Thermodynamics I

Practice Problems (Ch-1)

Dr. Ahmed Rasheed

1–1C 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?

1–2C One of the most amusing things a person can experience is when a car in neutral appears to go uphill when its brakes are released. Can this really happen or is it an optical illusion? How can you verify if a road is pitched uphill or downhill?

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?

1–9E If the mass of an object is 10 lbm, what is its weight, in lbf, at a location where $g = 32.0 \text{ ft/s}^2$?

Analysis Applying Newton's second law, the weight is determined to be

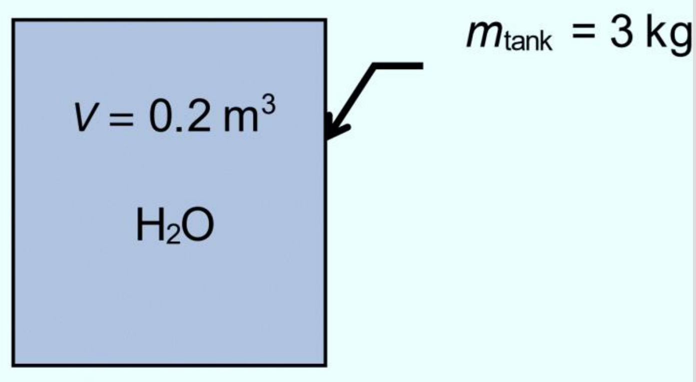
$$W = mg = (10 \text{ lbm})(32.0 \text{ ft/s}^2)\left(\frac{1 \text{ lbf}}{32.174 \text{ lbm} \cdot \text{ft/s}^2}\right) = \mathbf{9.95 \text{ lbf}}$$

1–10 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.

Analysis From the Newton's second law, the force applied is

$$F = ma = m(6\ \mathrm{g}) = (90\ \mathrm{kg})(6 \times 9.81\ \mathrm{m/s^2})\left(\frac{1\ \mathrm{N}}{1\ \mathrm{kg \cdot m/s^2}}\right) = \mathbf{5297\ N}$$

1–12 A 3-kg plastic tank that has a volume of 0.2 m^3 is filled with liquid water. Assuming the density of water is 1000 kg/m^3, determine the weight of the combined system.



$$m_w = \rho V = (1000\,\mathrm{kg/m^3})(0.2\,\mathrm{m^3}) = 200\,\mathrm{kg}$$

$$m_{\mathrm{total}} = m_w + m_{\mathrm{tank}} = 200 + 3 = 203\,\mathrm{kg}$$

$$W = mg = (203\ \mathrm{kg})(9.81\ \mathrm{m/s^2})\left(\frac{1\ \mathrm{N}}{1\ \mathrm{kg\cdot m/s^2}}\right) = \mathbf{1991\ N}$$

1–15 A 4-kW resistance heater in a water heater runs for 3 hours to raise the water temperature to the desired level. Determine the amount of electric energy used in both kWh and kJ.

$$\text{Total energy} = (\text{Energy per unit time})(\text{Time interval})$$
$$= (4\ \text{kW})(3\ \text{h})$$
$$= \mathbf{12\ kWh}$$

$$1\ \text{kWh} = (1\ \text{kJ/s})(3600\ \text{s}) = 3600\ \text{kJ}$$

$$\text{Total energy} = (12\ \text{kWh})(3600\ \text{kJ/kWh})$$
$$= \mathbf{43{,}200\ kJ}$$

1–24C The specific weight of a system is defined as the weight per unit volume (note that this definition violates the normal specific property-naming convention). Is the specific weight an extensive or intensive property?

$$\gamma_1 = \frac{W}{V} \quad \Longrightarrow \quad \gamma = \frac{W/2}{V/2} = \gamma_1$$

1–25C Is the number of moles of a substance contained in a system an extensive or intensive property?

1–34E Consider a system whose temperature is 18°C. Express this temperature in R, K, and °F.

$$T(\mathrm{K}] = T(°\mathrm{C}) + 273 = 18°\mathrm{C} + 273 = \mathbf{291\,K}$$

$$T(°\mathrm{F}] = 1.8T(°\mathrm{C}) + 32 = (1.8)(18) + 32 = \mathbf{64.4°F}$$

$$T(\mathrm{R}] = T(°\mathrm{F}) + 460 = 64.4 + 460 = \mathbf{524.4\,R}$$

1–36 The temperature of a system rises by 130°C during a heating process. Express this rise in temperature in kelvins.

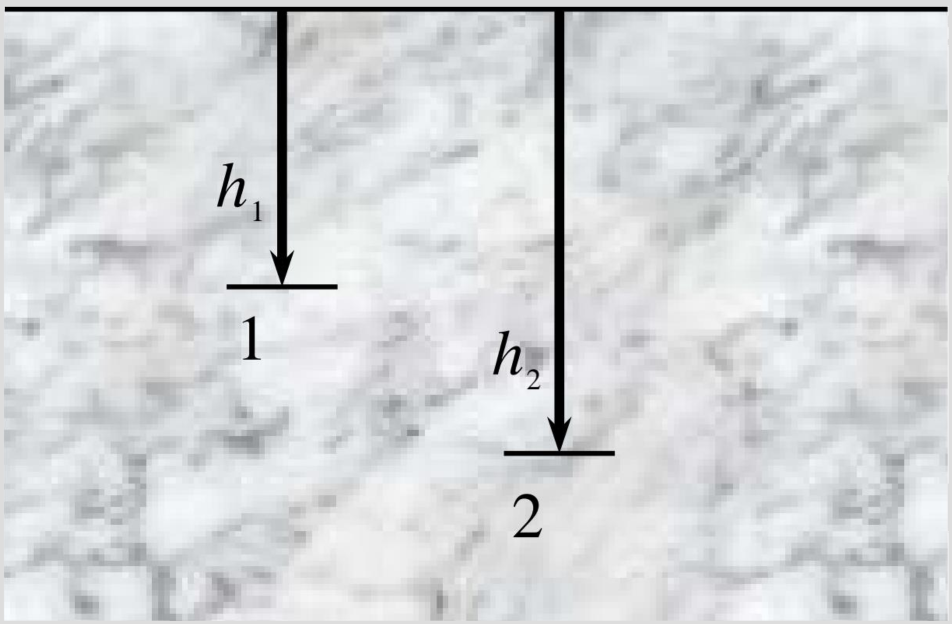
1–51E A 200-pound man has a total foot imprint area of 72 in^2. Determine the pressure this man exerts on the ground if (*a*) he stands on both feet and (*b*) he stands on one foot.

(*a*) On both feet: $$P = \frac{W}{2A} = \frac{200\ \text{lbf}}{2 \times 36\ \text{in}^2} = 2.78\ \text{lbf/in}^2 = \mathbf{2.78\ psi}$$

(*b*) On one foot: $$P = \frac{W}{A} = \frac{200\ \text{lbf}}{36\ \text{in}^2} = 5.56\ \text{lbf/in}^2 = \mathbf{5.56\ psi}$$

1–52 The gage pressure in a liquid at a depth of 3 m is read to be 42 kPa. Determine the gage pressure in the same liquid at a depth of 9 m.

$P_1 = \rho g h_1$ $P_2 = \rho g h_2$

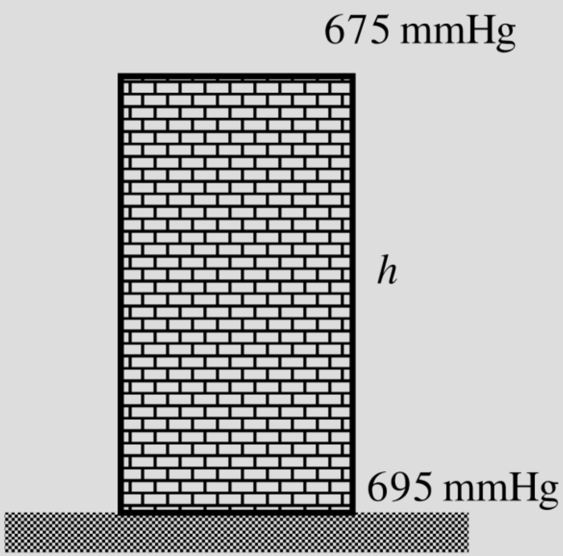


Taking their ratio,

$$\frac{P_2}{P_1} = \frac{\rho g h_2}{\rho g h_1} = \frac{h_2}{h_1}$$

$$P_2 = \frac{h_2}{h_1} P_1 = \frac{9 \text{ m}}{3 \text{ m}} (42 \text{ kPa}) = \mathbf{126 \text{ kPa}}$$

