Write Your Full Name on Every Page

Circle Your Division on Every page

Div. 1	**Div. 2**	**Div. 3**	**Div.4**
9:30 am	**11:30 am**	**12:30 pm**	**2:30 pm**
Xu	**Mukherjee**	**Warsinger**	**Verma**

ME315 Heat and Mass Transfer

School of Mechanical Engineering, Purdue University

Exam 1
September 25, 2019

Read These Instructions Carefully:

- **Write on front side of the page only. Do not write on the back side since it will NOT be scanned.** Keep all the pages in order.
- Circle your division number, write your Full name **on every page.**
- **Equation sheet and tables are attached.** One page of letter-size crib sheet, double-sided, is allowed. **No books, notes, and other materials are allowed.**
- ME Exam Calculator Policy is enforced. **Only TI-30XIIS and TI-30XA are allowed.**
- Power off all other digital devices, such as computer/tablet/phone and smart watch/glasses.
- **Write assumptions and answers to sub-problems in designated areas.**
- **Do not remove staples** from any page. If you use extra paper(s), you will need to **use the color papers provided to you, write division number, your full name, and problem number on each page,** attach them at the end of the exam, stapled at the upper left corner, and **indicate below how many extra sheets are attached.**

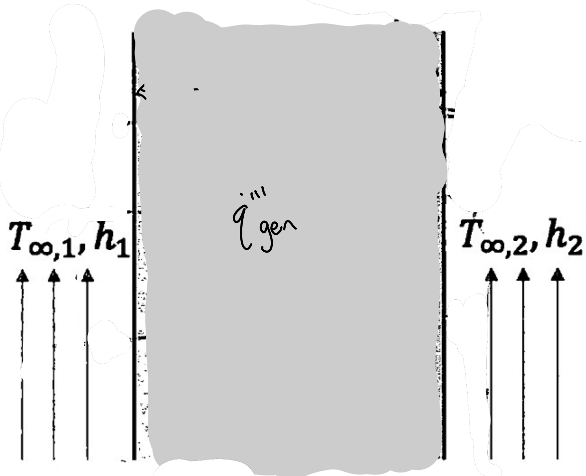
Performance		
1	40	
2	30	
3	30	
Total	100	

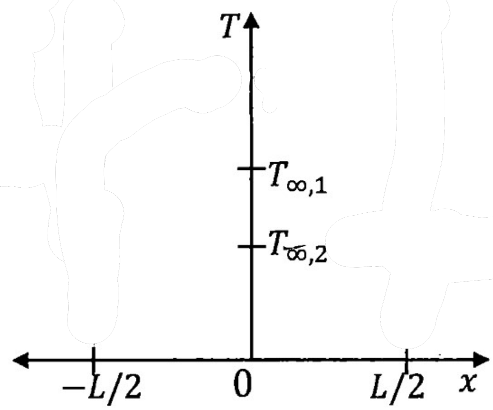
Number of extra papers if any:

Problem 1 (40 points)

1.a Draw the temperature profile for the following three scenarios and describe key features:

I: (10 pts) Solid wall of thickness L with a uniform internal volumetric heat generation rate $\dot{q}'''_{gen}$ exposed to fluid streams on either side. Steady-state. Assume that $T_{\infty,1} > T_{\infty,2}$ and $h_1 > h_2$, where $T_{\infty,i}$ and h_i, are the temperature and convective heat transfer coefficient for fluid stream i.

