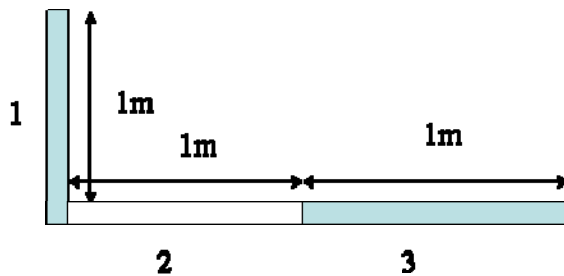


MIE 354 - Heat Transfer
Professor Rothstein
Exam #2
May 18, 2004

You will have 2 hours to complete the following problems. Please write carefully and clearly and make sure that you justify any assumption that you make. The exam is open book and open notes. Don't forget print your name at the top of this page. Good luck.

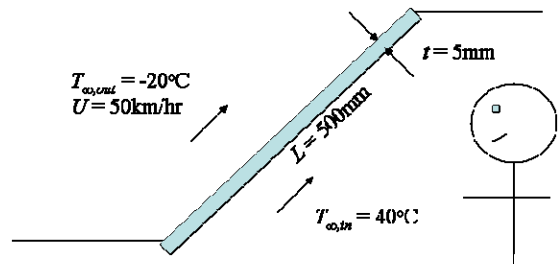
1. Some Quick Questions (20 Points)

- a) Is the heat transfer coefficient larger for a laminar or a turbulent flow?
- b) Under what conditions can the lumped capacity model be used to predict transient response of a solid?
- c) What is the Reynolds-Colburn analogy?
- d) If the temperature gradient in the fluid near a surface is increased, will the heat transfer coefficient be increased or decreased?
- e) What is the view factor from surface 1 to 3 below? The surfaces can be considered infinitely deep into the paper and are each 1m long.



2. Windshield Defroster (40 points)

A car defroster works by discharging warm air on the inner surface of the windshield. To prevent condensation of water vapor on the surface, the temperature of the air and the heat transfer coefficient must be sufficient to keep the inside surface of your windshield at least as high as the dewpoint of the air ($T_{s,in} \geq T_{dp}$). Consider the old school Cooper Mini shown below. The windshield has a length of $L = 0.5\text{m}$, a width of $W = 1\text{m}$ and a thickness of $t = 5\text{mm}$. The car is driving with a velocity of $U = 50\text{km/hr}$ and the outside temperature is $T_{\infty,out} = -20^\circ\text{C}$. Assuming that you can treat the windshield as a flat plate, the dew point of the air inside of the car is $T_{dp} = 5^\circ\text{C}$ and the air blown across the windshield by the defroster is at $T_{\infty,in} = 40^\circ\text{C}$, answer the following questions.

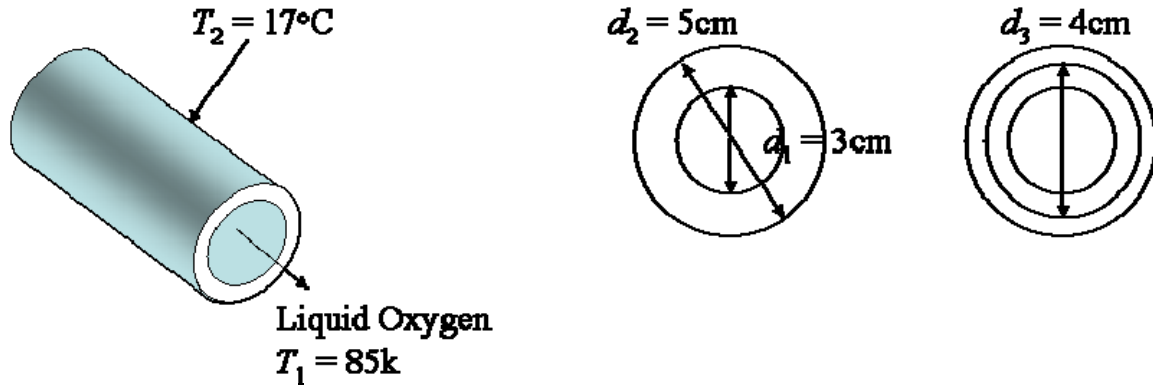


- Draw out the thermal resistance network diagram, labeling all the resistance and nodes. Don't solve yet.
- What is the average Nusselt number and heat transfer coefficient of the flow on the outside windshield?
- What is the minimum average heat transfer coefficient, \bar{h}_{in} , that will keep the windshield from fogging up?
- Assuming the flow on the inside of the windshield is fully turbulent, what is the minimum air velocity required to prevent the windshield from fogging? (EXTRA: What is the error associated with neglecting the laminar portion of the boundary layer?)

Air	Windshield
$k = 0.022 \text{ W/m K}$	$k = 1.4 \text{ W/m K}$
$c_p = 1.0 \text{ kJ/kg K}$	
$\rho = 1.2 \text{ kg/m}^3$	
$Pr = 0.7$	
$\nu = 1.1 \times 10^{-5} \text{ m}^2/\text{s}$	

2. Transporting Liquid Oxygen

In order to transport liquid oxygen it is pumped through the special tube shown below. The tube has an outer diameter of $d_1 = 3\text{cm}$, an emissivity of $\varepsilon_1 = 0.03$ and is kept at $T_1 = 85\text{K}$. The tube is enclosed by a larger concentric tube with inner diameter of $d_2 = 5\text{cm}$, an emissivity of $\varepsilon_2 = 0.05$ and is kept at $T_2 = 17^\circ\text{C}$. The space between the two tubes is completely evacuated to prevent heat transfer through conduction.



- Draw up the thermal resistance network diagram labeling all the nodes and resistances.
- What is the heat transfer rate to the liquid oxygen per unit length of pipe?
- What would be the heat transfer rate if all the walls were considered black bodies? What if all the walls were considered reflectors?
- How much is the heat transfer rate reduced if a thin-walled radiation shield with an emissivity of $\varepsilon_3 = 0.03$ on each side is placed midway between the tubes?

