

PROBLEMS*

Thermodynamics

1-1C What is the difference between the classical and the statistical approaches to thermodynamics?

1-2C Why does a bicyclist pick up speed on a downhill road even when he is not pedaling? Does this violate the conservation of energy principle?

1-3C An office worker claims that a cup of cold coffee on his table warmed up to 80°C by picking up energy from the surrounding air, which is at 25°C. Is there any truth to his claim? Does this process violate any thermodynamic laws?

Mass, Force, and Units

1-4C What is the difference between pound-mass and pound-force?

1-5C What is the difference between kg-mass and kg-force?

1-6C What is the net force acting on a car cruising at a constant velocity of 70 km/h (*a*) on a level road and (*b*) on an uphill road?

1-7 A 3-kg plastic tank that has a volume of 0.2 m³ is filled with liquid water. Assuming the density of water is 1000 kg/m³, determine the weight of the combined system.

1-8 Determine the mass and the weight of the air contained in a room whose dimensions are 6 m × 6 m × 8 m. Assume the density of the air is 1.16 kg/m³. *Answers: 334.1 kg, 3277 N*

1-9 At 45° latitude, the gravitational acceleration as a function of elevation *z* above sea level is given by $g = a - bz$, where $a = 9.807 \text{ m/s}^2$ and $b = 3.32 \times 10^{-6} \text{ s}^{-2}$. Determine the height above sea level where the weight of an object will decrease by 1 percent. *Answer: 29,539 m*

1-10E A 150-lbm astronaut took his bathroom scale (a spring scale) and a beam scale (compares masses) to the moon where the local gravity is $g = 5.48 \text{ ft/s}^2$. Determine how much he will weigh (*a*) on the spring scale and (*b*) on the beam scale. *Answers: (a) 25.5 lbf; (b) 150 lbf*

1-11 The acceleration of high-speed aircraft is sometimes expressed in *g*'s (in multiples of the standard acceleration of gravity). Determine the upward force, in N, that a 90-kg man would experience in an aircraft whose acceleration is 6 *g*'s.

*Problems designated by a "C" are concept questions, and students are encouraged to answer them all. Problems designated by an "E" are in English units, and the SI users can ignore them. Problems with the  icon are solved using EES, and complete solutions together with parametric studies are included on the enclosed DVD. Problems with the  icon are comprehensive in nature and are intended to be solved with a computer, preferably using the EES software that accompanies this text.

1-12  A 5-kg rock is thrown upward with a force of 150 N at a location where the local gravitational acceleration is 9.79 m/s². Determine the acceleration of the rock, in m/s².

1-13  Solve Prob. 1-12 using EES (or other) software. Print out the entire solution, including the numerical results with proper units.

1-14 The value of the gravitational acceleration *g* decreases with elevation from 9.807 m/s² at sea level to 9.767 m/s² at an altitude of 13,000 m, where large passenger planes cruise. Determine the percent reduction in the weight of an airplane cruising at 13,000 m relative to its weight at sea level.

Systems, Properties, State, and Processes

1-15C A large fraction of the thermal energy generated in the engine of a car is rejected to the air by the radiator through the circulating water. Should the radiator be analyzed as a closed system or as an open system? Explain.

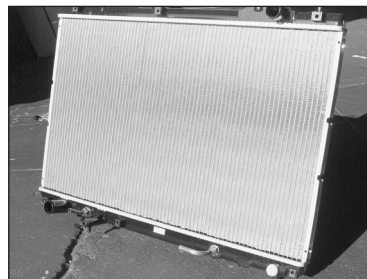


FIGURE P1-15C

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1-16C A can of soft drink at room temperature is put into the refrigerator so that it will cool. Would you model the can of soft drink as a closed system or as an open system? Explain.

1-17C What is the difference between intensive and extensive properties?

1-18C For a system to be in thermodynamic equilibrium, do the temperature and the pressure have to be the same everywhere?

1-19C What is a quasi-equilibrium process? What is its importance in engineering?

1-20C Define the isothermal, isobaric, and isochoric processes.

1-21C What is the state postulate?

1-22C Is the state of the air in an isolated room completely specified by the temperature and the pressure? Explain.

1-23C What is a steady-flow process?

1-24C What is specific gravity? How is it related to density?

1-25  The density of atmospheric air varies with elevation, decreasing with increasing altitude. (a) Using the data given in the table, obtain a relation for the variation of density with elevation, and calculate the density at an elevation of 7000 m. (b) Calculate the mass of the atmosphere using the correlation you obtained. Assume the earth to be a perfect sphere with a radius of 6377 km, and take the thickness of the atmosphere to be 25 km.

z , km	ρ , kg/m ³
6377	1.225
6378	1.112
6379	1.007
6380	0.9093
6381	0.8194
6382	0.7364
6383	0.6601
6385	0.5258
6387	0.4135
6392	0.1948
6397	0.08891
6402	0.04008

Temperature

1-26C What is the zeroth law of thermodynamics?

1-27C What are the ordinary and absolute temperature scales in the SI and the English system?

1-28C Consider an alcohol and a mercury thermometer that read exactly 0°C at the ice point and 100°C at the steam point. The distance between the two points is divided into 100 equal parts in both thermometers. Do you think these thermometers will give exactly the same reading at a temperature of, say, 60°C? Explain.

1-29 The deep body temperature of a healthy person is 37°C. What is it in kelvins?

1-30E Consider a system whose temperature is 18°C. Express this temperature in R, K, and °F.

1-31 The temperature of a system rises by 15°C during a heating process. Express this rise in temperature in kelvins.

1-32E The temperature of a system drops by 45°F during a cooling process. Express this drop in temperature in K, R, and °C.

1-33 Consider two closed systems A and B. System A contains 3000 kJ of thermal energy at 20°C, whereas system B contains 200 kJ of thermal energy at 50°C. Now the systems are brought into contact with each other. Determine the direction of any heat transfer between the two systems.

