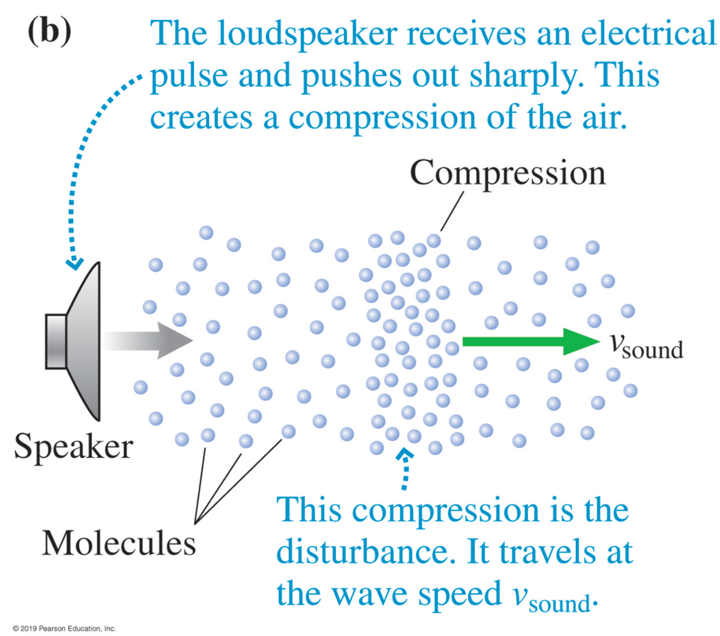
15.4 Sound and Light Waves

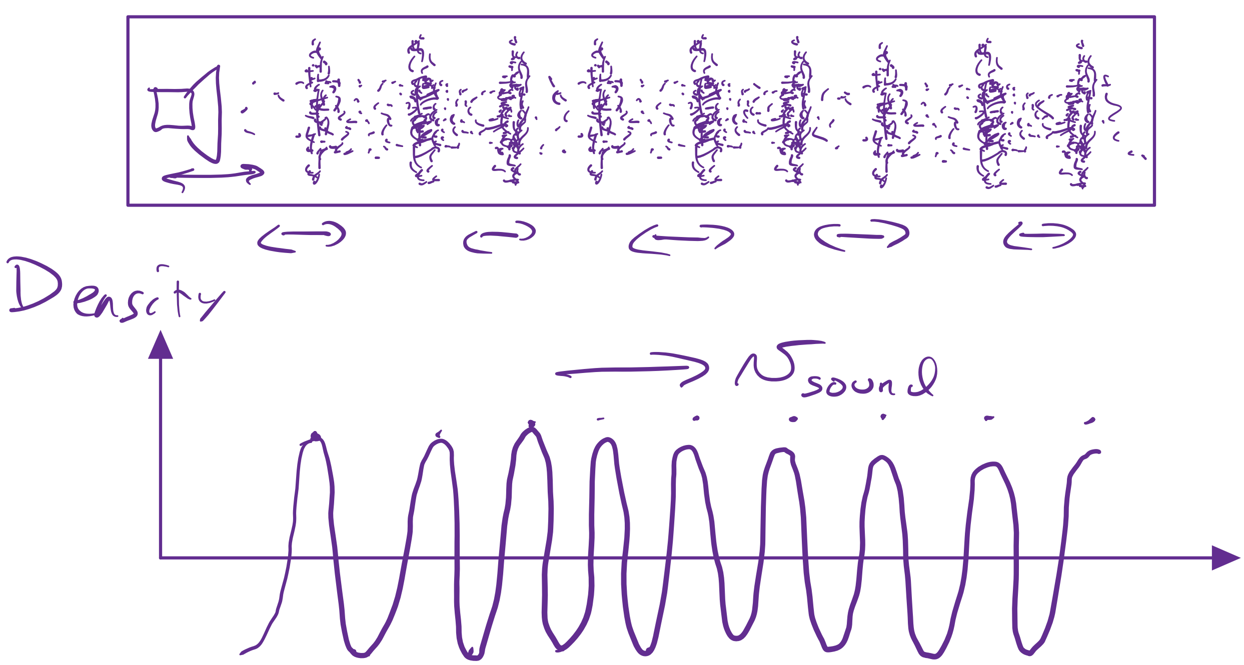
Look at 2 specific types of waves, sound and light. Sound: a longitudinal wave:



See also video Figure 15.4.

Particles move back and forth.

