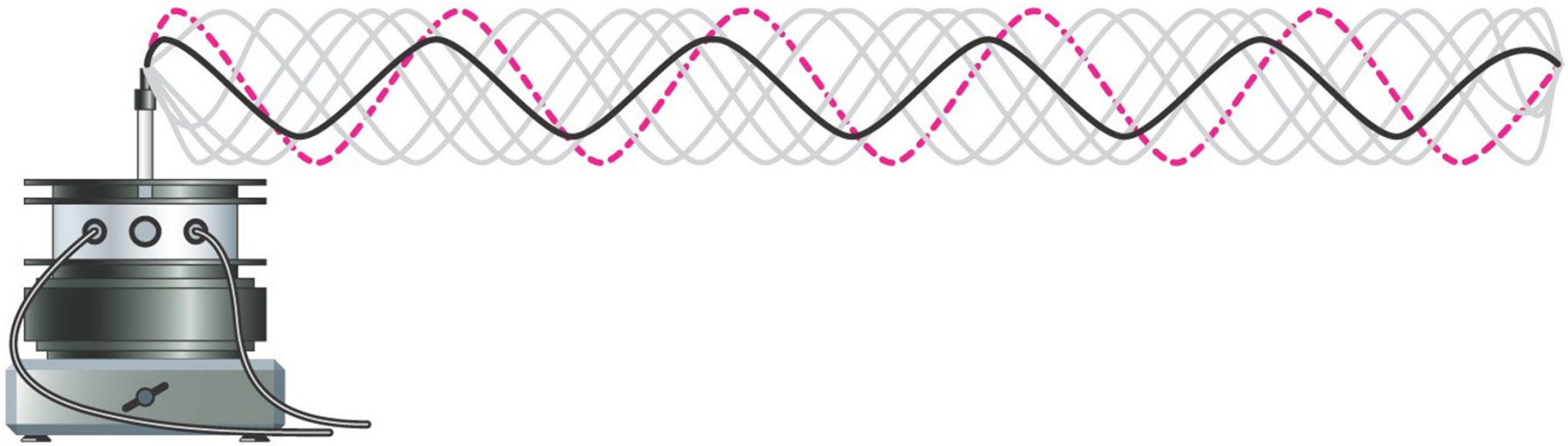
Standing Waves

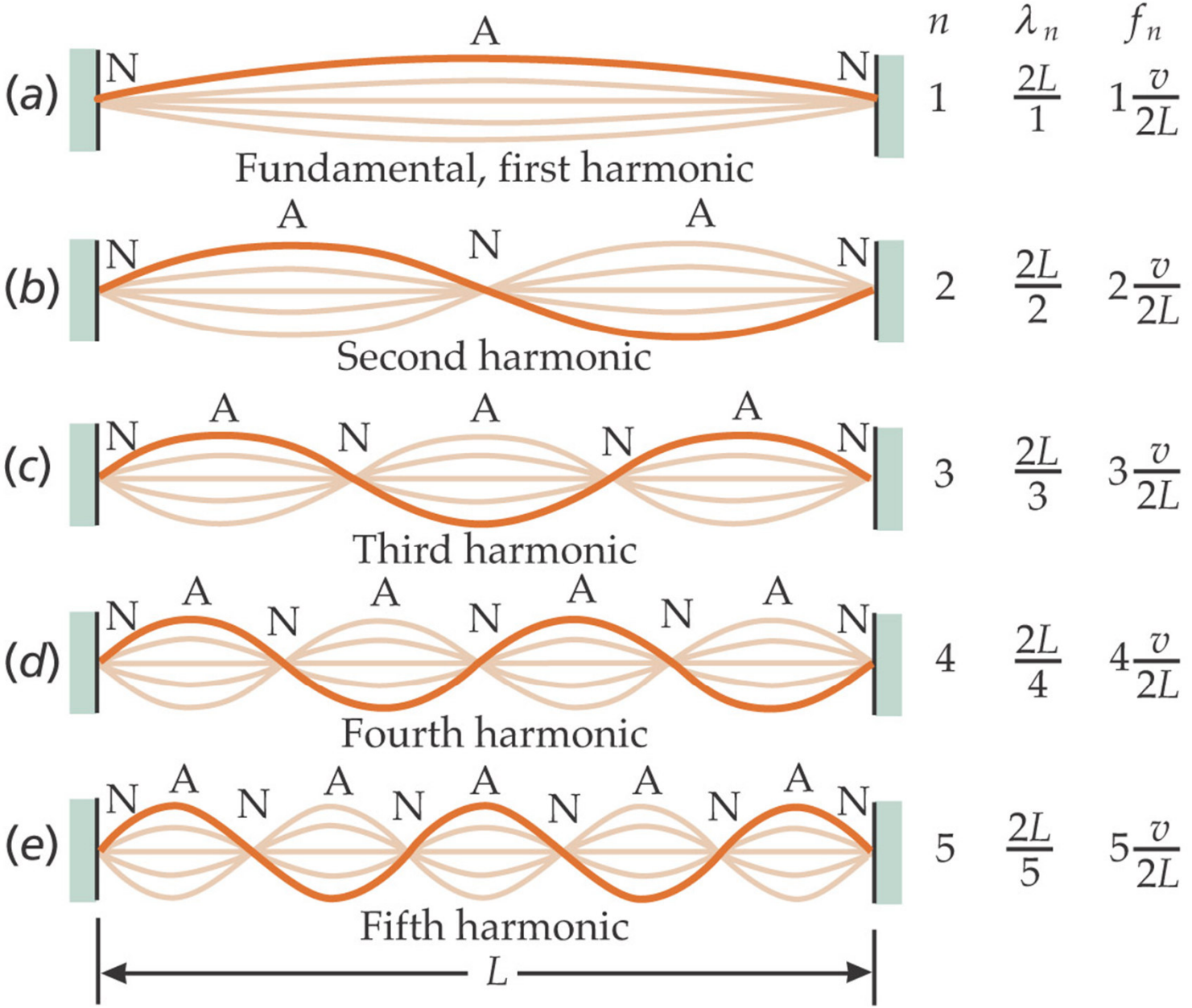

Support rod
Wire or string
Pulley
Function generator
Mechanical driver
Clamp
Waves in a string or a wire
Mass

