Solutions Manual for

Thermodynamics: An Engineering Approach
9th Edition
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Chapter 1
INTRODUCTION AND BASIC CONCEPTS

Thermodynamics

1-1C 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.

1-2C A car going uphill without the engine running would increase the energy of the car, and thus it would be a violation of the first law of thermodynamics. Therefore, this cannot happen. Using a level meter (a device with an air bubble between two marks of a horizontal water tube) it can shown that the road that looks uphill to the eye is actually downhill.

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

1-4C Classical thermodynamics is based on experimental observations whereas statistical thermodynamics is based on the average behavior of large groups of particles.

Mass, Force, and Units

1-5C In this unit, the word *light* refers to the speed of light. The light-year unit is then the product of a velocity and time. Hence, this product forms a distance dimension and unit.

1-6C 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.

1-7C There is no acceleration, thus the net force is zero in both cases.

1-8 The mass of an object is given. Its weight is to be determined.

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

$$W = mg = (200\ \text{kg})(9.6\ \text{m/s}^2) = \mathbf{1920\ N}$$

1-9E The mass of an object is given. Its weight is to be determined.

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

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

1-10 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

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

1-11 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

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

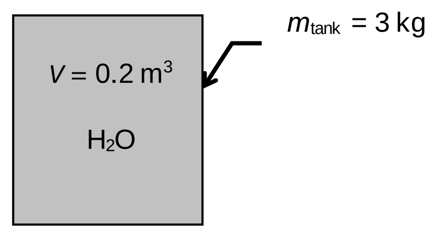
Therefore, the airplane and the people in it will weight 0.41% less at 13,000 m altitude.

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

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 ρ = 1000 kg/m^3.



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

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

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

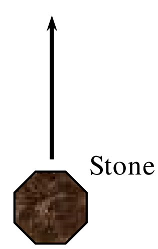
Thus,

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

1-13 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

$$W = mg = (2 \text{ kg})(9.79 \text{ m/s}^2)\left(\frac{1 \text{ N}}{1 \text{ kg}\cdot\text{m/s}^2}\right) = 19.58 \text{ N}$$



Then the net force that acts on the rock is

$$F_{net} = F_{up} - F_{down} = 200 - 19.58 = 180.4 \text{ N}$$

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

$$a = \frac{F}{m} = \frac{180.4 \text{ N}}{2 \text{ kg}}\left(\frac{1 \text{ kg}\cdot\text{m/s}^2}{1 \text{ N}}\right) = \mathbf{90.2 \text{ m/s}^2}$$

1-14 Problem 1-13 is reconsidered. The entire solution by appropriate software is to be printed out, including the numerical results with proper units.