Cartoon:



Recall v is set by the medium
(e.g. 343 m/s ordinary room air)
f is set by speaker going back and forth. λ is set by

$$v = \lambda f$$

$$\lambda = \frac{v}{f}$$. Eg Middle C,

$f \approx 262$ Hz

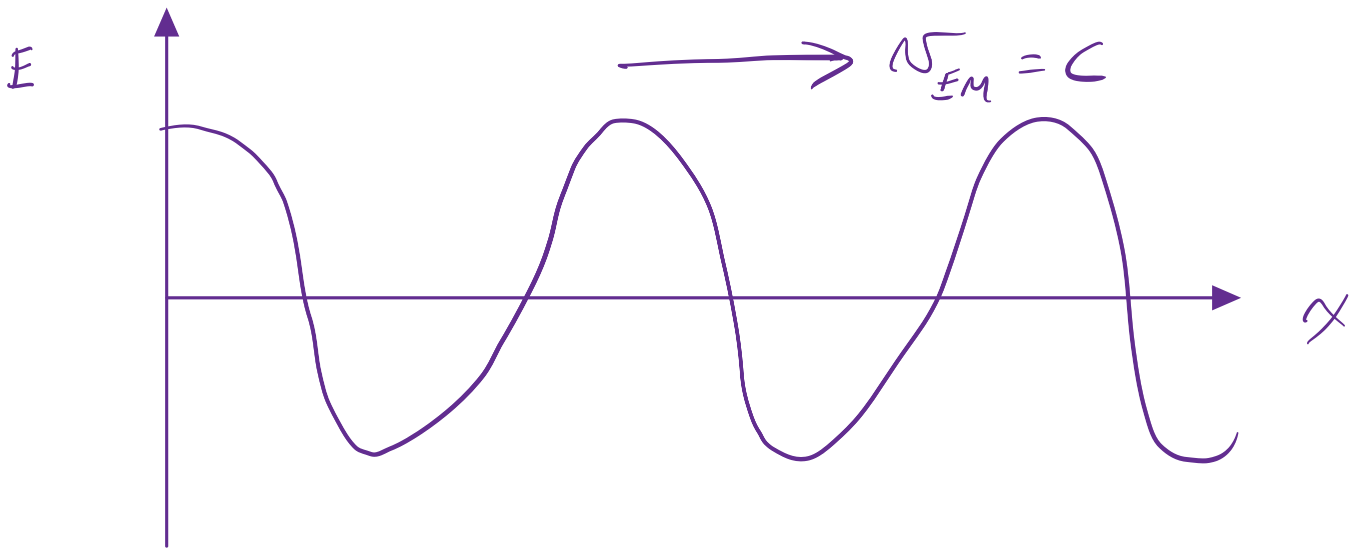
$$\lambda = \frac{v}{f} = \frac{343 \text{ m/s}}{262 \text{ Hz}} \approx 1.31 \text{ m}$$

Higher frequency $\Longleftrightarrow$ shorter wavelength

Electromagnetic waves

(more in ch. 35)

- Oscillations in the Electric and Magnetic fields.
- Transverse



Speed in vacuum = c

$c = 299\ 792\ 458$ m/s

$c \simeq 3.00 \times 10^8$ m/s in vacuum.

we will see $c = \dfrac{1}{\sqrt{\mu_0 \epsilon_0}}$, i.e. it depends on the physics of what's waving. (speed in a medium, such as glass, is lower).

λ, f can cover a wide range.

e.g. red HeNe laser

$$\lambda = 632.8 \times 10^{-9}\ m$$

$$c = 3.00 \times 10^{8}\ m/s$$

$$c = \lambda f \Rightarrow f = \frac{c}{\lambda}$$

$$f = \frac{3.00 \times 10^{8}\ m/s}{632.8 \times 10^{-9}\ m} = 4.74 \times 10^{14}\ Hz$$

