ME 327 HEAT TRANSFER

Final Exam

December 8, 2005 (Time: 3 hours)

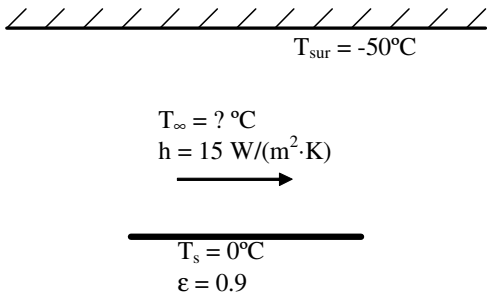
This is an **open book** exam (text, notes, assignments, etc. are allowed).
Answer **all 5 questions**.
State all **assumptions** and justify, where possible.
Reference all data used.

Marks

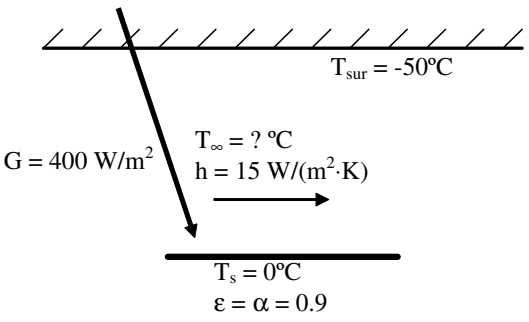
1. In Saskatchewan, the sky temperature can be as cold as -50°C and often results in frost formation during the night even when the outdoor ambient temperature is above 0°C. One example of this is frost formation on the outside of automobile windows. For the conditions below, determine the ambient temperature (T_∞) that will result in freezing when **(a)** there is no solar radiation and **(b)** when the solar radiation incident on the surface is 400 W/m^2 and the surface absorptivity is 0.9. (10)

(a) 10.5°C
(b) -13.5°C

(a)

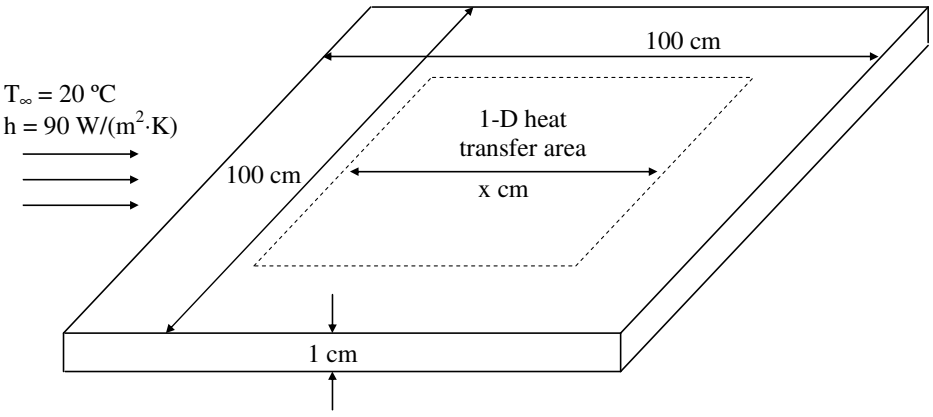


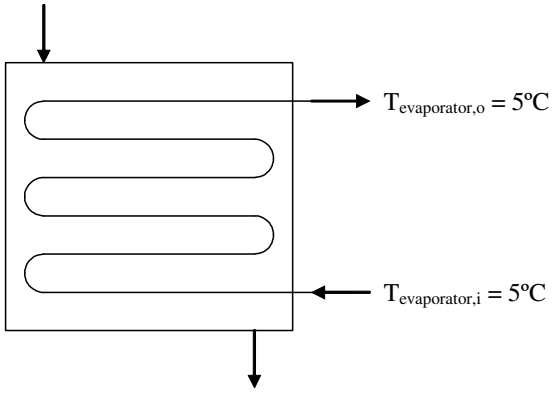
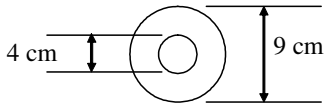
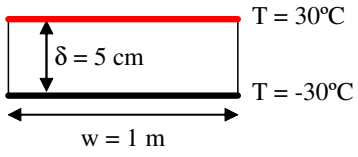
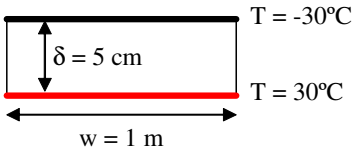
(b)



2. A thin ceramic block (ρ = 2000 kg/m^3, Cp = 700 J/(kg·K) and k = 0.05 W/(m·K)) that is prepared in an oven at 500°C must be cooled until all parts of the block are at a temperature less than 70°C before it can be cut into pieces. To achieve cooling, the block is placed in an 20°C airstream that creates a convection coefficient of 90 W/(m^2·K) on all edges (top, bottom and sides) of the block. For this large block (shown below), there exist an area in the centre of the block that has 1-D heat transfer and an area near the edge that has 2-D and 3-D effects. **(a)** Determine how long it will take for the entire block to cool to 70°C and **(b)** estimate the size of the 1-D heat transfer area at this time by applying the solution for an infinite solid with a step change in the surface temperature. (The area of the block that has 1-D heat transfer can be assumed to be the area in the centre of the block where heat transfer from the edges has less than a 1% effect on the temperature.) (10)

(a) 15 min.
(b) x=96 mm



3.	In the summer on the prairies, many farmers and ranchers use a rain gauge to monitor the depth of rain that has fallen in the area (e.g., 25 mm or 1 inch). After a rain, water will begin to evaporate from the rain gauge and the reading will decrease with time. Determine the average rate at which the rain gauge reading will decrease in a day (mm/day) when the average outdoor temperature is 22°C and the convection heat transfer coefficient between the water in the gauge and the ambient air is 3 W/(m^2·K)). Assume that the water in the rain gauge is at the same temperature as the ambient air and that the ambient air relative humidity is 40%.	(10) 2.6 mm/day
4.	Design a shell and tube heat exchanger that can cool water with a heat capacity rate of 300 W/K from 50°C to 10°C using an evaporating fluid that maintains a temperature of 5°C as it passes through the exchanger. The design must specify: **(a)** the required UA of the heat exchanger and **(b)** the number of fins required to provide this UA value if the convection heat transfer coefficients are 400 W/(m^2·K) in the water and 15,000 W/(m^2·K) in the evaporating fluid and the heat transfer surface area of the thin stainless steel pipe is 0.2 m^2. To simplify the problem, assume that the surface area of the bare pipe that is in contact with the water is negligible compared to the surface area of the fins that are in contact with the water. $T_{water,i}$ = 50ºC C_{water} = 300 W/K  $T_{water,o}$ = 10ºC C_{water} = 300 W/K Annular stainless steel fin  fin thickness = 4 mm	(10) (a) 660 W/K (b) 700 fins
5.	Determine the heat transfer through a horizontal rectangular cavity filled with air and made of polished stainless steel plates (1 m x 0.5 m) for the configurations of **(a)** and **(b)** shown below. (a)  (b)  	(10) (a) 27 W (b) 111 W
	TOTAL	**50**