Problem available in *WileyPLUS* at instructor's discretion.

Tutoring problem available in *WileyPLUS* at instructor's discretion.

Problem is related to a chapter video available in *WileyPLUS*.

* Problem to be solved with aid of programmable calculator or computer.

† Open-ended problem that requires critical thinking. These problems require various assumptions to provide the necessary input data. There are not unique answers to these problems.

Review Problems

Go to Appendix G (*WileyPLUS* or the book's web site, www.wiley.com/college/munson) for a set of review problems with answers. Detailed solutions can be found in the *Student Solution Manual and Study Guide for Fundamentals of Fluid Mechanics*, by Munson et al. © 2013 John Wiley and Sons, Inc.).

Conceptual Questions

1.1C The correct statement for the definition of density is

a) Density is the mass per unit volume.

b) Density is the volume per unit mass.

c) Density is the weight per unit volume.

d) Density is the weight divided by gravity.

e) Density is the mass divided by the weight.

1.2C Given the following equation where p is pressure in lb/ft^2, γ is the specific weight in lb/ft^3, V is the magnitude of velocity in ft/s, g is in ft/s^2, and z is height in feet. If values are substituted into the equation, will the correct value of C be determined?

$$\frac{p}{\gamma} + \frac{V^2}{2g} + z = C$$

a) Yes if the constant C has units of ft.

b) Yes if the constant C is dimensionless.

c) No, the equation cannot produce the correct value of C.

d) Yes if the constant C has units of ft and the specific weight is multiplied by the conversion factor from lbm to lbf.

1.3C The no-slip condition is:

a) An experimental observation that the velocity of a fluid in contact with a solid surface is equal to the velocity of the surface.

b) Valid only for liquids.

c) Useful only for very low density gases.

d) Indicates that two solids in contact will not slip if the joining force is large.

1.4C In fluids, the shearing strain rate $\dfrac{du}{dy}$ for a Newtonian fluid has dimensions of:

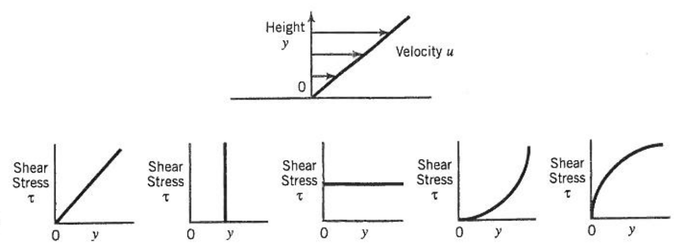
a) L/T^2.

b) 1/T.

c) L^2/T.

d) L^2/T^2.

1.5C The laminar velocity profile for a Newtonian fluid is shown below.



Which figure best describes the variation of shear stress with distance from the plate?

Additional conceptual questions are available in *WileyPLUS* at the instructor's discretion.

Problems

Note: Unless specific values of required fluid properties are given in the problem statement, use the values found in the tables on the inside of the front cover. Answers to the even-numbered problems are listed at the end of the book. The Lab Problems as well as the videos that accompany problems can be accessed in WileyPLUS or the book's web site, www.wiley.com/college/munson.

Section 1.2 Dimensions, Dimensional Homogeneity, and Units

1.1 The force, F, of the wind blowing against a building is given by $F = C_D \rho V^2 A/2$, where V is the wind speed, ρ the density of the air, A the cross-sectional area of the building, and C_D is a constant termed the drag coefficient. Determine the dimensions of the drag coefficient.

1.2 Determine the dimensions, in both the *FLT* system and the *MLT* system, for **(a)** the product of mass times velocity, **(b)** the product of force times volume, and **(c)** kinetic energy divided by area.

1.3 Verify the dimensions, in both the *FLT* and *MLT* systems, of the following quantities which appear in Table 1.1: **(a)** volume, **(b)** acceleration, **(c)** mass, **(d)** moment of inertia (area), and **(e)** work.

1.4 Determine the dimensions, in both the *FLT* system and the *MLT* system, for **(a)** the product of force times acceleration, **(b)** the product of force times velocity divided by area, and **(c)** momentum divided by volume.

1.5 Verify the dimensions, in both the *FLT* and *MLT* systems, of the following quantities which appear in Table 1.1: **(a)** angular velocity, **(b)** energy, **(c)** moment of inertia (area), **(d)** power, and **(e)** pressure.

1.6 Verify the dimensions, in both the *FLT* system and the *MLT* system, of the following quantities which appear in Table 1.1: **(a)** frequency, **(b)** stress, **(c)** strain, **(d)** torque, and **(e)** work.

