Question 1(8 points): The "efficiency" of a light bulb is the ratio of the:

a. heat plus electricity produced to the electrical input

b. voltage output of the bulb to the power input

c. energy into the bulb to the energy out of the bulb

d. light output to the electrical energy input

Question 2(8 points): Your feet feel warmer on a rug than on a tile floor because the rug

a. is usually warmer than the tile

b. is a better insulator than tile

c. has more internal energy than tile for the same mass

d. all of these

Problem 1(10 points): The Nuna2 (Tech. Univ. Delft) won the 2002 and 2003 World Solar Challenge. Its gallium arsenide triple junction solar cells covered a 9 sq. meter surface and were over 24.5% efficient. What is its top power in W and hp?

$P = \left(\frac{P}{A}\right)_{\text{arriving from sun}} \times \text{Area can} \times \text{efficiency}$

$P = \frac{1}{2}\left(1354 \frac{W}{m^2}\right)\left(9 m^2\right) \times (0.245) = 1500 W$

$1500 W \times \frac{1 hp}{746 W} = 2.0 hp.$

Problem 2(10 points): Calculate the percentage carbon per mass of the following materials.

Sugar ($C_6H_{12}O_6$)

Octane (C_8H_{18})

Natural gas (CH_4)

Hydrogen (H_2)

Sugar $C_6H_{12}O_6$:

$6m_C + 12m_H + 6m_O = 6(12) + 12(1) + 6(16) = 180$

octane C_8H_{18}

$8m_C + 18m_H = 8(12) + 18(1) = 114$

Natural gas CH_4

$m_C + 4m_H = 12 + 4(1) = 16$

Hydrogen

$2m_H = 2 = 2$

Fractional mass of carbon:

in sugar $\frac{72}{180} \times 100\% = 40\%$

in octane $\frac{8(12)}{114} \times 100\% = 84.2\%$

in CH_4: $\frac{12}{16} \times 100\% = 75\%$

in hydrogen $\frac{0}{2} \times 100\% = 0$

Problem 3(10 points): Thermonuclear fusion takes place inside the Sun at a temperature of about 100million Kelvin. If we could run a heat engine that extracts that energy at 100MK and dump it at Earth's "room temperature", (say 27°C) what is the maximum theoretical efficiency we could expect?

$$\text{Efficiency}_{max} = 1 - \frac{T_C}{T_H} \qquad T_C = 27°C + 273°K = 300\,K \quad T_H = 10^8\,K$$

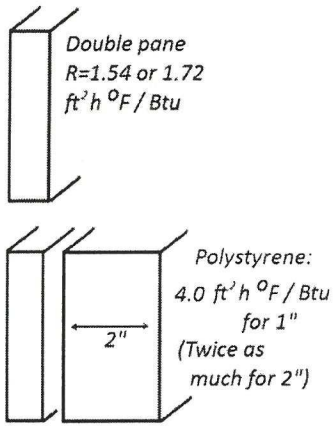
$$\text{Efficiency}_{max} = 1 - \frac{300\,K}{10^8\,K} = 0.999997 = 99.997\,\%$$

Problem 4(10 points): Styrofoam has a thermal conductivity of 0.006 Btu/hr/°F/ft^2. How thick a piece do we need to produce an R38 insulator?

$$R = \frac{\delta}{k} \Rightarrow \delta = Rk = 38(0.006) = 0.228\,ft$$

$$= 0.228\,ft \times \frac{12''}{ft} = 3\,inch.$$

Problem 5(10 points): Heat loss through windows is substantial. What percentage savings will be gained by covering a double-pane window with 2-in. sheet of rigid polystyrene board?



1" of polystereine board has an R of $4.0\ ft^2 h\ ^\circ F/Btu$,

R for 2" is twice as much

$R_S = 1.54$ & 1.72

$P = \frac{1}{R} \times A \times \Delta T$ so $P \sim \frac{1}{R}$

$$\frac{P'}{P} = \frac{1/R' \times A \times \Delta T}{1/R \times A \times \Delta T} = \frac{R}{R'}.$$

$$= \frac{1.72}{1.72+8.0} = 0.176 = 17.6\%$$

So saving is $100 - 17.6 = 82.4\%$.

or $\frac{1.54}{1.54+8} = 0.162 \Rightarrow 83.8\%$

So it is between $82.4 - 84\%$ in saving

Problem 6(12points): Estimate the Calorie content of 65 g of candy from the following measurements. A 15 g sample of the candy is placed in a small aluminum container of mass 0.325 kg filled with oxygen. This container is placed in 2.00 kg of water in an aluminum calorimeter cup of mass 0.624 kg at an initial temperature of 15.0°C. The oxygen-candy mixture in the small container is ignited, and the final temperature of the whole system is 53.5°C.

$$Q_{\substack{15\,g\\ candy}} = (m_{Al}c_{Al} + m_{H_2O}c_{H_2O})\Delta T$$

$$= \left[(0.325\ kg + 0.624\ kg)\left(0.22\ \frac{kcal}{kg^\circ C}\right) + (2.00\ kg)\left(1\ \frac{kcal}{kg^\circ C}\right)\right]$$

$$(53.5^\circ C - 15.0^\circ C) = 85.04\ kcal$$

$$Q_{\substack{65\,g\\ candy}} = \frac{65}{15} Q_{\substack{15\,g\\ candy}} = \frac{65}{15}(85.04\ kcal) = 369\ kcal$$

Problem 7(10 points): A British thermal unit (Btu) is a unit of heat in the British system of units. One Btu is defined as the heat needed to raise 1 lb of water by 1 F°. Show that

1Btu= 0.252 Kcal=1056J.

$$1\,\text{Btu} = (1\,\text{lb})(1^\circ\text{F})\left(\frac{0.454\,\text{kg}}{1\,\text{lb}}\right)\left(\frac{5/9\,^\circ\text{C}}{1^\circ\text{F}}\right)\frac{1\,\text{Kcal}}{(1\,\text{kg})(1^\circ\text{C})} = 0.2522\,\text{Kcal}$$

$$0.2522\,\text{Kcal}\left(\frac{4186\,\text{J}}{1\,\text{Kcal}}\right) = 1056\,\text{J}$$

Problem 8(12 points): : A wall is made up of four elements, as follows:

½" wood siding (lapped)	[$R_1 = 0.81$ ft²·h·°F/Btu]
½" plywood sheathing	[$R_2 = 0.62$ ft²·h·°F/Btu]
3½" fiberglass	[$R_3 = 10.9$ ft²·h·°F/Btu]
½" Sheetrock	[$R_4 = 0.45$ ft²·h·°F/Btu]

Using the R-values above, how many Btu per hour per square foot will be lost through the wall when the outside temperature is 50°F colder than the inside?

$$R = R_1 + R_2 + R_3 + R_4$$

$$= (0.81 + 0.62 + 10.9 + 0.45)\,\frac{\text{ft}^2\,\text{h}^\circ\text{F}}{\text{Btu}} = 12.78\,\frac{\text{ft}^2\,\text{h}^\circ\text{F}}{\text{Btu}}$$

$$\text{So} \quad P_2\,\frac{Q_c}{t} = \frac{1}{R}A\Delta T$$

$$\frac{P}{A} = \frac{\Delta T}{R} = \frac{50^\circ\text{F}}{12.78\,\text{ft}^2\,\text{h}^\circ\text{F/Btu}} = 3.9\,\text{Btu/hr/ft}^2$$