Pressure, Manometer, and Barometer

1-34C What is the difference between gage pressure and absolute pressure?

1-35C Explain why some people experience nose bleeding and some others experience shortness of breath at high elevations.

1-36C Someone claims that the absolute pressure in a liquid of constant density doubles when the depth is doubled. Do you agree? Explain.

1-37C A tiny steel cube is suspended in water by a string. If the lengths of the sides of the cube are very small, how would you compare the magnitudes of the pressures on the top, bottom, and side surfaces of the cube?

1-38C Express Pascal's law, and give a real-world example of it.

1-39C Consider two identical fans, one at sea level and the other on top of a high mountain, running at identical speeds. How would you compare (a) the volume flow rates and (b) the mass flow rates of these two fans?

1-40 A vacuum gage connected to a chamber reads 35 kPa at a location where the atmospheric pressure is 92 kPa. Determine the absolute pressure in the chamber.

1-41E A manometer is used to measure the air pressure in a tank. The fluid used has a specific gravity of 1.25, and the differential height between the two arms of the manometer is 28 in. If the local atmospheric pressure is 12.7 psia, determine the absolute pressure in the tank for the cases of the manometer arm with the (a) higher and (b) lower fluid level being attached to the tank.

1-42 The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in Fig. P1-42. Determine the gage pressure of air in the tank if

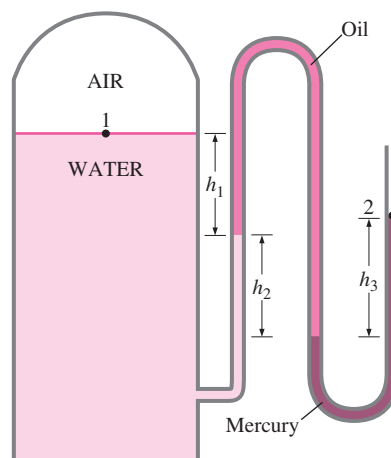


FIGURE P1-42

$h_1 = 0.2$ m, $h_2 = 0.3$ m, and $h_3 = 0.46$ m. Take the densities of water, oil, and mercury to be 1000 kg/m^3 , 850 kg/m^3 , and $13,600 \text{ kg/m}^3$, respectively.

1-43 Determine the atmospheric pressure at a location where the barometric reading is 750 mm Hg. Take the density of mercury to be $13,600 \text{ kg/m}^3$.

1-44 The gage pressure in a liquid at a depth of 3 m is read to be 28 kPa. Determine the gage pressure in the same liquid at a depth of 9 m.

1-45 The absolute pressure in water at a depth of 5 m is read to be 145 kPa. Determine (a) the local atmospheric pressure, and (b) the absolute pressure at a depth of 5 m in a liquid whose specific gravity is 0.85 at the same location.

1-46E Show that $1 \text{ kgf/cm}^2 = 14.223 \text{ psi}$.

1-47E A 200-pound man has a total foot imprint area of 72 in^2 . Determine the pressure this man exerts on the ground if (a) he stands on both feet and (b) he stands on one foot.

1-48 Consider a 70-kg woman who has a total foot imprint area of 400 cm^2 . She wishes to walk on the snow, but the snow cannot withstand pressures greater than 0.5 kPa. Determine the minimum size of the snowshoes needed (imprint area per shoe) to enable her to walk on the snow without sinking.

1-49 A vacuum gage connected to a tank reads 15 kPa at a location where the barometric reading is 750 mm Hg. Determine the absolute pressure in the tank. Take $\rho_{\text{Hg}} = 13,590 \text{ kg/m}^3$. **Answer:** 85.0 kPa

1-50E A pressure gage connected to a tank reads 50 psi at a location where the barometric reading is 29.1 mm Hg. Determine the absolute pressure in the tank. Take $\rho_{\text{Hg}} = 848.4 \text{ lbf/ft}^3$. **Answer:** 64.3 psia

1-51 A pressure gage connected to a tank reads 500 kPa at a location where the atmospheric pressure is 94 kPa. Determine the absolute pressure in the tank.

1-52 The barometer of a mountain hiker reads 930 mbars at the beginning of a hiking trip and 780 mbars at the end. Neglecting the effect of altitude on local gravitational acceleration, determine the vertical distance climbed. Assume an average air density of 1.20 kg/m^3 . **Answer:** 1274 m

1-53 The basic barometer can be used to measure the height of a building. If the barometric readings at the top and at the bottom of a building are 730 and 755 mm Hg, respectively, determine the height of the building. Take the densities of air and mercury to be 1.18 kg/m^3 and $13,600 \text{ kg/m}^3$, respectively.



FIGURE P1-53

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1-54  Solve Prob. 1-53 using EES (or other) software. Print out the entire solution, including the numerical results with proper units.

1-55 Determine the pressure exerted on a diver at 30 m below the free surface of the sea. Assume a barometric pressure of 101 kPa and a specific gravity of 1.03 for seawater. **Answer:** 404.0 kPa

1-56E Determine the pressure exerted on the surface of a submarine cruising 175 ft below the free surface of the sea. Assume that the barometric pressure is 14.7 psia and the specific gravity of seawater is 1.03.

1-57 A gas is contained in a vertical, frictionless piston-cylinder device. The piston has a mass of 4 kg and a cross-sectional area of 35 cm^2 . A compressed spring above the piston exerts a force of 60 N on the piston. If the atmospheric pressure is 95 kPa, determine the pressure inside the cylinder. **Answer:** 123.4 kPa

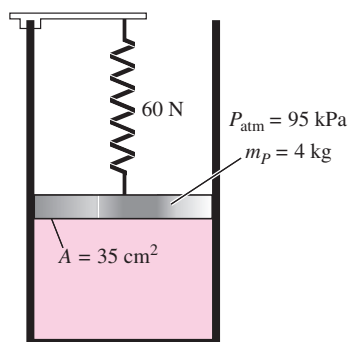


FIGURE P1-57

1-58  Reconsider Prob. 1-57. Using EES (or other) software, investigate the effect of the spring force in the range of 0 to 500 N on the pressure inside the cylinder. Plot the pressure against the spring force, and discuss the results.