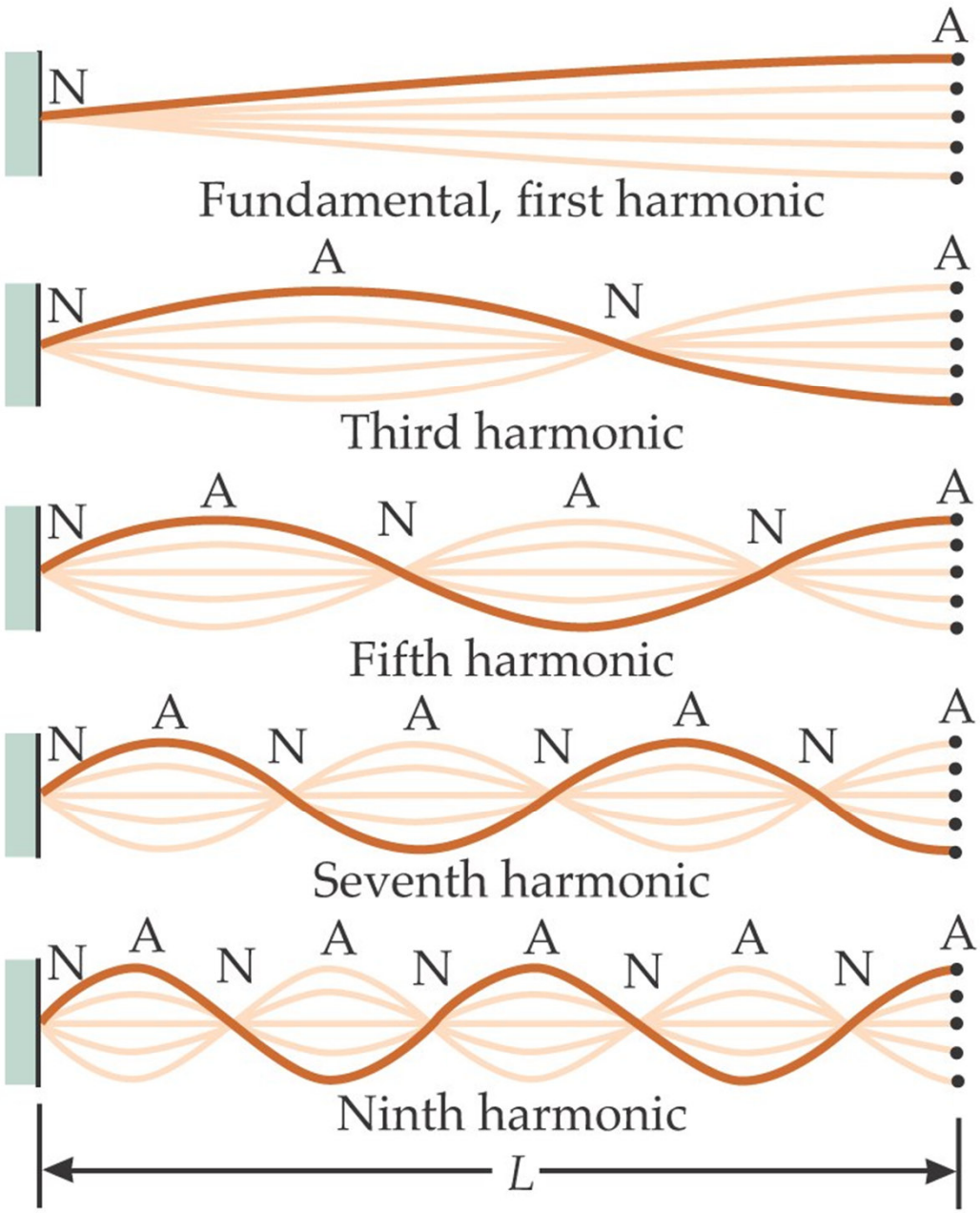




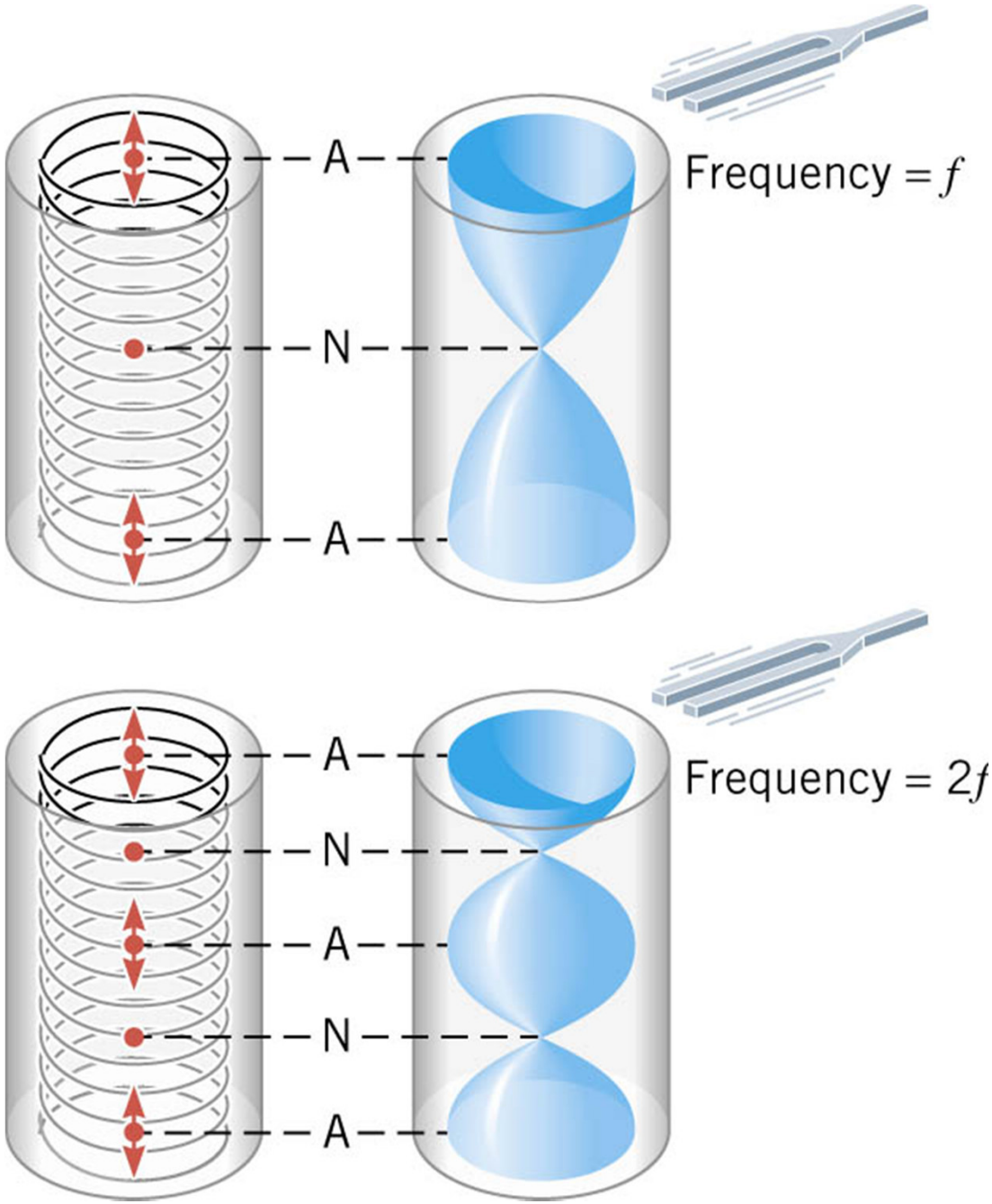


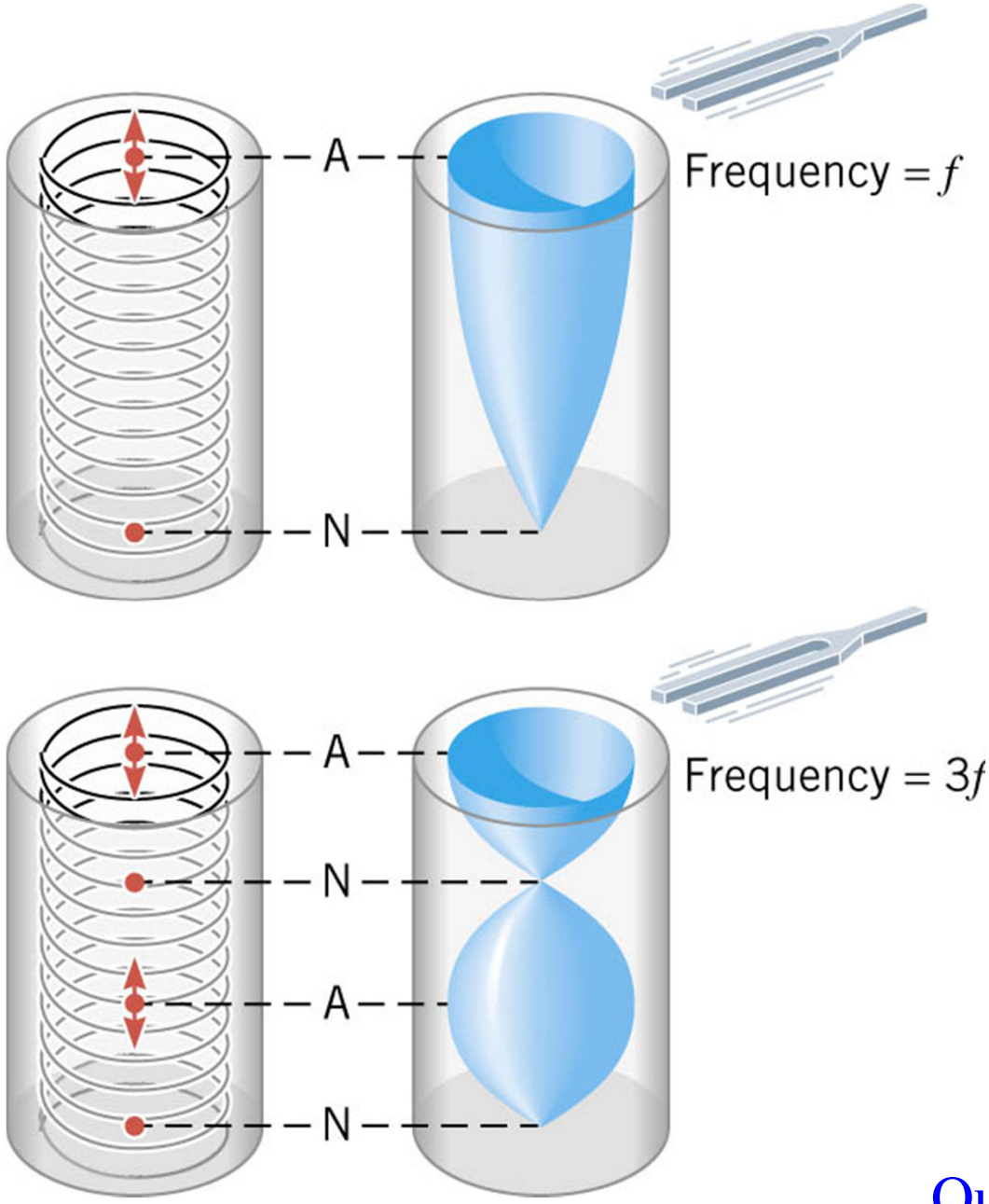



n
λ_n
f_n
(a)
A
N
N
1
$\frac{2L}{1}$
$1\frac{v}{2L}$
Fundamental, first harmonic
(b)
A
A
N
N
N
2
$\frac{2L}{2}$
$2\frac{v}{2L}$
Second harmonic
(c)
A
A
A
N
N
N
N
3
$\frac{2L}{3}$
$3\frac{v}{2L}$
Third harmonic
(d)
A
A
A
A
N
N
N
N
N
4
$\frac{2L}{4}$
$4\frac{v}{2L}$
Fourth harmonic
(e)
A
A
A
A
A
N
N
N
