Faculty of Engineering
Department of Mechanical Engineering
Fall 2015
MEN310 - Heat Transfer

Instructors: Dr. Charbel Habchi

Exam #2 - 10%
75 minutes (December 10, 2015 – 8:00-9:15)

Student Name: ______________________________ **Student ID:** ________________ **Section:** ____

There are **2 questions** in the booklet each has several parts, please answer all parts of these questions to the best of your ability.

Marking Scheme

Questions	Weight	Mark
Question 1	**30 points**	
Question 2	**70 points**	
Total	**100 points**	

1. **Open book examination. Only original books are allowed.**
2. **Do not take the staple out. The exam booklet must remain intact.**
3. **Cheating penalty will be an "F" grade on the exam.**
4. **Mobile phones/devices are to be turned off and stowed away.**
5. **If something is not understood write your assumptions and solve the problem without asking questions.**

Good luck

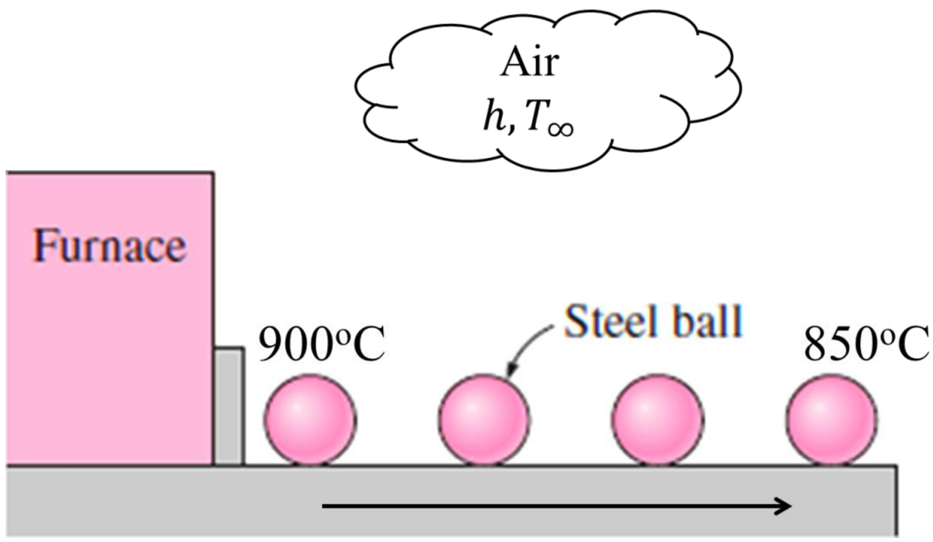
QUESTION 1: Lumped Capacitance Method

During the annealing process, steel ball bearings leaving the oven at a uniform temperature of 900^{o}C are exposed to cold air at h = 125 W/m^2.K and a temperature of 30^{o}C for a while before they are dropped into the water for quenching. The diameter of each ball is 12 mm. The properties of the steel balls are $\rho = 8000\ \mathrm{kg/m^3}$, $k = 15.1\ \mathrm{W/m.K}$ and $C_p = 480\ \mathrm{J/kg.K}$.

Assume uniform temperature distribution for the steel balls.

a) **Calculate the time that the balls can stand in the air before their temperature falls below 850^{o}C.**

b) **Calculate the rate of heat loss from the balls during this process if we have 120 balls moving per minute.**



QUESTION 2: Transient Conduction and External Convection

Consider the steady-state convection heat transfer between an air flow, with $T_\infty = 10°\text{C}$, and a flat plate with an obstacle having both a surface temperature $T_s = 44°\text{C}$ as shown in the figure. The obstacle, inserted at $x_0 = 25$ cm, is called vortex generator because it generates vortices to enhance the heat transfer process. Experiments show that for $u_\infty = 1\ m/s$, the local heat transfer coefficient can be expressed by:

$$\begin{cases} h_1(x) = -1000x + 1000 & \text{for } 0 < x \le x_0 \\ h_2(x) = -1000x + 1800 & \text{for } x > x_0 \end{cases}$$

where x is in m and h in W/m^2.K.

The plate is 1 m width into the plane of the paper and it is made of iron steel 1% with:

$$\Delta x = 25\ cm;\ \Delta y = 12.5 \text{ cm}.$$

a) **Sketch $h_1(x)$ and $h_2(x)$ on the same graph showing the main features.**

b) **Determine the average Nusselt number for the entire plate.**

c) Now let's consider the unsteady conduction heat transfer process in the plate. The bottom surface and sides of the plate are considered heat sinks which means that nodes 1, 3, 4, 5 and 6 are maintained at constant temperature of 70°C. Assume that the air properties and convection coefficients are unchanged and that the heat transfer coefficient for each node is equal to the heat transfer coefficient averaged on the corresponding control volume.

   Calculate the temperature at node 2 after 600 seconds if its initial temperature was 70°C.

d) **Calculate the instantaneous heat loss from the upper surface of the plate for t = 300 s.**