

CH EN 3453 – HEAT TRANSFER – FALL 2014

HOMework #1

Due Friday, August 29 at 4:00 PM

Turn in to the CH EN 3453 basket at the main desk of the Chemical Engineering offices (MEB 3290)

Help session Wednesday, August 27 at 4:30 p.m. in MEB 2325

For this assignment, you must...

- show your work
- write legibly and not in micro-font
- circle or put a box around your final answer

1. (15 pts) An understanding of the basic laws governing heat transfer is imperative to everything you will learn this semester. With your book as a guide, write the equation for and explain the following laws governing the three basic modes of heat transfer. Do not forget to explain each symbol or constant along with any pertinent units.

- (a) Fourier's Law
- (b) Newton's Law of cooling
- (c) The Stefan-Boltzmann Law

2.* (10 pts) The concrete slab of a basement is 11 m long, 8 m wide and 0.20 m thick. During the winter, temperatures are nominally 17°C and 10°C at the top and bottom surfaces, respectively. The concrete has a thermal conductivity of 1.4 W/m·K. If the basement is heated by a gas furnace operating at an efficiency of $\eta_f = 0.90$ and natural gas costs $C_g = \$0.01/\text{MJ}$,

- (a) what is the rate of heat loss through the slab?
- (b) what is the daily cost of the heat loss?

3.* (10 pts) A freezer compartment consists of a cubical cavity that is 2 m on a side. Assume the bottom to be perfectly insulated. What is the minimum thickness of Styrofoam insulation ($k = 0.030 \text{ W/m}\cdot\text{K}$) that must be applied to the top and side walls to ensure a heat load of less than 500 Watts, when the inner and outer surfaces are -10 and 35°C ?

4.* (10 pts) Air at 40°C flows over a long, 25-mm-diameter cylinder with an embedded electrical heater. In a series of tests, measurements were made of the power per unit length, P' , required to maintain the cylinder surface temperature at 300°C for different velocities V of the air. The results are as follows:

Air velocity, V (m/s):	1	2	4	8	12
Power, P' (W/m):	450	658	983	1507	1963

- (a) Determine the convection coefficient for each velocity, and display your results graphically
- (b) Assuming the dependence of the convection coefficient on the velocity to be of the form $h = CV^n$, determine the parameters C and n from the results of part (a).

5.* (10 pts) Liquid oxygen, which has a boiling point of 90 K and a latent heat of vaporization of 214 kJ/kg, is stored in a spherical container whose outer surface is of 500-mm diameter and at a temperature of -10°C . The container is housed in a laboratory whose air and walls are at 25°C . If the surface emissivity is 0.20 and the heat transfer coefficient associated with free convection at the outer surface of the container is $10 \text{ W/m}^2\cdot\text{K}$, what is the rate, in kg/s, at which oxygen vapor must be vented from the system?

More problems on the other side...

6. (20 pts) For most materials, thermal conductivity k varies with temperature. The specification sheet for Plicast LWI 26, a high temperature refractory material used for lining furnaces, indicates that the thermal conductivity varies with temperature as shown below:

Temperature, °C:	260	540	815	1095
Thermal conductivity, W/m·K:	0.389	0.404	0.433	0.490

The wall of a process heater is constructed of a 35-cm-thick layer of Plicast LWI 26. A surface thermocouple on the outside of the heater wall indicates a temperature of 270°C. A second thermocouple buried within the wall, 10 cm from the outside, indicates a temperature of 330°C. Determine the following:

- (a) The temperature on the hot side (inside) of the process heater
(b) Heat flux through the wall in W/m^2

Note: Do not simply average the temperature. You are expected to solve this using the differential form of the conductive heat transfer expression.

7. (20 pts) A boiler in a coal-fired power plant burns 2000 metric tons per day (24 hr) of coal having a heating value of 20 MJ/kg. Seventy percent of the energy input from the coal is used to make steam, and 60% of the energy in this steam is converted to mechanical (shaft) energy in a steam turbine. The turbine is connected to a water-cooled generator that is 75% efficient at producing electricity. (The other 25% produces heat.) The cooling water averages 20°C and the convective heat transfer coefficient between the water and generator is $h = 14,000 \text{ W/m}^2\cdot\text{K}$. If the diameter of the cooling channels averages 1.5 cm, what total length of cooling channels is required if the average generator temperature should not exceed 120°C? Ignore convective and radiative losses from the surface of the generator.
8. (5 pts) Complete the survey on the next page.

STUDENT SURVEY
CH EN 3453 – Heat Transfer

Please turn this in with your solutions to homework #1

Name: _____ UofU ID: _____

Preferred Email Address: _____

1. Have you read the syllabus and do you understand the policies for homework and exams for this course? () yes () no

2. What is your major? _____ Chem. Eng. _____ Mech. Eng. _____ Other

3. What is your situation regarding the prerequisites for this course? Please mark one in each column.

	I have already passed the course	I am taking the course now	I plan to take the course later
CH EN 2300 (Thermo I)	_____	_____	_____
CH EN 2450 (Numerical methods)	_____	_____	_____
CH EN 2800 (Process engineering)	_____	_____	_____

4. Do you have major status in the department of chemical engineering? () yes () no

5. Are you a transfer student (i.e., is this your first semester at the University of Utah)? () yes () no

6. How experienced/comfortable are you with the following software? (circle one in each row)

Microsoft Excel	very	somewhat	not at all
Microsoft Word	very	somewhat	not at all
Matlab	very	somewhat	not at all

7. What are the make and model of the scientific calculator you use? _____

Is it able to calculate hyperbolic sine, hyperbolic cosine and hyperbolic tangents? () yes () no

8. Are you a member of the University of Utah's student chapter of the American Institute of Chemical Engineers (AIChE)? () yes () no

9. What is the highest degree you plan to pursue?

_____ Bachelor's _____ Masters _____ Ph.D.

10. Do you have an internship lined up for next summer?

_____ Yes, with a company here in Utah. (Company: _____)

_____ Yes, with a company outside Utah (Company: _____)

_____ Not yet, although I am in contact with companies or have interviewed for internships

_____ No, but of course I am planning on pursuing an internship!