REFERENCES


INTERNET SITES

1. Hydraulic Institute (HI) www.pumps.org HI is a nonprofit association serving the pump industry. It provides product standards in North America and worldwide.

2. ASTM International www.astm.org ASTM establishes standards in a variety of fields, including fluid mechanics. Many ASTM standards are cited in this book for testing methods and fluid properties.

3. Flow Control Network www.flowcontrolnetwork.com The Web site for Flow Control Magazine is a source of information on fluid flow technology, applications of fluid mechanics, and products that measure, control, and contain liquids, gases, and powders. It also includes links to standards organizations important to the fluids industry.

4. GlobalSpec www.globalspec.com A searchable database of a wide variety of technical products, including pumps, flow control, and flow measurement.

PRACTICE PROBLEMS

Conversion Factors

1.1 Convert 1250 millimeters to meters.

1.2 Convert 1600 square millimeters to square meters.

1.3 Convert $3.65 \times 10^3$ cubic millimeters to cubic meters.

1.4 Convert 2.05 square meters to square millimeters.

1.5 Convert 0.391 cubic meters to cubic millimeters.

1.6 Convert 55.0 gallons to cubic meters.

1.7 An automobile is moving at 80 kilometers per hour. Calculate its speed in meters per second.

1.8 Convert a length of 25.3 feet to meters.

1.9 Convert a distance of 1.86 miles to meters.

1.10 Convert a length of 8.65 inches to millimeters.

1.11 Convert a distance of 2580 feet to meters.

1.12 Convert a volume of 480 cubic feet to cubic meters.

1.13 Convert a volume of 7390 cubic centimeters to cubic meters.

1.14 Convert a volume of 6.35 liters to cubic meters.

1.15 Convert 6.0 feet per second to meters per second.

1.16 Convert 2500 cubic feet per minute to cubic meters per second.

(Note: In all Practice Problems sections in this book, the problems will use both SI and U.S. Customary System units. When SI units are used, "M" will follow the problem number and the problem will be printed in italic. When U.S. Customary System units are used, "E" will follow the problem number. When both systems of units are combined in a problem, "C" will follow the problem number.)
Consistent Units in an Equation

A body moving with constant velocity obeys the relationship \( s = vt \), where \( s = \text{distance} \), \( v = \text{velocity} \), and \( t = \text{time} \).

1.17M A car travels 0.50 km in 10.6 s. Calculate its average speed in m/s.

1.18M In an attempt at a land speed record, a car travels 1.50 km in 5.2 s. Calculate its average speed in km/h.

1.19E A car travels 1000 ft in 14 s. Calculate its average speed in ft/s.

1.20E In an attempt at a land speed record, a car travels 1 mi in 5.7 s. Calculate its average speed in mi/h.

A body starting from rest with constant acceleration moves according to the relationship \( s = \frac{1}{2}at^2 \), where \( s = \text{distance} \), \( a = \text{acceleration} \), and \( t = \text{time} \).

1.21M If a body moves 3.2 km in 4.7 min while moving with constant acceleration, calculate the acceleration in m/s².

1.22M An object is dropped from a height of 13 m. Neglecting air resistance, how long would it take for the body to strike the ground? Use \( a = g = 9.81 \text{ m/s}^2 \).

1.23C If a body moves 3.2 km in 4.7 min while moving with constant acceleration, calculate the acceleration in ft/s².

1.24E An object is dropped from a height of 53 in. Neglecting air resistance, how long would it take for the body to strike the ground? Use \( a = g = 32.2 \text{ ft/s}^2 \).

The formula for kinetic energy is \( KE = \frac{1}{2}mv^2 \), where \( m = \text{mass} \) and \( v = \text{velocity} \).

1.25M Calculate the kinetic energy in N·m of a 15-kg mass if it has a velocity of 1.20 m/s.

1.26M Calculate the kinetic energy in N·m of a 3600-kg truck moving at 16 km/h.

1.27M Calculate the kinetic energy in N·m of a 75-kg box moving on a conveyor at 6.85 m/s.

1.28M Calculate the mass of a body in kg if it has a kinetic energy of 38.6 N·m when moving at 31.5 km/h.

1.29M Calculate the mass of a body in kg if it has a kinetic energy of 94.6 N·m when moving at 2.25 m/s.

1.30M Calculate the velocity in m/s of a 12-kg object if it has a kinetic energy of 15 N·m.

1.31M Calculate the velocity in m/s of a 175-g body if it has a kinetic energy of 212 mN·m.

1.32E Calculate the kinetic energy in ft·lb of a 1-slug mass if it has a velocity of 4 ft/s.

1.33E Calculate the kinetic energy in ft·lb of an 8000-lb truck moving 10 mi/h.

1.34E Calculate the kinetic energy in ft·lb of a 150-lb box moving on a conveyor at 20 ft/s.

1.35E Calculate the mass of a body in slugs if it has a kinetic energy of 15 ft·lb when moving at 2.2 ft/s.

1.36E Calculate the weight of a body in lb if it has a kinetic energy of 38.6 ft·lb when moving at 19.5 mi/h.

1.37E Calculate the velocity in ft/s of a 30-lb object if it has a kinetic energy of 10 ft·lb.

1.38E Calculate the velocity in ft/s of a 6-oz body if it has a kinetic energy of 30 in·oz.

One measure of a baseball pitcher’s performance is earned run average, or ERA. It is the average number of earned runs allowed if all the innings pitched were converted to equivalent nine-inning games. Therefore, the units for ERA are runs per game.

1.39 If a pitcher has allowed 39 runs during 141 innings, calculate the ERA.

1.40 A pitcher has an ERA of 3.12 runs/game and has pitched 150 innings. How many earned runs has the pitcher allowed?

1.41 A pitcher has an ERA of 2.79 runs/game and has allowed 40 earned runs. How many innings have been pitched?

1.42 A pitcher has allowed 49 earned runs during 123 innings. Calculate the ERA.

The Definition of Pressure

1.43E Compute the pressure produced in the oil in a closed cylinder by a piston exerting a force of 2500 lb on the enclosed oil. The piston has a diameter of 3.00 in.

1.44E A hydraulic cylinder must be able to exert a force of 8700 lb. The piston has a diameter of 1.50 in. Compute the required pressure in the oil.

1.45M Compute the pressure produced in the oil in a closed cylinder by a piston exerting a force of 12.0 kN on the enclosed oil. The piston has a diameter of 75 mm.

1.46M A hydraulic cylinder must be able to exert a force of 38.8 kN. The piston diameter is 40 mm. Compute the required pressure in the oil.

1.47E The hydraulic lift for an automobile service garage has a cylinder with a diameter of 8.0 in. What pressure must the oil have to be able to lift 6000 lb?

1.48E A coining press is used to produce commemorative coins with the likenesses of all the U.S. presidents. The coining process requires a force of 18 000 lb. The hydraulic cylinder has a diameter of 2.50 in. Compute the required oil pressure.

1.49M The maximum pressure that can be developed for a certain fluid power cylinder is 20.5 MPa. Compute the force it can exert if its piston diameter is 50 mm.

1.50E The maximum pressure that can be developed for a certain fluid power cylinder is 6000 psi. Compute the force it can exert if its piston diameter is 2.00 in.
1.51E The maximum pressure that can be developed for a certain fluid power cylinder is 5000 psi. Compute the required diameter for the piston if the cylinder must exert a force of 20,000 lb.

1.52M The maximum pressure that can be developed for a certain fluid power cylinder is 15.0 MPa. Compute the required diameter for the piston if the cylinder must exert a force of 30 kN.

1.53E A line of fluid power cylinders has a range of diameters in 1.00-in increments from 1.00 to 8.00 in. Compute the force that could be exerted by each cylinder with a fluid pressure of 500 psi. Draw a graph of the force versus cylinder diameter.

1.54E A line of fluid power cylinders has a range of diameters in 1.00-in increments from 1.00 to 8.00 in. Compute the pressure required by each cylinder if it must exert a force of 5000 lb. Draw a graph of the pressure versus cylinder diameter.

1.55C Determine your weight in newtons. Then, compute the pressure in pascals that would be created on the oil in a 20-mm-diameter cylinder if you stood on a piston in the cylinder. Convert the resulting pressure to psi.