N
N
N
5
$\frac{2L}{5}$
$5\frac{v}{2L}$
Fifth harmonic
L



n	λ_n	f_n
1	$\frac{4L}{1}$	$1\frac{v}{4L}$
3	$\frac{4L}{3}$	$3\frac{v}{4L}$
5	$\frac{4L}{5}$	$5\frac{v}{4L}$
7	$\frac{4L}{7}$	$7\frac{v}{4L}$
9	$\frac{4L}{9}$	$9\frac{v}{4L}$


A
N
A
Frequency = f
A
N
A
N
A
Frequency = 2f



Questions

Equation of Standing Wave

Consider two waves travelling in opposite directions

$$D_1(x,t) = A\sin(kx - \omega t)$$

$$D_2(x,t) = A\sin(kx + \omega t)$$

$$D_{Net}(x,t) = ?$$

Recall trig identity

$$sin\theta_1 + sin\theta_2 = 2\cos\frac{\theta_1+\theta_2}{2}sin\frac{\theta_1-\theta_2}{2}$$

$$\Rightarrow D_{net}(x,t) = 2A\cos(\omega t)\sin(kx)$$

For many reflections:

$$D_{net}(x,t) = A_{net}\cos(\omega t)\sin(kx)$$

Amplitude oscillates

Stationary in space

String fixed at x = 0 and x = L

At x =0, sin(k*0) = sin(0) = 0 √

At x = L, want sin(kL) = 0 (Node)