1.7 If u is a velocity, x a length, and t a time, what are the dimensions (in the *MLT* system) of **(a)** $\partial u/\partial t$, **(b)** $\partial^2 u/\partial x \partial t$, and **(c)** $\int (\partial u/\partial t)\, dx$?

1.8 Verify the dimensions, in both the *FLT* system and the *MLT* system, of the following quantities which appear in Table 1.1: **(a)** acceleration, **(b)** stress, **(c)** moment of a force, **(d)** volume, and **(e)** work.

1.9 If p is a pressure, V a velocity, and ρ a fluid density, what are the dimensions (in the *MLT* system) of **(a)** p/ρ, **(b)** $pV\rho$, and **(c)** $p/\rho V^2$?

1.10 If P is a force and x a length, what are the dimensions (in the *FLT* system) of **(a)** dP/dx, **(b)** d^3P/dx^3, and **(c)** $\int P\, dx$?

1.11 WILEY If V is a velocity, ℓ a length, and ν a fluid property (the kinematic viscosity) having dimensions of L^2T^{-1}, which of the following combinations are dimensionless: **(a)** $V\ell\nu$, **(b)** $V\ell/\nu$, **(c)** $V^2\nu$, **(d)** $V/\ell\nu$?

1.12 If V is a velocity, determine the dimensions of Z, α, and G, which appear in the dimensionally homogeneous equation

$$V = Z(\alpha - 1) + G$$

1.13 The volume rate of flow, Q, through a pipe containing a slowly moving liquid is given by the equation

$$Q = \frac{\pi R^4 \Delta p}{8 \mu \ell}$$

where R is the pipe radius, Δp the pressure drop along the pipe, μ a fluid property called viscosity ($FL^{-2}T$), and ℓ the length of pipe. What are the dimensions of the constant $\pi/8$? Would you classify this equation as a general homogeneous equation? Explain.

1.14 According to information found in an old hydraulics book, the energy loss per unit weight of fluid flowing through a nozzle connected to a hose can be estimated by the formula

$$h = (0.04 \text{ to } 0.09)(D/d)^4 V^2/2g$$

where h is the energy loss per unit weight, D the hose diameter, d the nozzle tip diameter, V the fluid velocity in the hose, and g the acceleration of gravity. Do you think this equation is valid in any system of units? Explain.

1.15 WILEY The pressure difference, Δp, across a partial blockage in an artery (called a *stenosis*) is approximated by the equation

$$\Delta p = K_v \frac{\mu V}{D} + K_u \left(\frac{A_0}{A_1} - 1\right)^2 \rho V^2$$

where V is the blood velocity, μ the blood viscosity ($FL^{-2}T$), ρ the blood density (ML^{-3}), D the artery diameter, A_0 the area of the unobstructed artery, and A_1 the area of the stenosis. Determine the dimensions of the constants K_v and K_u. Would this equation be valid in any system of units?

1.16 Assume that the speed of sound, c, in a fluid depends on an elastic modulus, E_v, with dimensions FL^{-2}, and the fluid density, ρ, in the form $c = (E_v)^a(\rho)^b$. If this is to be a dimensionally homogeneous equation, what are the values for a and b? Is your result consistent with the standard formula for the speed of sound? (See Eq. 1.19.)

1.17 WILEY A formula to estimate the volume rate of flow, Q, flowing over a dam of length, B, is given by the equation

$$Q = 3.09\, BH^{3/2}$$

where H is the depth of the water above the top of the dam (called the head). This formula gives Q in ft^3/s when B and H are in feet. Is the constant, 3.09, dimensionless? Would this equation be valid if units other than feet and seconds were used?

1.18 The force, P, that is exerted on a spherical particle moving slowly through a liquid is given by the equation

$$P = 3\pi\mu DV$$

where μ is a fluid property (viscosity) having dimensions of $FL^{-2}T$, D is the particle diameter, and V is the particle velocity. What are the dimensions of the constant, 3π? Would you classify this equation as a general homogeneous equation?

†1.19 Cite an example of a restricted homogeneous equation contained in a technical article found in an engineering journal in your field of interest. Define all terms in the equation, explain why it is a restricted equation, and provide a complete journal citation (title, date, etc.).

1.20 WILEY Make use of Table 1.3 to express the following quantities in SI units: **(a)** 10.2 in./min, **(b)** 4.81 slugs, **(c)** 3.02 lb, **(d)** 73.1 ft/s^2, **(e)** 0.0234 $lb \cdot s/ft^2$.

1.21 WILEY Make use of Table 1.4 to express the following quantities in BG units: **(a)** 14.2 km, **(b)** 8.14 N/m^3, **(c)** 1.61 kg/m^3, **(d)** 0.0320 $N \cdot m/s$, **(e)** 5.67 mm/hr.

