**UNIVERSITY OF TORONTO**

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, 13 December 2021

Duration 2 ½ hours

# CHE 260 – THERMODYNAMICS AND HEAT TRANSFER

Examiner – S. Chandra

*Each of the following five questions is of equal value. You may use any type of non-communicating calculator.*

1) A 1-cm diameter copper sphere is at a uniform temperature of 80°C. At time $t$=0 it is exposed to air at 20°C. It is found that the convective heat transfer coefficient in air for this case is approximated by:

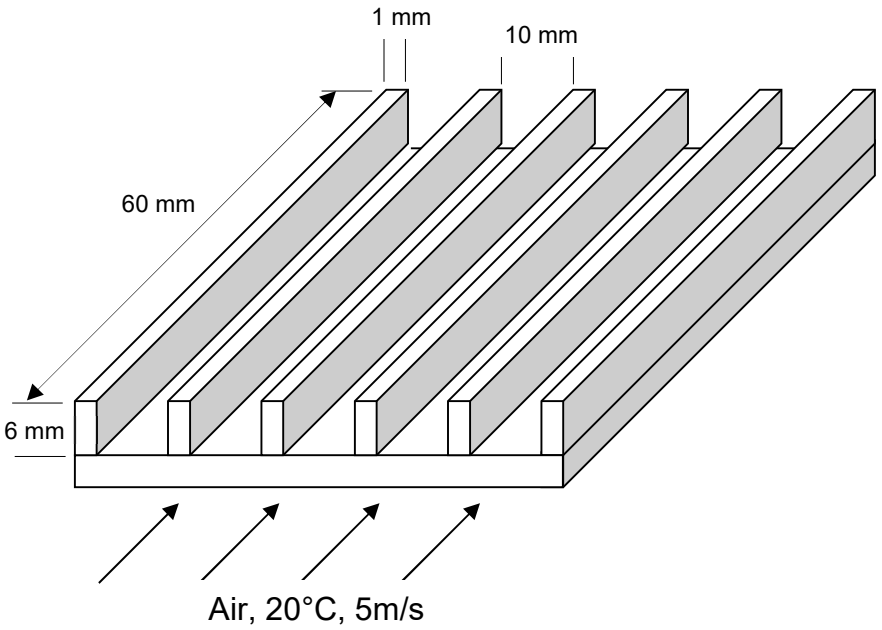
$$h = 4.44\ (T\text{-}T_\infty)^{1/4} \qquad \text{W/m}^2\text{°C}$$

where $T$ is the instantaneous surface temperature of the sphere and $T_\infty$ is the temperature of the air (all temperatures in °C). Determine the time taken for the temperature of the sphere to fall from 80°C to 60°C.

2) A thick-walled cylindrical tube has inner diameter 2 cm and outer diameter 5 cm. Air is evacuated from the inside of the tube and a high temperature radiation source placed along its axis that creates a uniform heat flux of $10^5$ W/m$^2$ on the inner surface of the tube. The outer surface of the tube is convectively cooled by air at 27°C with a convective heat transfer coefficient of 120 W/m$^2$°C. If the thermal conductivity of the tube material is 2.2 W/m°C, determine the outer and inner surface temperatures of the tube.

3) It is proposed to supply fresh water to arid zones by towing icebergs to them. A rectangular iceberg, 50 m long, is to be towed in water whose average temperature is 10 °C. Determine the rate at which the flat bottom of the iceberg will melt (in units of mm/h) when it is towed at 1 km/h. (Latent heat of fusion of ice $h_{sl}$=333.4 kJ/kg and density $\rho$=917 kg/m$^3$).

4) An aluminium heat sink with six identical fins (as shown in the figure) is attached to an electronic device for cooling. Cooling air at 20°C is supplied with a velocity of 5 m/s by a fan. If the average base temperature is not to exceed 100°C, calculate the maximum power dissipation from the heat sink.




5) A long, evacuated duct has a cross-section that is a quarter circle with a radius of 10 cm. All interior surfaces are diffuse and grey. The flat surfaces (labelled 1) are at 1200 K and have an emissivity of 0.5. The curved surface (labelled 2) is at 500 K and has an emissivity of 0.9.

a) Find the view factor $F_{12}$
b) Calculate the net rate of radiation heat transfer to surface 2 per unit length of the duct.