Mr. Demick
Principles of Engineering
1.3.3 Thermodynamics Practice Test (*5 points*)

Name: KEY

Instructions: Answer each problem completely. You must show all formulas, all steps and work, including units.

Conduction Equations:

$$Q = mc\Delta T \qquad P = \frac{kA\,\Delta T}{L} \qquad k = \frac{PL}{A\,\Delta T} \qquad P = \frac{Q}{\Delta t}$$

1. A 2.50 kg piece of aluminum metal at 75.0 °C is placed in 4.00 liters (= 4.00 kg) of water at 20.0 °C. Determine the final temperature (T_f). (The specific heat capacity of aluminum: c_{Al} = 900 (J/kg°C); the specific heat capacity of water: c_W = 4184 (J/kg°C).)

PLTW — TITLE: Thermodynamics Prob. #1 — 87

2/19/16

A 2.50 Kg piece of aluminum metal at 75.0°C is placed in 4.00 (=4.00Kg) of water a 20.0°C. Determine the final temperature (T_f).

Known values

$m_{Al} = 2.50$ Kg $\qquad m_w = 4.00$ Kg

$T_{Al} = 75.0°C \qquad T_w = 20.0°C$

$c_{Al} = 900 \frac{J}{Kg \times C°} \qquad c_w = 4184 \frac{J}{Kg \times °C}$

Also at end.

Unknown: Q, T_f $\qquad Q_{Al}$ (lost) = Q_w (gained)

$Q = m_{Al} c_{Al} \Delta T_{Al} = m_w c_w \Delta T_w$

$2.50 Kg \; 900 \frac{J}{Kg \times °C} (75.0°C - T_f) = 4.00 Kg \; 4184 \frac{J}{Kg \times °C} (T_f - 20.0°C)$

$2{,}250 \left(\frac{J}{°C}\right)(75.0°C - T_f) = 16{,}736 \left(\frac{J}{°C}\right)(T_f - 20.0°C)$

$168{,}750 J - 2{,}250 \left(\frac{J}{°C}\right)(T_f) = 16{,}736 \left(\frac{J}{°C}\right)(T_f) - 334{,}720 J$

$+334{,}720 J \qquad + 334{,}720 J$

$503{,}470 J - 2{,}250 \left(\frac{J}{°C}\right)(T_f) = 16{,}736 \left(\frac{J}{°C}\right)(T_f)$

$+2{,}250 (J/°C)(T_f) \qquad + 2{,}250 (J/°C)(T_f)$

$\frac{503{,}470 J}{18{,}986 (J/°C)} = \frac{18{,}986 \left(\frac{J}{°C}\right)(T_f)}{18{,}986 (J/°C)}$

$\boxed{T_f = 26.52°C}$

KEY

2. Calculate the energy transferred when a block of aluminum at 80.0 °C is placed in 5.00 liters (=5 kg) of water at 10.0 °C if the final temperature becomes 17.0 °C. Also, find the mass of the aluminum block m_{Al}. (The specific heat capacity of aluminum: c_{Al} = 900 (J/kg°C); the specific heat capacity of water: c_W = 4184 (J/kg°C).)

PLTW TITLE Practice Thermodynamics Prob. #2 89

Calculate the energy transferred when a block of aluminum at 80.0°C is placed in 5.00 liters (=5.00 Kg) of water at 10.0°C if the final temperature becomes 17.0°C. Also, find m_{Al}.

Known values | Unknown: Q, m_{Al}

$m_w = 5.00\ Kg$ $T_{Al} = 80.0°C$

$T_w = 10.0°C$ $c_{Al} = 900\left(\frac{J}{Kg \times °C}\right)$ $\Delta T_{Al} = 80 - 17 = 63°C$

$c_w = 4184\left(\frac{J}{Kg°C}\right)$ $\Delta T_w = 17 - 10 = 7.0°C$

Equations: $Q = mc\Delta T$, $Q_{Al}(lost) = Q_w(gained)$

$Q_w = m_w c_w \Delta T_w = 5.00Kg\ 4184\left(\frac{J}{Kg \times °C}\right)(7.0°C)$

$Q_w = 146440J$

Solve for m_{Al}

$Q_{Al} = m_{Al} c_{Al} \Delta T_{Al}$

$m_{Al} = \frac{Q_{Al}}{c_{Al}\Delta T_{Al}}$

$= \frac{146{,}440J}{900\left(\frac{J}{Kg \times °C}\right)(63.0°C)}$

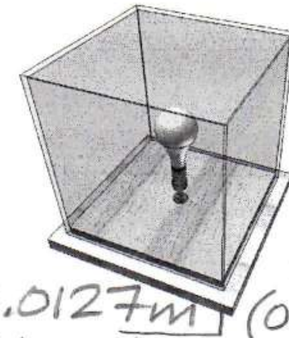
$m_{Al} = 2.58\ Kg$

KEY

3. The top of a 7/16 inch thick acrylic testing box is covered with an unknown ½ -inch insulation material (black). The dimensions of box are 15 inch x 15 inch on each side. The sides and are wrapped with a control insulting material (blue) so that the almost all heat loss is through the 15 inch x 15 inch unknown insulating material on the top of the box (assume no heat is lost from the bottom or sides of the box). Determine the thermal conductivity for the insulating material if a 30 W bulb is used to heat the box. You may assume the only heat loss from the box occurs through the 15 x 15 test area. The bulb maintains the inside temperature at 13.0 ºC higher than the outside temperature.