1.22 WILEY Express the following quantities in SI units: **(a)** 160 acres, **(b)** 15 gallons (U.S.), **(c)** 240 miles, **(d)** 79.1 hp, **(e)** 60.3 °F.

1.23 For Table 1.3 verify the conversion relationships for: **(a)** area, **(b)** density, **(c)** velocity, and **(d)** specific weight. Use the basic conversion relationships: 1 ft = 0.3048 m; 1 lb = 4.4482 N; and 1 slug = 14.594 kg.

1.24 For Table 1.4 verify the conversion relationships for: **(a)** acceleration, **(b)** density, **(c)** pressure, and **(d)** volume flowrate. Use the basic conversion relationships: 1 m = 3.2808 ft; 1N = 0.22481 lb; and 1 kg = 0.068521 slug.

1.25 WILEY Water flows from a large drainage pipe at a rate of 1200 gal/min. What is this volume rate of flow in **(a)** m^3/s, **(b)** liters/min, and **(c)** ft^3/s?

1.26 Dimensionless combinations of quantities (commonly called dimensionless parameters) play an important role in fluid mechanics. Make up five possible dimensionless parameters by using combinations of some of the quantities listed in Table 1.1.

1.27 WILEY GO An important dimensionless parameter in certain types of fluid flow problems is the *Froude number* defined as $V/\sqrt{g\ell}$, where V is a velocity, g the acceleration of gravity, and ℓ a length. Determine the value of the Froude number for V = 10 ft/s, g = 32.2 ft/s^2, and ℓ = 2 ft. Recalculate the Froude number using SI units for V, g, and ℓ. Explain the significance of the results of these calculations.

Section 1.4 Measures of Fluid Mass and Weight

1.28 Obtain a photograph/image of a situation in which the density or specific weight of a fluid is important. Print this photo and write a brief paragraph that describes the situation involved.

1.29 A tank contains 500 kg of a liquid whose specific gravity is 2. Determine the volume of the liquid in the tank.

1.30 WILEY Clouds can weigh thousands of pounds due to their liquid water content. Often this content is measured in grams per cubic meter (g/m^3). Assume that a cumulus cloud occupies a volume of one cubic kilometer, and its liquid water content is 0.2 g/m^3. **(a)** What is the volume of this cloud in cubic miles? **(b)** How much does the water in the cloud weigh in pounds?

1.31 A tank of oil has a mass of 25 slugs. **(a)** Determine its weight in pounds and in newtons at the Earth's surface. **(b)** What would be its mass (in slugs) and its weight (in pounds) if located on the moon's surface where the gravitational attraction is approximately one-sixth that at the Earth's surface?

1.32 A certain object weighs 300 N at the Earth's surface. Determine the mass of the object (in kilograms) and its weight (in newtons) when located on a planet with an acceleration of gravity equal to 4.0 ft/s^2.

1.33 The density of a certain type of jet fuel is 775 kg/m^3. Determine its specific gravity and specific weight.

1.34 A *hydrometer* is used to measure the specific gravity of liquids. (See **Video V2.8**.) For a certain liquid, a hydrometer reading indicates a specific gravity of 1.15. What is the liquid's density and specific weight? Express your answer in SI units.

1.35 The specific weight of a certain liquid is 85.3 lb/ft^3. Determine its density and specific gravity.

1.36 An open, rigid-walled, cylindrical tank contains 4 ft^3 of water at 40 °F. Over a 24-hour period of time the water temperature varies from 40 to 90 °F. Make use of the data in Appendix B to determine how much the volume of water will change. For a tank diameter of 2 ft, would the corresponding change in water depth be very noticeable? Explain.

†1.37 Estimate the number of pounds of mercury it would take to fill your bathtub. List all assumptions and show all calculations.

1.38 A mountain climber's oxygen tank contains 1 lb of oxygen when he begins his trip at sea level where the acceleration of gravity is 32.174 ft/s^2. What is the weight of the oxygen in the tank when he reaches the top of Mt. Everest where the acceleration of gravity is 32.082 ft/s^2? Assume that no oxygen has been removed from the tank; it will be used on the descent portion of the climb.

1.39 GO The information on a can of pop indicates that the can contains 355 mL. The mass of a full can of pop is 0.369 kg, while an empty can weighs 0.153 N. Determine the specific weight, density, and specific gravity of the pop and compare your results with the corresponding values for water at 20 °C. Express your results in SI units.

*1.40 The variation in the density of water, ρ, with temperature, T, in the range 20 °C $\leq T \leq$ 50 °C, is given in the following table.