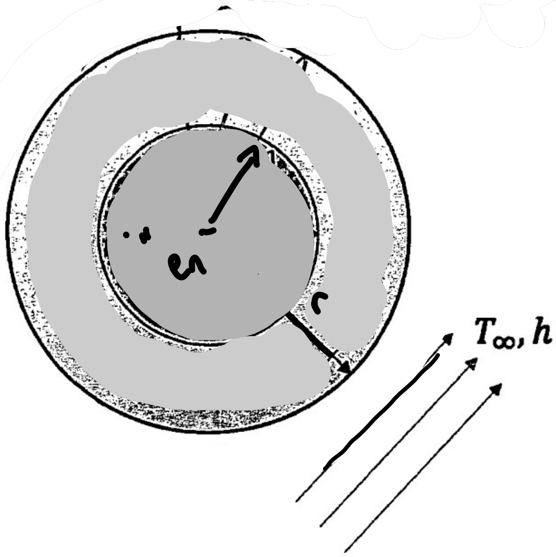


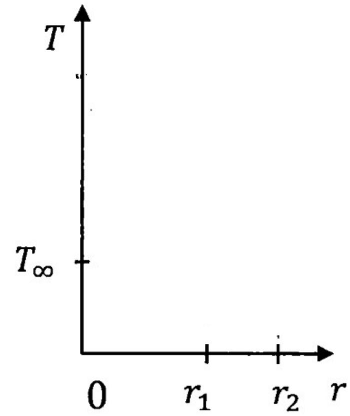


Draw temperature profile in the T-x figure (above right), describe key features and provide your justification:

Problem 1 – cont'd

II: (10 pts) Insulation around a pipe of radius r_1 which has a uniform internal volumetric heat generation rate $\dot{q}'''_{gen}$. The outer surface of the insulation is exposed to a fluid stream of temperature T_∞ and convective heat transfer coefficient h. Steady-state.



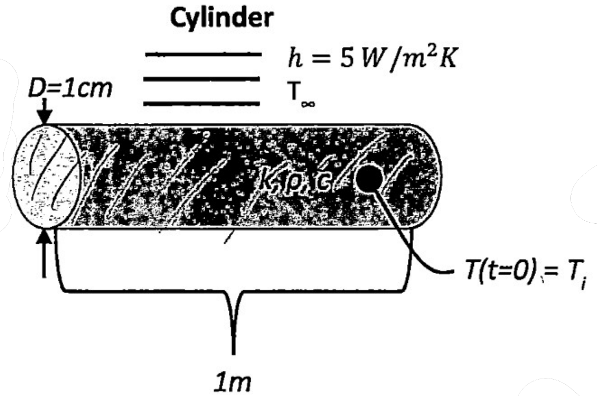


Draw temperature profile in the T-r figure (above right), describe key features and provide your justification:

Problem 1 – cont'd

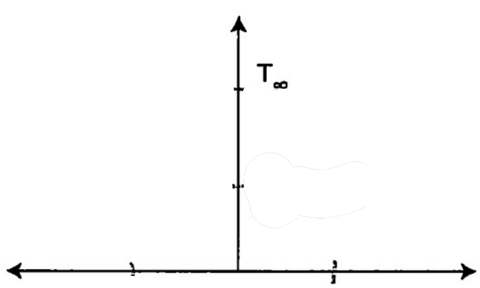
III: A cold metal cylinder has an initially homogenous temperature distribution with $T = T_{i,center}$. The cylinder is then exposed to air at a higher temperature T_∞ and the following parameters are given for the cylinder: diameter $d = 0.01m$, length $L = 1m$ heat transfer coefficient $h = 5\ W/m^2K$ and $k_c = 20\ W/mK$.

i) (5 pts) Will the object remain isothermal? Justify your answer.



Answer and justification:

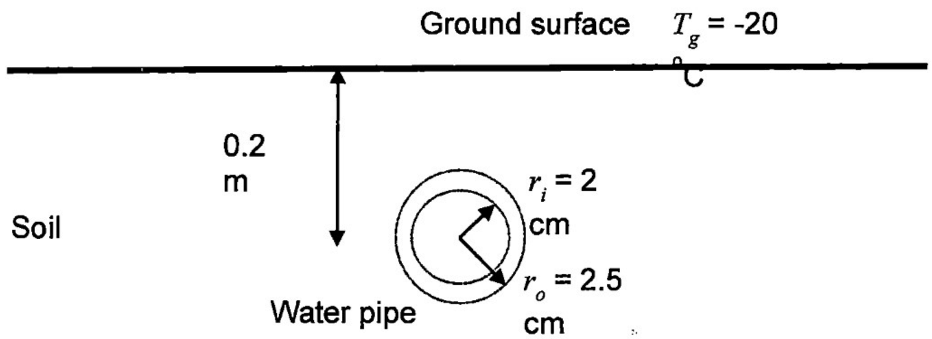
ii) (5 pts) Plot temperature profiles below, for **both the initial state and the state after a long time.** Choose a dimension (*d* or *L*) and label it on the x-axis.



