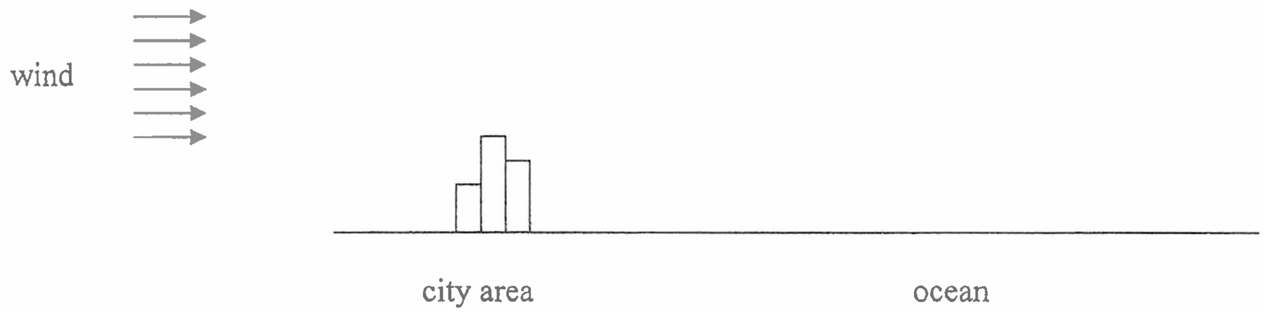
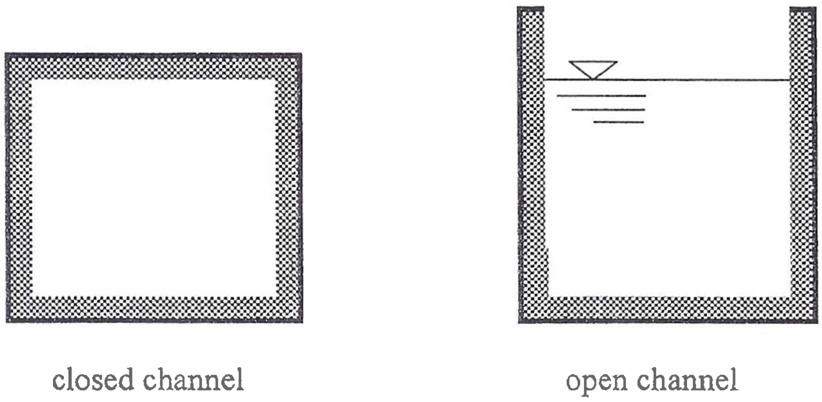
1. Please draw the flow distributions of the wind in the city and in the ocean, respectively, in a diagram. Explain why two curves are different? (5 %)




2. Draw lines of constant velocity on the cross sections of a closed channel and of an open channel. (5 %)




3. Derive an equation to reveal the relation among fluid density, $\rho$, flow velocity, $V$, and the cross-sectional area of a closed flow channel, $A$. (hint: You may start from the Bernoulli's equation and $\dot{m} = \rho A V$ ). How does the fluid compressibility affect the acceleration or deceleration of the flow if the cross-sectional area is variable? (15 points)

4. List the restrictions of the application of boundary layer approximation and explain the reason of the answer. (5 points)

5. A circular ice rink is 25 m in diameter and is to be temporarily enclosed in a hemispherical dome of the same diameter. The ice is maintained at -5 $°C$ . The inner surface of the dome is measured to be 20 $°C$ on a particular day. Estimate the radiant heat transfer from the dome to the rink if both surfaces can be taken as black. (10%)

6. In an experiment to study laser heating, a stainless steel component is exposed to a powerful laser beam, and a jet of argon gas impinging on the surface sweeps away the molten metal. The component is initially at 300 K, and after a short transient the surface is measured to recede at a rate of $250\,\mu m/s$. Estimate the total heat flux to the surface and the depth of thermal penetration into the solid metal. The stainless steel properties include $\rho = 7800\,kg/m^3$, c = 600 J/kg K (specific heat), $\alpha = 4\times10^{-6}\,m^2/s$ (thermal diffusivity), $h_{fs} = 2.7\times10^5$ J/kg (latent heat), and a melting temperature of 1670 K. (20%)

7. (22%)
Consider the heat transfer process within the thermal boundary layer associated with a hot uniform parallel flow of air at $T_a$ over a cold wall at $T_s$. The thermal conductivity of air and the wall are $k_a$ and $k_s$, respectively,

(a) Write the expression for the local heat flux q" on the wall surface involving $k_a$. (4%)
(b) Write another expression for q" involving the heat convection coefficient h, and equate it with that in (a). (3%)
(c) Non-dimensionalize the equation in (b) with the appearance of an important non-dimensional parameter. Also give the name of this non-dimensional parameter. (4%)
(d) Based on the above non-dimensional equation, discuss the physical meanings of this non-dimensional parameter, as well as the importance of it. (5%)
(e) Draw two gas-phase temperature distributions, respectively for a small and large air velocity, at a certain cross-section perpendicular to the wall, and compare for their magnitudes of q". From this, discuss the mechanism of convection heat transfer and its relation with heat conduction. (6%)

8. (18%)
Consider the criterion for thermally fully-developed flow in a circular pipe with a uniform wall temperature. The wall temperature is $T_s$ and the mean temperature of the fluid is $T_m$. We know the criterion for the hydrodynamically fully-developed flow is that the velocity distribution becomes unchanged along the flow direction.

(a) Write the criterion for thermally fully-developed flow. Discuss its physical meaning of this criterion by comparing the radial temperature distributions T(r) at various axial positions. Also compare it with the criterion for the hydrodynamically fully-developed flow. (8%)
(b) Show that the convection coefficient h is constant for a thermally fully-developed flow. (6%)
(c) Along the flow direction x, draw and discuss the distribution of $T_m$ (x) and h(x) including the entrance region and the thermally fully-developed region. Please draw the two curves on a single diagram. (4%)