Physics 2c Lecture 11

Chapter 18: Fluid Dynamics

Venturi flow meter

Chapter 16: Waves

Wave properties

Some math on waves

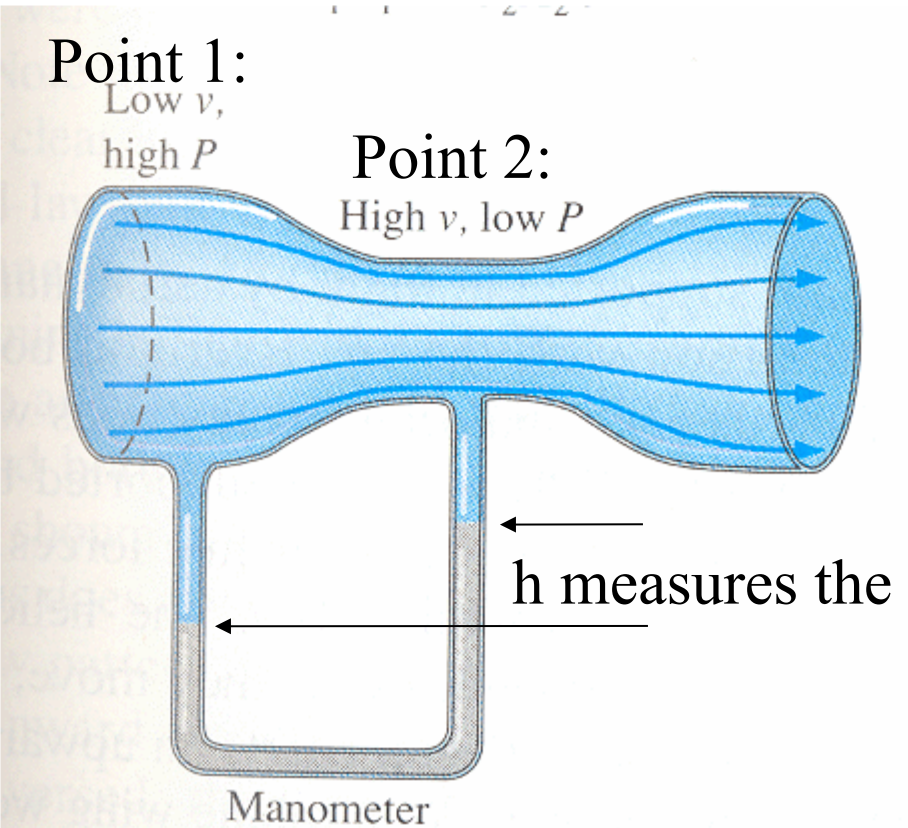
Waves on a string

Applications:

Venturi Flowmeter

flight & lift

Venturi flow meter



Pressure difference in the manometer measures the flow speed at the left side of the flow meter.

h measures the pressure difference.

Venturi Flow Meter

- Use Bernoulli & Continuity Equation to solve for v coming in based on measuring:
  - Pressure difference
  - and knowing ratio of Areas as well as density.

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

Gravity is irrelevant here.

$$v_1 A_1 = v_2 A_2$$

Use this to eliminate v_2 from problem.

Venturi Derivation

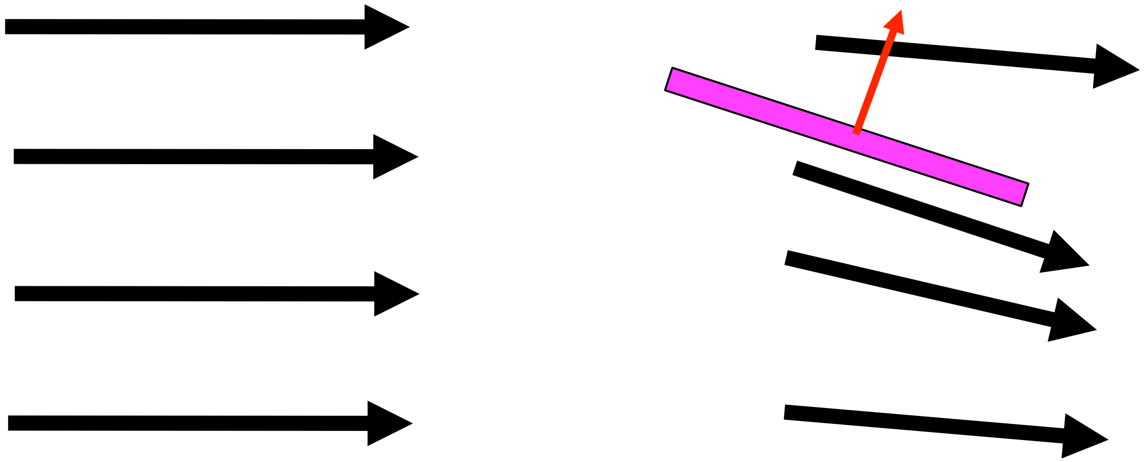
$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) \Rightarrow \frac{2(P_1 - P_2)}{\rho} = \left(v_1 \frac{A_1}{A_2}\right)^2 - v_1^2$$

$$\sqrt{\frac{2(P_1 - P_2)}{\rho}} = v_1 \sqrt{\left(\frac{A_1}{A_2}\right)^2 - 1}$$

$$v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho\left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}}$$

You measure the pressure difference.
You know the area ratio and density.
You calculate the flow speed.

Lift and Flight



The wing is "in the way" of the flowing fluid (i.e. air).
Direction of fluid flow changed to point downwards.
Newton's third law responsible for force upwards.

Chapter 16

Waves

Review of Oscillations

- Oscillations are characterized by:
  - Amplitude, A_0 .
  - Period, T, or frequency, f .
- Mathematical description of simple harmonic motion:

$$x(t) = A_0 \cdot \cos(\omega t + \phi)$$

ϕ= phase offset
I will ignore this offset
most of the time !!!

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

Example of Spring

- Newton's and Hook's Law provide:

$$-kx = m\frac{d^2x}{dt^2}$$

- Simple harmonic motion solves this differential equation, leading to:

$$\omega = \sqrt{\frac{k}{m}}$$

Basic Idea

- Simple Harmonic Oscillator is a physical system that follows a well defined second order differential equation.
- Physics provides understanding of forces, and thus T in terms of physical characteristics of the system.
- Math provides the rest.

Suggestion:

- Read up on chapter 15 in the book if this seems even a tiny bit unfamiliar!
- I am assuming that you know this blind and in your sleep!

Mechanical Waves

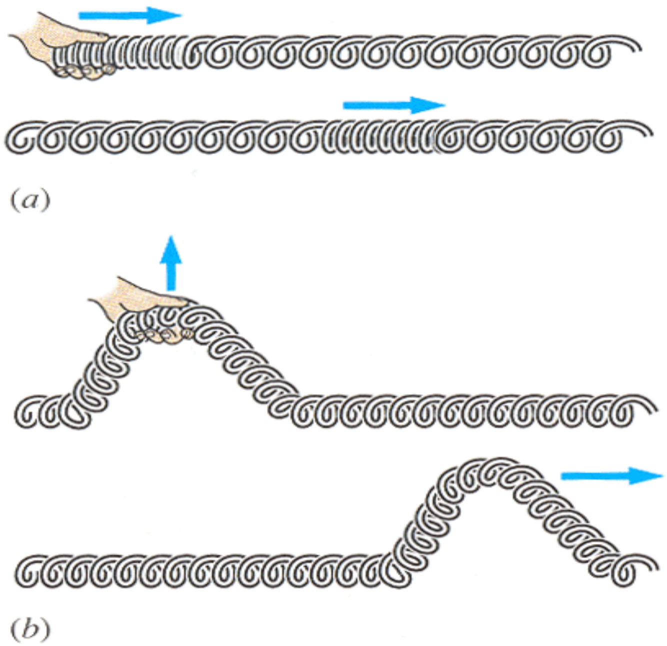


FIGURE 16-4 Waves on a stretched spring, like a Slinky. (*a*) Compressing a section of the spring produces a longitudinal wave pulse. (*b*) Displacing the spring perpendicular to its length produces a transverse wave pulse.

Longitudinal

Transverse

In both cases, waves transport energy but no matter. Motion of matter is local. Wave propagation is not local!

