# Chapter 2 Discussion Questions

## Section 2.1

2.1 A *system* is a region in space having at least a volume.

2.2 A system needs a boundary to define the volume of that system.

## Section 2.2

2.3 A *mole* or *mol* is a given number of molecules or atoms. Avogadro's Number is the number of molecules or atoms in one mole based on a gram. That is, one gram-mole of a substance has $6.022 \times 10^{23}$ atoms or molecules, which is Avogadro's number.

2.4 Yes, a gram-mole is only 1/454 of a lbm-mol.

## Section 2.3

2.5 A property helps describe a system.

2.6 Intensive properties of a system are properties based on one unit of mass of the system. Extensive properties describe the total system.

2.7 Specific energy is the energy per unit mass of a system.

## Section 2.4

2.8 A state of a system is the complete description of a system, or the list of properties describing the system.

## Section 2.5

2.9 A process is a change in a system's state.

## Section 2.6

2.10 A cycle is a set of processes of a system which returns the system to its

1.31 OPEN EES EQUATION WINDOW AND ENTER:

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{Problem 1-31}

Wk=p*v**1.4
p*v=4.56*T
Wk=Q-0.234*T
Q=456/T
T=23*p
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THEN CLICK CALCULATE AND SOLVE TO OBTAIN:

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

p = 0.1708 Q = 116.1 T = 3.928 v = 104.9
Wk = 115.2

No unit consistency or conversion problems were detected.

original state.

Section 2.7

2.11 Weight is the gravitational attraction between two bodies. The mass is a quantity of matter and weight is mass multiplied by the gravitational acceleration.

2.12 The term $g_c$ is a constant of proportionality between momentum change (or mass times acceleration) and force (or weight)

Section 2.8

2.13 Specific volume is the volume per unit mass of a system.

2.14 Specific weight is the weight per unit volume of a system.

2.15 Specific Gravity is the ratio of the density of a substance to that of water at $4^0$ C, standard atmospheric pressure of 1 bar.

2.16 Density is the mass per unit volume, or inverse specific volume.

2.17 Gage pressure is the pressure measured by a gage, usually when the gage is placed in a standard atmosphere of 1 bar pressure. It is a difference in pressure between absolute pressure of a system and the atmospheric pressure. Gage pressure is the pressure "felt" by a system at its boundary.

Section 2.9

2.18 The zeroth law of thermodynamics makes a temperature measurement independent of a system. Thus, a temperature of, say 30 degrees, is the same anywhere and anytime.

Section 2.10

2.19 Temperature is a measure of the "hotness" of a system.

2.20 A thermopile a group of thermocouples, all connected in series to each other.

Section 2.11

2.21 Energy is the capacity of a system to affect changes to its surroundings.

2.22 Internal energy is the form of energy manifested by the hotness or temperature, or the thermal energy. It is the kinetic energy of the individual atmos or molecules making up the system.

Section 2.12

2.23 Some outputs from a system would be, for instance, power produced by an engine, amount of water boiled in a boiler, or an amount of air pressurized in an air compressor.

2.24 Some inputs to a system would be, for instance, rate of fuel used by an engine, amount of energy used by a boiler, or power to drive a compressor.

Section 2.13

2.25 A derived unit is a unit or combination of fundamental units for describing a particular property or quantity.

# CHAPTER 2

THE PROBLEMS IN SECTIONS 2.7 AND 2.8 ARE INTENDED TO HELP UNDERSTAND THE CONCEPTS OF WEIGHT, MASS, VOLUME, DENSITY, SPECIFIC VOLUME, AND PRESSURE.

2.1 WEIGHT $W = mg$. THUS, AT $g = 9.8\ m/s^2$

$$W = (2\ kg)(9.8\ m/s^2) = 19.6 \text{ NEWTONS } (N)$$

AT $g = 9.78\ m/s^2$

$$W = (2\ kg)(9.78\ m/s^2) = 19.56\ N$$

SO THAT <u>THE GOLD CUBE HAS GREATER WEIGHT AT LOCATION WHERE $g = 9.8\ m/s^2$.</u> THE MASS IS THE SAME AT BOTH LOCATIONS.

