PROBLEMS

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Guided Online (GO) Problem, available in *WileyPLUS* at instructor's discretion.

Defining the System (§2.1)

2.1 A system is separated from its surrounding by a

- **a.** border
- **b.** boundary
- **c.** dashed line
- **d.** dividing surface

Characterizing Weight and Mass (§2.2)

2.2 How are density and specific weight related?

2.3 Density is (select all that apply)

- **a.** weight/volume
- **b.** mass/volume
- **c.** volume/mass
- **d.** mass/weight

2.4 Which of these are units of density? (select all that apply)

- **a.** kg/m^3
- **b.** mg/cm^3

2.5 Specific gravity (select all that apply)

- **a.** can have units of N/m^3
- **b.** is dimensionless
- **c.** increases with temperature
- **d.** decreases with temperature

2.6 If a liquid has a specific gravity of 1.7, what is the density in kg/m^3? What is the specific weight in N/m^3?

2.7 What are SG, γ, and ρ for mercury? State your answers in SI units.

2.8 If a gas has $\gamma = 15\ N/m^3$, what is its density? State your answers in SI units.

Bulk Modulus of Elasticity (§2.3)

2.9 If you have a bulk modulus of elasticity that is a very large number, then a small change in pressure would cause

- **a.** a very large change in volume
- **b.** a very small change in volume

2.10 Dimensions of the bulk modulus of elasticity are

- **a.** the same as the dimensions of pressure/density
- **b.** the same as the dimensions of pressure/volume
- **c.** the same as the dimensions of pressure

2.11 The bulk modulus of elasticity of ethyl alcohol is 1.06×10^9 Pa. For water, it is 2.15×10^9 Pa. Which of these liquids is easier to compress?

- **a.** ethyl alcohol
- **b.** water

2.12 A pressure of $2 \times 10^6\ N/m^2$ is applied to a mass of water that initially filled a 2000 cm^3 volume. Estimate its volume after the pressure is applied.

2.13 Calculate the pressure increase that must be applied to water to reduce its volume by 2%.

2.14 An open vat in a food processing plant contains 400 L of water at 20°C and atmospheric pressure. If the water is heated to 80°C, what will be the percentage change in its volume? If the vat has a diameter of 3 m, how much will the water level rise due to this temperature increase?

Finding Fluid Properties (§2.4)

2.15 Where in this text can you find:

- **a.** density data for such liquids as oil and mercury?
- **b.** specific weight data for air (at standard atmospheric pressure) at different temperatures?
- **c.** specific gravity data for sea water and kerosene?

2.16 Regarding water and seawater:

- **a.** Which is more dense, seawater or freshwater?
- **b.** Find the density of seawater (10°C, 3.3% salinity).
- **c.** What pressure is specified for the values in (b)?

2.17 If the density, ρ, of air (in an open system at atmospheric pressure) increases by a factor of 1.4x due to a temperature change,

- **a.** specific weight increases by 1.4x
- **b.** specific weight increases by 13.7x
- **c.** specific weight remains the same

Describing Viscous Effects (§2.5)

2.18 The following questions relate to viscosity.

- **a.** What are the primary dimensions of viscosity? What are five common units?
- **b.** What is the viscosity of SAE 10W-30 motor oil at 319.26 K?

2.19 Shear stress has dimensions of

- **a.** force/area
- **b.** dimensionless

2.20 The term dV/dy, the velocity gradient

- **a.** has dimensions of L/T and represents shear strain
- **b.** has dimensions of T^{-1} and represents the rate of shear strain

2.21 For the velocity gradient dV/dy

a. the change in velocity dV is in the direction of flow

b. the change in velocity dV is perpendicular to flow

2.22 The no-slip condition

a. only applies to ideal flow

b. only applies to rough surfaces

c. means velocity, V, is zero at the wall

d. means velocity, V, is the velocity of the wall

2.23 Kinematic viscosity (select all that apply)

a. is another name for absolute viscosity

b. is viscosity/density

c. is dimensionless because forces are canceled out

d. has dimensions of L^2/T

e. is only used with compressible fluids

2.24 What is the change in the viscosity and density of water between 10°C and 70°C? What is the change in the viscosity and density of air between 10°C and 70°C? Assume standard atmospheric pressure (p = 101 kN/m^2 absolute).

