1. Please choose a most suitable answer to the following questions. (20%)

(1) The viscous force in a gas flow is mainly due to
(a) the cohesive force between the gas molecules.
(b) the gas molecular random motion.
(c) the body force of gas molecule
(d) the pressure force between gas molecules.

(2) In a general case, a thermodynamic property is
(a) independent of any other thermodynamic properties.
(b) dependent of one thermodynamic property.
(c) dependent of two thermodynamic properties.
(d) dependent of three or more thermodynamic properties.

(3) The relationship of absolute temperature and thermal expansion coefficient of an ideal gas is
(a) $\beta = CT$.
(b) $\beta =$ constant.
(c) $\beta = 1/T$.
(d) $\beta = 1/T^{1/2}$.

(4) The Joule-Thompson coefficient is to
(a) examine the maximum density effect of water during solidification.
(b) measure the heat flux in a convective flow.
(c) study the viscous dissipation in a fluid flow.
(d) measure the temperature change of a fluid during a throttling process.

(5) The heat conduction equation is related to
(a) the First Law of Thermodynamics only.
(b) the Second Law of Thermodynamics only.
(c) both the First and Second Laws of Thermodynamics.
(d) neither of the First nor the Second Law of Thermodynamics.

2. Consider a body initially at temperature T_0 cooled in water of temperature T_s. The density of body is ρ, the volume is V, the specific heat is c, the surface area is A, and the heat transfer coefficient is h. The body temperature is assumed uniform during the cooling process.
   (a) Please write the transient energy equation for the body.
   (b) Please solve the equation for the body temperature.
   (c) Please discuss the transient energy equation from the point of view of irreversibility of the Second Law of Thermodynamics.
   (d) Please discuss the variation of body temperature from the view point of Second Law of Thermodynamics.

   (20%)

3. Thermodynamic Cycles (20%)
   (a) Using P-v and T-s diagrams to describe the Carnot Cycle. (3%)
   (b) Please derive its thermodynamic cycle efficiency. (5%)
   (c) How to promote this cycle efficiency to 100 % ? (2%)
   (d) Please design additional four different cycles which have exactly the same cycle efficiency as the Carnot cycle. (8%)
   (e) What are the common basic principles to design an almost 100% efficiency cycles in practice ? (2%)

4. Potential Flow (20%)
   (a) What is the mathematical definition of "vorticity" ? (2%)
   (b) Please distinguish the irrotational flow and the rotational flow from the above definition and also show the difference on a stream line diagram. (4%)
   (c) A fluid flow which is initially irrotational may become rotational. Please give four examples of this effect. (8%)
   (d) What is the definition of "circulation" in a rotational flow ? (2%)
   (e) Please derive the relationship between the "circulation" and the "vorticity". (4%)

5. (a) What is the "Prandtl's mixing length hypothesis"? (10 %)
   (b) Calculate the ratio of turbulent viscosity μ_t to the molecular (laminar) viscosity μ_ℓ for a free jet of air at an axial location X where the mean centerline velocity $U_{x,max}$ has decayed to 60 % of the initial velocity. The jet width, $\delta_{99\%}$, at this location is 15 cm and the mixing length is ℓ_m=0.075 $\delta_{99\%}$. The initial jet velocity is 70 m/s. The pressure is 1 atm and the temperature is 300 ° K. Given : μ_t =0.1365 $\rho \ell_m$ $(U_{x,max} - U_{x,min})$, μ_ℓ =184.6 × 10^{-7} N-S/m^2, universal gas constant R_u=8315 J/Kmole·° K, molecular weight of air=28.85, 1atm=101325 Pa, and $U_{x,min}$=0. What conclusion can you draw from the ratio? (10 %)