Write Down Your NAME

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Last First

Circle Your DIVISION

Div. 1	**Div. 2**	**Div. 3**	**Div.4**
8:30 am	**9:30 pm**	**12:30 pm**	**3:30 pm**
Naik	**Pan**	**Xu**	**Chen**

ME315 Heat and Mass Transfer
School of Mechanical Engineering
Purdue University

Exam 1
October 4, 2016

Read Instructions Carefully:

- Write your name on **each page** and circle your division number.
- Equation sheet and tables are attached to this exam (see last 3 pages). One page of letter-size crib sheet is allowed.
- No books, notes, and other materials are allowed.
- ME Exam Calculator Policy is enforced. Only the TI-30XIIS and TI-30XA are allowed.
- **Power off** all other digital devices, such as computer/tablet/phone and smart watch/glasses.
- Keep all the pages in order.
- You are asked to write your assumptions and answers to sub-problems in designated areas. Write on front side of the page only. If needed, you can insert extra pages but mark this clearly in the designated areas.

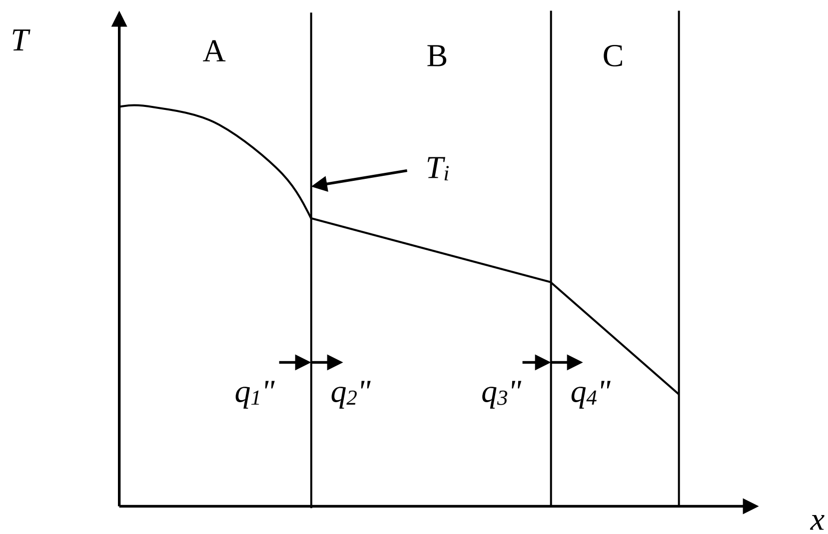
Performance		
1	**35**	
2	**35**	
3	**30**	
Total	**100**	

Circle your division: 1 2 3 4 Name________________________________

Problem 1 [35 points]

The steady-state temperature distribution in a 1-D composite plane wall of three different materials, each of constant but different thermal conductivity, k_A, k_B, and k_C, is shown in the figure below. Material A has a uniform volumetric heat generation $\dot{q}$ [W/m^3]. The thicknesses of the walls in A, B, and C are L_A, L_B, and L_C, respectively. The left side of the wall is insulated, and the right side of the wall is subjected to convection cooling, with T_∞ and h.

(a) Comment on the relative magnitudes of q_1'' and q_2'', and relative magnitudes of q_3'' and q_4''. Provide a brief justification.
(b) Comment of the relative magnitudes of k_A and k_B, and of k_B and k_C, and provide a brief justification.
(c) Sketch heat flux q'' as a function of x, in the figure on the next page.
(d) Find the expression of the temperature at the interface between wall A and wall B, T_i, in terms of given parameters $\dot{q}$, L_A, L_B, L_C, k_A, k_B, k_C, h, and T_∞.



List your assumptions below. [3 pts]

Start you answer to part (a) here. [6 pts]

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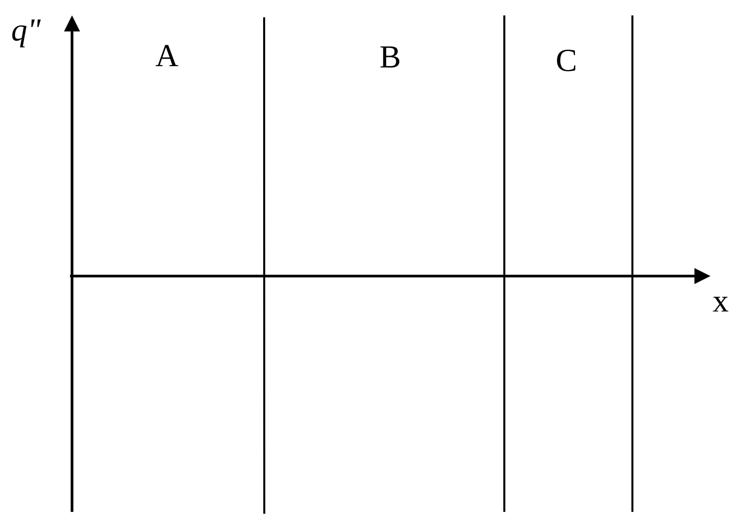
Problem 1 – continued

Start your answer to part (b) here. [6 pts]

(c) Plot q" vs. x in the figure below. [10 pts]



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Problem 1 – continued

Start your answer to part (d) here. [10 pts]