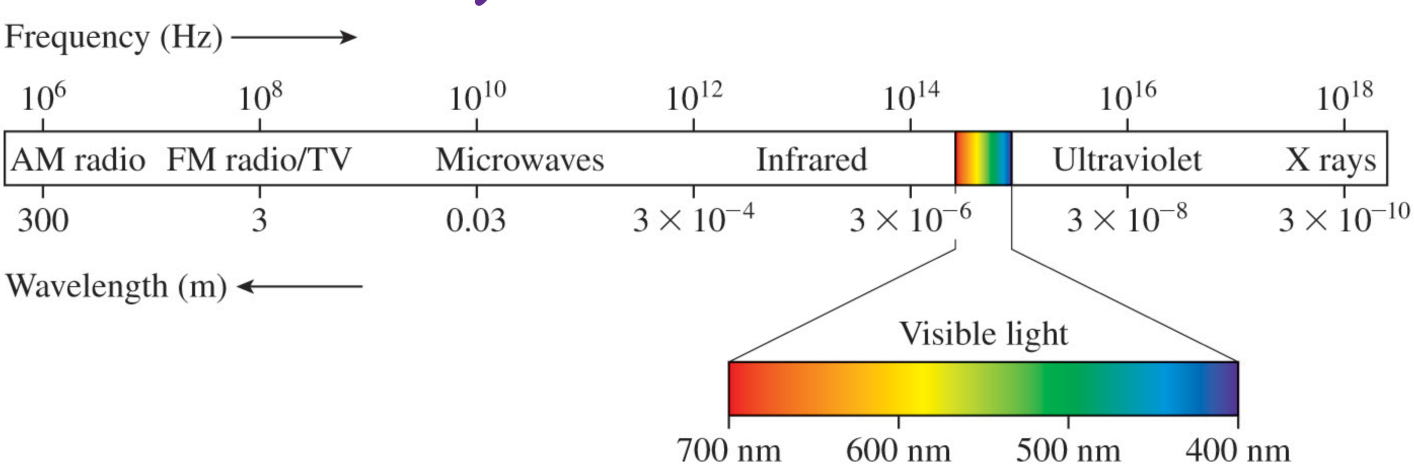
e.g. FM Radio - 99.9 - The Hawk

$$f = 99.9\ MHz = 99.9 \times 10^{6}\ Hz$$

$$c = 3.00 \times 10^{8}\ m/s$$

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^{8}\ m/s}{99.9 \times 10^{6}\ Hz} = \underline{3.00\ m}$$

The Electromagnetic Spectrum:



Waves transport energy. The most useful characterizations are P=Power and I=Intensity.

$$P = \text{Power} = \frac{\text{Energy}}{\text{Time}}. \quad \text{Units: } \frac{J}{s} = \text{Watts} = W.$$

$$I = \text{Intensity} = \frac{\text{Power}}{\text{Area}}. \quad \text{Units: } \frac{W}{m^2}$$

e.g. waves on a string

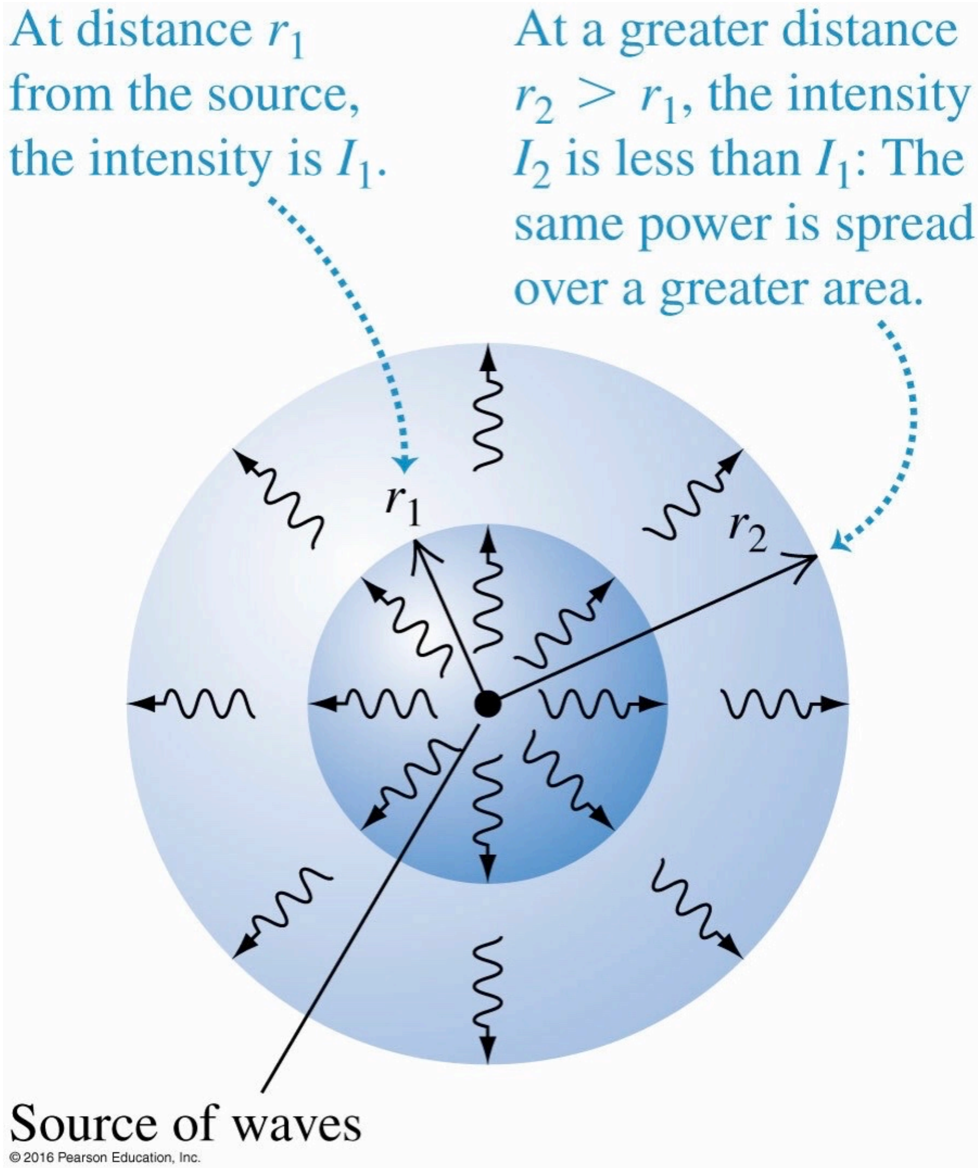
$$P_{average} = \frac{1}{2}\mu (2\pi f)^2 A^2 v$$