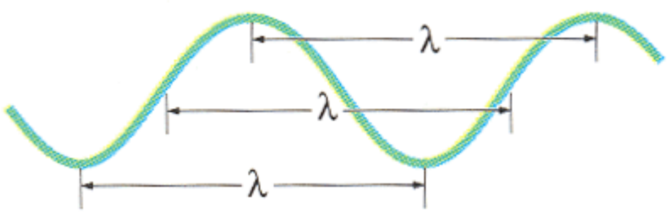


FIGURE 16-7 The wavelength λ is the distance over which the wave pattern repeats.

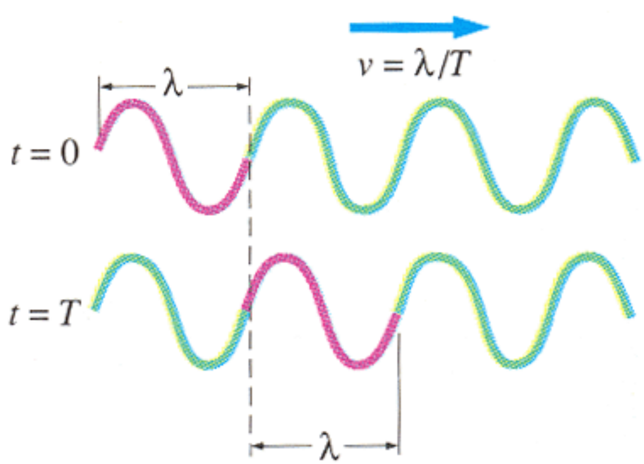


FIGURE 16-8 One full cycle—occupying a distance of one wavelength—passes a given point in one wave period. The wave speed is therefore $v = \lambda/T$.

Characterizing waves

Period T in seconds.

Wavelength λ in meters.

Wave velocity $v = \lambda / T$ in m/s.

Frequency $f = 1/T$ in Hz = 1/s .

Angular frequency $\omega = 2\pi/T$ in 1/s.

Wave number $k = 2\pi/\lambda$ in 1/m.

Some math of waves

y(x,t) = displacement (y) versus location (x) and time (t).

Consider simple harmonic wave

-> similar to harmonic oscillator,

except it propagates!

Start with fixed position x=0

$$y(x=0,t) = A\cos(2\pi\, t/T) = A\cos(\omega\, t)$$

A = amplitude of oscillation
= amplitude of wave

Harmonic Wave viewed at fixed position is simply an oscillator!

Now allow propagation of wave

$$y(x,t) = A\cos(2\pi\, t/T + 2\pi\, x/\lambda)$$

$$y(x,t) = A\cos(\omega t + kx)$$

Define: k = wave number in analogy to

ω = angular frequency

Wave velocity: $v = \lambda/T = (2\pi/k)/(2\pi/\omega) = \omega/k$

Which direction does this wave move?

$$y(x;t) = A\cos(kx - \omega t)$$

$$k,\omega > 0$$

(a)Wave has positive velocity, i.e. moves ->
(b)Wave has negative velocity, i.e. moves <-

A word about signs

$$y(x;t) = A\cos(kx \pm \omega t)$$

A wave with positive v is described by (kx-ωt).
A wave with negative v is described by (kx+ωt).