2.2 $W = mg = (3\ kg)(9.79\ m/s^2) = \underline{29.37\ N}$

2.3 $W = mg/g_c$ FOR ENGLISH ENGR. UNITS.
SO THAT $m = Wg_c/g$.
AT SEA LEVEL $g = 32.174\ ft/s^2$ SO THAT

$$m = (8.333\ lb_f)\left(32.174 \frac{ft \cdot lb_m}{lb_f \cdot s^2}\right) \Big/ (32.174\ ft/s^2)$$

$m = 8.333\ lbm$

ALSO, $32.174\ lbm = 1\ slug$ SO THAT

$m = 8.333/32.174 = 0.2589\ldots$ SLUGS

2.4 THE MASS OF THE BATTERY IS THE SAME ON THE EARTH AND ON THE MOON.

$$m = Wg_c/g = \frac{(32\ lbf)(32.174\ ft\cdot lbm/lbm\cdot s^2)}{(32.174\ ft/s^2)}$$

$$= 32\ lbm.$$

ON THE MOON, WHERE $g = 5.47\ ft/s^2$

$$W = mg/g_c = (32\ lbm)(5.47)/(32.174)$$

$$W = 5.44..\ lbf$$

2.5 (a.) $1\ lbm = 453.59\ grams \approx 454\ grams$

(b.) $2\ lbm = 2 \times 0.45359\ kg = 0.90718\ kg$

(c.) POUNDS-FORCE IS A FORCE OR WEIGHT UNIT. IF $g = 32.174\ ft/s^2$ AND SINCE 20 SLUGS IS A MASS, WE HAVE

$$W = mg = (20\ slugs)(32.174\ ft/s^2)$$

$$= 643.48\ lbf$$

(d.) DYNE IS A FORCE OR WEIGHT UNIT.

IF $g = 9.8\ m/s^2$ AND $m = 100$ grams $=$ $0.1\ kg$, THEN

$$W = mg = (0.1\ kg)(9.8\ m/s^2) = 0.98\ N$$

BUT $1\ N = 10^5$ DYNES, SO

$$\underline{W = 98{,}000 \text{ DYNES}}$$

(e.) THIS IS A CONVERSION FROM MASS TO FORCE AND FROM SI TO ENGLISH UNITS. SINCE $m = 200\ kg$ AND $g = 9.8\ m/s^2$, WE HAVE

$$W(F) = mg = (200\ kg)(9.8\ m/s^2)$$
$$= 1960\ N$$

SINCE $1\ N = 0.2248\ lb_f$ WE HAVE

$$\underline{W(F) = 440.6..\ lb_f}$$

2.6 (a.) VOLUME $= V = \pi \times \frac{(\text{DIAMETER})^2}{4} \times$ LENGTH

$$V = \pi\left(\frac{1m^2}{4}\right)(1.5\ m) = \underline{1.178..\ m^3}$$

(b.) SPECIFIC WEIGHT $= \frac{W}{V} = \frac{6000\ N}{1.178\ m^3} = \gamma$

$$\underline{\gamma = 5093\ N/m^3}$$

(c.) DENSITY $= \rho = m/V = W/gV = \gamma/g$

$$\rho = \frac{5093\ N/m^3}{9.82\ m/s^2} = \underline{518.6\ kg/m^3}$$

(d.) SPECIFIC GRAVITY $S.G. = \rho/1000$

$$\underline{S.G. = 0.5186..}$$

2.7 $W = mg$ AND $V = mv$. THEN $m = V/v$ AND $W = Vg/v$. SUBSTITUTING VALUES:

$$W = \frac{(4800\ cm^3)(9.78\ m/s^2)(10^{-6}\ m^3/cm^3)}{0.9\ m^3/kg}$$

$$\underline{W = 0.052 \ldots N}$$

2.8 (a.) $p = p_g +$ atmospheric pressure

$$p = 1.0\ kPa + 101\ kPa = \underline{102\ kPa}$$

(b.) IF atmospheric pressure = 768 mm Hg

1 mm Hg $\approx$ 0.1333 kPa

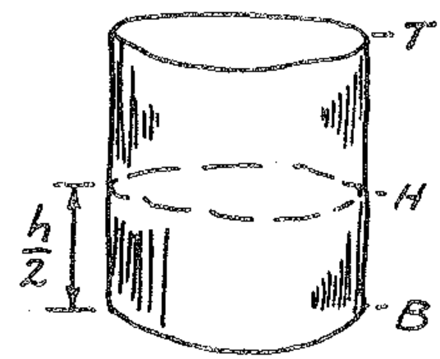
AND THEN

$$p = 1.0\ kPa + 768 \times 0.1333\ kPa$$

$$\underline{p = 103.39\ kPa \approx 103.4\ kPa}$$

2.9 A TANK IS 5 m HIGH AND HALF-FULL OF WATER.

(a.) ASSUME AIR PRESSURE IS CONSTANT AT 13 kPa IN TOP HALF OF TANK. THEN THE GAGE PRESSURE IS THE SAME AT THE TOP OF THE WATER.




