

Chapter 1

INTRODUCTION AND OVERVIEW

Thermodynamics, Heat Transfer, and Fluid Mechanics

1-1C Classical thermodynamics is based on experimental observations whereas statistical thermodynamics is based on the average behavior of large groups of particles.

1-2C On a downhill road the potential energy of the bicyclist is being converted to kinetic energy, and thus the bicyclist picks up speed. There is no creation of energy, and thus no violation of the conservation of energy principle.

1-3C There is no truth to his claim. It violates the second law of thermodynamics.

1-4C Thermodynamics deals with the amount of heat transfer as a system undergoes a process from one equilibrium state to another. Heat transfer, on the other hand, deals with the rate of heat transfer as well as the temperature distribution within the system at a specified time.

1-5C The driving force is (*a*) the temperature difference for heat transfer, (*b*) the electric potential difference for electric current flow (voltage), and (*c*) the pressure difference for fluid flow.

1-6C Heat transfer is a non-equilibrium phenomena since in a system that is in equilibrium there can be no temperature differences and thus no heat flow.

1-7C No, there cannot be any heat transfer between two bodies that are at the same temperature (regardless of pressure) since the driving force for heat transfer is temperature difference.

1-8C Stress is defined as force per unit area, and is determined by dividing the force by the area upon which it acts. The normal component of a force acting on a surface per unit area is called the **normal stress**, and the tangential component of a force acting on a surface per unit area is called **shear stress**. In a fluid, the normal stress is called **pressure**.

Mass, Force, and Units

1-9C Pound-mass lbm is the mass unit in English system whereas pound-force lbf is the force unit. One pound-force is the force required to accelerate a mass of 32.174 lbm by 1 ft/s². In other words, the weight of a 1-lbm mass at sea level is 1 lbf.

1-10C Kg is the mass unit in the SI system whereas kg-force is a force unit. 1-kg-force is the force required to accelerate a 1-kg mass by 9.807 m/s². In other words, the weight of 1-kg mass at sea level is 1 kg-force.

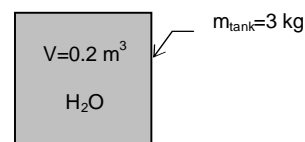
1-11C There is no acceleration, thus the net force is zero in both cases.

1-12 A plastic tank is filled with water. The weight of the combined system is to be determined.

Assumptions The density of water is constant throughout.

Properties The density of water is given to be $\rho = 1000 \text{ kg/m}^3$.

Analysis The mass of the water in the tank and the total mass are



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

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

Thus,

$$W = mg = (203 \text{ kg})(9.807 \text{ m/s}^2) \left(\frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \right) = \mathbf{1991 \text{ N}}$$

1-13 The interior dimensions of a room are given. The mass and weight of the air in the room are to be determined.

Assumptions The density of air is constant throughout the room.

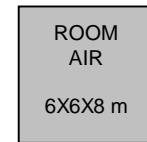
Properties The density of air is given to be $\rho = 1.16 \text{ kg/m}^3$.

Analysis The mass of the air in the room is

$$m = \rho V = (1.16 \text{ kg/m}^3)(6 \times 6 \times 8 \text{ m}^3) = \mathbf{334.1 \text{ kg}}$$

Thus,

$$W = mg = (334.1 \text{ kg})(9.807 \text{ m/s}^2) \left(\frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \right) = \mathbf{3277 \text{ N}}$$



1-14 The variation of gravitational acceleration above the sea level is given as a function of altitude. The height at which the weight of a body will decrease by 1% is to be determined.

Analysis The weight of a body at the elevation z can be expressed as

$$W = mg = m(9.807 - 3.32 \times 10^{-6} z)$$

In our case,

$$W = 0.99 W_s = 0.99 mg_s = 0.99(m)(9.807)$$

Substituting,

$$0.99(9.807) = (9.807 - 3.32 \times 10^{-6} z) \longrightarrow z = \mathbf{29,539\text{m}}$$



1-15E An astronaut took his scales with him to space. It is to be determined how much he will weigh on the spring and beam scales in space.

Analysis (a) A spring scale measures weight, which is the local gravitational force applied on a body:

$$W = mg = (150\text{lbm})(5.48\text{ft/s}^2) \left(\frac{1\text{lbf}}{32.174\text{lbm} \cdot \text{ft/s}^2} \right) = \mathbf{25.5\text{lbf}}$$

(b) A beam scale compares masses and thus is not affected by the variations in gravitational acceleration. The beam scale will read what it reads on earth,

$$W = \mathbf{150\text{lbf}}$$

1-16 The acceleration of an aircraft is given in g 's. The net upward force acting on a man in the aircraft is to be determined.

