QUESTION 1 **15%**

Air flows through a smooth pipe of 4-*mm* diameter with a mean velocity $V = 50\,m/s$. The flow is fully developed. Evaluate the pressure drop per meter pipe length ($L = 1\,m$). The friction coefficient is $f = \frac{64}{Re}$ if the flow is laminar. Otherwise, assume $f = \frac{0.3164}{Re^{1/4}}$ if the flow is turbulent. The density and the viscosity of the air are $\rho = 1.23\,kg/m^3$ and $\mu = 1.79 \times 10^{-5}\,N\,s/m^2$.

QUESTION 2 **15%**

There could be five distinct flow patterns in the case of a uniform flow across a smooth circular cylinder. The corresponding Reynolds numbers of the five flow patterns are at an order of 0.1, 10, 100, 20000, and 500000. Please describe and explain the five distinct flow patterns.

QUESTION 3 **30%**

(a) Please discuss the differences between forced and natural heat convections. (10%)

(b) If fluid enters a tube at a uniform temperature $T(r,0)=T_i=$ constant that is less than the surface temperature of the tube wall ($T_w > T(r,0)$), please draw the thermal boundary layer development in the tube and discuss it. (5%)

(c) Repeat (b) for fluid flowing over a flat plate. (5%)

(d) Please explain the physical meaning of Grashof number and its effect on the flow regime. (5%) What is its relation to the Rayleigh number and Prandtl number ? (3%) What is its relation to the Nusselt number ? (2%)

QUESTION 4 **12%**

(a) What is a gray body?

(b) A hot object is located in a large room. If the surface of the

object can be assumed to be a gray-body surface, write the mathematical expression for the radiative heat loss rate of the object. Choose the necessary parameters by yourself.

QUESTION 5 **28%**

Consider a thin flat fin having a uniform cross-sectional area, as shown in the Figure below, is used for heat dissipation. The heat conductivity of the fin metal is k_s, the temperature of the ambient air is T_∞, and the heat convection coefficient between the fin surface and the air is h. Under steady-state condition, the temperature of the fin base ($x = 0$) is fixed at T_b ($>T_\infty$).

(a) Schematically plot the temperature distribution of the fin $T(x)$ along the x-direction from the fin base to the fin tip.

(b) If the thickness of the fin is doubled, with all the other parameters unchanged, compare the fin temperature distribution $T(x)$ for this situation with that of (a) on one diagram. Also compare the heat transfer rate and explain for the differences.

(c) If the conductivity of the fin k_s is doubled, with all the other parameters unchanged, compare the fin temperature distribution $T(x)$ for this situation with that of (a) on one diagram. Also compare the heat transfer rate and explain for the differences.

(d) If the heat convection coefficient h is doubled, with all the other parameters unchanged, compare the fin temperature distribution $T(x)$ for this situation with that of (a) on one diagram. Also compare the heat transfer rate and explain for the differences.

(e) Derive the steady-state differential energy equation for the fin as shown in the Figure. Choose necessary parameters by yourself.