Density (kg/m^3)	998.2	997.1	995.7	994.1	992.2	990.2	988.1
Temperature (°C)	20	25	30	35	40	45	50

Use these data to determine an empirical equation of the form $\rho = c_1 + c_2T + c_3T^2$ which can be used to predict the density over the range indicated. Compare the predicted values with the data given. What is the density of water at 42.1 °C?

1.41 If 1 cup of cream having a density of 1005 kg/m^3 is turned into 3 cups of whipped cream, determine the specific gravity and specific weight of the whipped cream.

1.42 A liquid when poured into a graduated cylinder is found to weigh 8 N when occupying a volume of 500 ml (milliliters). Determine its specific weight, density, and specific gravity.

†1.43 The presence of raindrops in the air during a heavy rainstorm increases the average density of the air–water mixture. Estimate by what percent the average air–water density is greater than that of just still air. State all assumptions and show calculations.

Section 1.5 Ideal Gas Law

1.44 Determine the mass of air in a 2 m^3 tank if the air is at room temperature, 20 °C, and the absolute pressure within the tank is 200 kPa (abs).

1.45 Nitrogen is compressed to a density of 4 kg/m^3 under an absolute pressure of 400 kPa. Determine the temperature in degrees Celsius.

1.46 The temperature and pressure at the surface of Mars during a Martian spring day were determined to be −50 °C and 900 Pa, respectively. **(a)** Determine the density of the Martian atmosphere for these conditions if the gas constant for the Martian atmosphere is assumed to be equivalent to that of carbon dioxide. **(b)** Compare the answer from part (a) with the density of the Earth's atmosphere during a spring day when the temperature is 18 °C and the pressure 101.6 kPa (abs).

1.47 A closed tank having a volume of 2 ft^3 is filled with 0.30 lb of a gas. A pressure gage attached to the tank reads 12 psi when the gas temperature is 80 °F. There is some question as to whether the gas in the tank is oxygen or helium. Which do you think it is? Explain how you arrived at your answer.

1.48 A tire having a volume of 3 ft^3 contains air at a gage pressure of 26 psi and a temperature of 70 °F. Determine the density of the air and the weight of the air contained in the tire.

1.49 A compressed air tank contains 5 kg of air at a temperature of 80 °C. A gage on the tank reads 300 kPa. Determine the volume of the tank.

1.50 A rigid tank contains air at a pressure of 90 psia and a temperature of 60 °F. By how much will the pressure increase as the temperature is increased to 110 °F?

1.51 The density of oxygen contained in a tank is 2.0 kg/m^3 when the temperature is 25 °C. Determine the gage pressure of the gas if the atmospheric pressure is 97 kPa.

1.52 The helium-filled blimp shown in Fig. P1.52 is used at various athletic events. Determine the number of pounds of helium within it if its volume is 68,000 ft^3 and the temperature and pressure are 80 °F and 14.2 psia, respectively.

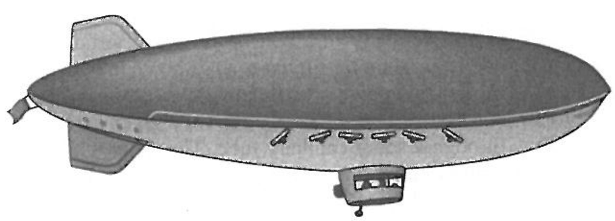


Figure P1.52

*1.53 Develop a computer program for calculating the density of an ideal gas when the gas pressure in pascals (abs), the temperature in degrees Celsius, and the gas constant in J/kg · K are specified. Plot the density of helium as a function of temperature from 0 °C to 200 °C and pressures of 50, 100, 150, and 200 kPa (abs).

Section 1.6 Viscosity (also see Lab Problems 1.1LP and 1.2LP)

1.54 Obtain a photograph/image of a situation in which the viscosity of a fluid is important. Print this photo and write a brief paragraph that describes the situation involved.

liquid of interest, the viscosity is given by Andrade's equation (Eq. 1.11) with $D = 5 \times 10^{-7}$ lb · s/ft^2 and $B = 4000$ °R. By what percentage will the velocity increase as the liquid temperature is increased from 40 °F to 100 °F? Assume all other factors remain constant.