$P_H = 13\ kPa$

(b.) PRESSURE AT BOTTOM $= P_B = P_H + \gamma_{H_2O} \times \frac{h}{2}$

$P_B = 13\ kPa + \left(998\ \frac{kg}{m^3} \times 9.8\ \frac{m}{s^2}\right)(2.5\ m)$

$= 13\ kPa + 24.451\ kPa = 37.451\ kPa$

(c.) $P_H = 13\ kPa + 101\ kPa = 114\ kPa$

$P_B = 37.451 + 101 = 138.451\ kPa$

2.10 (a.) DENSITY $\rho = \frac{1}{v} = \frac{1}{10.07\ ft^3/lbm} = .0993\ lbm/ft^3$

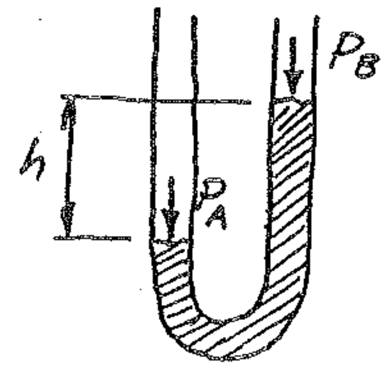
(b.) SPECIFIC WEIGHT $\gamma = \frac{g}{g_c}\rho$

$\gamma = \left(\frac{32.1\ ft/s^2}{32.174\ ft \cdot lbm/lbf \cdot s^2}\right)\left(.0993\ \frac{lbm}{ft^3}\right)$

$\gamma = .0991\ lbf/ft^3$

(c.) SPECIFIC GRAVITY $= \rho/62.43 = \underline{.00159}$

2.11 AIR IS ASSUMED TO HAVE A CONSTANT PRESSURE THROUGHOUT ANY ONE CLOSED VOLUME SO THAT $P_A$ ACTS ON MERCURY IN MANOMETER AS SHOWN. THE PRESSURE IN THE MERCURY IS THE SAME AT ANY ONE ELEVATION. THUS




$$P_A = P_B + \gamma_{Hg} \times h$$

SOLVING FOR $h$:

$$h = \frac{P_A - P_B}{\gamma_{Hg}} = \frac{(20\text{ psig} - 18\text{ psig})(144\text{ in}^2/\text{ft}^2)}{(845\text{ lb}_f/\text{ft}^3)}$$

$$\underline{h = 0.34\text{ ft}}$$

2.12 PRESSURE = FORCE/AREA

FORCE = PRESSURE × AREA

$$= \left(250\ \frac{\text{lb}_f}{\text{in}^2}\right)(\pi)\left(\frac{1\text{ ft}^2}{4}\right)(144\text{ in}^2/\text{ft}^2)$$

$$\underline{= 28{,}274\text{ lb}_f}$$

2.13 (a.) 14.8 psiv

(b.) 14 in. Hg VACUUM

2.14 (a.) 14.7 psi = 29.9389... in Hg

(b.) 460 mm Hg = 61.3... kPa

(c.) 300 in. Hg = 147.3 psi

(d.) 50 psi = 344.75 kPa

(e.) 20 kPa = 2.9008 psi

(f.) 20 inches WG = 0.722 psig

(g.) 50 cm WG = 4.903 kPa

2.15 $P = P_g + P_a$

$= 955 \text{ psig} + 14.4 \text{ psi}$

$P = 969.4 \text{ psia}$

2.16 $P = P_a - P_{gv} = 100.4 - 80$

$P = 20.4 \text{ kPa}$

PROBLEMS FROM SECTIONS 2.9 AND 2.10 ARE INTENDED TO HELP STUDENTS UNDERSTAND THERMAL EQUILIBRIUM AND TEMPERATURE MEASUREMENTS.

2.17 BLOCKS A AND B ARE NOT IN THERMAL EQUILIBRIUM. THEY WOULD BE IN THERMAL EQUILIBRIUM IF THEY WERE AT THE SAME TEMPERATURE.

2.18 COPPER-CONSTANTAN THERMOCOUPLE WILL GENERATE AN EMF (VOLTAGE) IN DIRECT PROPORTION TO THE JUNCTION TEMPERATURE. THE MAXIMUM VOLTAGE WILL BE OBSERVABLE AT 400°F AND FROM TABLE 2-3 THIS WOULD BE 9.523 MILLIVOLTS.

2.19 IRON-CONSTANTAN THERMOCOUPLE HAS A MEASURED EMF OF 8.700 mV. FROM TABLE 2-3 THE TEMPERATURE MAY BE FOUND BY LINEAR INTERPOLATION

$$\frac{T-177}{148.9-177} = \frac{8.700-9.483}{7.947-9.483} = .50977$$

$$\underline{T = 177 - 14.325 = 162.675°C}$$

2.20 WE MAY WRITE $T_N = mT_c + b$

WHERE $m$ AND $b$ ARE CONSTANTS. THEN WE SUBSTITUTE VALUES, $T_N = 0$ WHEN $T_c = 28.5°C$ AND $T_N = 100$ WHEN $T_c = 690°C$.

$$0 = m(28.5) + b$$

$$100 = m(690) + b$$

SOLVING THESE TWO EQUATIONS FOR $m$ AND $b$: $m = 0.1512$ AND $b = -4.308$

SO THAT.

$$T_N = 0.1512T_c - 4.308$$

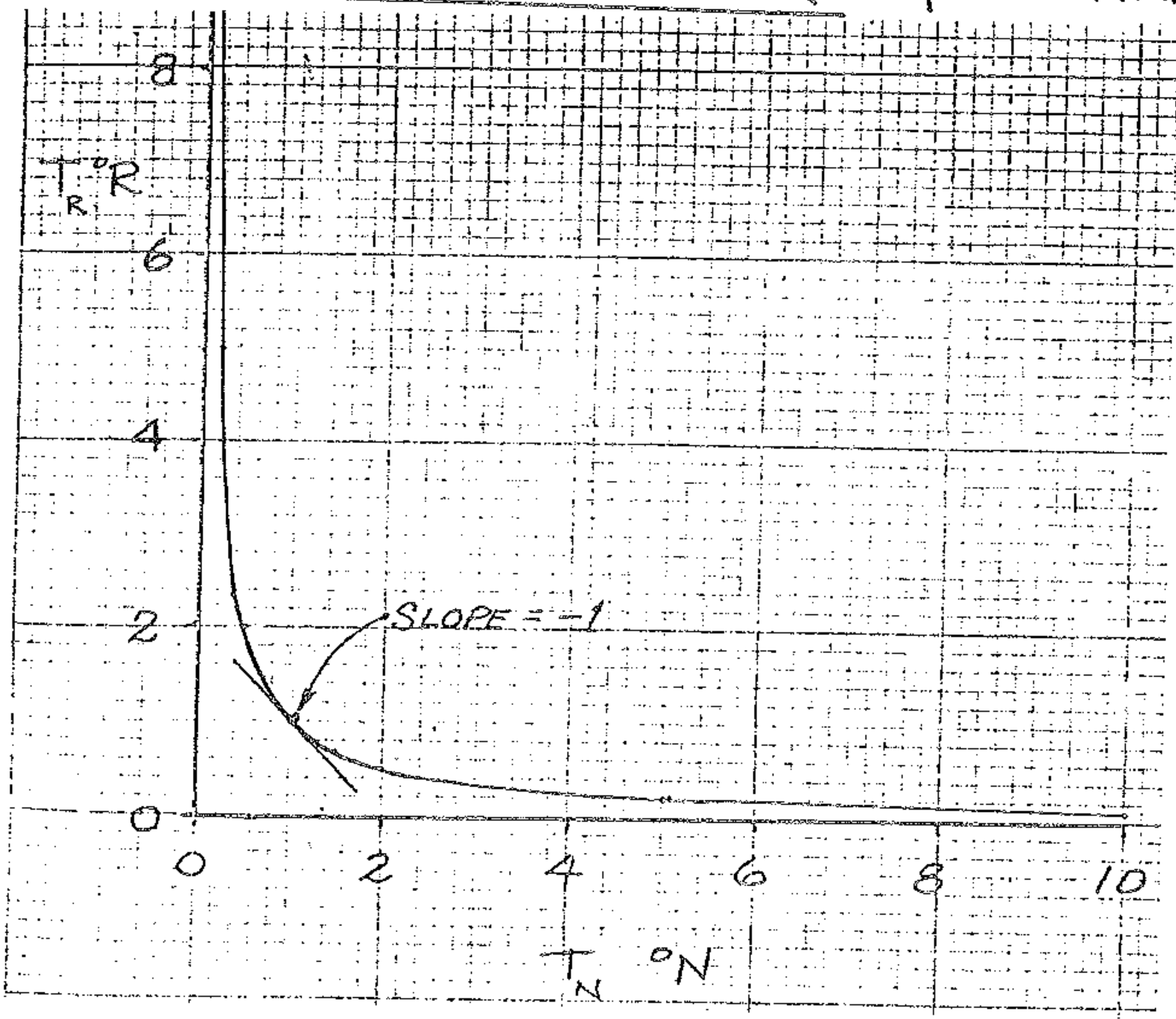
ALSO $T_c = T - 273$ WHERE $T$ IS IN KELVIN DEGREES. AT ABSOLUTE ZERO; $T=0$ SO

