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Exam 4

CM3110

Tuesday 1 December 2020

Name:

Rules:

- Closed book, closed notes.
- Two-page 8.5" by 11" study sheet allowed, double sided; you may use a calculator; you may not search the internet or receive help from anyone.
- Please text clarification questions to Dr. Morrison 906-487-9703. I will respond if I am able.
- All work submitted for the exam must be your own.
- Do not discuss the contents of the exam with anyone before midnight Tuesday 1 December 2020.
- ***Please copy the following Honors Pledge onto the first page of your exam submission and sign and date your agreement to it.***

Honor's Pledge:

On my honor, I agree to abide by the rules stated on the exam sheet.

Signature ________________________________

Date _____________________

Exam Instructions:

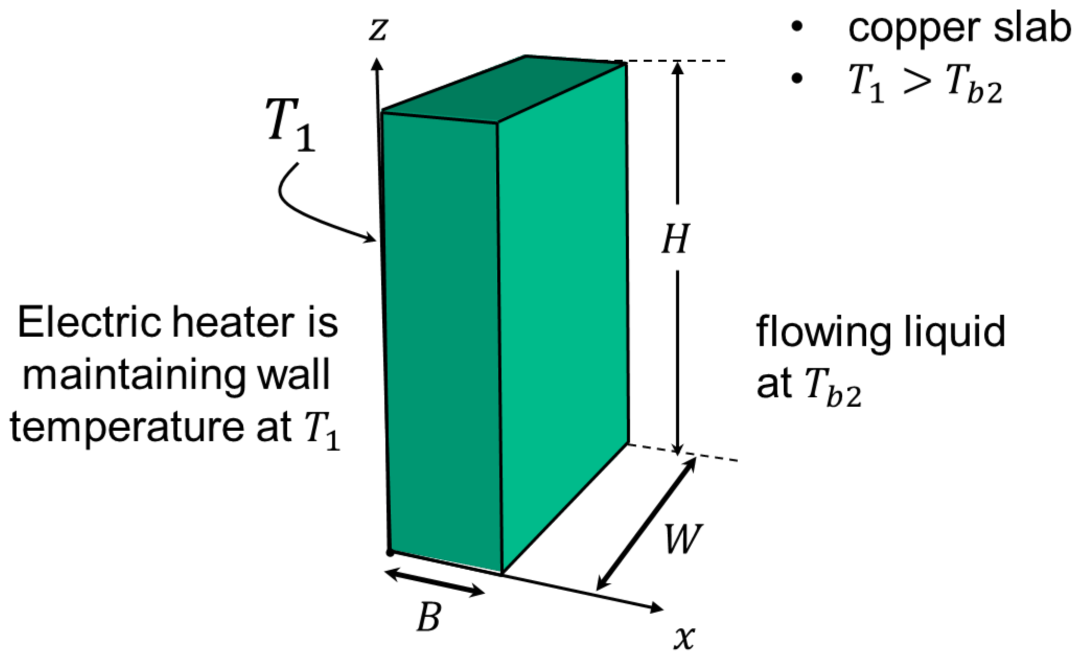
i. You may work on the exam for up to two hours and 15 minutes (135 minutes).
ii. Please be neat. Only neat answers will be granted partial credit. Please use a dark pencil or pen so that your work is readable once scanned.
iii. Significant figures always count.
iv. Please box your final answers.
v. Submit your work as a single PDF file; put your name on every page. (Genius Scan is a free app that can create a PDF from photos taken by your phone). If you take photos of your work, insert them into Word or Google Docs and create a PDF.
vi. Submit your exam study sheet as a separate PDF file; put your name on the first page (at a minimum)

1. (20 points) A long cast iron pipe (inner radius $= 2.0cm$, outer radius $= 3.0cm$) has stable inner wall temperature of 105^oC and stable outer wall temperature of 43^oC. What is the temperature in the wall at radial position $2.5cm$? Radial position $2.5cm$ is the midpoint of the pipe wall.

2. (20 points)
   a. What is the formula for the Nusselt number, Nu? Define clearly and completely any symbols you use in your answer. For example, if the formula contains density ρ, please indicate what material we need the density of.
   b. What do we use Nusselt number for and where do the equations for Nu come from? Please be specific.

3. (20 points) We may use the microscopic energy balance to analyze steady, one-dimensional heat conduction in a tall, wide, thin slab of copper. The coordinate system we choose is a Cartesian system (see figure). In order to determine the temperature distribution in the slab, we need to make a number of reasonable modeling assumptions. For each of the terms of the microscopic energy balance given below, indicate a) if it is reasonable to assume the term is zero and b) if the term is assumed zero, give the reason why you believe it should be assigned a value of zero.

	Zero?	Reason it's zero?
$\rho \hat{C}_p \left(\frac{\partial T}{\partial t}\right)$	______	______________________________
$\rho \hat{C}_p \left(v_x \frac{\partial T}{\partial x}\right)$	______	______________________________
$\rho \hat{C}_p \left(v_y \frac{\partial T}{\partial y}\right)$	______	______________________________
$\rho \hat{C}_p \left(v_z \frac{\partial T}{\partial z}\right)$	______	______________________________
$k \frac{\partial^2 T}{\partial x^2}$	______	______________________________
$k \frac{\partial^2 T}{\partial y^2}$	______	______________________________
$k \frac{\partial^2 T}{\partial z^2}$	______	______________________________
S_e	______	______________________________



4. (20 points) The following takes place outdoors on a winter day. A rectangular slab of copper ($1.0cm$ thick, much longer and wider than it is thick) is held at a constant temperature on one side and at a lower constant temperature on the other side. The steady state heat flux through the copper in the thickness direction is $180kW/m^2$.
    a. For the same temperature-difference driving force, what would be the new flux if we double the thickness of the copper? Show mathematically how you arrive at your answer.
    b. For the same temperature-difference driving force, what would be the new flux if instead of doubling the thickness we attached an identical slab of aluminum ($1.0cm$ thick) to make the thicker slab?

5. (20 points) In the CM3215 Transport Lab, water flows through the inner pipe of a double-pipe heat exchanger (the inner "pipe" is a metal tube; inner diameter = $0.545\ in = 0.01384m$; outer diameter = $0.625\ in = 0.01588m$). For typical water flow conditions of $\frac{3.0gal}{min} = 1.9927 \times 10^{-4} \frac{m^3}{s}$ and with measured inlet and outlet temperatures of $T_{water,in} = 21.4^oC$, $T_{water,out} = 32.0^oC$, what is the expected forced convection heat transfer coefficient h? The question is about the heat transfer coefficient governing the heat transfer from the hot inner surface of the metal tubing at R to the water flowing within the metal tube. Please give your answer in W/m^2K. You may ignore the effects of viscosity on the heat transfer coefficient h.