***1.72** Use the value of the viscosity of water given in Table B.2 at temperatures of 0, 20, 40, 60, 80, and 100 °C to determine the constants D and B which appear in Andrade's equation (Eq. 1.11). Calculate the value of the viscosity at 50 °C and compare with the value given in Table B.2. (*Hint:* Rewrite the equation in the form

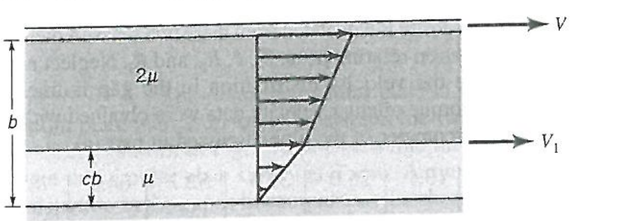
$$\ln \mu = (B)\frac{1}{T} + \ln D$$

and plot ln μ versus $1/T$. From the slope and intercept of this curve, B and D can be obtained. If a nonlinear curve-fitting program is available, the constants can be obtained directly from Eq. 1.11 without rewriting the equation.)

1.73 For a certain liquid $\mu = 7.1 \times 10^{-5}$ lb · s/ft^2 at 40 °F and $\mu = 1.9 \times 10^{-5}$ lb · s/ft^2 at 150 °F. Make use of these data to determine the constants D and B which appear in Andrade's equation (Eq. 1.11). What would be the viscosity at 80 °F?

1.74 WILEY GO For a parallel plate arrangement of the type shown in Fig. 1.5 it is found that when the distance between plates is 2 mm, a shearing stress of 150 Pa develops at the upper plate when it is pulled at a velocity of 1 m/s. Determine the viscosity of the fluid between the plates. Express your answer in SI units.

1.75 Two flat plates are oriented parallel above a fixed lower plate as shown in Fig. P1.75. The top plate, located a distance b above the fixed plate, is pulled along with speed V. The other thin plate is located a distance cb, where $0 < c < 1$, above the fixed plate. This plate moves with speed V_1, which is determined by the viscous shear forces imposed on it by the fluids on its top and bottom. The fluid on the top is twice as viscous as that on the bottom. Plot the ratio V_1/V as a function of c for $0 < c < 1$.

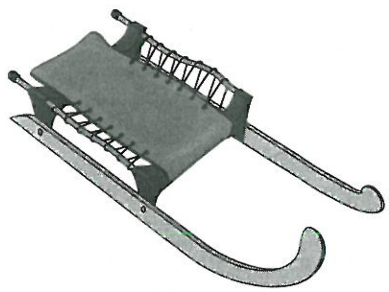


■ **Figure P1.75**

1.76 There are many fluids that exhibit non-Newtonian behavior (see, for example, **Video V1.6**). For a given fluid the distinction between Newtonian and non-Newtonian behavior is usually based on measurements of shear stress and rate of shearing strain. Assume that the viscosity of blood is to be determined by measurements of shear stress, τ, and rate of shearing strain, du/dy, obtained from a small blood sample tested in a suitable viscometer. Based on the data given below, determine if the blood is a Newtonian or non-Newtonian fluid. Explain how you arrived at your answer.

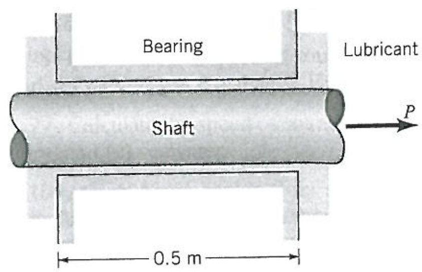
τ(N/m^2)	0.04	0.06	0.12	0.18	0.30	0.52	1.12	2.10
du/dy (s^{-1})	2.25	4.50	11.25	22.5	45.0	90.0	225	450

1.77 WILEY The sled shown in Fig. P1.77 slides along on a thin horizontal layer of water between the ice and the runners. The horizontal force that the water puts on the runners is equal to 1.2 lb when the sled's speed is 50 ft/s. The total area of both runners in contact with the water is 0.08 ft^2, and the viscosity of the water is 3.5×10^{-5} lb · s/ft^2. Determine the thickness of the water layer under the runners. Assume a linear velocity distribution in the water layer.



■ **Figure P1.77**

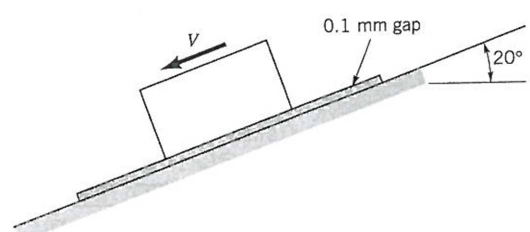
1.78 WILEY A 25-mm-diameter shaft is pulled through a cylindrical bearing as shown in Fig. P1.78. The lubricant that fills the 0.3-mm gap between the shaft and bearing is an oil having a kinematic viscosity of 8.0×10^{-4} m^2/s and a specific gravity of 0.91. Determine the force P required to pull the shaft at a velocity of 3 m/s. Assume the velocity distribution in the gap is linear.