Requires kL = nπ, n an integer

$$(2\pi/\lambda)L = n\pi \;\&\; v = \lambda f$$

$$f = nv/\,2L$$

String fixed at x = 0 and open at x = L

At x = 0, $\sin(k*0) = \sin(0) = 0$ √

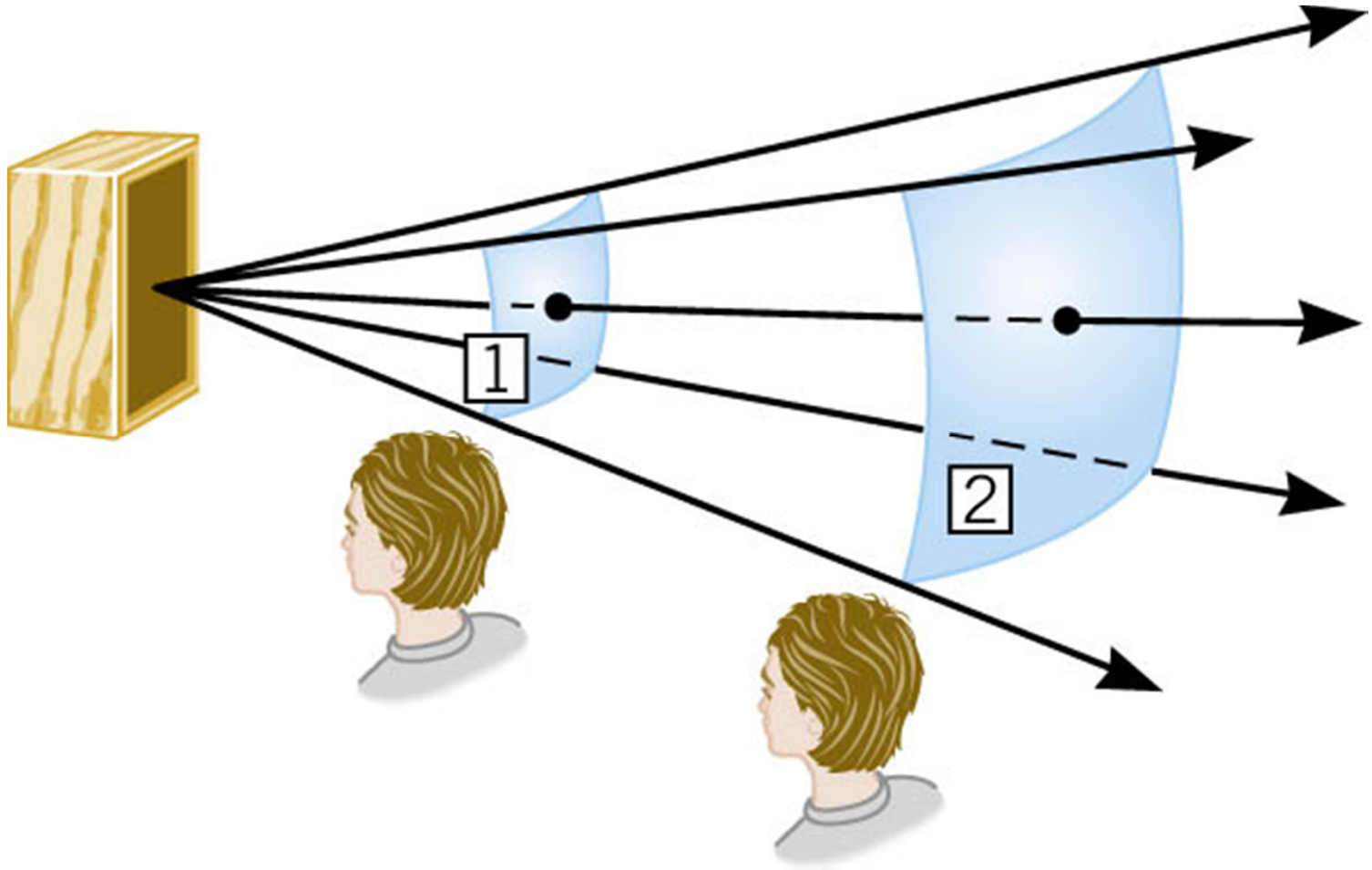
At x = L, want $\sin(kL) = 1$ (Antinode)