Don't memorize! Particles move up and down, and that energy is transported by the wave along the string.

Intensity: how concentrated is that power?

$$I = \frac{P}{\text{Area}}.$$

Waves that spread out in 3D:



Area = surface area of a sphere

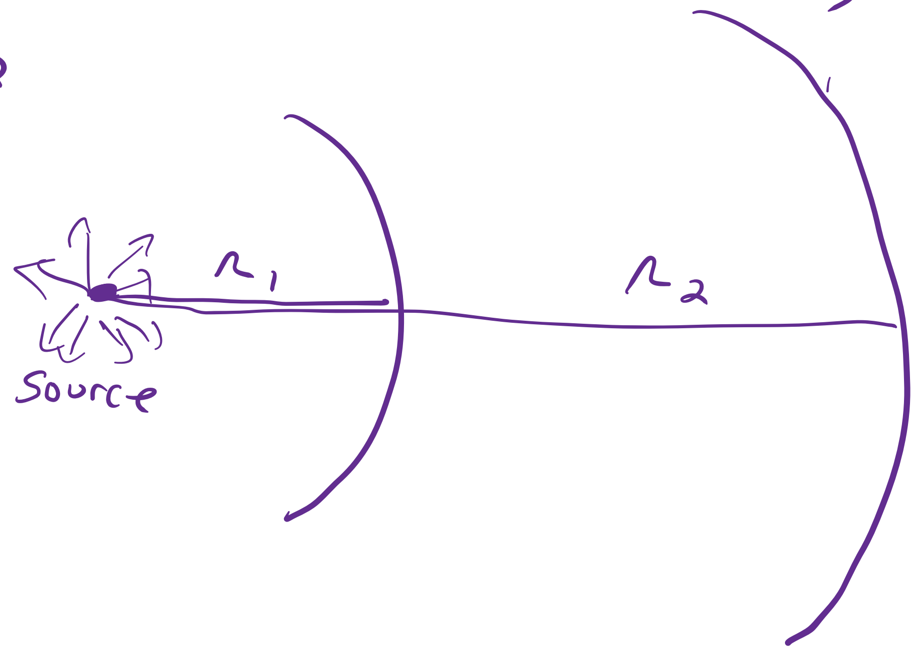
$A = 4\pi r^2$

$\therefore$

$$I = \frac{P}{4\pi r^2}$$ inverse square law

See Example 15.9

Useful in ratios, comparing intensities at 2 distances, r_1 and r_2



$$\frac{I_2}{I_1} = \frac{P/4\pi r_2^2}{P/4\pi r_1^2} = \frac{r_1^2}{r_2^2} = \left(\frac{r_1}{r_2}\right)^2$$

If you double r, I goes down by a factor of $(2)^2 = 4$.

See Example 15.10 (Mars rover solar panels).

Typical #'s:

sunlight above Eart's atmosphere

$I \sim 1400\ W/m^2$

Earth's surface, sunny day

$I \sim 1000\ W/m^2$

Earth's surface, averaged

$I \sim 200\ W/m^2$

This limits how much energy is available for solar power.

e.g. Replace a coal-fired power plant with solar power?

Eddystone unit #1 (Philadelphia)

$P = 325\,MW = 325 \times 10^6\ J/s$

Replace by solar panels with 18% efficiency. How big an array do you need?

Want $P = 325\,MW$

Given $I = 200\,W/m^2$

$e = 18\%$

$$P = e\,I\,A$$

W $\frac{W}{m^2}$ m^2

$$A = \frac{P}{eI} = \frac{325 \times 10^6\,W}{(0.18)(200\,W/m^2)}$$

$$A = 9.03 \times 10^6\,m^2$$

This is a square 3 km on a side, or 2,230 acres.

15.6 Loudness of Sound — OMIT decibel calculations.