1.56C For the pressure you computed in Problem 1.55, compute the force in newtons that could be exerted on a piston with 250-mm diameter. Then, convert the resulting force to pounds.

**Bulk Modulus**

1.57C Compute the pressure change required to cause a decrease in the volume of ethyl alcohol by 1.00 percent. Express the result in both psi and MPa.

1.58C Compute the pressure change required to cause a decrease in the volume of mercury by 1.00 percent. Express the result in both psi and MPa.

1.59C Compute the pressure change required to cause a decrease in the volume of machine oil by 1.00 percent. Express the result in both psi and MPa.

1.60E For the conditions described in Problem 1.59, assume that the 1.00-percent volume change occurred in a cylinder with an inside diameter of 1.00 in and a length of 12.00 in. Compute the axial distance the piston would travel as the volume change occurs.

1.61E A certain hydraulic system operates at 3000 psi. Compute the percentage change in the volume of the oil in the system as the pressure is increased from zero to 3000 psi if the oil is similar to the machine oil listed in Table 1.4.

1.62E A certain hydraulic system operates at 20.0 MPa. Compute the percentage change in the volume of the oil in the system if the oil is similar to the machine oil listed in Table 1.4.

1.63E A measure of the stiffness of a linear actuator system is the amount of force required to cause a certain linear deflection. For an actuator that has an inside diameter of 0.50 in and a length of 42.0 in and that is filled with a machine oil, compute the stiffness in lb/1n.

1.64E Repeat Problem 1.63 but change the length of the cylinder to 10.0 in. Compare the results.

1.65E Repeat Problem 1.63 but change the cylinder diameter to 2.00 in. Compare the results.

1.66E Using the results of Problems 1.63–1.65, generate a statement about the general design approach to achieving a very stiff system.

**Force and Mass**

1.67M Calculate the mass of a can of oil if it weighs 610 N.

1.68M Calculate the mass of a tank of gasoline if it weighs 1.35 kN.

1.69M Calculate the weight of 1 m³ of kerosene if it has a mass of 825 kg.

1.70M Calculate the weight of a jar of castor oil if it has a mass of 450 g.

1.71E Calculate the mass of 1 gal of oil if it weighs 7.8 lb.

1.72E Calculate the mass of 1 ft³ of gasoline if it weighs 42.0 lb.

1.73E Calculate the weight of 1 ft³ of kerosene if it has a mass of 1.58 slugs.

1.74E Calculate the weight of 1 gal of water if it has a mass of 0.258 slug.

1.75C Assume that a man weighs 160 lb (force).

   a. Compute his mass in slugs.
   b. Compute his weight in N.
   c. Compute his mass in kg.

1.76C In the United States, hamburger and other meats are sold by the pound. Assuming that this is 1.00-lb force, compute the mass in slugs, the mass in kg, and the weight in N.

1.77M The metric ton is 1000 kg (mass). Compute the force in newtons required to lift it.

1.78C Convert the force found in Problem 1.77M to lb.

1.79C Determine your weight in lb and N and your mass in slugs and kg.

**Density, Specific Weight, and Specific Gravity**

1.80M The specific gravity of benzene is 0.876. Calculate its specific weight and its density in SI units.

1.81M Air at 16°C and standard atmospheric pressure has a specific weight of 12.02 N/m³. Calculate its density.

1.82M Carbon dioxide has a density of 1.964 kg/m³ at 0°C. Calculate its specific weight.
1.83M A certain medium lubricating oil has a specific weight of 8.860 kN/m³ at 5°C and 8.483 kN/m³ at 50°C. Calculate its specific gravity at each temperature.

1.84M At 100°C mercury has a specific weight of 130.4 kN/m³. What volume of the mercury would weigh 2.25 kN?

1.85M A cylindrical can 150 mm in diameter is filled to a depth of 100 mm with a fuel oil. The oil has a mass of 1.56 kg. Calculate its density, specific weight, and specific gravity.

1.86M Glycerine has a specific gravity of 1.258. How much would 0.50 m³ of glycerine weigh? What would be its mass?