1-59  Both a gage and a manometer are attached to a gas tank to measure its pressure. If the reading on the pressure gage is 80 kPa, determine the distance between the two fluid levels of the manometer if the fluid is (a) mercury ($\rho = 13,600 \text{ kg/m}^3$) or (b) water ($\rho = 1000 \text{ kg/m}^3$).

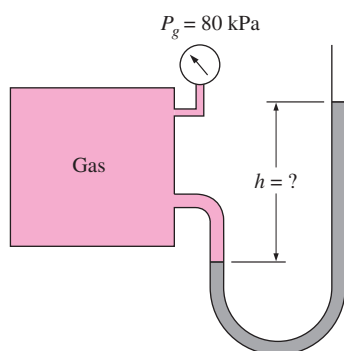


FIGURE P1-59

1-60  Reconsider Prob. 1-59. Using EES (or other) software, investigate the effect of the manometer fluid density in the range of 800 to 13,000 kg/m^3 on the differential fluid height of the manometer. Plot the differential fluid height against the density, and discuss the results.

1-61 A manometer containing oil ($\rho = 850 \text{ kg/m}^3$) is attached to a tank filled with air. If the oil-level difference between the two columns is 60 cm and the atmospheric pressure is 98 kPa, determine the absolute pressure of the air in the tank. **Answer:** 103 kPa

1-62 A mercury manometer ($\rho = 13,600 \text{ kg/m}^3$) is connected to an air duct to measure the pressure inside. The differ-

ence in the manometer levels is 15 mm, and the atmospheric pressure is 100 kPa. (a) Judging from Fig. P1-62, determine if the pressure in the duct is above or below the atmospheric pressure. (b) Determine the absolute pressure in the duct.

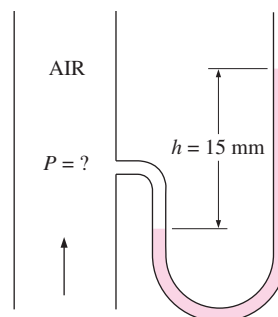


FIGURE P1-62

1-63 Repeat Prob. 1-62 for a differential mercury height of 45 mm.

1-64 Blood pressure is usually measured by wrapping a closed air-filled jacket equipped with a pressure gage around the upper arm of a person at the level of the heart. Using a mercury manometer and a stethoscope, the systolic pressure (the maximum pressure when the heart is pumping) and the diastolic pressure (the minimum pressure when the heart is resting) are measured in mm Hg. The systolic and diastolic pressures of a healthy person are about 120 mm Hg and 80 mm Hg, respectively, and are indicated as 120/80. Express both of these gage pressures in kPa, psi, and meter water column.

1-65 The maximum blood pressure in the upper arm of a healthy person is about 120 mm Hg. If a vertical tube open to the atmosphere is connected to the vein in the arm of the person, determine how high the blood will rise in the tube. Take the density of the blood to be 1050 kg/m^3 .

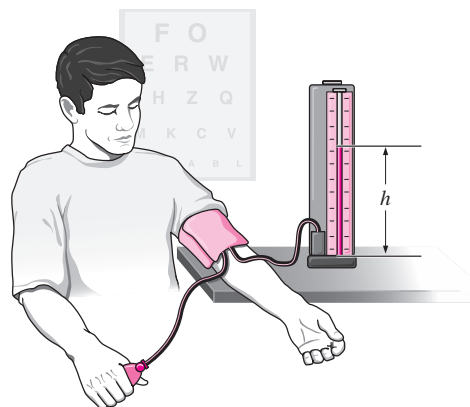


FIGURE P1-65

1-66 Consider a 1.8-m-tall man standing vertically in water and completely submerged in a pool. Determine the difference between the pressures acting at the head and at the toes of this man, in kPa.

1-67 Consider a U-tube whose arms are open to the atmosphere. Now water is poured into the U-tube from one arm, and light oil ($\rho = 790 \text{ kg/m}^3$) from the other. One arm contains 70-cm-high water, while the other arm contains both fluids with an oil-to-water height ratio of 4. Determine the height of each fluid in that arm.

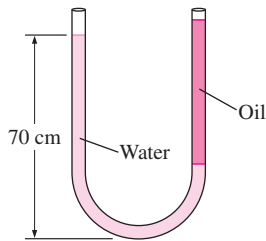


FIGURE P1-67

1-68 The hydraulic lift in a car repair shop has an output diameter of 30 cm and is to lift cars up to 2000 kg. Determine the fluid gage pressure that must be maintained in the reservoir.

1-69 Freshwater and seawater flowing in parallel horizontal pipelines are connected to each other by a double U-tube manometer, as shown in Fig. P1-69. Determine the pressure difference between the two pipelines. Take the density of seawater at that location to be $\rho = 1035 \text{ kg/m}^3$. Can the air column be ignored in the analysis?

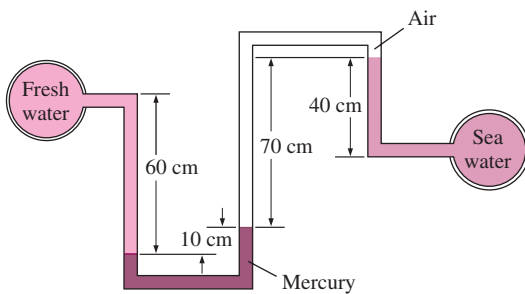


FIGURE P1-69

1-70 Repeat Prob. 1-69 by replacing the air with oil whose specific gravity is 0.72.