Requires $kL = m\pi/2$, m an odd integer

$$(2\pi/\lambda)L = m\pi/2 \;\&\; v = \lambda f$$

$$f = mv/4L$$

Sound Level



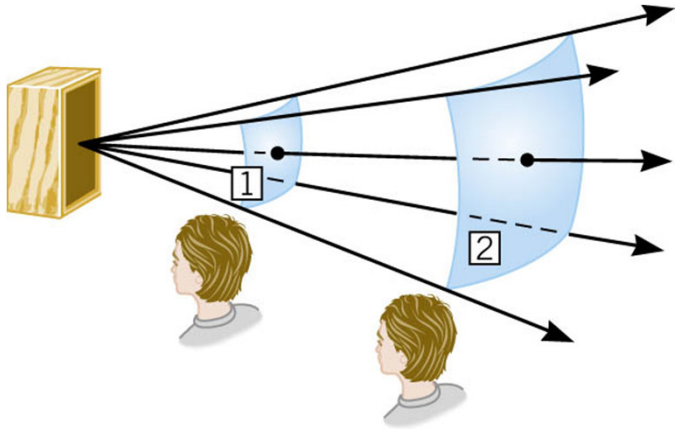
Questions

Sound Intensity

Intensity I = Power/Area (W/m^2)

Spherical sound source:

