Physics 231 Lecture 26

- Main points of today’s lecture:
  - Viscous flow and Poiseuille’s law
    \[ F = \eta \frac{A}{d} \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8 \eta L} \]
  - Transverse and longitudinal waves
  - Traveling waves \( v_{\text{wave}} = f \lambda \)
  - Wave speed for a string
    \[ v = \sqrt{\frac{F}{\mu}} \]
    Here \( F \) is the string tension and \( \mu \) is the mass/length.
  - Superposition and interference of waves; Reflection of waves.
  - Sound waves:
    - Sound intensity: \( \beta = 10 \log_{10} \left( \frac{I}{I_0} \right) \)
    - \( I = P/A, \ I_0 = 1 \times 10^{-12} \text{ W/m}^2 \)
Conceptual question

- Blood flows through a coronary artery that is partially blocked by deposits along the artery wall. Through which part of the artery is the flux (volume of blood per unit time) largest?

  - a) The narrow part.
  - b) The wide part.
  - c) The flux is the same in both parts.

If it increases, where does the blood come from. If it decreases where does the blood go?
Conceptual question

- Blood flows through a coronary artery that is partially blocked by deposits along the artery. Which pressure is greater $p_1$ or $p_2$?

$$A_1 v_1 = A_2 v_2$$

- a) $p_1$.
- b) $p_2$
- c) The pressure is the same in both parts.

$v_2 > v_1$, and

$$p_2 + \frac{1}{2} \rho v_2^2 = p_1 + \frac{1}{2} \rho v_1^2$$

so $p_1 > p_2$
Viscous flow

- Viscosity limits the relative velocity between a fluid, the walls of its container and between two nearby points in the fluid.
- Assume a viscous fluid between two solid surfaces.
- Because the fluid “sticks” to the surfaces a force is required to move the upper surface relative to the lower surface.

\[ F = \eta \frac{\text{Area} \cdot v}{d} \]

- \( \eta \) is the viscosity coefficient
- SI units are Ns/m\(^2\)
- cgs units are Poise
  - 1 Poise = 0.1 Ns/m\(^2\)

<table>
<thead>
<tr>
<th>Material</th>
<th>( \eta ) at T=20 °C</th>
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<tbody>
<tr>
<td>air</td>
<td>1.9x10(^{-5}) N·s/m(^2)</td>
</tr>
<tr>
<td>water</td>
<td>1.0x10(^{-3}) N·s/m(^2)</td>
</tr>
<tr>
<td>glycerin</td>
<td>1.5 N·s/m(^2)</td>
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Poiseuille’s Law

- Gives the *rate of flow* of a fluid in a tube with a pressure difference $\Delta P = P_1 - P_2$

\[
\text{Rate of flow} = \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L}
\]

- Example: A blood vessel is 0.1 m in length and has a radius of $1.5 \times 10^{-3}$ m. Blood flow at a rate of $1.0 \times 10^{-7}$ m³/s through this vessel. Determine the difference in pressure (in Pa) that must be maintained between the two ends of the vessel. ($\eta = 3 \times 10^{-3}$ N·s/m²)

  - a) 5 \[ \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L} \]
  - b) 10 \[ \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L} \]
  - c) 15 \[ \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L} \]
  - d) 20 \[ \Rightarrow P_1 - P_2 = \frac{\Delta V}{\Delta t} \frac{8\eta L}{\pi R^4} = \left(1 \times 10^{-7} \text{ m}^3 / \text{s}\right) \cdot 8 \cdot \left(3 \times 10^{-3} \text{ N} \cdot \text{s} / \text{m}^2\right) \cdot (0.1 \text{m}) \]
  - e) 25 \[ \Rightarrow P_1 - P_2 = 15 \text{Pa} \]
Example

- A thin 1.5-mm coating of glycerine ($\eta=1.5 \text{ N} \cdot \text{s/m}^2$) has been placed between two microscope slides of width 1.0 cm and length 4.0 cm. Find the force required to pull one of the microscope slides at a constant speed of 0.30 m/s relative to the other.

$$F = \frac{\eta A v}{d} = \frac{1.5 \text{ N} \cdot \text{s/m}^2 (0.01m)(0.04m)(0.3m/s)}{0.0015m} = 0.12N$$
Reading Quiz

1. Which of the following is a longitudinal wave?

   A. sound wave
   B. water wave
   C. light wave
Types of Waves -- Transverse

- In a transverse wave, each element that is disturbed moves perpendicularly to the wave motion

(a) Transverse wave
Types of Waves -- Longitudinal

- In a longitudinal wave, the elements of the medium undergo displacements parallel to the motion of the wave
- A longitudinal wave is also called a compression wave
Constructing a History Graph

(a) Snapshot graphs

Wave at time $t_1$

The wave moves to the right; points on the string move up and down.

(b) History graph

Graphing the motion of one point in the medium gives a history graph.
Traveling sinusoidal wave

- The figure at the right shows a wave traveling on a string at different times, measured in units of a period. The square point shows how the wave-front on the traveling wave moves.
- At a fixed time and as a function of distance, the wave reproduces itself after an $x$ displacement of one wavelength $\lambda$.
- At each point, the wave returns to its original $y$ displacement after a time $T$.
- At time $T$, the wave front has moved a distance $\lambda$. This makes the wave velocity $v = \lambda/T = \lambda f$. Here we use the relationship $f = 1/T$ between wavelength and frequency.
Checking Understanding

The graph below shows a snapshot graph of a wave on a string that is moving to the right. A point on the string is noted. Which of the choices is the history graph for the subsequent motion of this point?

What is the motion at this point?

- (a) 
- (b) 
- (c) 
- (d)
Example

- A wave traveling in the positive x direction has a frequency of 25.0 Hz as in the figure below. Find the (a) amplitude, (b) wavelength, (c) period, and (d) speed of the wave.

  - The amplitude is:
    - a) 9 cm
    - b) 18 cm
  - The wavelength is:
    - a) 10 cm
    - b) 20 cm

\[ a) \ A = \frac{18\text{cm}}{2} = 9\text{cm} \]
\[ b) \ \lambda = 10\text{cm} \cdot 2 = 20\text{cm} \]

\[ c) \ \ T = \frac{1}{f} = \frac{1}{25} \text{s} = 0.04 \text{s} \]
\[ d) \ \ v = \lambda f = 20\text{cm} \cdot 25\text{Hz} = 500\text{cm/s} \]