ENGG 109 – THERMODYNAMICS

PROFESSOR PATTERSON'S PATENTED PROBLEM-SOLVING PROCEDURE

1. Make a sketch of the situation.
2. Draw a system boundary.
3. Identify mass, heat, and work transfers across the boundary.
4. Write the 1st law of thermodynamics, either as an energy balance for the system, i.e.

$$(Q_{in} - Q_{out}) + (W_{in} - W_{out}) + \left(E_{mass,in} - E_{mass,out}\right) = \Delta U + \Delta KE + \Delta PE$$

   or the Steady Flow Energy Equation (SFEE) for a control volume, i.e.

$$\dot{Q}_{CV} - \dot{W}_{CV} = \dot{m}\left((h_2 - h_1) + \left(\frac{v_2^2 - v_1^2}{2}\right) + g(z_1 - z_2)\right)$$

5. To simplify the equation: state assumptions and cancel terms in 1st law accordingly.
6. To evaluate remaining terms: identify appropriate expressions based on definitions, e.g.

$$W_{mechnical} = \int pdV \quad \text{or} \quad W_{electrical} = VIt$$

$$\dot{Q}_{conv} = -hA\Delta T \quad \text{or} \quad \dot{Q}_{rad} = A\varepsilon\sigma\left(T_2^4 - T_1^4\right) \quad \text{or} \quad \dot{Q}_{cond} = -kA\frac{dT}{dx}$$

$$\Delta U = mc_p\Delta T \quad \text{or} \quad H = U + pV \quad \text{and} \quad \Delta KE = \frac{m(v_2^2 - v_1^2)}{2} \quad \text{and} \quad \Delta PE = mg\Delta z$$

7. Solve for unknown terms, and if necessary continue.
8. Write down second law of thermodynamics as an entropy balance, i.e.

$$\frac{dS_{system}}{dt} = \dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen} \quad \text{where} \quad \dot{S}_{in/out} = \frac{\dot{Q}_{in/out}}{T_{in/out}}$$

   and, or from Gibbs' law, i.e.

$$s_B - s_A = c_P \ln\frac{T_B}{T_A} - R\ln\frac{P_B}{P_A}$$

9. Solve equations.

Useful relationships:

For an ideal gas: $PV = nRT$ where R = 8.314 J/mol.K and $R = \frac{m}{n}R_{specific} = c_p - c_v$

Efficiency = desired output/required output

Carnot efficiency, $\eta_{max} = 1 - \frac{T_{sink}}{T_{source}}$