$$T_N = .1512(T-273) - 4.308$$

$\underline{T_N = -45.58°N}$ AT ABSOLUTE ZERO.

2.21 SLOPE AT $T_D = 1°D$:

$\underline{\text{SLOPE} = -1\ °D/°R}$ (SEE GRAPH)




2.22 $T_L = \text{LOG } T°R = \text{LOG } T_R$. ALSO

$T_R = \frac{9}{5} T_K$ SO THAT

$$T_L = \text{LOG}\left(\frac{9}{5} T_K\right) = \text{LOG } \frac{9}{5} + \text{LOG } T_K$$

OR

$$\underline{T_L = 0.255\ldots + \text{LOG } T_K}$$

2.23 (a.) $\underline{140°F = 600°R}$

(b.) $\underline{88°F = 548°R}$

(c.) $\underline{230°F = 110°C}$

(d.) $\underline{87\,K = 156.6°R}$

2.24 (a.) $412°F = \underline{872°R = 484\,K}$

(b.) $32°F = \underline{492°R = 273\,K}$

(c.) $117°C = \underline{390\,K = 702°R}$

(d.) $72°C = \underline{345\,K = 621.°R}$

2.25 USING TABLE 2-3, THE emf IN mV FOR A COPPER-CONSTANTIN THERMOCOUPLE IS 3.967 mV AT 200°F. A THERMOPILE IS A GROUP OF THERMOCOUPLES CONNECTED IN SERIES. THUS THE emf FOR 8 THERMOCOUPLES IS

$$\text{emf} = 8 \times 3.967\,mV$$
$$\underline{= 31.736\,mV}$$

THE PROBLEMS OF SECTION 2.11 ARE INTENDED TO GIVE A BETTER UNDERSTANDING OF ENERGY: KINETIC, POTENTIAL, AND INTERNAL.

2.26 (a.) KINETIC ENERGY $= \frac{1}{2} m \bar{V}^2$

$$KE = \left(\frac{1}{2}\right)(45{,}000\ kg)\left(1000\ \frac{km}{h}\right)^2\left(\frac{1h}{3600s}\right)^2$$

AND 1000 m $(10^3 m) = 1$ km SO THAT

$$KE = \left(1736\ \frac{kg\text{-}km^2}{s^2}\right)\left(10^6\ \frac{m^2}{km^2}\right) = \underline{1.736 \times 10^6\ kJ}$$

(b.) POTENTIAL ENERGY = $mgz$

$$= (45{,}000\ kg)\left(9.81\ \frac{m}{s^2}\right)(3000\ m)$$

$$\underline{PE = 13.2435 \times 10^5\ kJ}$$

2.27 (a.) ZERO (0), SINCE $\bar{V}$ APPEARS TO BE ZERO.

