1. Use ideal gas equation of state to show that the universal gas constant $R_u$ is equal to 8.314 kJ/(kmol·K). (10%)

2. The differential equation of pressure of a certain gas is given by one of the following equations:

$$ dp = \frac{2RT}{(v-b)^2} dv + \frac{R}{v-b} dT $$

or

$$ dp = -\frac{RT}{(v-b)^2} dv + \frac{R}{v-b} dT $$

where $b$ is a constant and $R$ is the gas constant.
Identify the correct equation, and then find the equation of state of that gas. (20%)

3. A 5-kg block of iron casting at 1000°C is thrown into a large lake which is at a temperature of 25°C. The iron block eventually reaches thermal equilibrium with the lake water. Assuming an average specific heat of 0.45kJ/(kg·°C) for the iron and 4.184 kJ/(kg·°C) for the water, determine (a) the entropy change of the iron block, (b) the entropy change of the lake water. (20%)
4. An ideal gas undergoes a reversible thermodynamic cycle 1-2-3-1, as shown in Fig. 1. Process 1-2 is adiabatic expansion, 2-3 is constant pressure, and process 3-1 is constant volume. Show that the thermal efficiency of this heat engine is

\[ \eta_{th} = 1 - k \frac{V_2}{V_1} - 1 \frac{P_2}{P_1} \]

where \( k = C_p / C_v \). (20%)
5. Ice of mass $M$ at the fusion temperature ($T_f = 0^\circ C$) is enclosed in a spherical cavity of diameter $D$. The cavity wall is of thickness $L$ ($L << D$), and thermal conductivity $k$. If the outer surface of the wall is at a temperature $T_i > T_f$, obtain an expression for the time required to completely melt the ice. (15%) 

6. A long bar of rectangular cross section is 60mm by 90mm on a side as shown in Fig. 2 and has a thermal conductivity of 2 W/m·K. One surface is maintained at 100°C, while the remaining surfaces are maintained at 50°C. Using finite difference method with grid spacing of 30mm, determine the nodal temperatures of the cross section. (15%)

![Diagram](image-url)