■ **Figure P1.78**

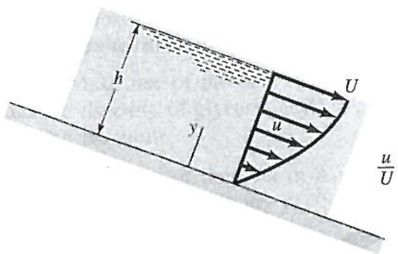
1.79 A piston having a diameter of 5.48 in. and a length of 9.50 in. slides downward with a velocity V through a vertical pipe. The downward motion is resisted by an oil film between the piston and the pipe wall. The film thickness is 0.002 in., and the cylinder weighs 0.5 lb. Estimate V if the oil viscosity is 0.016 lb · s/ft^2. Assume the velocity distribution in the gap is linear.

1.80 WILEY A 10-kg block slides down a smooth inclined surface as shown in Fig. P1.80. Determine the terminal velocity of the block if the 0.1-mm gap between the block and the surface contains SAE 30 oil at 60 °F. Assume the velocity distribution in the gap is linear, and the area of the block in contact with the oil is 0.1 m^2.



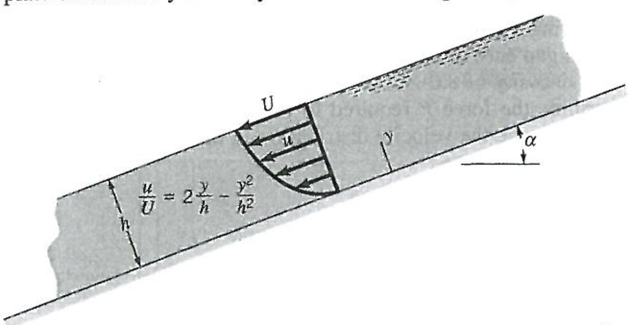
■ **Figure P1.80**

1.81 WILEY A layer of water flows down an inclined fixed surface with the velocity profile shown in Fig. P1.81. Determine the magnitude and direction of the shearing stress that the water exerts on the fixed surface for $U = 2$ m/s and $h = 0.1$ m.



■ **Figure P1.81**

1.82 A thin layer of glycerin flows down an inclined, wide plate with the velocity distribution shown in Fig. P1.82. For $h = 0.3$ in. and $\alpha = 20°$, determine the surface velocity, U. Note that for equilibrium, the component of weight acting parallel to the plate surface must be balanced by the shearing force developed along the plate surface. In your analysis assume a unit plate width.



■ **Figure P1.82**

***1.83** Standard air flows past a flat surface, and velocity measurements near the surface indicate the following distribution:

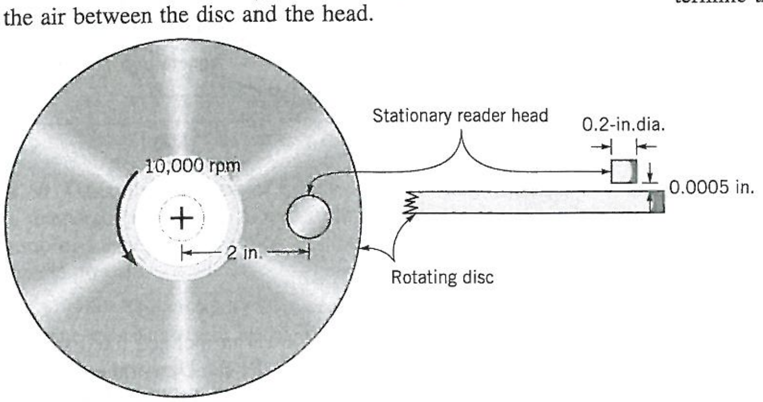
y (ft)	0.005	0.01	0.02	0.04	0.06	0.08
u (ft/s)	0.74	1.51	3.03	6.37	10.21	14.43

The coordinate y is measured normal to the surface and u is the velocity parallel to the surface. **(a)** Assume the velocity distribution is of the form

$$u = C_1 y + C_2 y^3$$

and use a standard curve-fitting technique to determine the constants C_1 and C_2. **(b)** Make use of the results of part (a) to determine the magnitude of the shearing stress at the wall ($y = 0$) and at $y = 0.05$ ft.