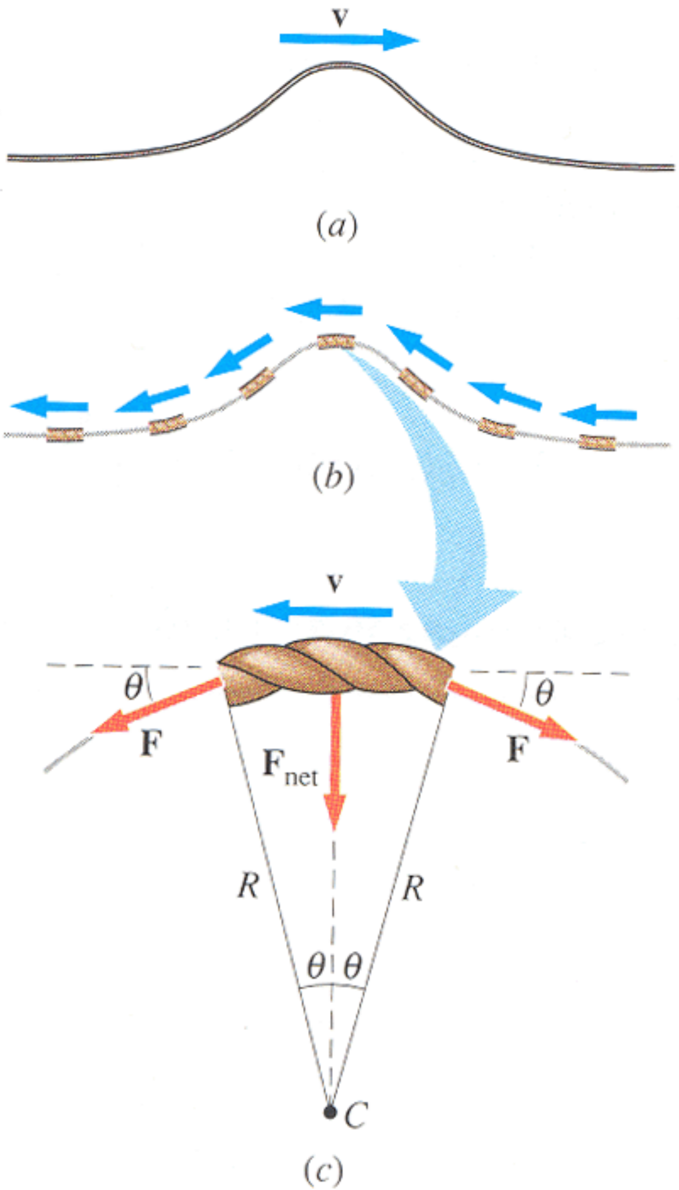
Example: Wave on a string

- We use our knowledge of mechanics to analyze physics of wave on a string.
- We make the simplifying assumption that movement of string near the top, i.e. at maximum amplitude, is circular motion.
- This gives us v of the wave, the rest is just math.

Introduce: $\mu = mass/length$

Aside on small angle approximation

- $\sin x = \tan x = x$ IFF $x << 1$
- We will be using this a few times for the remainder of this quarter.