1–56 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 675 and 695 mmHg, respectively, determine the height of the building. Take the densities of air and mercury to be 1.18 kg/m^3 and 13,600 kg/m^3, respectively.



$$
\begin{aligned}
P_{\text{top}} &= (\rho g h)_{\text{top}} \\
&= (13{,}600\ \text{kg/m}^3)(9.81\ \text{m/s}^2)(0.675\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) \\
&= 90.06\ \text{kPa}
\end{aligned}
$$

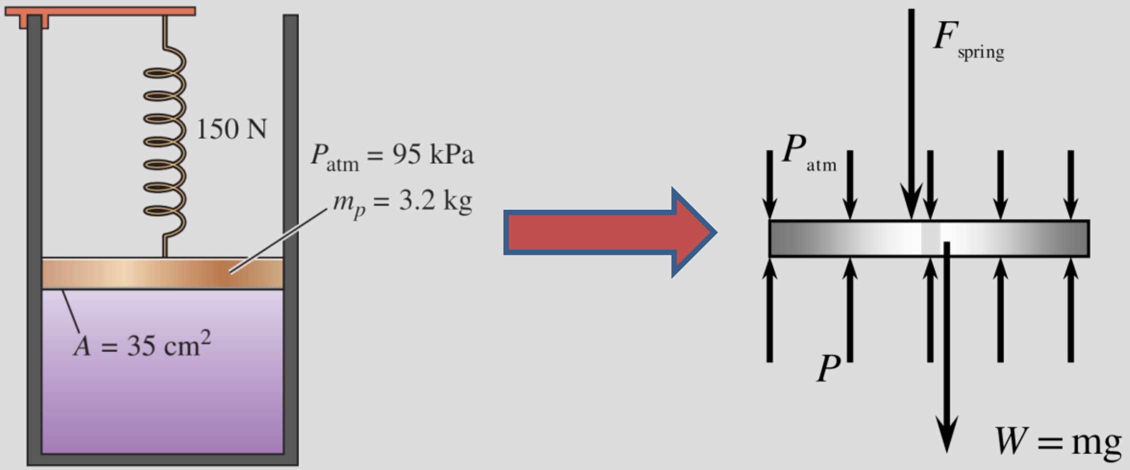
$$
\begin{aligned}
P_{\text{bottom}} &= (\rho g h)_{\text{bottom}} \\
&= (13{,}600\ \text{kg/m}^3)(9.81\ \text{m/s}^2)(0.695\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) \\
&= 92.72\ \text{kPa}
\end{aligned}
$$

Writing a force balance per unit base area, we obtain

$$
W_{\text{air}} / A = P_{\text{bottom}} - P_{\text{top}} \quad \Rightarrow \quad (\rho g h)_{\text{air}} = P_{\text{bottom}} - P_{\text{top}}
$$

$$
(1.18\ \text{kg/m}^3)(9.81\ \text{m/s}^2)(h)\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) = (92.72 - 90.06)\ \text{kPa} \quad \Rightarrow \quad h = \mathbf{231\ m}
$$

1–58 A gas is contained in a vertical, frictionless piston–cylinder device. The piston has a mass of 3.2 kg and a cross-sectional area of 35 cm^2. A compressed spring above the piston exerts a force of 150 N on the piston. If the atmospheric pressure is 95 kPa, determine the pressure inside the cylinder.