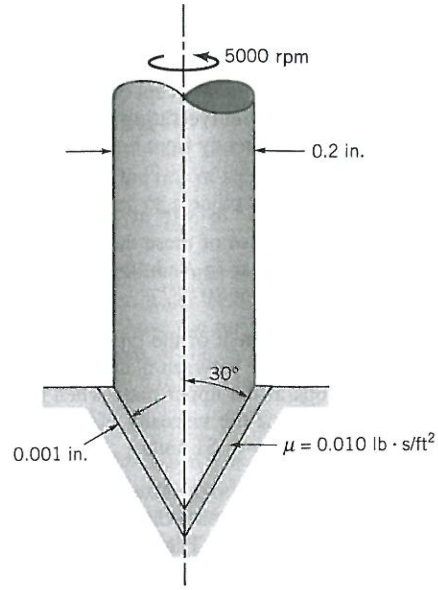
1.84 A new computer drive is proposed to have a disc, as shown in Fig. P1.84. The disc is to rotate at 10,000 rpm, and the reader head is to be positioned 0.0005 in. above the surface of the disc. Estimate the shearing force on the reader head as a result of the air between the disc and the head.



■ **Figure P1.84**

1.85 The space between two 6-in.-long concentric cylinders is filled with glycerin (viscosity $= 8.5 \times 10^{-3}$ lb · s/ft^2). The inner cylinder has a radius of 3 in. and the gap width between cylinders is 0.1 in. Determine the torque and the power required to rotate the inner cylinder at 180 rev/min. The outer cylinder is fixed. Assume the velocity distribution in the gap to be linear.

1.86 A pivot bearing used on the shaft of an electrical instrument is shown in Fig. P1.86. An oil with a viscosity of $\mu = 0.010$ lb · s/ft^2 fills the 0.001-in. gap between the rotating shaft and the stationary base. Determine the frictional torque on the shaft when it rotates at 5000 rpm.

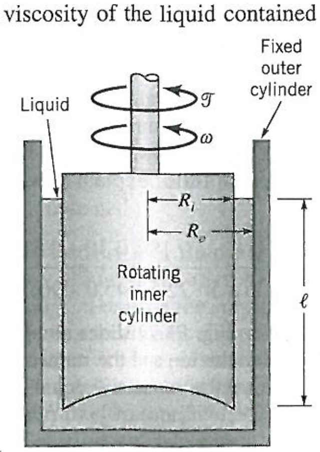


■ **Figure P1.86**

1.87 The viscosity of liquids can be measured through the use of a *rotating cylinder viscometer* of the type illustrated in Fig. P1.87. In this device the outer cylinder is fixed and the inner cylinder is rotated with an angular velocity, ω. The torque $\mathcal{T}$ required to develop ω is measured and the viscosity is calculated from these two measurements. **(a)** Develop an equation relating μ, ω, $\mathcal{T}$, ℓ, R_o, and R_i. Neglect end effects and assume the velocity distribution in the gap is linear. **(b)** The following torque-angular velocity data were obtained with a rotating cylinder viscometer of the type discussed in part (a).

Torque (ft · lb)	13.1	26.0	39.5	52.7	64.9	78.6
Angular velocity (rad/s)	1.0	2.0	3.0	4.0	5.0	6.0

For this viscometer $R_o = 2.50$ in., $R_i = 2.45$ in., and $\ell = 5.00$ in. Make use of these data and a standard curve-fitting program to determine the viscosity of the liquid contained in the viscometer.



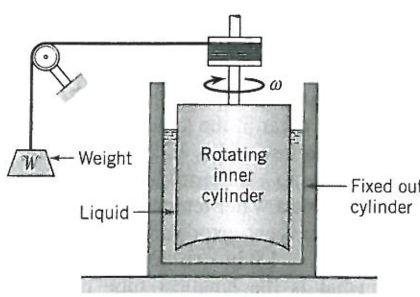
■ **Figure P1.87**

1.88 One type of rotating cylinder viscometer, called a *Stormer* viscometer, uses a falling weight, $\mathcal{W}$, to cause the cylinder to rotate with an angular velocity, ω, as illustrated in Fig. P1.88. For this device the viscosity, μ, of the liquid is related to $\mathcal{W}$ and ω through the equation $\mathcal{W} = K\mu\omega$, where K is a constant that depends only on the geometry (including the liquid depth) of the viscometer. The value of K is usually determined by using a calibration liquid (a liquid of known viscosity).
(a) Some data for a particular Stormer viscometer, obtained using glycerin at 20 °C as a calibration liquid, are given below. Plot values of the weight as ordinates and values of the angular velocity as abscissae. Draw the best curve through the plotted points and determine K for the viscometer.