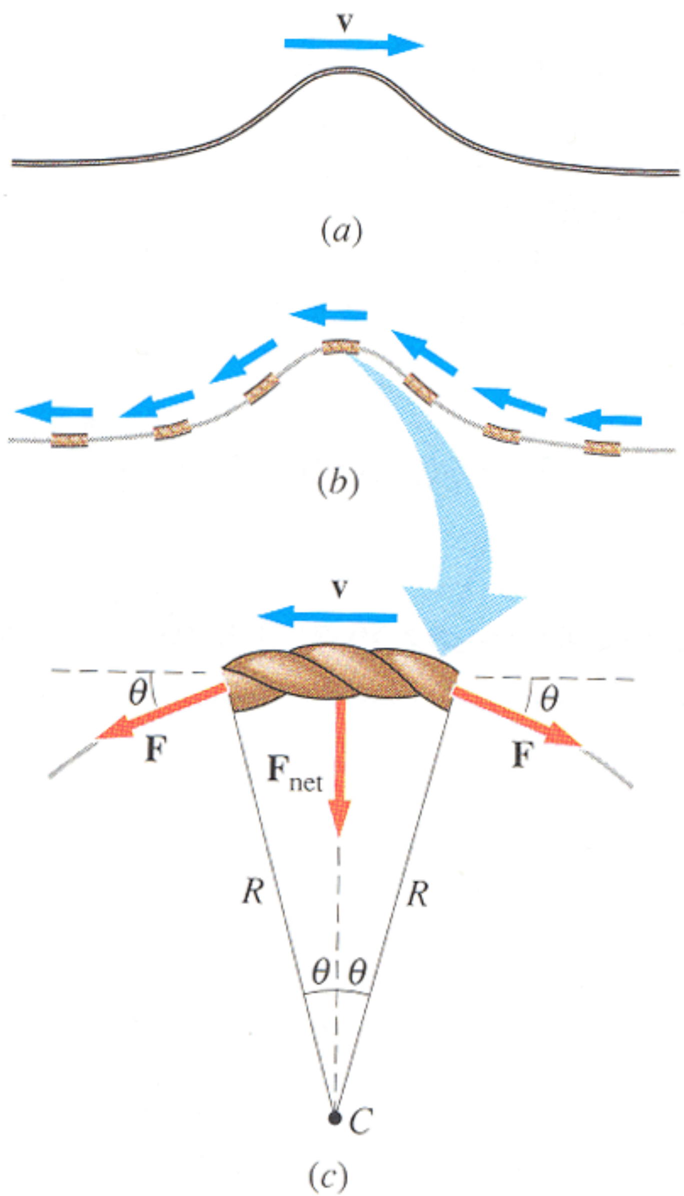
Waves on a string

$$F_{net} = 2F\sin\theta = 2F\theta$$

$$2F\theta = F_{zentripetal} = \frac{mv^2}{R}$$

$$\mu = \frac{m}{length} = \frac{m}{2R\sin\theta}$$

$$m = 2\theta R\mu$$



Waves on a string

$$2F\theta = \frac{mv^2}{R}$$

$$m = 2\theta R\mu$$

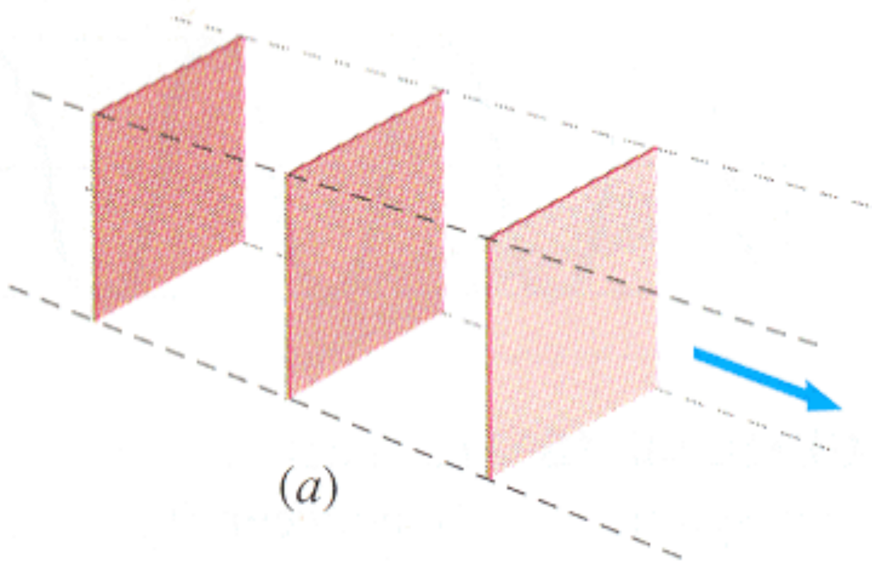
$$\Rightarrow 2F\theta = 2\theta\mu v^2$$

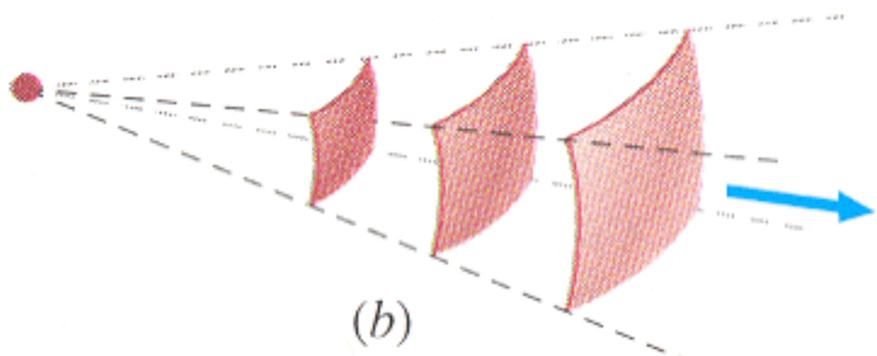
$$\Rightarrow v = \sqrt{\frac{F}{\mu}}$$

Note:

- The physics fixes the wave propagation velocity.
- The physics does not determine wavelength and period independently.
- Instead, a given medium will carry waves of many (all) periods.
- However, once you fix T the physics of the medium fixes λ for you because it fixes v!

Wave Intensity = Power/area


(a)


(b)

- Average rate at which the wave carries energy across a unit area surface perpendicular to the wave propagation.

Question

- 2km away from the source of a spherical wave a wave intensity I is measured.
- What's the wave intensity 4km away?

(a) Also I

(b) I/2

(c) I/4

Example: Spherical wave

$$I = \frac{Power}{Area} = \frac{Power}{4\pi R^2}$$