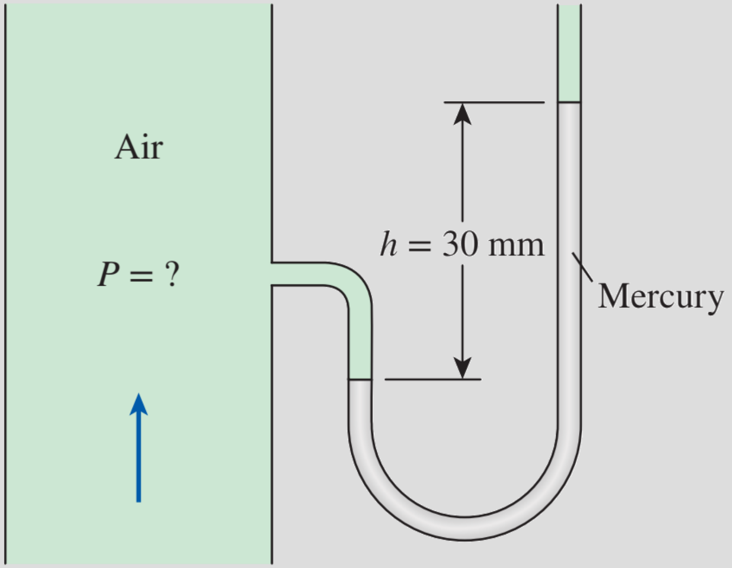
$$PA = P_{atm}A + W + F_{spring}$$

$$P = P_{atm} + \frac{mg + F_{spring}}{A}$$

$$= (95\text{ kPa}) + \frac{(3.2\text{ kg})(9.81\text{ m/s}^2) + 150\text{ N}}{35\times10^{-4}\text{m}^2}\left(\frac{1\text{ kPa}}{1000\text{ N/m}^2}\right)$$

$$= \mathbf{147\ kPa}$$

1–65 A mercury manometer ($\rho = 13{,}600\ \text{kg/m}^3$) is connected to an air duct to measure the pressure inside. The difference in the manometer levels is 30 mm, and the atmospheric pressure is 100 kPa. (*a*) Judging from Fig. P1–65, determine if the pressure in the duct is above or below the atmospheric pressure. (*b*) Determine the absolute pressure in the duct.



Analysis (*a*) The pressure in the duct is above atmospheric pressure since the fluid column on the duct side is at a lower level.

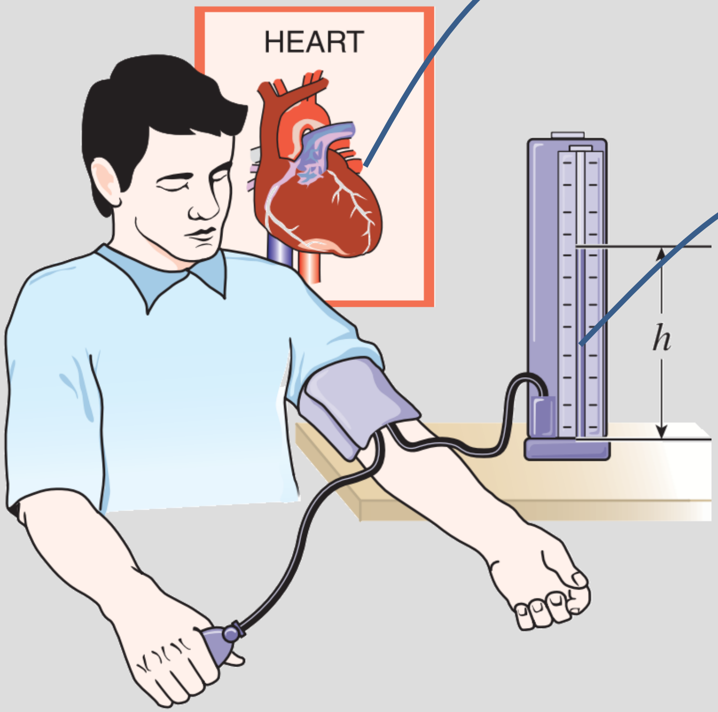
$$\boxed{P = P_{\text{atm}} + \rho g h}$$

$$= (100\ \text{kPa}) + (13{,}600\ \text{kg/m}^3)(9.81\ \text{m/s}^2)(0.030\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right)$$

$$= \mathbf{104\ kPa}$$

1–70 The maximum blood pressure in the upper arm of a healthy person is about 120 mmHg. 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.

$$P = \rho_{\text{blood}} g h_{\text{blood}}$$



$$P = \rho_{\text{mercury}} g h_{\text{mercury}}$$

$$P = \rho_{\text{blood}} g h_{\text{blood}} = \rho_{\text{mercury}} g h_{\text{mercury}}$$

$$h_{\text{blood}} = \frac{\rho_{\text{mercury}}}{\rho_{\text{blood}}} h_{\text{mercury}}$$

$$= \frac{13{,}600 \text{ kg/m}^3}{1050 \text{ kg/m}^3}(0.12 \text{ m}) = \mathbf{1.55 \text{ m}}$$