2.25 Determine the change in the kinematic viscosity of air that is heated from 10°C to 70°C. Assume standard atmospheric pressure.

2.26 Find the dynamic and kinematic viscosities of kerosene, SAE 10W-30 motor oil, and water at a temperature of 38°C.

2.27 What is the ratio of the dynamic viscosity of air to that of water at standard pressure and a temperature of 20°C? What is the ratio of the kinematic viscosity of air to that of water for the same conditions?

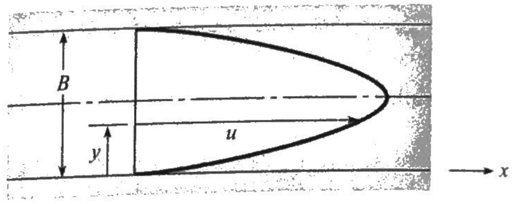
Applying the Viscosity Equation (§2.6)

2.28 At a point in a flowing fluid, the shear stress is 0.689 Pa, and the velocity gradient is 1 s^{-1}. Is this fluid more, or less, viscous than water?

2.29 SAE 10W-30 oil with viscosity 4.79×10^{-3} N · s/m^2 is used as a lubricant between two parts of a machine that slide past one another with a velocity difference of 1.83 m/s. What spacing, in cm, is required if you don't want a shear stress of more than 95.8 Pa?

2.30 The velocity distribution for water (20°C) near a wall is given by $u = a(y/b)^{1/6}$, where a = 10 m/s, b = 2 mm, and y is the distance from the wall in mm. Determine the shear stress in the water at y = 1 mm.

2.31 The velocity distribution for the flow of crude oil at 37.8°C ($\mu = 3.83 \times 10^{-3}$ Pa · s) between two walls is shown and is given by $u = 100y(0.1 - y)$ m/s, where y is measured in meters and the space between the walls is 3 cm. Plot the velocity distribution and determine the shear stress at the walls.



PROBLEMS 2.31, 2.32, 2.33

2.32 **(part a only)** A liquid flows between parallel boundaries as shown above. The velocity distribution near the lower wall is given in the following table:

y in mm	V in m/S
0.0	0.00
1.0	1.00
2.0	1.99
3.0	2.98

a. If the viscosity of the liquid is 10^{-3} N · s/m^2, what is the maximum shear stress in the liquid?

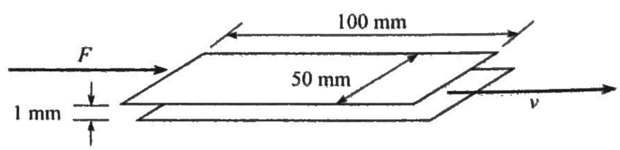
b. Where will the minimum shear stress occur?

2.33 Suppose that glycerin is flowing (T = 20°C) and that the pressure gradient dp/dx is −1.6 kN/m^3. What are the velocity and shear stress at a distance of 12 mm from the wall if the space B between the walls is 5.0 cm? What are the shear stress and velocity at the wall? The velocity distribution for viscous flow between stationary plates is

$$u = -\frac{1}{2\mu}\frac{dp}{dx}(By - y^2)$$

2.34 Two plates are separated by a 3.175 cm space. The lower plate is stationary; the upper plate moves at a velocity of 7.62 m/s. Oil (SAE 10W-30, 338.7 K), which fills the space between the plates, has the same velocity as the plates at the surface of contact. The variation in velocity of the oil is linear. What is the shear stress in the oil?

2.35 The sliding plate viscometer shown below is used to measure the viscosity of a fluid. The top plate is moving to the right with a constant velocity of 10 m/s in response to a force of 3 N. The bottom plate is stationary. What is the viscosity of the fluid? Assume a linear velocity distribution.



PROBLEM 2.35

2.42 Sutherland's equation (select all that apply):

a. relates temperature and viscosity

b. must be calculated using Kelvin

c. requires use of a single universal constant for all gases

d. requires use of a different constant for each gas

2.43 When looking up values for density, absolute viscosity, and kinematic viscosity, which statement is true for both liquids and gases?

a. all three of these properties vary with temperature

b. all three of these properties vary with pressure

c. all three of these properties vary with temperature and pressure

2.44 Common Newtonian fluids are

a. toothpaste, catsup, and paint

b. water, oil, and mercury

c. all of the above

2.45 Which of these flows (deforms) with even a small shear stress applied?

a. a Bingham plastic

b. a Newtonian fluid

2.46 Using Sutherland's equation and the ideal gas law, develop an expression for the kinematic viscosity ratio ν/ν_0 in terms of pressures p and p_0 and temperatures T and T_0, where the subscript 0 refers to a reference condition.