(b.) $KE = \frac{1}{2} m \bar{V}^2 = \frac{1}{2}\left(\frac{W}{g}\right)\bar{V}^2$

$$= \left(\frac{1}{2}\right)\left(\frac{170\ N}{9.8\ m/s^2}\right)\left(140{,}000\ \frac{m}{h}\right)^2\left(\frac{1h}{3600s}\right)^2$$

$$\underline{KE \cong 13{,}100\ kJ}$$

2.28 (a.) THE WOOD WILL FALL 40 meters. THUS

$$\Delta PE = mg(\Delta z) = (1\,kg)(9.8\,\tfrac{m}{s^2})(40\,m)$$
$$= \underline{392\ J}$$

(b.) THE STEEL WILL SINK AND THEREFORE FALL 60 meters.

$$\Delta PE = (1\,kg)(9.8\,m/s^2)(60\,m) = \underline{588\ J}$$

2.29 THE ENERGY SUPPLIED BY THE PUMP MUST BE EQUAL TO THE INCREASE IN POTENTIAL ENERGY OF THE WATER, WHICH IS

$$\Delta pe = \Delta PE/m = g(\Delta z)$$
$$= (9.8\,m/s^2)(75\,m) = \underline{735\ J/kg}$$

2.30 $ke = \frac{1}{2}\bar{V}^2 = \left(\frac{1}{2}\right)\left(24\,\frac{m}{s}\right)^2 = \underline{288\ J/kg}$

2.31 $KE = \frac{1}{2}m\bar{V}^2 = \frac{1}{2}(1\,kg)\left(60\,\frac{m}{s}\right)^2 = \underline{1800\ J}$

2.32 (a.) TOTAL ENERGY = AKE + KE + PE + U

$$= \underline{305\ kJ}$$

(b.) TOTAL MECHANICAL ENERGY = ΔKE + KE + PE

$= \underline{270 \text{ kJ}}$

2.33 (a.) POTENTIAL ENERGY, $PE = mgz/g_c$

AND $g = 32.09$ ft/s² FROM TABLE B.2

THE BALLOON MASS IS

$$m = \frac{g_c}{g} W = \left(\frac{32.17}{31.7}\right)\left(\frac{10}{16} \text{ lbf}\right) = 0.634 \text{ lbm}$$

THEN

$$PE = mgz/g_c = \frac{(0.634 \text{ lbm})(32.09 \text{ ft/s}^2)(5000 \text{ ft})}{(32.17 \text{ ft·lbm/lbf·s}^2)}$$

$\underline{PE = 3162.1 \text{ ft-lbf}}$

(b.) AT SEA LEVEL $g = 32.108$ FROM TABLE B.2. THEN, WITH $z = -1000$ ft

$$PE = \frac{(0.634 \text{ lbm})(32.108 \text{ ft/s}^2)(-1000 \text{ ft})}{(32.17 \text{ ft·lbm/lbf·s}^2)}$$

$\underline{= -632.778 \text{ ft-lbf}}$

(c.) <u>zero</u>, SINCE RELEASE POINT WAS ASSUMED TO BE ELEVATION OF ZERO POTENTIAL ENERGY.

2.34 TOTAL ENERGY = KE + PE + U

$$= 28\ \text{BTU} + 2\ \text{BTU} + 150\ \text{BTU}$$

$$\underline{= 180\ \text{BTU}.}$$

2.35 $$ke = \frac{1}{2g_c}\bar{V}^2 = \frac{(70\ \text{mi/hr})^2(1.47\ \text{ft/s}/\text{mi/hr})^2}{(2)(32.17\ \text{ft}\cdot\text{lbm}/\text{lbf}\cdot\text{s}^2)}$$

$$\underline{ke = 164.5..\ \text{ft lbf/lbm}}$$

2.36 TOTAL ENERGE, $E = KE + PE + U$

$$= (10\ \text{lbm})(500\ \text{BTU/lbm}) + (10\ \text{lbm})(100\ \text{BTU/lbm}) + 15{,}000\ \text{BTU}$$

$$\underline{E = 21{,}000\ \text{BTU}}$$

$$\underline{e = \frac{E}{m} = 2{,}100\ \text{BTU/lbm}}$$

2.37 DIFFERENCE IN ENERGY $= \Delta PE = \frac{gh}{g_c}$

$\underline{\Delta PE = 50\ \text{ft-lbf/lbm}}$ MORE AT (1) THAN AT (2)

2.38 $$ke = \frac{1}{2g_c}\bar{V}^2 = \frac{(2\ \text{ft/s})^2}{2(32.17\ \text{ft}\cdot\text{lbm}/\text{lbf}\cdot\text{s}^2)}$$

$$\underline{= 0.062\ \text{ft}\cdot\text{lbf/lbm}}$$

2.39 $pe = 150 \text{ ft}\cdot\text{lbf}/\text{lbm}$ AT (1)

$= 100 \text{ ft}\cdot\text{lbf}/\text{lbm}$ AT (2)

PROBLEMS IN SECTION 2.12 ARE INTENDED TO GIVE A BETTER UNDERSTANDING OF EFFICIENCY.

