Reminders

- Homework 13 is extra credit
- Final Exam: Friday, May 13, 10:15am-12:15pm CR 306
- Bring your ID to the exam!
- Sample equation sheet available
- Sample exams available
- **Review session** Tuesday 6-8pm, ENZI 195

Ch 16.7-9: Intensity, Doppler Effect

PHYS 1210 -- Prof. Jang-Condell

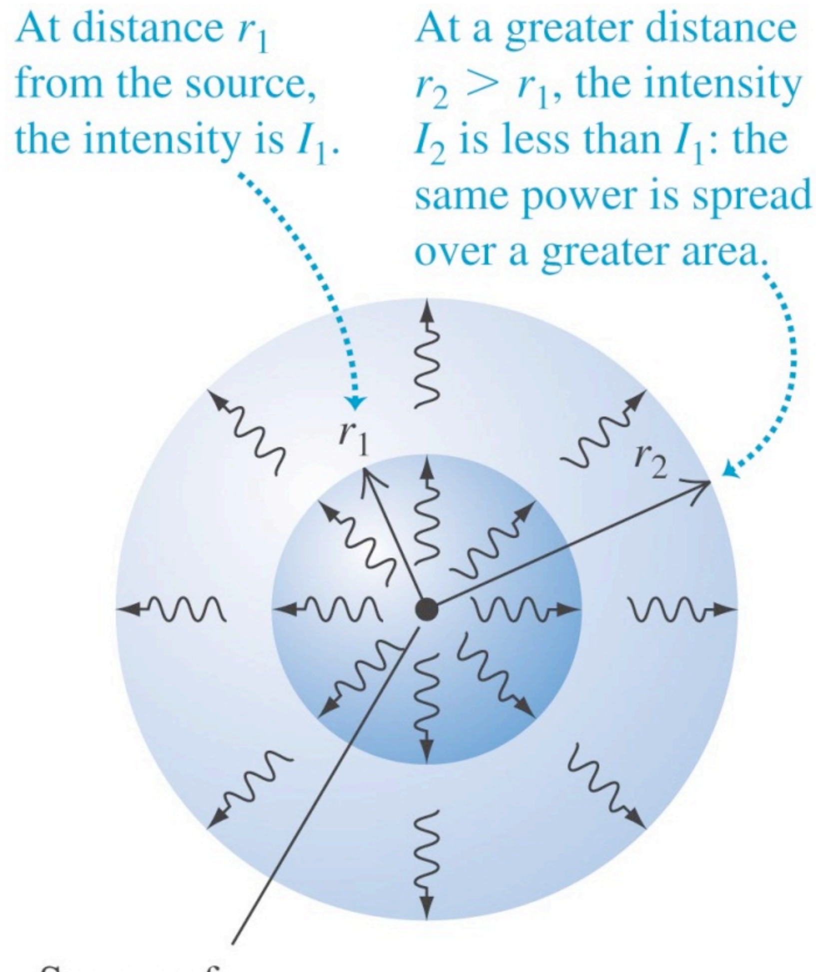
Goals for Chapter 16

- To describe sound waves in terms of particle displacements or pressure variations
- To calculate the speed of sound in different materials
- To calculate sound intensity
- To find what determines the frequencies of sound from a pipe
- To study resonance in musical instruments
- To see what happens when sound waves overlap
- To investigate the interference of sound waves of slightly different frequencies
- To learn why motion affects pitch

Inverse square law for Intensity

$$I = \text{Power/area}$$

$$I \propto 1/r^2$$



You are 2 m from a yowling cat. How far do you need to be for the intensity of its sound to be 100 times smaller?

A. 4 m
B. 10 m
C. 20 m
D. 200 m
E. 20,000 m

Sound intensity

- The intensity of a sinusoidal sound wave is proportional to the square of the amplitude, the square of the frequency, and the square of the pressure amplitude.

$$I = \tfrac{1}{2}\sqrt{\rho B}\,\omega^2 A^2$$

$$I = \frac{{p_{max}}^2}{2\rho v} = \frac{{p_{max}}^2}{2\sqrt{\rho B}}$$

The decibel scale

- The *sound intensity level* β is

$$\beta = (10\ \mathrm{dB}) \log(I/I_0).$$

Table 16.2 Sound Intensity Levels from Various Sources (Representative Values)