$A = 4\pi R^2$, $I = P / 4\pi R^2$



If $I = I_1$ at position 1,

$I_2 = I_1 / 2^2 = I_1 / 4$ since it is twice as far from source

Sound Level

Describes perception of intensity

$$\beta = 10log\frac{I}{I_0}, \quad I = I_0 \times 10^{\beta/10}$$

For multifrequency sound, intensity adds

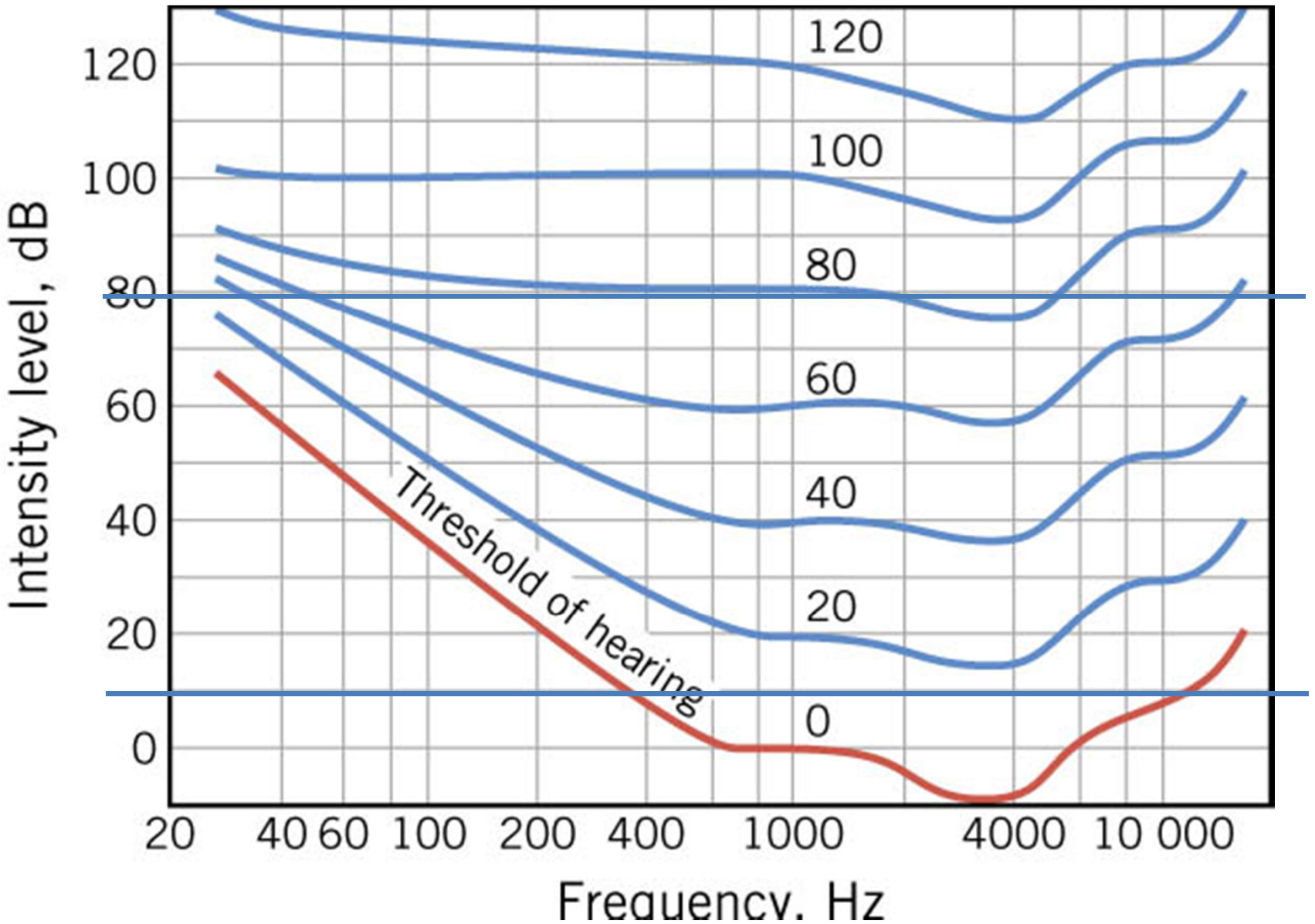
$$I_{net} = I_1 + I_2 + \ldots$$

Note! $\beta_{net} \neq \beta_1 + \beta_2 + \ldots$

TABLE 15-1

Intensity and Intensity Level of Some Common Sounds ($I_0 = 10^{-12}$ W/m^2)

Source	I/I_0	dB	Description
	10^0	0	Hearing threshold
Normal breathing	10^1	10	Barely audible
Rustling leaves	10^2	20	
Soft whisper (at 5 m)	10^3	30	Very quiet
Library	10^4	40	
Quiet office	10^5	50	Quiet
Normal conversation (at 1 m)	10^6	60	
Busy traffic	10^7	70	
Noisy office with machines; average factory	10^8	80	
Heavy truck (at 15 m); Niagara Falls	10^9	90	Constant exposure endangers hearing
Old subway train	10^{10}	100	
Construction noise (at 3 m)	10^{11}	110	
Rock concert with amplifiers (at 2 m); jet takeoff (at 60 m)	10^{12}	120	Pain threshold
Pneumatic riveter; machine gun	10^{13}	130	
Jet takeoff (nearby)	10^{15}	150	
Large rocket engine (nearby)	10^{18}	180	


Intensity level, dB
120
100
80
60
40
20
0
120
100
80
60
40
20
0
Threshold of hearing
20
40
60
100
200
400
1000
4000
10 000
Frequency, Hz