K L P A ΔT

$$K = \frac{PL}{A\Delta T}$$



a. List all known values.

$P = 30W$

$\Delta T = 13.0°C$

$L = 0.50in\left(\frac{1 ft}{12in}\right)\left(\frac{1m}{3.28ft}\right) = 0.0127m$

$A = 15 \times 15in\left(\frac{2.54cm}{1in}\right)\left(\frac{1m}{100cm}\right) = 0.381m \Rightarrow A = (0.381)^2 = 0.145m^2$

b. List all unknown values.

K

c. Select equations.

$$K = \frac{PL}{A\Delta T}$$

d. Apply known values.

$$K = \frac{(30W)(0.0127m)}{(0.145m^2)(13.0°C)}$$

e. Solve.

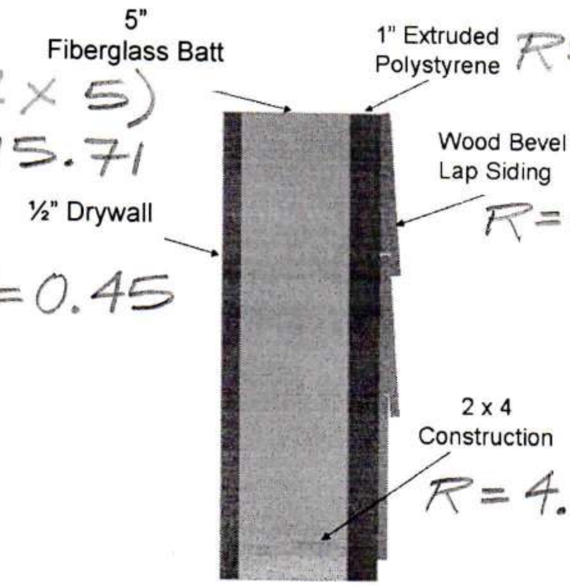
$$K = 0.202 \frac{J}{s \times m \times °C}$$

$$W = \frac{J}{s}$$

KEY

4. Use the provided R-value chart and the illustration below to calculate the R-value of the wall cavity and the R-value at the stud location.

a. Define U-value:



(3.142 × 5) R = 15.71

R = 4.00

R = 0.80

R = 0.45

R = 4.38

b. Define R-value:

c. Wall cavity R-value:

R = 0.45 + 15.71 + 4.00 + 0.80

R = 20.96

d. R-value at stud location

R = 0.45 + 4.38 + 4.00 + 0.80

R = 9.63

$Q = P \cdot \Delta t$ KEY

5. A student travels on a school bus in the middle of winter from home to school. The school bus temperature (T_1) is 57.0 °F. The student's skin temperature (T_2) is 96.2 °F. (Q) Determine the net energy transfer from the student's body during the 28.00 min ($\Delta t = 1680 s$) ride to school due to electromagnetic radiation. Note: Skin emissivity is 0.90 (e), and the surface area of the student is 1.60 m^2 (A).

$P = \sigma A e (T_2^4 - T_1^4)$

a. Define Stefan's Law.

All objects lose and gain energy by electromagnetic radiation.

b. List all known values.

$A = 1.60 m^2$ $\sigma = 5.6696 \times 10^{-8} \left(\frac{W}{m^2K^4}\right)$

$e = 0.90$ $\Delta t = 1680 s$

T_1 = bus temp. = 57.0°F T_2 = skin temp = 96.2°F

$T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(57 - 32) = 13.9°C$ $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(96.2 - 32) = 35.7°C$

$T_K = T_C + 273 = 13.9 + 273$ $T_K = T_C + 273 = 35.7 + 273$

$T_K = 286.9°K$ $T_K = 308.7°K$

c. List all unknown values.

P = rate of energy transfer

Q = energy transfer

d. Select equations.

$P = \sigma A e (T_2^4 - T_1^4)$ $Q = P \cdot \Delta t$

e. Apply known values to equations.

Find $(T_2^4 - T_1^4) = (308.7°K)^4 - (286.9°K)^4$

$= 2,306,067,392 K^4$

$P = \left(5.6696 \times 10^{-8} \frac{W}{m^2K^4}\right)(1.60 m^2)(0.90)(2,306,067,392 K^4)$

$P = 188.273 W$

$J = W \cdot s$

f. Solve.