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

$$F = ma = m(6g) = (90\text{ kg})(6 \times 9.807\text{m/s}^2) \left(\frac{1\text{N}}{1\text{ kg} \cdot \text{m/s}^2} \right) = \mathbf{5296\text{ N}}$$

1-17 [Also solved by EES on enclosed CD] A rock is thrown upward with a specified force. The acceleration of the rock is to be determined.

Analysis The weight of the rock is

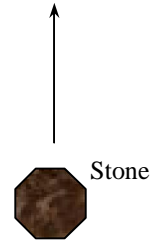
$$W = mg = (5\text{kg})(9.79\text{m/s}^2) \left(\frac{1\text{N}}{1\text{kg} \cdot \text{m/s}^2} \right) = 48.95\text{N}$$

Then the net force that acts on the rock is

$$F_{\text{net}} = F_{\text{up}} - F_{\text{down}} = 150 - 48.95 = 101.05 \text{ N}$$

From the Newton's second law, the acceleration of the rock becomes

$$a = \frac{F}{m} = \frac{101.05\text{N}}{5\text{kg}} \left(\frac{1\text{kg} \cdot \text{m/s}^2}{1\text{N}} \right) = 20.2\text{m/s}^2$$



1-18 Problem 1-17 is reconsidered. The entire EES solution is to be printed out, including the numerical results with proper units.

```
W=m*g"[N]"
m=5"[kg]"
g=9.79"[m/s^2]"
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"The force balance on the rock yields the net force acting on the rock as"

```
F_net = F_up - F_down"[N]"
F_up=150"[N]"
F_down=W"[N]"
```

"The acceleration of the rock is determined from Newton's second law."

```
F_net=a*m
```

"To Run the program, press F2 or click on the calculator icon from the Calculate menu"

SOLUTION

```
Variables in Main
a=20.21 [m/s^2]
F_down=48.95 [N]
F_net=101.1 [N]
F_up=150 [N]
g=9.79 [m/s^2]
m=5 [kg]
W=48.95 [N]
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1-19 Gravitational acceleration g and thus the weight of bodies decreases with increasing elevation. The percent reduction in the weight of an airplane cruising at 13,000 m is to be determined.

Properties The gravitational acceleration g is given to be 9.807 m/s^2 at sea level and 9.767 m/s^2 at an altitude of 13,000 m.

Analysis Weight is proportional to the gravitational acceleration g , and thus the percent reduction in weight is equivalent to the percent reduction in the gravitational acceleration, which is determined from

$$\% \text{Reduction in weight} = \% \text{Reduction in } g = \frac{\Delta g}{g} \times 100 = \frac{9.807 - 9.767}{9.807} \times 100 = \mathbf{0.41\%}$$

Therefore, the airplane and the people in it will weight 0.41% less at 13,000 m altitude.

Discussion Note that the weight loss at cruising altitudes is negligible.



Modeling and Solving Engineering Problems

1-20C The *rating* problems deal with the determination of the *heat transfer rate* for an existing system at a specified temperature difference. The *sizing* problems deal with the determination of the *size* of a system in order to transfer heat at a *specified rate* for a *specified temperature difference*.

1-21C The experimental approach (testing and taking measurements) has the advantage of dealing with the actual physical system, and getting a physical value within the limits of experimental error. However, this approach is expensive, time consuming, and often impractical. The analytical approach (analysis or calculations) has the advantage that it is fast and inexpensive, but the results obtained are subject to the accuracy of the assumptions and idealizations made in the analysis.

1-22C Modeling makes it possible to predict the course of an event before it actually occurs, or to study various aspects of an event mathematically without actually running expensive and time-consuming experiments. When preparing a mathematical model, all the variables that affect the phenomena are identified, reasonable assumptions and approximations are made, and the interdependence of these variables are studied. The relevant physical laws and principles are invoked, and the problem is formulated mathematically. Finally, the problem is solved using an appropriate approach, and the results are interpreted.

1-23C The right choice between a crude and complex model is usually the *simplest* model which yields *adequate* results. Preparing very accurate but complex models is not necessarily a better choice since such models are not much use to an analyst if they are very difficult and time consuming to solve. At the minimum, the model should reflect the essential features of the physical problem it represents.

1-24C The description of most scientific problems involve relations that relate the *changes* in some key variables to each other, and the smaller the increment chosen in the changing variables, the more accurate the description. In the limiting case of infinitesimal changes in variables, we obtain *differential equations*, which provide precise mathematical formulations for the physical principles and laws by representing the rates of changes as *derivatives*.