1.87M The fuel tank of an automobile holds 0.095 m³. If it is full of gasoline having a specific gravity of 0.68, calculate the weight of the gasoline.

1.88M The density of muriatic acid is 1200 kg/m³. Calculate its specific weight and its specific gravity.

1.89M Liquid ammonia has a specific gravity of 0.826. Calculate the volume of ammonia that would weigh 22.0 N.

1.90M Vinegar has a density of 1080 kg/m³. Calculate its specific weight and its specific gravity.

1.91M Methyl alcohol has a specific gravity of 0.789. Calculate its density and its specific gravity.

1.92M A cylindrical container is 150 mm in diameter and weighs 2.25 N when empty. When filled to a depth of 200 mm with a certain oil, it weighs 35.4 N. Calculate the specific gravity of the oil.

1.93M A storage vessel for gasoline (sg = 0.68) is a vertical cylinder 10 m in diameter. If it is filled to a depth of 6.75 m, calculate the weight and mass of the gasoline.

1.94M What volume of mercury (sg = 13.54) would weigh the same as 0.020 m³ of castor oil, which has a specific weight of 9.42 kN/m³?

1.95M A rock has a specific gravity of 2.32 and a volume of 1.42 × 10⁻⁶ m³. How much does it weigh?

1.96E The specific gravity of benzene is 0.876. Calculate its specific weight and its density in U.S. Customary System units.

1.97E Air at 59°F and standard atmospheric pressure has a specific weight of 0.0765 lb/ft³. Calculate its density.

1.98E Carbon dioxide has a density of 0.003 81 slug/ft³ at 32°F. Calculate its specific weight.

1.99E A certain medium lubricating oil has a specific weight of 56.4 lb/ft³ at 40°F and 54.0 lb/ft³ at 120°F. Calculate its specific gravity at each temperature.

1.100E At 212°F mercury has a specific weight of 834 lb/ft³. What volume of the mercury would weigh 500 lb?

1.101E One gallon of a certain fuel oil weighs 7.50 lb. Calculate its specific weight, its density, and its specific gravity.

1.102E Glycerine has a specific gravity of 1.258. How much would 50 gal of glycerine weigh?

1.103E The fuel tank of an automobile holds 25.0 gal. If it is full of gasoline having a density of 1.32 slugs/ft³, calculate the weight of the gasoline.

1.104C The density of muriatic acid is 1.20 g/cm³. Calculate its density in slugs/ft³, its specific weight in lb/ft³, and its specific gravity. (Note that specific gravity and density in g/cm³ are numerically equal.)

1.105C Liquid ammonia has a specific gravity of 0.826. Calculate the volume in cm³ that would weigh 5.0 lb.

1.106C Vinegar has a density of 1.08 g/cm³. Calculate its specific weight in lb/ft³.

1.107C Alcohol has a specific gravity of 0.79. Calculate its density both in slugs/ft³ and g/cm³.

1.108E A cylindrical container has a 6.0-in. diameter and weighs 0.50 lb when empty. When filled to a depth of 8.0 in. with a certain oil, it weighs 7.95 lb. Calculate the specific gravity of the oil.

1.109E A storage vessel for gasoline (sg = 0.68) is a vertical cylinder 30 ft in diameter. If it is filled to a depth of 22 ft, calculate the number of gallons in the tank and the weight of the gasoline.

1.110E How many gallons of mercury (sg = 13.54) would weigh the same as 5 gal of castor oil, which has a specific weight of 59.69 lb/ft³?

1.111E A rock has a specific gravity of 2.32 and a volume of 8.64 in³. How much does it weigh?

**COMPUTER PROGRAMMING ASSIGNMENTS**

1. Write a program that computes the specific weight of water for a given temperature using the data from Appendix A. Such a program could be part of a more comprehensive program to be written later. The following options could be used:
   a. Enter the table data for specific weight as a function of temperature into an array. Then, for a specified temperature, search the array for the corresponding specific weight.
   b. Include data in both SI units and U.S. Customary System units.
   c. Include density.
   d. Include checks in the program to ensure that the specific temperature is within the range given in the tables (i.e., above the freezing point and below the boiling point).
3.36M The pressure at the bottom of a tank of propyl alcohol at 25°C must be maintained at 52.75 kPa(gage). What depth of alcohol should be maintained?