$\mathcal{W}$(lb)	0.22	0.66	1.10	1.54	2.20
ω (rev/s)	0.53	1.59	2.79	3.83	5.49

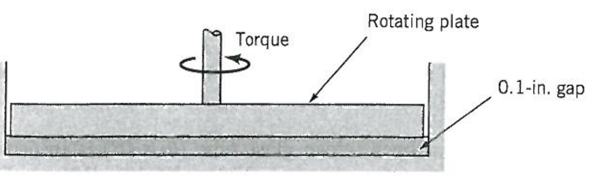
(b) A liquid of unknown viscosity is placed in the same viscometer used in part (a), and the data given below are obtained. Determine the viscosity of this liquid.

$\mathcal{W}$(lb)	0.04	0.11	0.22	0.33	0.44
ω (rev/s)	0.72	1.89	3.73	5.44	7.42



■ **Figure P1.88**

1.89 A 12-in.-diameter circular plate is placed over a fixed bottom plate with a 0.1-in. gap between the two plates filled with glycerin as shown in Fig. P1.89. Determine the torque required to rotate the circular plate slowly at 2 rpm. Assume that the velocity distribution in the gap is linear and that the shear stress on the edge of the rotating plate is negligible.



■ **Figure P1.89**

†1.90 Vehicle shock absorbers damp out oscillations caused by road roughness. Describe how a temperature change may affect the operation of a shock absorber.

1.91 Some measurements on a blood sample at 37 °C (98.6 °F) indicate a shearing stress of 0.52 N/m^2 for a corresponding rate of shearing strain of 200 s^{-1}. Determine the apparent viscosity of the blood and compare it with the viscosity of water at the same temperature.

Section 1.7 Compressibility of Fluids

1.92 Obtain a photograph/image of a situation in which the compressibility of a fluid is important. Print this photo and write a brief paragraph that describes the situation involved.

1.93 A sound wave is observed to travel through a liquid with a speed of 1500 m/s. The specific gravity of the liquid is 1.5. Determine the bulk modulus for this fluid.

1.94 A rigid-walled cubical container is completely filled with water at 40 °F and sealed. The water is then heated to 100 °F. Determine the pressure that develops in the container when the water reaches this higher temperature. Assume that the volume of the container remains constant and the value of the bulk modulus of the water remains constant and equal to 300,000 psi.

1.95 In a test to determine the bulk modulus of a liquid it was found that as the absolute pressure was changed from 15 to 3000 psi the volume decreased from 10.240 to 10.138 in.^{3} Determine the bulk modulus for this liquid.

1.96 Estimate the increase in pressure (in psi) required to decrease a unit volume of mercury by 0.1%.

1.97 A 1-m^3 volume of water is contained in a rigid container. Estimate the change in the volume of the water when a piston applies a pressure of 35 MPa.

1.98 Determine the speed of sound at 20 °C in **(a)** air, **(b)** helium, and **(c)** natural gas (methane). Express your answer in m/s.

1.99 Calculate the speed of sound in m/s for **(a)** gasoline, **(b)** mercury, and **(c)** seawater.

1.100 Air is enclosed by a rigid cylinder containing a piston. A pressure gage attached to the cylinder indicates an initial reading of 25 psi. Determine the reading on the gage when the piston has compressed the air to one-third its original volume. Assume the compression process to be isothermal and the local atmospheric pressure to be 14.7 psi.

1.101 Repeat Problem 1.100 if the compression process takes place without friction and without heat transfer (isentropic process).

1.102 Carbon dioxide at 30 °C and 300 kPa absolute pressure expands isothermally to an absolute pressure of 165 kPa. Determine the final density of the gas.

1.103 Oxygen at 30 °C and 300 kPa absolute pressure expands isothermally to an absolute pressure of 120 kPa. Determine the final density of the gas.

1.104 Natural gas at 70 °F and standard atmospheric pressure of 14.7 psi (abs) is compressed isentropically to a new absolute pressure of 70 psi. Determine the final density and temperature of the gas.

1.105 Compare the isentropic bulk modulus of air at 101 kPa (abs) with that of water at the same pressure.

*1.106 Develop a computer program for calculating the final gage pressure of gas when the initial gage pressure, initial and final volumes, atmospheric pressure, and the type of process (isothermal or isentropic) are specified. Use BG units. Check your program against the results obtained for Problem 1.100.

1.107 Often the assumption is made that the flow of a certain fluid can be considered as incompressible flow if the density of the fluid changes by less than 2%. If air is flowing through a tube such that the air pressure at one section is 9.0 psi and at a downstream section it is 8.6 psi at the same temperature, do you think that this flow could be considered an incompressible flow? Support your answer with the necessary calculations. Assume standard atmospheric pressure.