Analysis The problem is solved using EES, and the solution is given below.

```
m=2 [kg]
F_up=200 [N]
g=9.79 [m/s^2]
W=m*g
F_net=F_up-F_down
F_down=W
F_net=m*a
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SOLUTION

a=90.21 [m/s^2]

F_down=19.58 [N]

F_net=180.4 [N]

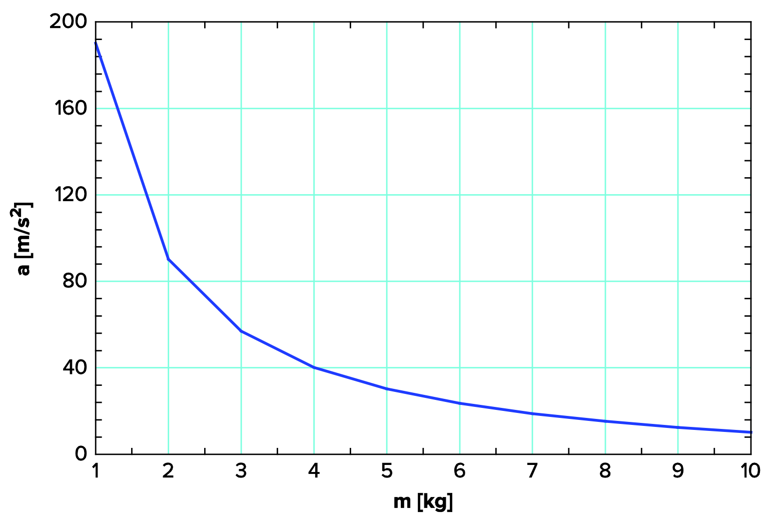
F_up=200 [N]

g=9.79 [m/s^2]

m=2 [kg]

W=19.58 [N]

m [kg]	a [m/s^2]
1	190.2
2	90.21
3	56.88
4	40.21
5	30.21
6	23.54
7	18.78
8	15.21
9	12.43
10	10.21



1-15 A resistance heater is used to heat water to desired temperature. The amount of electric energy used in kWh and kJ are to be determined.

Analysis The resistance heater consumes electric energy at a rate of 4 kW or 4 kJ/s. Then the total amount of electric energy used in 3 hours becomes

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

Noting that 1 kWh = (1 kJ/s)(3600 s) = 3600 kJ,

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

Discussion Note kW is a unit for power whereas kWh is a unit for energy.

1-16E 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:

$$W = mg = (150\text{ lbm})(5.48\text{ ft/s}^2)\left(\frac{1\text{ lbf}}{32.2\text{ lbm}\cdot\text{ft/s}^2}\right) = \mathbf{25.5\ lbf}$$

(*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,

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

1-17 A gas tank is being filled with gasoline at a specified flow rate. Based on unit considerations alone, a relation is to be obtained for the filling time.

Assumptions Gasoline is an incompressible substance and the flow rate is constant.

Analysis The filling time depends on the volume of the tank and the discharge rate of gasoline. Also, we know that the unit of time is 'seconds'. Therefore, the independent quantities should be arranged such that we end up with the unit of seconds. Putting the given information into perspective, we have

$$t\ [\text{s}] \quad \leftrightarrow \quad V\ [\text{L}],\ \text{and}\ \dot{V}\ [\text{L/s}\}$$

It is obvious that the only way to end up with the unit "s" for time is to divide the tank volume by the discharge rate. Therefore, the desired relation is

$$t = \frac{V}{\dot{V}}$$

Discussion Note that this approach may not work for cases that involve dimensionless (and thus unitless) quantities.

Systems, Properties, State, and Processes

1-18C Carbon dioxide is generated by the combustion of fuel in the engine. Any system selected for this analysis must include the fuel and air while it is undergoing combustion. The volume that contains this air-fuel mixture within piston-cylinder device can be used for this purpose. One can also place the entire engine in a control boundary and trace the system-surroundings interactions to determine the rate at which the engine generates carbon dioxide.

1-19C The radiator should be analyzed as an open system since mass is crossing the boundaries of the system.

1-20C A can of soft drink should be analyzed as a closed system since no mass is crossing the boundaries of the system.

1-21C When analyzing the control volume selected, we must account for all forms of water entering and leaving the control volume. This includes all streams entering or leaving the lake, any rain falling on the lake, any water evaporated to the air above the lake, any seepage to the underground earth, and any springs that may be feeding water to the lake.

1-22C In order to describe the state of the air, we need to know the value of all its properties. Pressure, temperature, and water content (i.e., relative humidity or dew point temperature) are commonly cited by weather forecasters. But, other properties like wind speed and chemical composition (i.e., pollen count and smog index, for example} are also important under certain circumstances.

Assuming that the air composition and velocity do not change and that no pressure front motion occurs during the day, the warming process is one of constant pressure (i.e., isobaric).

1-23C Intensive properties do not depend on the size (extent) of the system but extensive properties do.

1-24C The original specific weight is

$$\gamma_1 = \frac{W}{V}$$

If we were to divide the system into two halves, each half weighs $W/2$ and occupies a volume of $V/2$. The specific weight of one of these halves is