2.40 EFFICIENCY, $\eta = \dfrac{\text{OUTPUT}}{\text{INPUT}} = 0.92$

THE INPUT IS $140{,}000 \dfrac{\text{BTU}}{\text{GAL}} \times 100 \text{ GAL}$

$= 14{,}000{,}000 \text{ BTU}.$

THE EXPECTED OUTPUT IS

$\text{OUTPUT} = (0.92)(14{,}000{,}000 \text{ BTU})$

$= 12{,}880{,}000 \text{ BTU}.$

2.41 $\eta = \dfrac{\text{OUTPUT}}{\text{INPUT}} = 0.08$ AND $\text{OUTPUT} = 2.5 \text{kW}$

SO THAT $\text{INPUT} = \dfrac{2.5 \text{kW}}{0.08} = 31.25 \text{ kW}$

ALSO

$\text{INPUT} = (1000 \text{ W/m}^2)(\text{AREA OF PANEL})$

AND

$\text{AREA OF PANEL} = \dfrac{31.25 \text{kW}}{1000 \text{ W/m}^2} = \mathbf{31.25 \, m^2}$

2.42 $\eta = \frac{\text{OUTPUT}}{\text{INPUT}} = 0.70$

THE INPUT IS THE POTENTIAL ENERGY OF THE WATER: 60 lbf·ft/lbm AND THE RATE IS $60 \times 1{,}000{,}000$ ft·lf/min

$= 60{,}000{,}000$ ft-lbf/min

$= 1{,}000{,}000$ ft·lbf/s $= 1818.18\ldots$ hp

$= 1356.36\ldots$ kW

THE OUTPUT IS THEN

$$\text{OUTPUT} = (0.70)(1356.36 \text{ kW})$$

$$= \underline{949.45 \text{ kW}}$$

2.43 EFFICIENCY, $\eta = \frac{\text{OUTPUT}}{\text{INPUT}}$

OUTPUT = 200 MW = 200,000 kW

$$\text{INPUT} = 30{,}000 \frac{\text{kJ}}{\text{kg}} \times 1.6 \times 10^6 \frac{\text{kg}}{\text{day}}$$

$$= 48 \times 10^9 \text{ kJ/day} = 2 \times 10^9 \text{ kJ/hr}$$

$$= 555{,}555\ldots \text{ kW}$$

SO $\eta = \frac{200{,}000 \text{ kW}}{555{,}555 \text{ kW}} = \underline{36\% \ (.36)}$

2.44 EFFICIENCY $= \frac{\text{OUTPUT}}{\text{INPUT}} = \eta$

OUTPUT = 5 kW

$$\text{INPUT} = 180{,}000 \frac{\text{BTU}}{\text{GAL}} \times 0.4 \frac{\text{GAL}}{\text{hr}}$$

$$\text{INPUT} = 72{,}000 \frac{\text{BTU}}{\text{hr}} = 20 \frac{\text{BTU}}{\text{s}}$$

$$= 21.1 \text{ kW}$$

SO THAT

$$\eta = \frac{5 \text{ kW}}{21.1 \text{ kW}} = \underline{23.7\%}$$

2.45 $\text{EFFICIENCY} = \frac{\text{OUTPUT}}{\text{INPUT}} = \eta$

$$\text{INPUT} = 3800 \text{ J}$$

$$\text{OUTPUT} = 3600 \text{ W}\cdot\text{s} = 3600 \text{ J}$$

SO

$$\eta = \frac{3600 \text{ J}}{3800 \text{ J}} = \underline{94.7\%}$$

2.46 FOR 100 WIND GENERATORS PRODUCING 250 kW EACH,

$$\text{TOTAL POWER} = 100 \times 250 \text{ kW}$$

$$= 25 \text{ MW}$$

FOR 38% EFFICIENCY

$$\eta = \frac{\text{OUTPUT}}{\text{WIND POWER}} = 0.38$$

AND

$$\text{WIND POWER} = \frac{25 \text{ MW}}{0.38}$$

$$\underline{= 65.789 \text{ MW}}$$

PROBLEMS OF SECTION 2.13 ARE INTENDED TO PROVIDE ADDITIONAL PRACTICE IN HANDLING UNITS.