1-71E The pressure in a natural gas pipeline is measured by the manometer shown in Fig. P1-71E with one of the arms open to the atmosphere where the local atmospheric pressure is 14.2 psia. Determine the absolute pressure in the pipeline.

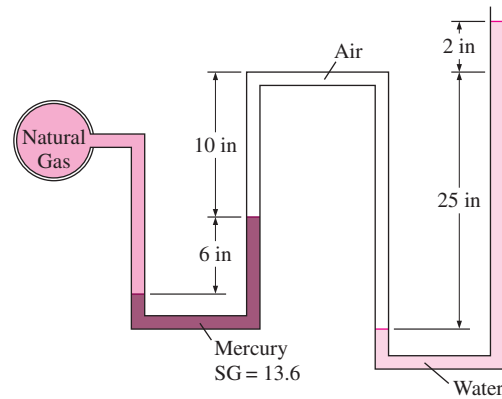


FIGURE P1-71E

1-72E Repeat Prob. 1-71E by replacing air by oil with a specific gravity of 0.69.

1-73 The gage pressure of the air in the tank shown in Fig. P1-73 is measured to be 80 kPa. Determine the differential height h of the mercury column.

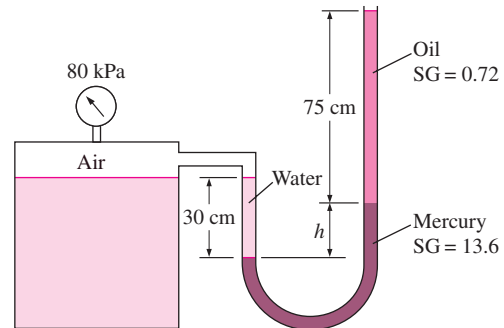


FIGURE P1-73

1-74 Repeat Prob. 1-73 for a gage pressure of 40 kPa.

1-75 The top part of a water tank is divided into two compartments, as shown in Fig. P1-75. Now a fluid with an

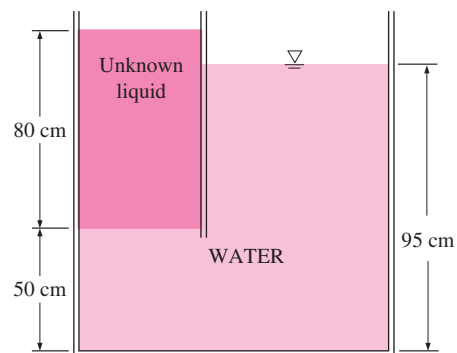


FIGURE P1-75

unknown density is poured into one side, and the water level rises a certain amount on the other side to compensate for this effect. Based on the final fluid heights shown on the figure, determine the density of the fluid added. Assume the liquid does not mix with water.

1-76 Consider a double-fluid manometer attached to an air pipe shown in Fig. P1-76. If the specific gravity of one fluid is 13.55, determine the specific gravity of the other fluid for the indicated absolute pressure of air. Take the atmospheric pressure to be 100 kPa. *Answer: 5.0*

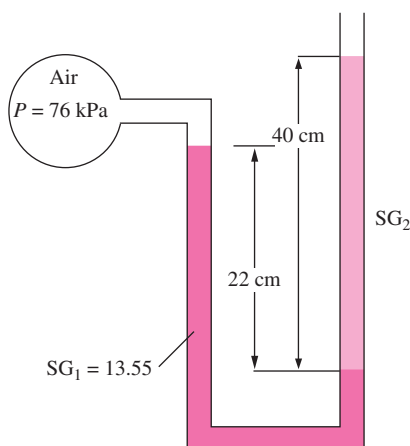


FIGURE P1-76

1-77 Consider the system shown in Fig. P1-77. If a change of 0.7 kPa in the pressure of air causes the brine–mercury interface in the right column to drop by 5 mm in the brine level in the right column while the pressure in the brine pipe remains constant, determine the ratio of A_2/A_1 .

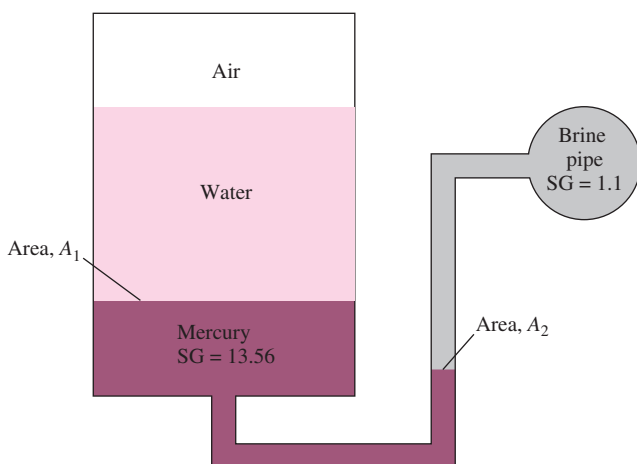


FIGURE P1-77

1-78 A multifluid container is connected to a U-tube, as shown in Fig. P1-78. For the given specific gravities and fluid column heights, determine the gage pressure at A. Also determine the height of a mercury column that would create the same pressure at A. *Answers: 0.471 kPa, 0.353 cm*

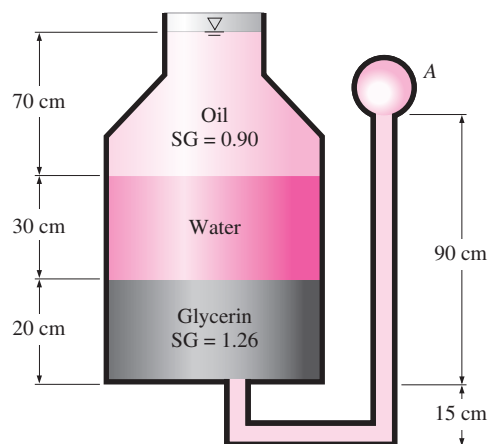


FIGURE P1-78

Solving Engineering Problems and EES

1-79C What is the value of the engineering software packages in (a) engineering education and (b) engineering practice?

