DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS

AP PHYSICS

TSOKOS LESSON 10-11 TO 10-12

10-11: VISCOSITY
10-12: FLOW IN TUBES: POISEUILLE'S EQUATION, BLOOD FLOW

Objectives

- Be flexible because objectives in this section are somewhat fluid at this juncture.

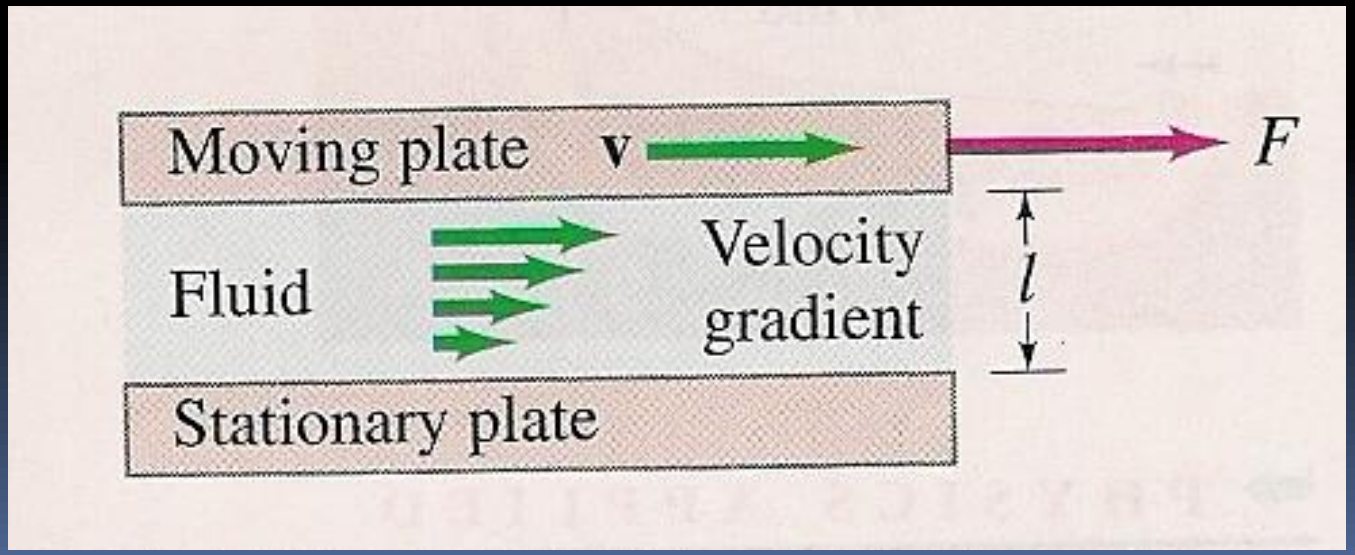
Reading Activity Questions?

Viscosity

- A friction force between adjacent layers of fluid as the layers move past one another
- In liquids, it is mainly due to the cohesive forces between molecules
- In gases, it is caused by collisions between molecules.
- *Coefficient of viscosity*, η (lowercase eta) (Pa-s)

Viscosity

- Determined by measuring the force required to move a plate over a stationary one with a given amount of liquid between them



Viscosity

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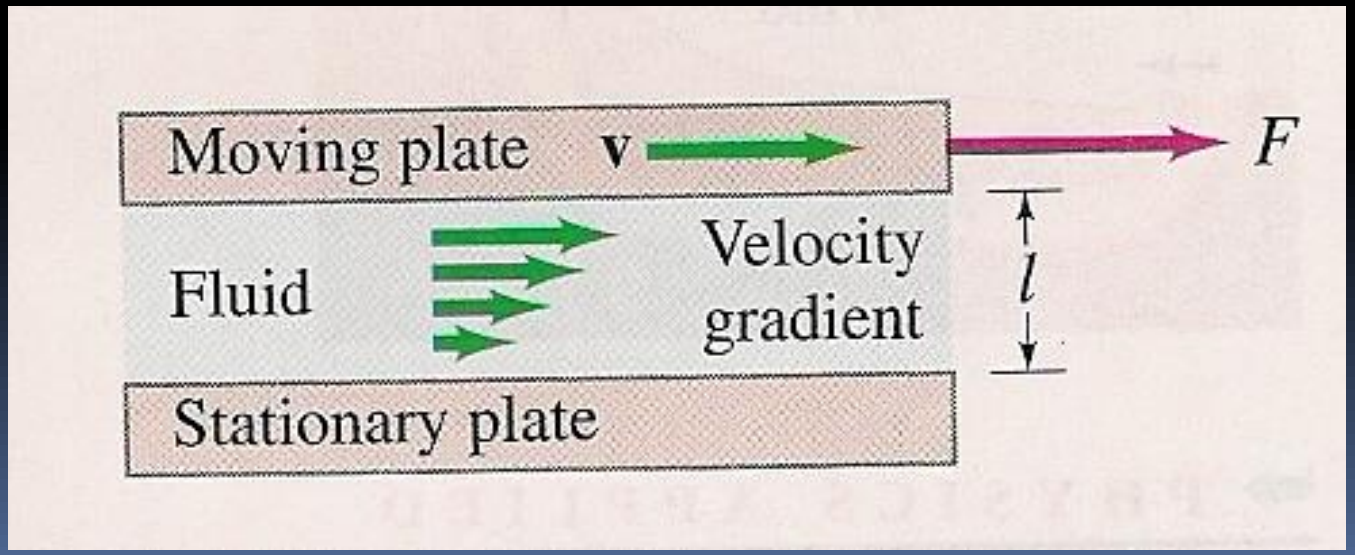
$$F = \eta A \frac{v}{l}$$

$$\frac{F}{A}\frac{l}{v} = \eta$$



Viscosity

- Units for η (eta) are N·s/m² or Pa·s
- CGS is dyne·s/cm² which is called a poise (P)
- 100 centipoise (cP) = 1P

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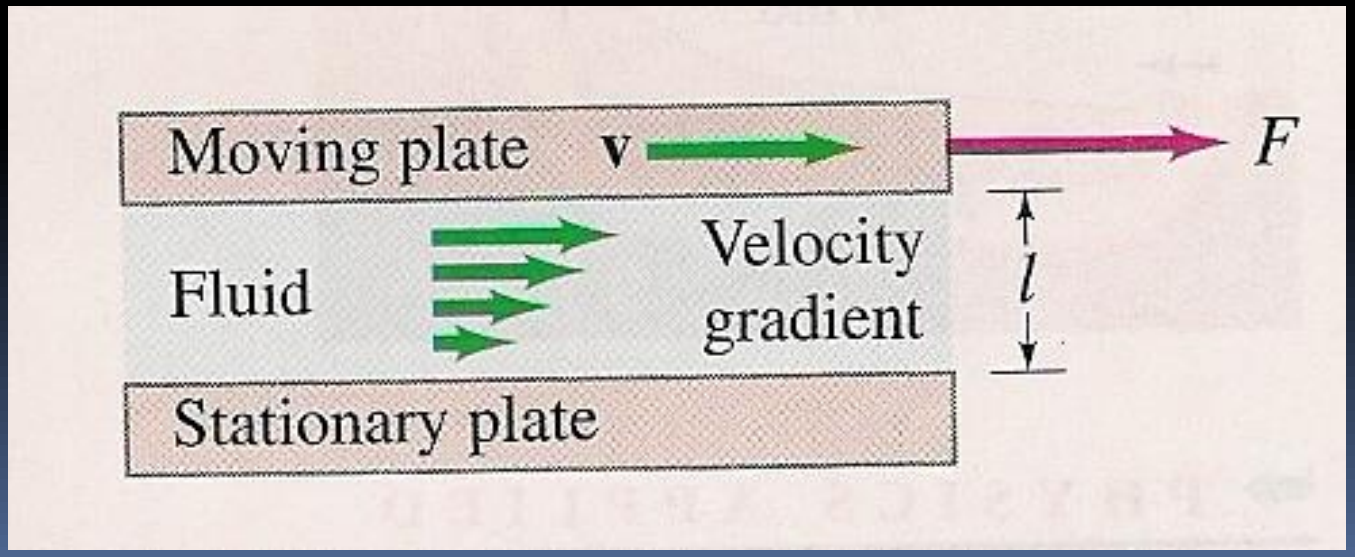

Coefficients of Viscosity

TABLE 10–3 Coefficient of Viscosity for Various Fluids

Fluid	Temperature (°C)	Coefficient of Viscosity, η (Pa·s)†
Water	0	1.8×10^{-3}
	20	1.0×10^{-3}
	100	0.3×10^{-3}
Whole blood	37	$\approx 4 \times 10^{-3}$
Blood plasma	37	$\approx 1.5 \times 10^{-3}$
Ethyl alcohol	20	1.2×10^{-3}
Engine oil (SAE 10)	30	200×10^{-3}
Glycerine	20	1500×10^{-3}
Air	20	0.018×10^{-3}
Hydrogen	0	0.009×10^{-3}
Water vapor	100	0.013×10^{-3}

†1 Pa·s = 10 P = 1000 cP

Coefficients of Viscosity

- Temperatures are specified because it has a strong effect on viscosity
- Viscosity for most fluids decreases rapidly with increase in temperature

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Flow In Tubes: Poiseuille's Equation

- Without viscosity, fluids could flow freely without an applied force
- Because of viscosity, a pressure difference between the ends of the tube are necessary to cause the fluid to flow

Flow In Tubes: Poiseuille's Equation

- Rate of flow of a fluid depends on:
  - Viscosity
  - Pressure difference
  - Dimensions of the tube
- Poiseuille's Equation assumes
  - Fluid is incompressible
  - Laminar flow

Flow In Tubes: Poiseuille's Equation

$$Q = \frac{\pi r^4 (P_1 - P_2)}{8\eta L}$$

- ***Q is the volume rate of flow in m^3/s***
- r is the inside radius of the tube
- L is the length of the tube
- P_1-P_2 is the pressure difference between the ends
- η is the coefficient of viscosity

Flow In Tubes: Poiseuille's Equation

$$Q = \frac{\pi r^4 (P_1 - P_2)}{8\eta L}$$

- Q, the volume rate of flow is
  - Directly proportional to the pressure difference
  - Inversely proportional to the viscosity and length of the tube
  - Directly proportional to the ***fourth*** power of the radius

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- ***Do blood vessels have constant diameter?***

Flow In Tubes: Poiseuille's Equation

$$Q = \frac{\pi r^4 (P_1 - P_2)}{8\eta L}$$

- Q, the volume rate of flow is
  - Directly proportional to the ***fourth*** power of the radius
- ***Do blood vessels have constant diameter?***
  - Blood vessel diameter decreases as they branch out
  - The body controls blood vessel diameter by bands of muscles surrounding the arteries
  - Arteriosclerosis and cholesterol buildup decrease diameter forcing a higher pressure gradient for same blood flow

QUESTIONS?

Homework

#51-57