1.b (10 pts) Draw adiabats (with arrows ⟶) and isotherms (with dotted lines ------) on the above three shapes. If isothermal, shade the region and label accordingly.

Problem 2 (30 points)

An underground water pipe with inner radius $r_i = 2$ cm, outer radius $r_o = 2.5$ cm, and conductivity $k_p = 50$ W/mK carries water at a temperature $T_w = 20$ °C. The convection heat transfer coefficient between water and pipe is $h = 40$ W/m^{2}K. The pipe is parallel to the ground, and the center of the pipe is 0.2 m below the ground surface which has a surface temperature T_g = -20 °C and thermal conductivity of soil $k_g = 2$ W/mK.



2.a (10 pts) Draw a resistance network, from water to ground surface. Calculate the value of each resistance *per unit length.*
2.b (10 pts) Calculate heat loss *per unit length* of the water pipe.
2.c (10 pts) Compute the temperature of the inner wall of the water pipe.

Assumptions - list your assumption here:

Answer to 2a:

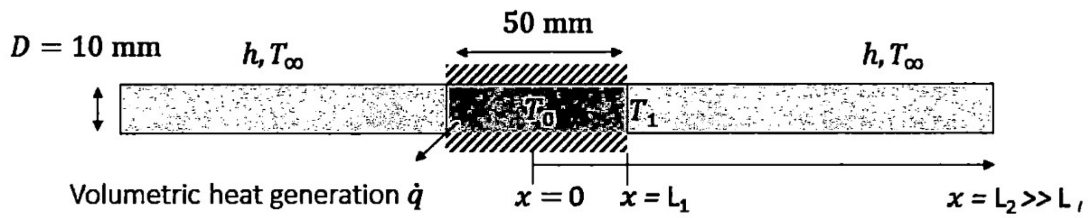
Problem 2 – cont'd

Answer to 2b:

Answer to 2c:

Problem 3 (30 points)

A very long rod of 10-mm diameter and uniform thermal conductivity k=50 W/m-K has a heating coil wrapped around its middle region whose length is 50 mm. Joule heating from current flowing through the coil induces a uniform volumetric heat generation of 5×10^6 W/m^3 in the middle region.



The unheated portions of the rod, which protrude from the heating coil on either side, experience convection with the ambient air at T_∞= 25°C and h=20 W/m^{2}K. Assume the outer surface of the coil is insulated and there is no convection heat loss in the middle region.

3.a (8 pts) Without solving for the temperature profile, sketch the steady-state temperature profile along the rod from $x=0$ to $x=L_2$ (see figure). Identify and justify key features in the profile. Denote the locations of maximum and minimum temperatures along the rod.

3.b (8 pts) In a symbolic form, express **the steady-state temperature $T_o(x=0)$ at the midpoint** of the rod with the temperature at the edge of the heated portion T_1 ($x=L_1$) and other given parameters.

3.c (8 pts) In a symbolic form, express **the steady-state temperature at the edge of the heated portion T_1 ($x=L_1$)** with the ambient temperature T_∞ and other given parameters.

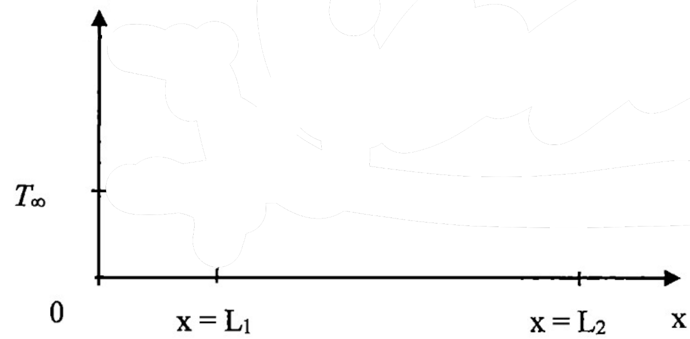
3.d (6 pts) Compute numerical values of T_0 and T_1.

Assumptions - list your assumptions here:

Start your answer to 3.a from the next page

Problem 3 – cont'd

Answer to 3.a:



3.a Identify key features and justifications:

Answer to 3.b:

Problem 3 – cont'd

Answer to 3.c:

Answer to 3.d: