Sound

and the Doppler effect

L7 c1

In general the velocity of a wave is

a. f/T T=tension

b. λ/T T=period

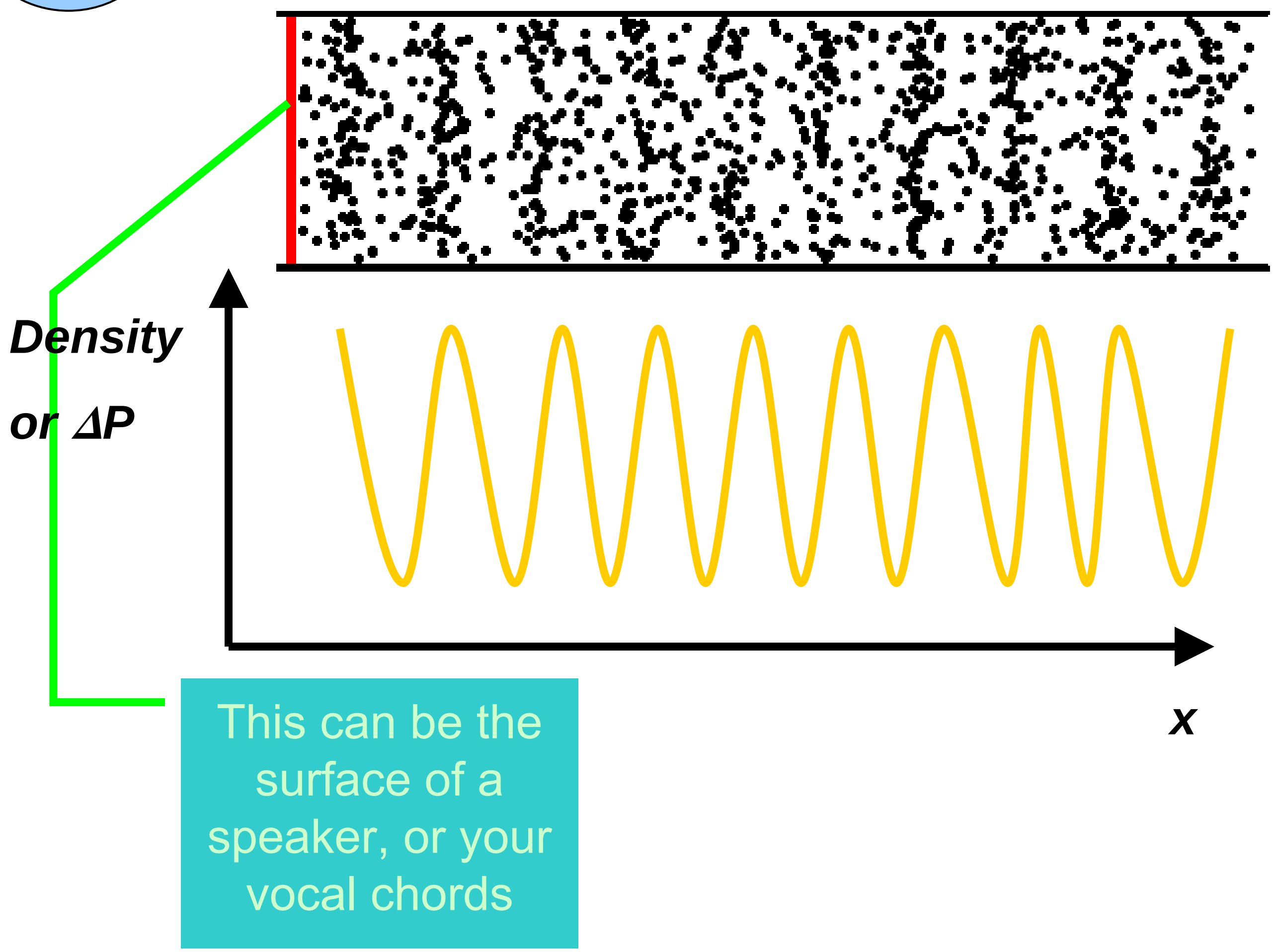
c. $2\pi/\omega$

d. $2\pi/k$

e. ωt

Sound

Sound waves represent compressions and rarefactions of the medium



The **higer the pressure** the **faster** the speed of the waves

v* must grow with *P

The **denser** a medium is the **slower** the speed of the waves

***v* must drop with ρ**

- P has units of force/area: mass/(length • time^2)
- ρ has units of mass /length^3

The ***only*** combination that has units of speed is:

These arguments determine ***v* up to a numerical constant *c*.** Its value depends on the medium

$$v = c\sqrt{\frac{P}{\rho}}$$

13.25

- A sinusoidal sound wave is described by the displacement

  $$D(x,t)=(2\mu m)\cos[(15.7m^{-1})x-(858s^{-1})t]$$

a) find the amplitude, wavelength and speed of this wave

b) Determine the instantaneous displacement of an element of air at the position x=0.5 m at t=3ms

c) Determine the maximum speed of an elements oscillatory motion

Exercise 13.25

I need the general expression for a wave.
The rest is plug and chug

$$D = A\sin(kx - \omega t + \phi)$$
$$= (2\mu\text{m})\cos\left[\left(15.7\ \text{m}^{-1}\right)\ x - \left(858\ \text{s}^{-1}\right)\ t\right]$$

$$(a) \quad A = 2\ \mu\text{m} \qquad \phi = \pi/2$$
$$k = 15.7\text{m}^{-1} = \frac{2\pi}{\lambda} \to \lambda = \frac{2\pi}{15.7}\text{m} = 0.4\text{m}$$
$$v = \frac{\omega}{k} = \frac{858}{15.7}\frac{\text{m}}{\text{s}} = 54.65\frac{\text{m}}{\text{s}}$$

remember
$\cos\theta = \sin(\theta + \pi/2)$

$$(b) \quad \text{x} = 0.05\text{m}, \quad t = 0.003\text{s}$$
$$D = (2\mu\text{m})\cos\left[\left(15.7\ \right)\ 0.05 - \left(858\ \right)\ 0.003\right]$$
$$= -1.95\mu\text{m}$$

$$(c) \quad \frac{dD}{dt} = -\omega\ \text{A}\cos(kx - \omega t + \phi) \le \omega\ \text{A} = \left(858\ \text{s}^{-1}\right)\ (2\mu\text{m}) = 0.0017\text{m/s}$$

L7 c2) All mechanical waves require

a. some source of disturbance.

b. a medium that can be disturbed.

c. a physical mechanism through which particles of the medium can exert forces on one another.

d. all of the above.

e. only (a) and (b) above.