1-25C Despite the convenience and capability the engineering software packages offer, they are still just tools, and they will not replace the traditional engineering courses. They will simply cause a shift in emphasis in the course material from mathematics to physics. They are of great value in engineering practice, however, as engineers today rely on software packages for solving large and complex problems in a short time, and perform optimization studies efficiently.



1-26 Determine a positive real root of the following equation using EES:

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

Solution by EES Software (Copy the following lines and paste on a blank EES screen to verify solution):

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

Answer: x = 2.063 (using an initial guess of x=2)



1-27 Solve the following system of 2 equations with 2 unknowns using EES:

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

$$3xy + y = 3.5$$

Solution by EES Software (Copy the following lines and paste on a blank EES screen to verify solution):

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

$$3*x*y+y=3.5$$

Answer x=2 y=0.5



1-28 Solve the following system of 3 equations with 3 unknowns using EES:

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

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

$$xy + 2z = 8$$

Solution by EES Software (Copy the following lines and paste on a blank EES screen to verify solution):

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

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

$$x*y+2*z=8$$

Answer x=1.141, y=0.8159, z=3.535



1-29 Solve the following system of 3 equations with 3 unknowns using EES:

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

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

$$x + y - z = 2$$

Solution by EES Software (Copy the following lines and paste on a blank EES screen to verify solution):

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

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

$$x+y-z=2$$

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Answer $x=1$, $y=1$, $z=0$

Review Problems

1-30 The gravitational acceleration changes with altitude. Accounting for this variation, the weights of a body at different locations are to be determined.

Analysis The weight of an 80-kg man at various locations is obtained by substituting the altitude z (values in m) into the relation

$$W = mg = (80 \text{ kg})(9.807 - 3.32 \times 10^{-6} z \text{ m/s}^2) \left(\frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \right)$$

Sea level:	($z = 0 \text{ m}$): $W = 80 \times (9.807 - 3.32 \times 10^{-6} \times 0) = 80 \times 9.807 = \mathbf{784.6 \text{ N}}$
Denver:	($z = 1610 \text{ m}$): $W = 80 \times (9.807 - 3.32 \times 10^{-6} \times 1610) = 80 \times 9.802 = \mathbf{784.2 \text{ N}}$
Mt. Ev.:	($z = 8848 \text{ m}$): $W = 80 \times (9.807 - 3.32 \times 10^{-6} \times 8848) = 80 \times 9.778 = \mathbf{782.2 \text{ N}}$

1-31 A man is considering buying a 12-oz steak for \$3.15, or a 320-g steak for \$2.80. The steak that is a better buy is to be determined.

Assumptions The steaks are of identical quality.

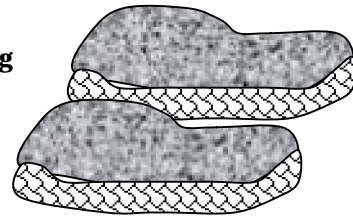
Analysis To make a comparison possible, we need to express the cost of each steak on a common basis. Let us choose 1 kg as the basis for comparison. Using proper conversion factors, the unit cost of each steak is determined to be

$$\text{12 ounce steak: Unit Cost} = \left(\frac{\$3.15}{12 \text{ oz}} \right) \left(\frac{16 \text{ oz}}{1 \text{ lbm}} \right) \left(\frac{1 \text{ lbm}}{0.45359 \text{ kg}} \right) = \mathbf{\$9.26/\text{kg}}$$

320 gram steak:

$$\text{Unit Cost} = \left(\frac{\$2.80}{320 \text{ g}} \right) \left(\frac{1000 \text{ g}}{1 \text{ kg}} \right) = \mathbf{\$8.75/\text{kg}}$$

Therefore, the steak at the international market is a better buy.



1-32 The thrust developed by the jet engine of a Boeing 777 is given to be 85,000 pounds. This thrust is to be expressed in N and kgf.

Analysis Noting that 1 lbf = 4.448 N and 1 kgf = 9.81 N, the thrust developed can be expressed in two other units as

$$\text{Thrust in N: Thrust} = (85,000 \text{ lbf}) \left(\frac{4.448 \text{ N}}{1 \text{ lbf}} \right) = \mathbf{3.78 \times 10^5 \text{ N}}$$

$$\text{Thrust in kgf: Thrust} = (37.8 \times 10^5 \text{ N}) \left(\frac{1 \text{ kgf}}{9.81 \text{ N}} \right) = \mathbf{3.85 \times 10^4 \text{ kgf}}$$



1-33 Design and Essay Problem

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