3.37E When you dive to a depth of 12.50 ft in seawater, what is the pressure?

3.38E A water storage tank is on the roof of a factory building and the surface of the water is 50.0 ft above the floor of the factory. If a pipe connects the storage tank to the floor level and the pipe is full of static water, what is the pressure in the pipe at floor level?

3.39M An open tank contains ethylene glycol at 25°C. Compute the pressure at a depth of 3.0 m.

3.40M For the tank of ethylene glycol described in Problem 3.39, compute the pressure at a depth of 12.0 m.

3.41E Figure 3.20 shows a diagram of the hydraulic system for a vehicle lift. An air compressor maintains pressure above the oil in the reservoir. What must the air pressure be if the pressure at point A must be at least 180 psig?

3.42E Figure 3.21 shows a clothes washing machine. The pump draws fluid from the tub and delivers it to the disposal sink. Compute the pressure at the inlet to the pump when the water is static (no flow). The soapy water solution has a specific gravity of 1.15.
3.43M An airplane is flying at 10.6 km altitude. In its nonpressurized cargo bay is a container of mercury 325 mm deep. The container is vented to the local atmosphere. What is the absolute pressure at the surface of the mercury and at the bottom of the container? Assume the conditions of the standard atmosphere prevail for pressure. Use $sg = 13.54$ for the mercury.

3.44E For the tank shown in Fig. 3.22, determine the reading of the bottom pressure gage in psig if the top of the tank is vented to the atmosphere and the depth of the oil $h$ is 28.50 ft.

3.45E For the tank shown in Fig. 3.22, determine the reading of the bottom pressure gage in psig if the top of the tank is sealed, the top gage reads 50.0 psig, and the depth of the oil $h$ is 28.50 ft.

3.46E For the tank shown in Fig. 3.22, determine the reading of the bottom pressure gage in psig if the top of the tank is sealed, the top gage reads $-10.8$ psig, and the depth of the oil $h$ is 6.25 ft.

3.47E For the tank shown in Fig. 3.22, determine the depth of the oil $h$ if the reading of the bottom pressure gage is 35.5 psig, the top of the tank is sealed, and the top gage reads 30.0 psig.

3.48M For the tank in Fig. 3.23, compute the depth of the oil if the depth of the water is 2.80 m and the gage at the bottom of the tank reads 52.3 kPa(gage).

3.49M For the tank in Fig. 3.23, compute the depth of the water if the depth of the oil is 6.90 m and the gage at the bottom of the tank reads 125.3 kPa(gage).

3.50M Figure 3.23 represents an oil storage drum that is open to the atmosphere at the top. Some water was accidentally pumped into the tank and settled to the bottom as shown in the figure. Calculate the depth of the water $h_w$ if the pressure gage at the bottom reads 158 kPa(gage). The total depth $h_T = 18.0$ m.

3.51M A storage tank for sulfuric acid is 1.5 m in diameter and 4.0 m high. If the acid has a specific gravity of 1.80, calculate the pressure at the bottom of the tank. The tank is open to the atmosphere at the top.

3.52E A storage drum for crude oil ($sg = 0.89$) is 32 ft deep and open at the top. Calculate the pressure at the bottom.

3.53M The greatest known depth in the ocean is approximately 11.0 km. Assuming that the specific weight of the water is constant at 10.0 kN/m$^3$, calculate the pressure at this depth.

3.54M Figure 3.24 shows a closed tank that contains gasoline floating on water. Calculate the air pressure above the gasoline.
3.55M Figure 3.25 shows a closed container holding water and oil. Air at 34 kPa below atmospheric pressure is above the oil. Calculate the pressure at the bottom of the container in kPa(gage).

3.56M Determine the pressure at the bottom of the tank in Fig. 3.26.

**Manometers**

3.57E Describe a simple U-tube manometer.
3.58E Describe a differential U-tube manometer.
3.59E Describe a well-type manometer.
3.60E Describe an inclined well-type manometer.
3.61E Describe a compound manometer.
3.62M Water is in the pipe shown in Fig. 3.27. Calculate the pressure at point A in kPa(gage).