Source or Description of Sound	Sound Intensity Level, β (dB)	Intensity, I $(\mathrm{W/m^2})$
Military jet aircraft 30 m away	140	10^{2}
Threshold of pain	120	1
Riveter	95	3.2×10^{-3}
Elevated train	90	10^{-3}
Busy street traffic	70	10^{-5}
Ordinary conversation	65	3.2×10^{-6}
Quiet automobile	50	10^{-7}
Quiet radio in home	40	10^{-8}
Average whisper	20	10^{-10}
Rustle of leaves	10	10^{-11}
Threshold of hearing at 1000 Hz	0	10^{-12}

Sound Intensity

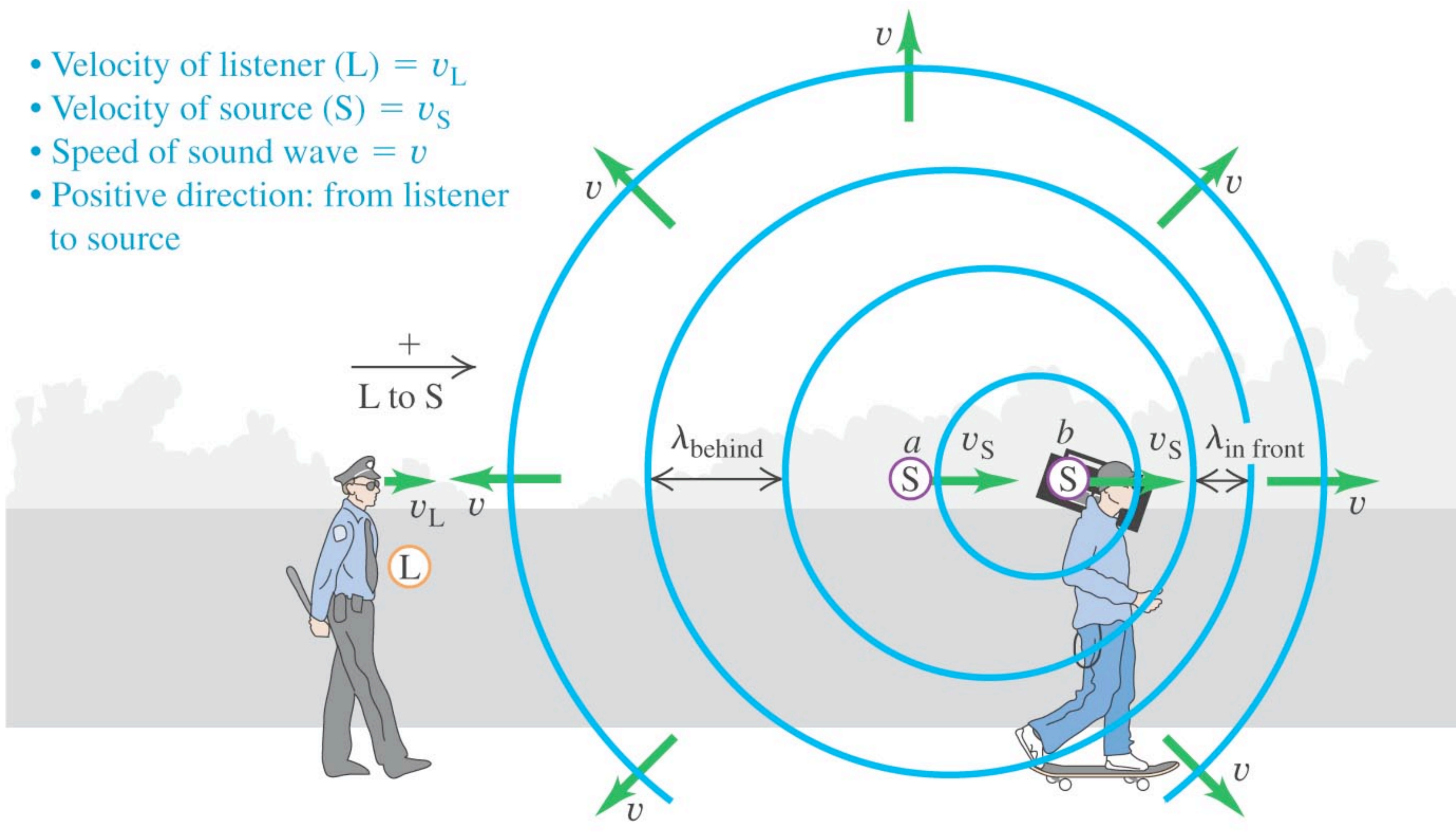
- Decibel level:
  - $\beta = (10\ \text{dB}) \log(I/I_0)$
- Relative decibels:
  - $\Delta\beta = (10\ \text{dB}) \log(I_2/I_1)$
- Every 10 decibels is a factor of 10 increase in intensity.