2.47 FROM THE DEFINING EQUATION FOR THE REYNOLDS NUMBER

$$\mu = \frac{\rho \bar{V} D}{Re}$$

AND $Re$ IS UNITLESS, $\rho$ IS DENSITY, $\bar{V}$ IS VELOCITY, AND $D$ IS A DIAMETER OR LENGTH. IN SI:

$$\mu = \left(\frac{kg}{m^3}\right)\left(\frac{m}{s}\right)(m) = \underline{kg/m \cdot s}$$

IN ENGLISH UNITS

$$\mu = \left(\frac{lbm}{ft^3}\right)\left(\frac{ft}{s}\right)(ft) = \underline{lbm/ft \cdot s}$$

2.48 (a.) UNITS FOR $\chi$ ARE $\underline{\frac{kJ}{kg \cdot s}}$ OR $\underline{\frac{BTU}{lbm \cdot s}}$

(b.) $\chi$ UNITS ARE $\underline{\frac{kJ}{kg \cdot K}}$ OR $\underline{\frac{kJ}{kg \cdot °C}}$ IN SI

$\underline{\frac{BTU}{lbm \, °R}}$ OR $\underline{\frac{BTU}{lbm \, °F}}$ IN ENGL.

(c.) $\chi$ UNITS ARE $\underline{kJ}$ OR $\underline{BTU}$.

(d.) $\chi$ UNITS ARE $\underline{kJ \cdot kg/m^6}$ OR $\underline{\dfrac{BTU \cdot lbm}{ft^6}}$

(e.) $\chi$ UNITS ARE $\underline{\dfrac{kJ}{kg \cdot K}}$ OR $\underline{\dfrac{BTU}{lbm \cdot °R}}$

2.49 IN SI, THE LEFT SIDE HAS UNITS OF $kg/m^4$. THE RIGHT SIDE:

$$\frac{(kg/m^3)(m^2/s^2)}{(m)(kg \cdot m/s^2 \cdot N)}\left[\frac{kg/m \cdot s}{(m)(m/s)(N/m^2)}\right] = kg/m^4$$

SO THE UNITS ARE THE SAME. IN ENGLISH UNITS THE LEFT SIDE HAS UNITS OF $lbm/ft^4$. THE RIGHT SIDE:

$$\frac{(lbm/ft^3)(ft^2/s^2)}{(ft)(lbm \cdot ft/lbf \cdot s^2)}\left[\frac{lbm/ft \cdot s}{(ft)(ft/s)(lbf/ft^2)}\right] = lbm/ft^4$$

WHICH GIVES THE SAME UNITS AS THE LEFT SIDE.

2.50 (a.) UNITS OF $C = \left(\dfrac{N}{m^2}\right)\left(\dfrac{m^3}{kg}\right)^{1.7} = \dfrac{N \cdot m^{3.1}}{kg^{1.7}}$ (SI)

$= \left(\dfrac{lbf}{ft^2}\right)\left(\dfrac{ft^3}{lbm}\right)^{1.7} = \dfrac{lbf \cdot ft^{3.1}}{lbm^{1.7}}$ (ENGLISH)

2.50 (CONT.)

(b.) $\left(\frac{N}{m^2}\right)\left(\frac{m^3}{kg}\right)^{1.3} = \frac{N \cdot m^{1.9}}{kg^{1.3}}$ (SI)

$\left(\frac{lbf}{ft^2}\right)\left(\frac{ft^3}{lbm}\right)^{1.3} = \frac{lbf \cdot ft^{1.9}}{lb_m^{1.3}}$ (ENGLISH)

(c.) $\left(\frac{N}{m^2}\right)\left(\frac{m^3}{kg}\right) \Big/ \left(\frac{m^3}{kg}\right)^{2.3} = \frac{N \cdot kg^{1.3}}{m^{5.9}}$ (SI)

$\left(\frac{lbf}{ft^2}\right)\left(\frac{ft^3}{lbm}\right) \Big/ \left(\frac{ft^3}{lbm}\right)^{2.3} = \frac{lbf \cdot lb_m^{1.3}}{ft^{5.9}}$ (ENGL.)

(d.) $N/m^2$ (Pa) OR $lbf/ft^2$

OR $lbf/in^2$ (psi)

(e.) K OR °R