1-80 Determine a positive real root of this equation using EES:

$$2x^3 - 10x^{0.5} - 3x = -3$$

1-81 Solve this system of two equations with two unknowns using EES:

$$x^3 - y^2 = 7.75$$

$$3xy + y = 3.5$$

1-82 Solve this system of three equations with three unknowns using EES:

$$2x - y + z = 5$$

$$3x^2 + 2y = z + 2$$

$$xy + 2z = 8$$

1-83 Solve this system of three equations with three unknowns using EES:

$$x^2y - z = 1$$

$$x - 3y^{0.5} + xz = -2$$

$$x + y - z = 2$$

1-84E  Specific heat is defined as the amount of energy needed to increase the temperature of a unit mass of a substance by one degree. The specific heat of water at room temperature is $4.18 \text{ kJ/kg} \cdot ^\circ\text{C}$ in SI unit system. Using the unit conversion function capability of EES, express the specific heat of water in (a) $\text{kJ/kg} \cdot \text{K}$, (b) $\text{Btu/lbm} \cdot \text{F}$, (c) $\text{Btu/lbm} \cdot \text{R}$, and (d) $\text{kCal/kg} \cdot ^\circ\text{C}$ units.

Answers: (a) 4.18, (b) (c) 0.9984

Review Problems

1-85 A hydraulic lift is to be used to lift a 2500 kg weight by putting a weight of 25 kg on a piston with a diameter of 10 cm. Determine the diameter of the piston on which the weight is to be placed.

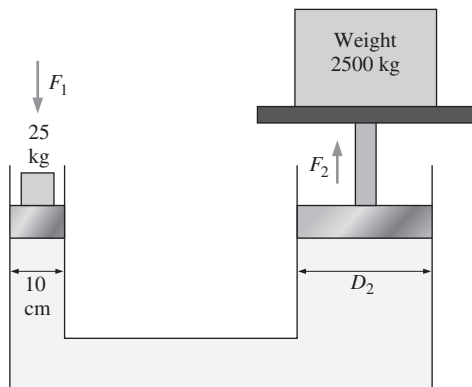


FIGURE P1-85

1-86 A vertical piston–cylinder device contains a gas at a pressure of 100 kPa. The piston has a mass of 5 kg and a diameter of 12 cm. Pressure of the gas is to be increased by placing some weights on the piston. Determine the local atmospheric pressure and the mass of the weights that will double the pressure of the gas inside the cylinder. Answers: 95.7 kPa, 115.3 kg

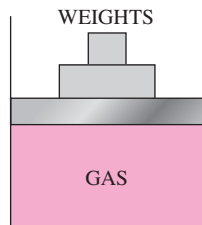


FIGURE P1-86

1-87 The pilot of an airplane reads the altitude 3000 m and the absolute pressure 58 kPa when flying over a city. Calculate the local atmospheric pressure in that city in kPa and in mm Hg. Take the densities of air and mercury to be 1.15 kg/m^3 and $13,600 \text{ kg/m}^3$, respectively.

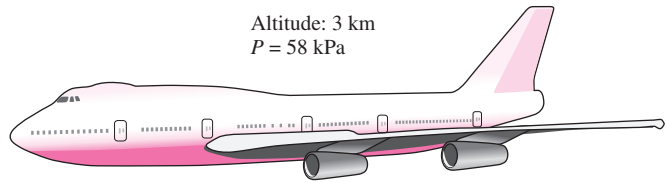


FIGURE P1-87

1-88 The weight of bodies may change somewhat from one location to another as a result of the variation of the gravitational acceleration g with elevation. Accounting for this variation using the relation in Prob. 1-9, determine the weight of an 80-kg person at sea level ($z = 0$), in Denver ($z = 1610 \text{ m}$), and on the top of Mount Everest ($z = 8848 \text{ m}$).

1-89 A man goes to a traditional market to buy a steak for dinner. He finds a 12-oz steak ($1 \text{ lbm} = 16 \text{ oz}$) for \$3.15. He then goes to the adjacent international market and finds a 320-g steak of identical quality for \$2.80. Which steak is the better buy?

1-90 The reactive force developed by a jet engine to push an airplane forward is called thrust, and the thrust developed by the engine of a Boeing 777 is about 85,000 lbf. Express this thrust in N and kgf.

1-91E The efficiency of a refrigerator increases by 3 percent for each $^\circ\text{C}$ rise in the minimum temperature in the device. What is the increase in the efficiency for each (a) K, (b) $^\circ\text{F}$, and (c) R rise in temperature?

1-92E The boiling temperature of water decreases by about 3°C for each 1000-m rise in altitude. What is the decrease in the boiling temperature in (a) K, (b) $^\circ\text{F}$, and (c) R for each 1000-m rise in altitude?

1-93E The average body temperature of a person rises by about 2°C during strenuous exercise. What is the rise in the body temperature in (a) K, (b) $^\circ\text{F}$, and (c) R during strenuous exercise?

1-94E Hyperthermia of 5°C (i.e., 5°C rise above the normal body temperature) is considered fatal. Express this fatal level of hyperthermia in (a) K, (b) $^\circ\text{F}$, and (c) R.

1-95E A house is losing heat at a rate of 4500 kJ/h per $^\circ\text{C}$ temperature difference between the indoor and the outdoor temperatures. Express the rate of heat loss from this house per (a) K, (b) $^\circ\text{F}$, and (c) R difference between the indoor and the outdoor temperature.