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

which is the same as the original specific weight. Hence, specific weight is an *intensive property*.

1-25C The number of moles of a substance in a system is directly proportional to the number of atomic particles contained in the system. If we divide a system into smaller portions, each portion will contain fewer atomic particles than the original system. The number of moles is therefore an *extensive property*.

1-26C Yes, because temperature and pressure are two independent properties and the air in an isolated room is a simple compressible system.

1-27C A process during which a system remains almost in equilibrium at all times is called a quasi-equilibrium process. Many engineering processes can be approximated as being quasi-equilibrium. The work output of a device is maximum and the work input to a device is minimum when quasi-equilibrium processes are used instead of nonquasi-equilibrium processes.

1-28C A process during which the temperature remains constant is called isothermal; a process during which the pressure remains constant is called isobaric; and a process during which the volume remains constant is called isochoric.

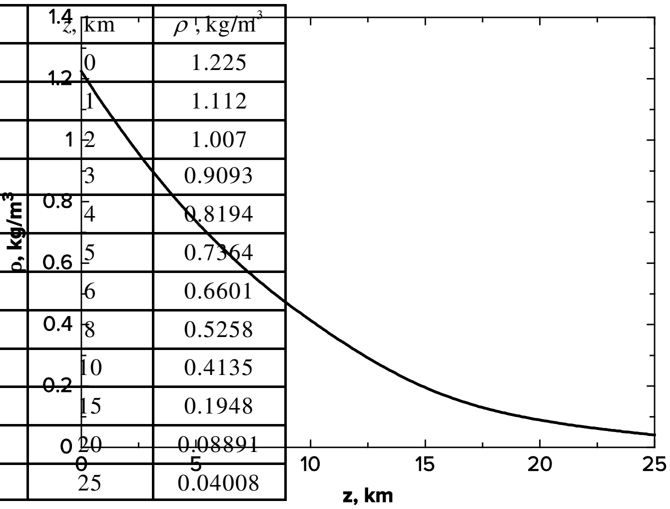
1-29C The **specific gravity,** or **relative density,** and is defined as the ratio of the density of a substance to the density of some standard substance at a specified temperature (usually water at 4°C, for which ρ_{H2O} = 1000 kg/m^3). That is, $SG = \rho / \rho_{H2O}$. When specific gravity is known, density is determined from $\rho = SG \times \rho_{H2O}$.

1-30 The variation of density of atmospheric air with elevation is given in tabular form. A relation for the variation of density with elevation is to be obtained, the density at 7 km elevation is to be calculated, and the mass of the atmosphere using the correlation is to be estimated.

Assumptions **1** Atmospheric air behaves as an ideal gas. **2** The earth is perfectly sphere with a radius of 6377 km, and the thickness of the atmosphere is 25 km.

Properties The density data are given in tabular form as

r, km	*z*, km	ρ, kg/m^3
6377	0	1.225
6378	1	1.112
6379	2	1.007
6380	3	0.9093
6381	4	0.8194
6382	5	0.7364
6383	6	0.6601
6385	8	0.5258
6387	10	0.4135
6392	15	0.1948
6397	20	0.08891
6402	25	0.04008



Analysis Using EES, (1) Define a trivial function rho= a+z in equation window, (2) select new parametric table from Tables, and type the data in a two-column table, (3) select Plot and plot the data, and (4) select plot and click on "curve fit" to get curve fit window. Then specify 2nd order polynomial and enter/edit equation. The results are:

$$\rho(z) = a + bz + cz^2 = 1.20252 - 0.101674z + 0.0022375z^2 \quad \text{for the unit of kg/m}^3,$$

$$(\text{or, } \rho(z) = (1.20252 - 0.101674z + 0.0022375z^2)\times 10^9 \quad \text{for the unit of kg/km}^3)$$

where z is the vertical distance from the earth surface at sea level. At z = 7 km, the equation would give ρ = 0.60 kg/m^3.

(*b*) The mass of atmosphere can be evaluated by integration to be

$$m = \int_V \rho dV = \int_{z=0}^{h} (a + bz + cz^2)4\pi(r_0 + z)^2 dz = 4\pi\int_{z=0}^{h} (a + bz + cz^2)(r_0^2 + 2r_0 z + z^2)dz$$

$$= 4\pi\left[ar_0^2 h + r_0(2a + br_0)h^2/2 + (a + 2br_0 + cr_0^2)h^3/3 + (b + 2cr_0)h^4/4 + ch^5/5\right]$$

where r_0 = 6377 km is the radius of the earth, h = 25 km is the thickness of the atmosphere, and a = 1.20252, b = -0.101674, and c = 0.0022375 are the constants in the density function. Substituting and multiplying by the factor 10^9 for the density unity kg/km^3, the mass of the atmosphere is determined to be

m = **5.092** $\times$ **10^{18} kg**

Performing the analysis with excel would yield exactly the same results.

EES Solution:

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"Using linear regression feature of EES based on the data on parametric table, we obtain"
rho=1.20251659E+00-1.01669722E-01*z+2.23747073E-03*z^2
z=7 [km]
"The mass of the atmosphere is obtained by integration to be"
m=4*pi*(a*r0^2*h+r0*(2*a+b*r0)*h^2/2+(a+2*b*r0+c*r0^2)*h^3/3+(b+2*c*r0)*h^4/4+c*h^5/5)*1E9
a=1.20252
b=-0.101670
c=0.0022375
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r0=6377 [km]
h=25 [km]