MCG 3110 - HEAT TRANSFER

Quiz #1 - Review of Thermodynamics
Thursday, May 18th, 2017

60 minutes

Part 1 - Short questions (35 marks)

1. Write the mass conservation equation and explain the meaning of every term. (5 marks)

2. Write the full general form of the 1st Law of thermodynamics and explain the meaning of every term. (10 marks)

3. Explain the difference between Steady-State, Steady Flow and Transient Flow. (5 marks)

4. Explain the difference between latent and sensible energy. (5 marks)

5. As a thermal engineer, name three things you would want to consider when working on the design of a building's new HVAC system. (5 marks)

6. Draw a P-T diagram and a T-*v* diagram and identify all the phases, the triple point and the critical point. (5 marks)

Part 2 - Problem (65marks)

You may be familiar with M&M Meat Shops, a popular Canadian retail chain of specialty frozen foods. As a young mechanical engineering student, you have been hired for a coop workterm within this organization. For your first task, you have been asked to assist the lead engineer in selecting an adequate industrial freezer for the processing of M&M's new deep dish apple pie product.

The apples pies (each placed in a thin aluminium pan) are pre-baked in the factory and are then allowed to air cool until they reach a uniform temperature of 45°C. At this point, each pie is individually packaged in a cardboard box, placed on a plastic pallet and brought into the industrial freezer where everything is cooled to a final temperature of -22°C. Each aluminium pan weighs 80g whereas each cardboard box weighs 100g. Each plastic pallet weighs 1.4kg and holds 16 pies. The objective is to load 40 pallets in the freezer for a given pie processing batch. The pies have the following composition:

Ingredient	Water Content	Mass	Freezing point
Apple slices	60%	400g	0°C
Sauce filling	80%	350g	0°C
Crust	15%	250g	0°C

a) Assuming the pies (and aluminum pans) are still at 45°C and that the cardboard boxes and pallets are at 20°C when they are initially placed in the freezer, determine the amount of heat that needs to be removed by the freezer to achieve the desired cooling process. For full marks, you must use the methodology presented in class (with assumptions and conservation equations). (55 marks)

You can use Siebel's formula:

$Cp_{fresh} = 3.35\ a + 0.84$ [kJ/kg °C]

$Cp_{frozen} = 1.26\ a + 0.84$ [kJ/kg °C]

$\Delta h_{latent} = 334\ a$ [kJ/kg]

Other data:

Aluminum pan specific heat: $Cp_{Al} = 0.875$ kJ/kg °C

Cardboard box specific heat: $Cp_{Cardboard} = 1.340$ kJ/kg °C

Plastic pallet specific heat: $Cp_{Plastic} = 1.670$ kJ/kg °C

b) One of the industrial freezers that you are considering is rated for a cooling capacity of 30kW. How much time (in minutes) would it take to achieve the pie cooling process from part a) with this freezer unit? (5 marks)

c) When you eat freshly baked warm apple pie, explain (from a thermodynamic perspective) why you are more likely to burn your tongue on the pie filling as opposed to the crust. (5 marks)