1-96 The average temperature of the atmosphere in the world is approximated as a function of altitude by the relation

$$T_{\text{atm}} = 288.15 - 6.5z$$

where T_{atm} is the temperature of the atmosphere in K and z is the altitude in km with $z = 0$ at sea level. Determine the average temperature of the atmosphere outside an airplane that is cruising at an altitude of 12,000 m.

1-97 Joe Smith, an old-fashioned engineering student, believes that the boiling point of water is best suited for use as the reference point on temperature scales. Unhappy that the boiling point corresponds to some odd number in the current absolute temperature scales, he has proposed a new absolute temperature scale that he calls the Smith scale. The temperature unit on this scale is *smith*, denoted by S, and the boiling point of water on this scale is assigned to be 1000 S. From a thermodynamic point of view, discuss if it is an acceptable temperature scale. Also, determine the ice point of water on the Smith scale and obtain a relation between the Smith and Celsius scales.

1-98E It is well-known that cold air feels much colder in windy weather than what the thermometer reading indicates because of the “chilling effect” of the wind. This effect is due to the increase in the convection heat transfer coefficient with increasing air velocities. The *equivalent wind chill temperature* in °F is given by [ASHRAE, *Handbook of Fundamentals* (Atlanta, GA, 1993), p. 8.15]

$$T_{\text{equiv}} = 91.4 - (91.4 - T_{\text{ambient}}) \times (0.475 - 0.0203V + 0.304\sqrt{V})$$

where V is the wind velocity in mi/h and T_{ambient} is the ambient air temperature in °F in calm air, which is taken to be air with light winds at speeds up to 4 mi/h. The constant 91.4°F in the given equation is the mean skin temperature of a resting person in a comfortable environment. Windy air at temperature T_{ambient} and velocity V will feel as cold as the calm air at temperature T_{equiv} . Using proper conversion factors, obtain an equivalent relation in SI units where V is the wind velocity in km/h and T_{ambient} is the ambient air temperature in °C.

Answer: $T_{\text{equiv}} = 33.0 - (33.0 - T_{\text{ambient}}) \times (0.475 - 0.0126V + 0.240\sqrt{V})$

1-99E  Reconsider Problem 1-98E. Using EES (or other) software, plot the equivalent wind chill temperatures in °F as a function of wind velocity in the range of 4 to 100 mph for the ambient temperatures of 20, 40, and 60°F. Discuss the results.

1-100 An air-conditioning system requires a 20-m-long section of 15-cm diameter duct work to be laid underwater.

Determine the upward force the water will exert on the duct. Take the densities of air and water to be 1.3 kg/m³ and 1000 kg/m³, respectively.

1-101 Balloons are often filled with helium gas because it weighs only about one-seventh of what air weighs under identical conditions. The buoyancy force, which can be expressed as $F_b = \rho_{\text{air}}gV_{\text{balloon}}$, will push the balloon upward. If the balloon has a diameter of 10 m and carries two people, 70 kg each, determine the acceleration of the balloon when it is first released. Assume the density of air is $\rho = 1.16 \text{ kg/m}^3$, and neglect the weight of the ropes and the cage. **Answer:** 16.5 m/s²

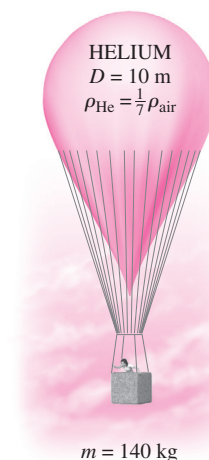


FIGURE P1-101

1-102  Reconsider Prob. 1-101. Using EES (or other) software, investigate the effect of the number of people carried in the balloon on acceleration. Plot the acceleration against the number of people, and discuss the results.

1-103 Determine the maximum amount of load, in kg, the balloon described in Prob. 1-101 can carry. **Answer:** 520.5 kg

1-104E The pressure in a steam boiler is given to be 92 kgf/cm². Express this pressure in psi, kPa, atm, and bars.

1-105 The basic barometer can be used as an altitude-measuring device in airplanes. The ground control reports a barometric reading of 753 mm Hg while the pilot's reading is 690 mm Hg. Estimate the altitude of the plane from ground level if the average air density is 1.20 kg/m³. **Answer:** 714 m

1-106 The lower half of a 10-m-high cylindrical container is filled with water ($\rho = 1000 \text{ kg/m}^3$) and the upper half with oil that has a specific gravity of 0.85. Determine the pressure difference between the top and bottom of the cylinder.
Answer: 90.7 kPa

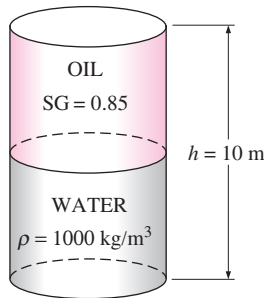


FIGURE P1-106

1-107 A vertical, frictionless piston–cylinder device contains a gas at 250 kPa absolute pressure. The atmospheric pressure outside is 100 kPa, and the piston area is 30 cm^2 . Determine the mass of the piston.

1-108 A pressure cooker cooks a lot faster than an ordinary pan by maintaining a higher pressure and temperature inside. The lid of a pressure cooker is well sealed, and steam can escape only through an opening in the middle of the lid. A separate metal piece, the petcock, sits on top of this opening and prevents steam from escaping until the pressure force overcomes the weight of the petcock. The periodic escape of the steam in this manner prevents any potentially dangerous pressure buildup and keeps the pressure inside at a constant value. Determine the mass of the petcock of a pressure cooker whose operation pressure is 100 kPa gage and has an opening cross-sectional area of 4 mm^2 . Assume an atmospheric pressure of 101 kPa, and draw the free-body diagram of the petcock. **Answer:** 40.8 g



FIGURE P1-108

1-109 A glass tube is attached to a water pipe, as shown in Fig. P1-109. If the water pressure at the bottom of the tube is 115 kPa and the local atmospheric pressure is 92 kPa, determine how high the water will rise in the tube, in m. Take the density of water to be 1000 kg/m^3 .

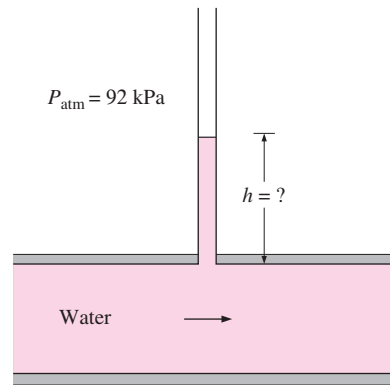


FIGURE P1-109

1-110 The average atmospheric pressure on earth is approximated as a function of altitude by the relation $P_{\text{atm}} = 101.325 (1 - 0.02256z)^{5.256}$, where P_{atm} is the atmospheric pressure in kPa and z is the altitude in km with $z = 0$ at sea level. Determine the approximate atmospheric pressures at Atlanta ($z = 306 \text{ m}$), Denver ($z = 1610 \text{ m}$), Mexico City ($z = 2309 \text{ m}$), and the top of Mount Everest ($z = 8848 \text{ m}$).

1-111 When measuring small pressure differences with a manometer, often one arm of the manometer is inclined to improve the accuracy of reading. (The pressure difference is still proportional to the vertical distance and not the actual length of the fluid along the tube.) The air pressure in a circular duct is to be measured using a manometer whose open arm is inclined 35° from the horizontal, as shown in Fig. P1-111. The density of the liquid in the manometer is 0.81 kg/L , and the vertical distance between the fluid levels in the two arms of the manometer is 8 cm. Determine the gage pressure of air in the duct and the length of the fluid column in the inclined arm above the fluid level in the vertical arm.

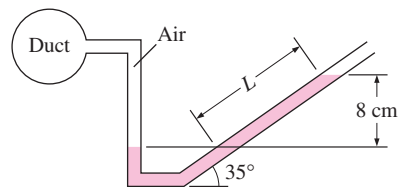


FIGURE P1-111

1-112E Consider a U-tube whose arms are open to the atmosphere. Now equal volumes of water and light oil ($\rho = 49.3 \text{ lbm/ft}^3$) are poured from different arms. A person blows from the oil side of the U-tube until the contact surface of the two fluids moves to the bottom of the U-tube, and thus the liquid levels in the two arms are the same. If the fluid height in each arm is 30 in, determine the gage pressure the person exerts on the oil by blowing.

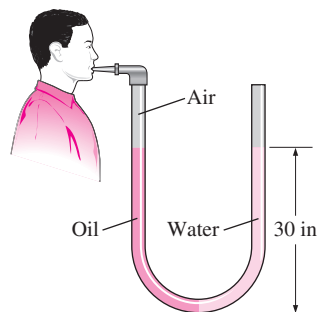


FIGURE P1-112E

1-113 Intravenous infusions are usually driven by gravity by hanging the fluid bottle at sufficient height to counteract the blood pressure in the vein and to force the fluid into the body. The higher the bottle is raised, the higher the flow rate of the fluid will be. (a) If it is observed that the fluid and the blood pressures balance each other when the bottle is 1.2 m above the arm level, determine the gage pressure of the blood. (b) If the gage pressure of the fluid at the arm level needs to be 20 kPa for sufficient flow rate, determine how high the bottle must be placed. Take the density of the fluid to be 1020 kg/m^3 .

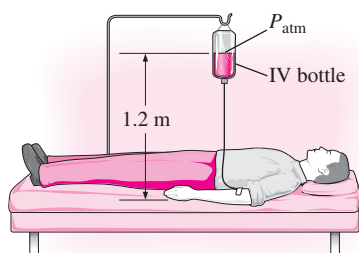


FIGURE P1-113

1-114 A gasoline line is connected to a pressure gage through a double-U manometer, as shown in Fig. P1-114. If the reading of the pressure gage is 370 kPa, determine the gage pressure of the gasoline line.

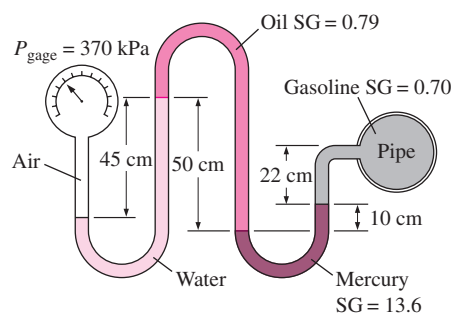


FIGURE P1-114

1-115 Repeat Prob. 1-114 for a pressure gage reading of 180 kPa.

1-116E A water pipe is connected to a double-U manometer as shown in Fig. P1-116E at a location where the local atmospheric pressure is 14.2 psia. Determine the absolute pressure at the center of the pipe.

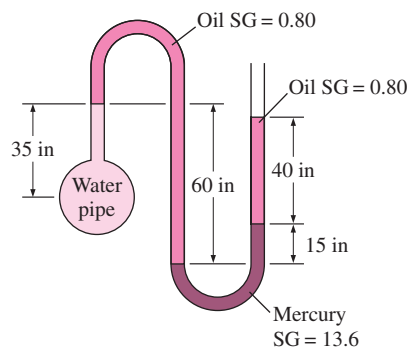


FIGURE P1-116E

1-117 It is well-known that the temperature of the atmosphere varies with altitude. In the troposphere, which extends to an altitude of 11 km, for example, the variation of temperature can be approximated by $T = T_0 - \beta z$, where T_0 is the temperature at sea level, which can be taken to be 288.15 K, and $\beta = 0.0065 \text{ K/m}$. The gravitational acceleration also changes with altitude as $g(z) = g_0/(1 + z/6,370,320)^2$ where $g_0 = 9.807 \text{ m/s}^2$ and z is the elevation from sea level in m. Obtain a relation for the variation of pressure in the troposphere (a) by ignoring and (b) by considering the variation of g with altitude.

1-118 The variation of pressure with density in a thick gas layer is given by $P = C\rho^n$, where C and n are constants. Noting that the pressure change across a differential fluid layer of thickness dz in the vertical z -direction is given as $dP = -\rho g dz$, obtain a relation for pressure as a function of

elevation z . Take the pressure and density at $z = 0$ to be P_0 and ρ_0 , respectively.

1-119 Pressure transducers are commonly used to measure pressure by generating analog signals usually in the range of 4 mA to 20 mA or 0 V-dc to 10 V-dc in response to applied pressure. The system whose schematic is shown in Fig. P1-119 can be used to calibrate pressure transducers. A rigid container is filled with pressurized air, and pressure is measured by the manometer attached. A valve is used to regulate the pressure in the container. Both the pressure and the electric signal are measured simultaneously for various settings, and the results are tabulated. For the given set of measurements, obtain the calibration curve in the form of $P = aI + b$, where a and b are constants, and calculate the pressure that corresponds to a signal of 10 mA.

Δh , mm	28.0	181.5	297.8	413.1	765.9
I , mA	4.21	5.78	6.97	8.15	11.76
Δh , mm	1027	1149	1362	1458	1536
I , mA	14.43	15.68	17.86	18.84	19.64

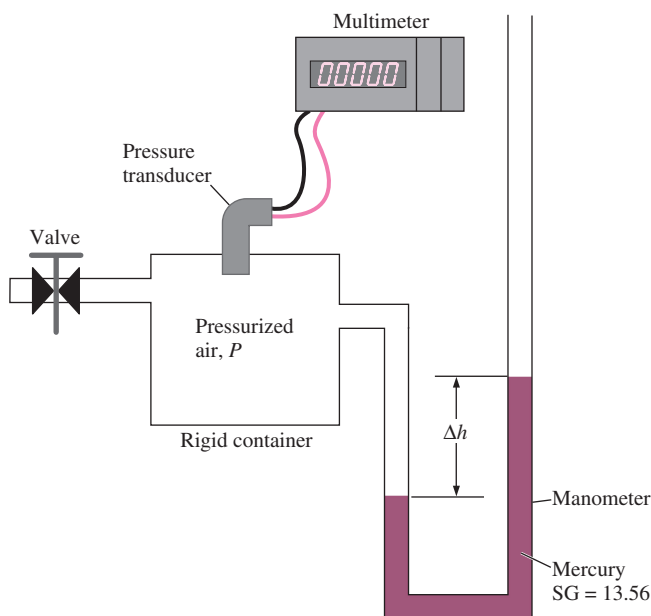


FIGURE P1-119

Fundamentals of Engineering (FE) Exam Problems

1-120 Consider a fish swimming 5 m below the free surface of water. The increase in the pressure exerted on the fish when it dives to a depth of 45 m below the free surface is

- (a) 392 Pa (b) 9800 Pa (c) 50,000 Pa
(d) 392,000 Pa (e) 441,000 Pa

1-121 The atmospheric pressures at the top and the bottom of a building are read by a barometer to be 96.0 and 98.0

kPa. If the density of air is 1.0 kg/m^3 , the height of the building is

- (a) 17 m (b) 20 m (c) 170 m
(d) 204 m (e) 252 m

1-122 An apple loses 4.5 kJ of heat as it cools per $^\circ\text{C}$ drop in its temperature. The amount of heat loss from the apple per $^\circ\text{F}$ drop in its temperature is

- (a) 1.25 kJ (b) 2.50 kJ (c) 5.0 kJ
(d) 8.1 kJ (e) 4.1 kJ

1-123 Consider a 2-m deep swimming pool. The pressure difference between the top and bottom of the pool is

- (a) 12.0 kPa (b) 19.6 kPa (c) 38.1 kPa
(d) 50.8 kPa (e) 200 kPa

1-124 At sea level, the weight of 1 kg mass in SI units is 9.81 N. The weight of 1 lbm mass in English units is

- (a) 1 lbf (b) 9.81 lbf (c) 32.2 lbf
(d) 0.1 lbf (e) 0.031 lbf

1-125 During a heating process, the temperature of an object rises by 20°C . This temperature rise is equivalent to a temperature rise of

- (a) 20°F (b) 52°F (c) 36 K
(d) 36 R (e) 293 K

Design, Essay, and Experiment Problems

1-126 Write an essay on different temperature measurement devices. Explain the operational principle of each device, its advantages and disadvantages, its cost, and its range of applicability. Which device would you recommend for use in the following cases: taking the temperatures of patients in a doctor's office, monitoring the variations of temperature of a car engine block at several locations, and monitoring the temperatures in the furnace of a power plant?

1-127 Write an essay on the various mass- and volume-measurement devices used throughout history. Also, explain the development of the modern units for mass and volume.

1-128 Write an essay on the various mass- and volume-measurement devices used throughout history. Also, explain the development of the modern units for mass and volume.

1-129 Density of Water as a Function of Temperature Experiment

The density of water as a function of temperature is obtained with a sensitive cylindrical float constructed from brass tubing. The float is placed in a Thermos bottle filled with water at different temperatures. From 0 to 4°C (water density is a maximum at 4°C) the float *rose* about 8 mm and from 4 to 25°C the float *sank* about 40 mm. The analysis includes differential and integral calculus to account for thermal expansion of the float. The final results closely follow the published density curve including the characteristic hump at 4°C . Obtain this density curve using the video clip, the complete write-up, and the data provided on the DVD accompanying this book.