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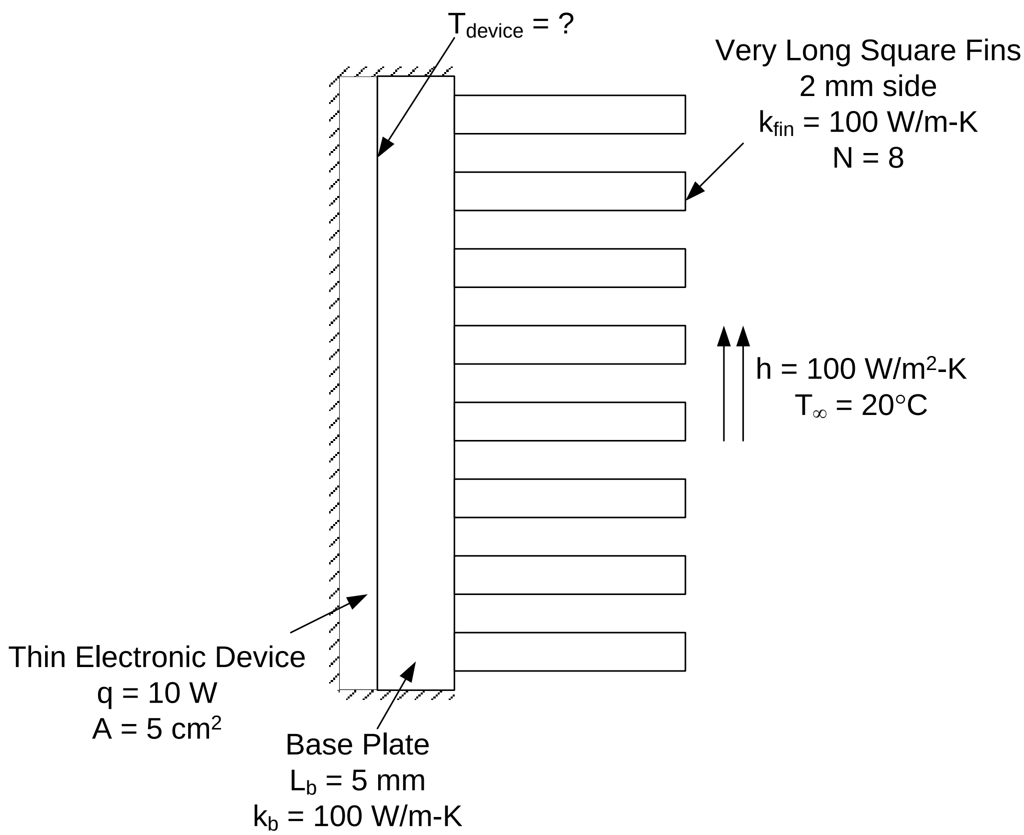
Problem 2 [35 points]

A thin electronic device of cross-sectional area 5 cm^2 dissipates 10 W of heat. The device is insulated on one side. A heat sink of the same surface area is directly attached to the electronic device. Thermal conductivity of the heat sink material is 100 W/(m·K). The base plate of the heat sink has a thickness of 5 mm. Eight infinitely long fins are attached to the base plate and the fins have a square cross-section of 2 mm side. Air with ambient temperature of 20°C and convective heat transfer coefficient 100 W/(m^2K) flows on the heat sink.

(a) Draw a thermal circuit for the system and label all resistances.
(b) Determine temperature (°C) at the interface between the device and the base plate.
(c) Calculate the effectiveness of a single fin.
(d) What is the value of efficiency of a single fin?



List your assumptions below. [2 pts]

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Problem 2 – continued

Start you answer to part (a) here. [8 pts]

Start your answer to part (b) here. [15 pts]

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Problem 2 – continued

Start your answer to part (c) here. [6 pts]

Start your answer to part (d) here. [4 pts]

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Problem 3 [30 points]

Part I (20 Pts): A metal alloy sphere of 2cm diameter and 20°C of uniform temperature is placed inside a convection oven at h = 20 W/(m^{2}K) and T_∞ = 800°C for thermal treatment. Neglect radiation heat exchange. *For metal alloy*: thermal conductivity = 200 W/(m·K); density = 2,000kg/m^3; specific heat = 500 J/(kg·K).

(a) Can we assume that the sphere is a lumped thermal system? Briefly justify.
(b) How long does it take (in seconds) for the surface temperature of the sphere to reach 500°C?

Part II (10 Pts): After reaching 500°C, the sphere is quenched by dipping into 100 ml of mineral oil at 20°C initial temperature. This process can be treated as convection between the sphere and the oil with h = 1,000 W/(m^{2}K) and T_∞ equal to the average oil temperature. Notice that T_∞ for oil is rising during this process. Neglect the heat loss to ambient and radiation. *For mineral oil*: density = 1,000 kg/m^3 and specific heat = 1,000 J/(kg·K). Note: 1 ml = 10^{-6} m^3

(c) Use energy conservation to find the steady state temperature (°C) of the sphere and the oil bath system.
(d) Derive a differential equation for the sphere temperature (°C) and solve to obtain an expression for sphere temperature as function of time (seconds).

Part I: **Start you answer to part (a) here. [7 pts]**

Part I: **Start your answer to part (b) here. [8 pts]**

Circle your division: 1 2 3 4 Name________________________________

Problem 3 – continued

<u>Part II:</u> Start your answer to part (c) here. [7 pts]

Start your answer to part (d) here. [8 pts]