2.47 The dynamic viscosity of air at 288 K is 1.78×10^{-5} $N \cdot s/m^2$. Using Sutherland's equation, find the viscosity at 373 K.

2.48 The kinematic viscosity of methane at 288 K and atmospheric pressure is 1.59×10^{-5} m^2/s. Using Sutherland's equation and the ideal gas law, find the kinematic viscosity at 474 K and 202.65 kPa.

2.49 The dynamic viscosity of nitrogen at 288 K is 1.72×10^{-5} $N \cdot s/m^2$. Using Sutherland's equation, find the dynamic viscosity at 366.48 K.

2.50 The kinematic viscosity of helium at 288 K and 101.325 kPa is 1.13×10^{-4} m^2/s. Using Sutherland's equation and the ideal gas law, find the kinematic viscosity at 272 K and a pressure of 152 kPa.

2.51 Ammonia is very volatile, so it may be either a gas or a liquid at room temperature. When it is a gas, its absolute viscosity at 293 K is 9.91×10^{-6} $N \cdot s/m^2$ and at 473 K is 1.66×10^{-5} $N \cdot s/m^2$. Using these two data points, find Sutherland's constant for ammonia.

2.52 The viscosity of SAE 10W-30 motor oil at 311 K is 0.067 $N \cdot s/m^2$ and at 372 K is 0.011 $N \cdot s/m^2$. Using Eq. (2.20) (p. 42, §2.7) for interpolation, find the viscosity at 333 K. Compare this value with that obtained by linear interpolation.

2.53 The viscosity of grade 100 aviation oil at 310.9 K is 0.212 $N \cdot s/m^2$ and at 372 K is 1.87×10^{-2} $N \cdot s/m^2$. Using Eq. (2.20) (p. 42, §2.7), find the viscosity 338.7 K.

2.54 Find the kinematic and dynamic viscosities of air and water at a temperature of 40°C and an absolute pressure of 170 kPa.

2.55 Consider the ratio μ_{100}/μ_{50}, where μ is the viscosity of oxygen and the subscripts 100 and 50 are the temperatures of the oxygen in degrees Celsius. Does this ratio have a value (a) less than 1, (b) equal to 1, or (c) greater than 1?

Characterizing Surface Tension (§2.8)

2.56 Surface tension: (select all that apply)

a. only occurs at an interface, or surface

b. has dimensions of energy/area

c. has dimensions of force/area

d. has dimensions of force/length

e. depends on adhesion and cohesion

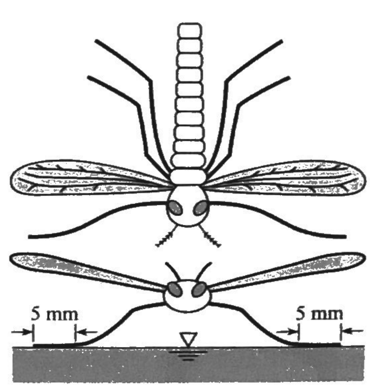
f. varies as a function of temperature

2.57 Which of the following is the formula for the gage pressure within a very small spherical droplet of water:

(a) $p = \sigma/d$, (b) $p = 4\sigma/d$, or (c) $p = 8\sigma/d$?

2.58 A spherical soap bubble has an inside radius R, a film thickness t, and a surface tension σ. Derive a formula for the pressure within the bubble relative to the outside atmospheric pressure. What is the pressure difference for a bubble with a 4 mm radius? Assume σ is the same as for pure water.

2.59 A water bug is suspended on the surface of a pond by surface tension (water does not wet the legs). The bug has six legs, and each leg is in contact with the water over a length of 5 mm. What is the maximum mass (in grams) of the bug if it is to avoid sinking?



PROBLEM 2.59

2.60 A water column in a glass tube is used to measure the pressure in a pipe. The tube is 6.35 mm (1/4 in.) in diameter. How much of the water column is due to surface-tension effects? What would be the surface-tension effects if the tube were 3.2 mm or 0.8 mm in diameter?