The Doppler effect

- Passing Train
- Doppler applet
- Doppler2

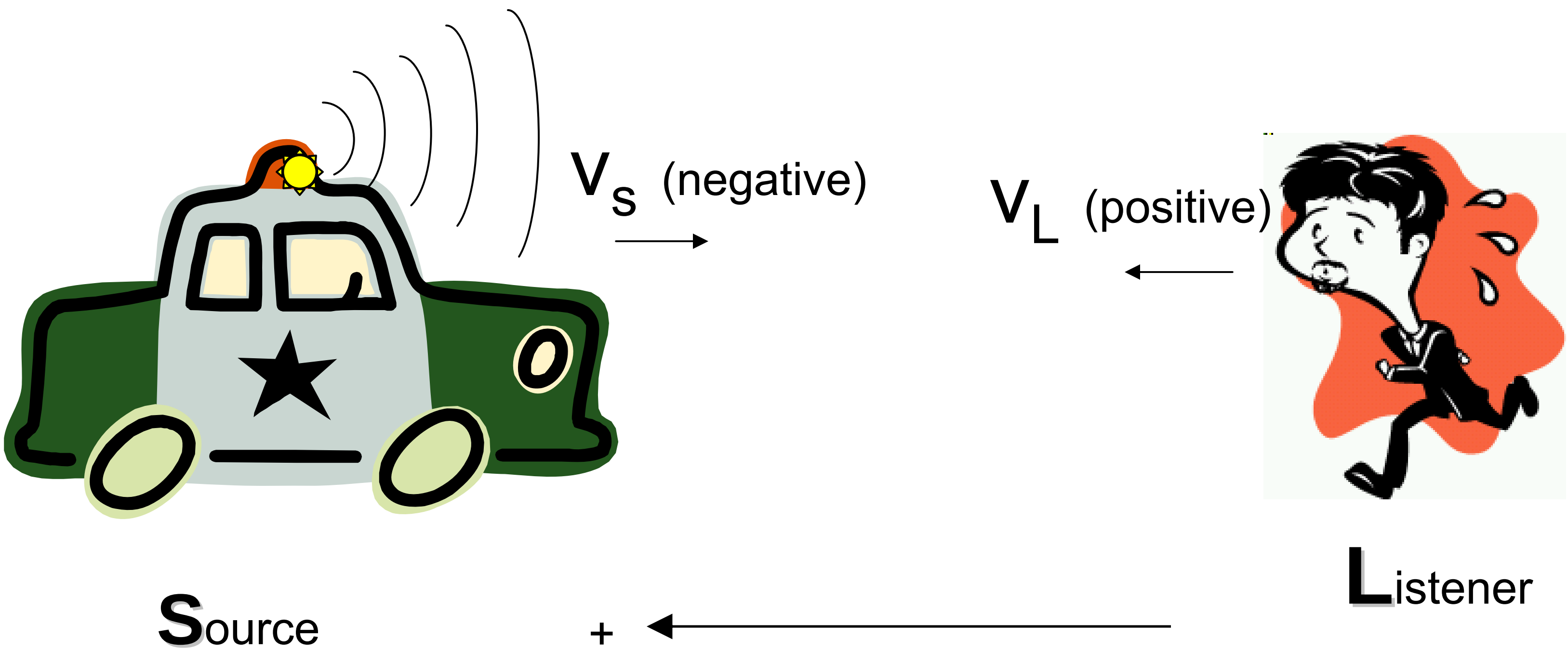
General Doppler Formula

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

f_s= frequency emitted by source v_S=Velocity of source

f_L= frequency received by listener v_L=Velocity of listener

positive direction is from L to S   so $f_L > f_S$ when they are moving toward each other



- L7 C3) The Doppler effect causes the sound from a source moving toward an observer to appear to have a

a. greater amplitude.

b. smaller amplitude.

c. greater speed.

d. lower frequency.

e. higher frequency.

Example

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

f_s= frequency emitted by source v_S=Velocity of source

f_L= frequency received by listener v_L=Velocity of listener

positive direction is from L to S so $f_L > f_S$ when they are moving toward each other

Example: Police car w/ siren and passenger car approaching each other; both moving.

$f_{\text{siren}} = 250$ Hz $v_s = 27$ m/s (60 mph) $v_L = 27$ m/s

$$f' = (250)\left(\frac{330 + 27}{330 - 27}\right) = 295 \text{ Hz}$$

Once they pass each other and are moving away

$$f' = (250)\left(\frac{330 - 27}{330 + 27}\right) = 213 \text{ Hz}$$

Ultrasound

10 wks

f=3Hz λ_{water}~0.5 mm

$\omega = 2\pi f \qquad f = \frac{1}{T}$

SHO F=-kx x=Acos(ωt+ϕ) $\omega = \sqrt{\frac{k}{m}}$

$Pendulum\ \omega = \sqrt{\frac{g}{L}}$

$PE_{spring} = \frac{1}{2} kx^2 \qquad Energy = PE + KE$

dampled SHO

$$x = Ae^{-(b/2m)t}\cos(\omega t + \phi)$$

$$\omega = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$$

$$E = E_0 e^{-t/\tau} \quad where \quad \tau = \frac{m}{b}$$

driven and dampled SHO

$$ma = F_{\text{total}} = -kx - bv + F_0 \sin(\omega t)$$

$$A = \frac{F_0 / m}{\sqrt{(b\omega/m)^2 + (\omega^2 - \omega_0^2)^2}}$$

$$\tan\phi = \frac{b\omega/m}{\omega^2 - \omega_0^2}$$

traveling waves

$$D(x,t) = A\sin(kx \mp \omega t)$$

$$k = \frac{2\pi}{\lambda} \quad v = \frac{\omega}{k}$$

$$\frac{d^2\mathbf{E}}{dt^2} = \frac{1}{c^2}\frac{d^2\mathbf{E}}{dx^2}$$

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3\times 10^8\,\text{m/s}$$

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

positive direction is from L to S

$$\mathbf{E} = \hat{\mathbf{x}}\, E_0 \cos(kx - \omega t)$$

$$\mathbf{B} = \hat{\mathbf{z}}\, B_0 \cos(kx - \omega t)$$

$$\Rightarrow E_0 = cB_0 \quad u_{\text{av}} = \frac{1}{2}\varepsilon_0 E_0^{\,2}$$

$$\mathbf{S} = \frac{\mathbf{1}}{\boldsymbol{\mu_0}}\mathbf{E}\times\mathbf{B} \quad |\mathbf{S}| = \frac{EB}{\mu_0} = \frac{E^2}{c\mu_0} \sim Power / area$$

$$I = \frac{Power}{Area} = S_{avg} = \frac{E_0^{\,2}}{2c\mu_0}$$

p=E/c

$$\text{P} = \frac{F}{A} = \frac{1}{A}\frac{\Delta p}{\Delta t} = \frac{1}{A}\frac{E/c}{\Delta t} = \frac{1}{A}\frac{\text{Power}}{c} = \frac{I}{c}$$

$$I = I_0 \cos^2\theta$$