You are 2 m from a yowling cat. How far do you need to be for the intensity of its sound to be 20 dB smaller?

F. 4 m
G. 20 m
H. 22 m
I. 200 m
J. 440 m

The Doppler effect

- The *Doppler effect* for sound is the shift in frequency when there is motion of the source of sound, the listener, or both.
- Use Figure 16.27 below to follow the derivation of the frequency the listener receives.



Doppler Effect

$$f_L = \frac{v + v_L}{v + v_S} f_S$$

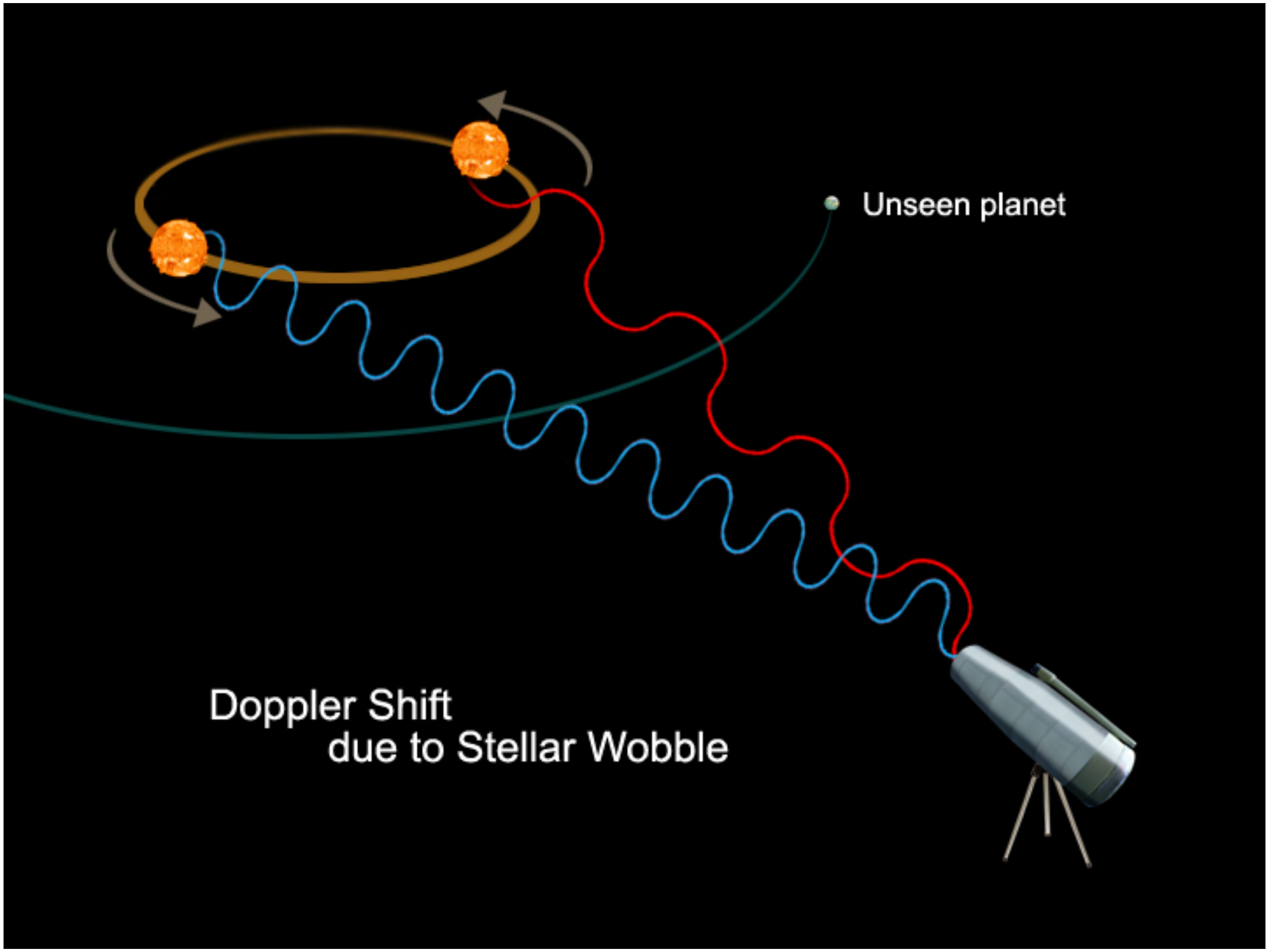
Doppler Shift Demo

On a day when there is no wind, **you are moving toward a stationary source of sound waves.** Compared to what you would hear if you were not moving, the sound that you hear has

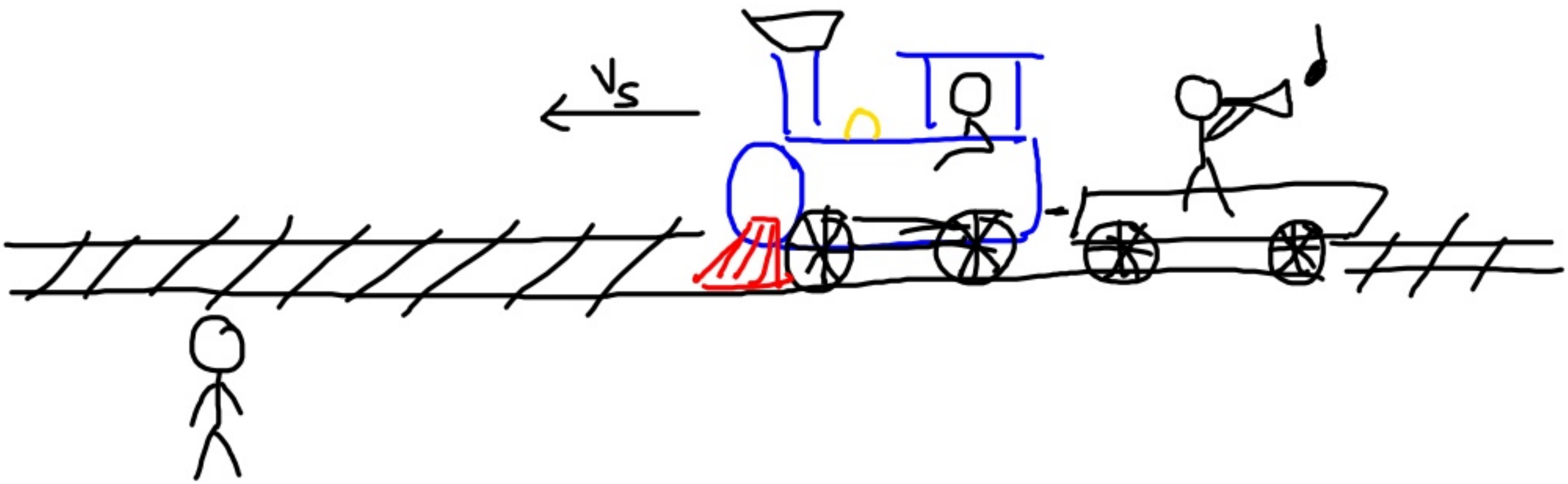
K) a higher frequency and a shorter wavelength.
L) the same frequency and a shorter wavelength.
M) a higher frequency and the same wavelength.
N) the same frequency and the same wavelength.

On a day when there is no wind, **you are at rest and a source of sound waves is moving toward you.** Compared to what you would hear if the source were not moving, the sound that you hear has

Q) a higher frequency and a shorter wavelength.
R) the same frequency and a shorter wavelength.
S) a higher frequency and the same wavelength.
T) the same frequency and the same wavelength.


Unseen planet
Doppler Shift
due to Stellar Wobble

A trumpeter on a moving train plays and holds an A (440 Hz). The train moves toward a stationary bystander with perfect pitch, who hears a B-flat (466 Hz). How fast is the train moving? Assume a sound speed of 344 m/s.



Supersonic Shock Waves