$Q = P\Delta t$

$= (188.273 W)(1680 s)$

$Q = 316,297.8 J$

R-Value Chart	
Construction Material	**R-Value**
½ in. Drywall	0.45
5/8 in. Drywall	0.56
Particle Board – ½ in.	0.63
Particle Board – ¾ in.	0.94
Fiberboard ½ in.	1.32
Extruded Polystyrene 1 in.	4.00
Extruded Polystyrene 1 ½ in.	6.00
Foil-faced Polyisocyanurate 1 in.	7.20
2 x 4	4.38
2 x 6	6.88
Hardwood	0.90
Masonry Systems	**R-Value**
Brick 4 in. common	0.80
Brick 4 in. face	0.44
Concrete Block – Normal wt. 12 in. empty core	1.23
Concrete Block – Light wt. 12 in. empty core	2.60–2.30
Cement Mortar	0.20
Sand and Gravel	0.60
Stucco	0.20
Roofing	**R-Value**
Asphalt Roll	0.15
Asphalt Shingle	0.44
Slate	0.05
Wood	0.94
Siding	**R-Value**
Wood Shingles	0.87
Wood Drop	0.79
Wood Bevel Lapped	0.80
Aluminum/Steel – Hollow	0.61
Aluminum/Steel – with 3/8 in. Backer	1.82
Insulation	**R-Value per in.**
Fiberglass Batt	3.142
Blankets – Rock Wool	3.0–3.8
Loose Fill – Cellulose	2.8–3.7
Loose Fill – Fiberglass 0.7 lb/cu.ft	2.2–4.0
Loose Fill – Rock Wool	3.1
Loose Fill – Vermiculite	2.2
Extruded Polystyrene	4.00

TITLE

Thermodynamics Prob. #1

2/19/16

A 2.50 Kg piece of aluminum metal at 75.0°C is placed in 4.00 (=4.00Kg) of water a 20.0°C. Determine the final temperature (T_f).

Known values

$m_{Al} = 2.50\,Kg$ $m_w = 4.00\,Kg$

$T_{Al} = 75.0°C$ $T_w = 20.0°C$

$c_{Al} = 900 \frac{J}{Kg \times C°}$ $c_w = 4184 \frac{J}{Kg \times °C}$

Unknown: Q, T_f $Q_{Al}(lost) = Q_w(gained)$

$$Q = m_{Al} c_{Al} \Delta T_{Al} = m_w c_w \Delta T_w$$

$$2.50\,Kg\ 900 \frac{J}{Kg \times °C}(75.0°C - T_f) = 4.00\,Kg\ 4184 \frac{J}{Kg \times °C}(T_f - 20.0°C)$$

$$2{,}250\left(\frac{J}{°C}\right)(75.0°C - T_f) = 16{,}736\left(\frac{J}{°C}\right)(T_f - 20.0°C)$$

$$168{,}750\,J - 2{,}250\left(\frac{J}{°C}\right)(T_f) = 16{,}736\left(\frac{J}{°C}\right)(T_f) - 334{,}720\,J$$

$$+334{,}720\,J \qquad +334{,}720\,J$$

$$503{,}470\,J - 2{,}250\left(\frac{J}{°C}\right)(T_f) = 16{,}736\left(\frac{J}{°C}\right)(T_f)$$

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$$\frac{503{,}470\,J}{18{,}986\,(J/°C)} = \frac{18{,}986\left(\frac{J}{°C}\right)(T_f)}{18{,}986\,(J/°C)}$$

$$\boxed{T_f = 26.52°C}$$

DESIGNED BY: Demick DATE 2/19/16

WITNESSED BY: DATE

TITLE

Practice Thermodynamics Prob. #2

Calculate the energy transferred when a block of aluminum at 80.0°c is placed in 5.00 liters (=5.00Kg) of water at 10.0°C if the final temperature becomes 17.0°C. Also, find m_{Al}.

Known values

$m_w = 5.00\,Kg$ $T_{Al} = 80.0°C$

$T_w = 10.0°C$ $c_{Al} = 900\left(\frac{J}{Kg \times °C}\right)$ $\Delta T_{Al} = 80-17 = 63°C$

$c_w = 4184\left(\frac{J}{Kg°C}\right)$ $\Delta T_w = 17 - 10 = 7.0°C$

Unknown

Q

m_{Al}

Equations: $Q = mc\Delta T$, $Q_{Al}(\text{lost}) = Q_w(\text{gained})$

$$Q_w = m_w c_w \Delta T_w = 5.00\,Kg\; 4184\left(\frac{J}{Kg \times °C}\right)(7.0°C)$$

$$\boxed{Q_w = 146{,}440\,J}$$

Solve for m_{Al}

$$Q_{Al} = m_{Al} c_{Al} \Delta T_{Al}$$

$$m_{Al} = \frac{Q_{Al}}{c_{Al} \Delta T_{Al}}$$

$$= \frac{146{,}440\,J}{900\left(\frac{J}{Kg \times °C}\right)(63.0°C)}$$

$$\boxed{m_{Al} = 2.58\,Kg}$$

DESIGNED BY: DEMICK

DATE: 2/19/16

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DATE: