LIST OF IMPORTANT FORMULAE

- For simple compressible closed system, quasi-equilibrium work due to moving boundary between two end points 1 and 2 can be expressed as

$$W_{1-2} = \int_{V_1}^{V_2} PdV$$

- The expression for quasi-equilibrium work due to moving boundary for different processes are given as

Constant pressure process: $W_{1-2} = P(V_2 - V_1)$

Constant volume process: $W_{1-2} = 0$

Hyperbolic process: $W_{1-2} = P_1V_1 \ln\frac{V_2}{V_1} = P_1V_1 \ln\frac{P_1}{P_2}$

Polytropic process: $W_{1-2} = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{P_1V_1 - P_2V_2}{n-1}$

Adiabatic process: $W_{1-2} = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$

- First law of thermodynamics for a closed system undergoing a cycle is given by $\oint \delta W = \oint \delta Q$
- First law of thermodynamics for any system undergoing any process can be expressed in differential form as

$$\delta Q - \delta W = dU$$

- The mass balance equation for a single stream entering and a single stream leaving the control volume when the flow is steady can be written as

$$\frac{A_1V_1}{v_1} = \frac{A_2V_2}{v_2}$$

where A_1 and A_2 are the cross-sectional area of fluid stream at inlet and outlet respectively, V_1 and V_2 are the average velocity of fluid stream at inlet and outlet respectively, v_1 and v_2 are the specific volume of fluid at inlet and outlet respectively.
- The steady flow energy balance equation for a single stream entering and a single stream leaving the control volume can be written as

$$\dot{m}(h_1 + \frac{V_1^2}{2} + gz_1) + \dot{Q} = \dot{m}(h_2 + \frac{V_2^2}{2} + gz_2) + \dot{W}$$

where $\dot{m}$ is the mass flux, h_1 and h_2 are the specific enthalpies of fluid at inlet and outlet respectively, z_1 and z_2 are the elevation of inlet and outlet with respect to some arbitrary datum respectively, $\dot{Q}$ is the rate of heat transfer and $\dot{W}$ is the rate of work done.

- Thermal efficiency of a cyclic heat engine is given by

$$\eta_{ther} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

where Q_1 is the heat transfer from source to heat engine, Q_2 is the heat rejection from the heat engine to sink and W is the work done by the heat engine.

- The efficiency of a Carnot heat engine is given by

$$\eta_{ther,\,Carnot} = 1 - \frac{T_2}{T_1}$$

where T_1 and T_1 are the temperature of source and sink respectively.

- The coefficient of performance (COP) of refrigerator and heat pump are given by

$$COP_R = \frac{Q_2}{Q_1 - Q_2}$$

$$COP_{HP} = \frac{Q_1}{Q_1 - Q_2}$$

where Q_2 is the heat transfer from sink to the device (refrigerator or heat pump) and Q_1 is the heat transfer from the device to the source.

- The coefficient of performance of Carnot refrigerator and heat pump are given by

$$COP_R = \frac{T_2}{T_1 - T_2}$$

$$COP_{HP} = \frac{T_1}{T_1 - T_2}$$

- For a cyclic process, $\oint \frac{\delta Q}{T} \le 0$

If $\oint \frac{\delta Q}{T} = 0$ then the cyclic process is possible and reversible.

If $\oint \frac{\delta Q}{T} < 0$ then the cyclic process is possible and irreversible.

If $\oint \frac{\delta Q}{T} > 0$ then the cyclic process is impossible.

- The change in the entropy of a system is given by $dS = \frac{\delta Q_R}{T}$ for reversible process.
- Thermodynamic property relations are given by

$$Tds = du + Pdv$$

$$Tds = dh - vdP$$

which are applicable to all processes whether reversible or irreversible.

- Properties of a liquid-vapour mixture may be found by relations such as

$$v = v_f + xv_{fg}$$

$$h = h_f + xh_{fg}$$

$$s = s_f + xs_{fg}$$

$$u = u_f + xu_{fg}$$

where x is the quality or dryness fraction of liquid-vapour mixture, and the subscripts f and g denote the properties of liquid and vapour respectively.

- The equation of state of an ideal gas can be expressed as

$$PV = n\bar{R}T$$

$$P\bar{v} = \bar{R}T$$

$$PV = mRT$$

$$Pv = RT$$

where P is the pressure, V is the total volume of the gas, $\bar{v}$ is the molar volume (i.e., volume per unit mole), n is the number of moles of the gas, m is the mass of the gas, v is specific volume of the gas, $\bar{R}$ is the universal gas constant, R is the characteristic gas constant and T is the temperature of the gas in K.

- Change in specific internal energy of a calorically perfect gas between states 1 and 2 is

$$u_2 - u_1 = C_v(T_2 - T_1)$$

- Change in specific enthalpy of a calorically perfect gas between states 1 and 2 is

$$h_2 - h_1 = C_p(T_2 - T_1)$$

- Change in specific entropy of a calorically perfect gas between states 1 and 2 is

$$s_2 - s_1 = C_v \ln\frac{T_2}{T_1} + R\ln\frac{V_2}{V_1}$$

$$= C_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$$

$$= C_p \ln\frac{V_2}{V_1} + C_v \ln\frac{P_2}{P_1}$$

- The thermal efficiency of the Otto cycle can be expressed as

$$\eta_{Otto} = 1 - \frac{1}{r^{\gamma-1}}$$

where r is the compression ratio and γ is the specific heat ratio.

- The thermal efficiency of the Diesel cycle can be expressed as

$$\eta_{Diesel} = 1 - \frac{1}{r^{\gamma-1}}\frac{1}{\gamma}\frac{r_c^{\gamma} - 1}{r_c - 1}$$

where r_c is the cut-off ratio, r is the compression ratio and γ is the specific heat ratio.

- The thermal efficiency of the Rankine cycle is given by

$$\eta = \frac{W_{net}}{Q_1} = \frac{W_T - W_P}{Q_1}$$

where W_T is the turbine work, W_P is the pump work and Q_1 is the heat input in the boiler.

- According to Newton's law of viscosity, for one-dimensional flow shear stress is given by

$$\tau = \mu\frac{du}{dy}$$

where μ is the coefficient of viscosity.

- Capillary rise of or depression is given by

$$h = \frac{4\sigma\cos\theta}{\rho g d}$$

where σ is the surface tension coefficient, θ is the area wetting contact angle, ρ is the density of fluid, and d is the diameter of tube.

- Three-dimensional continuity equations in differential form is given by

$$\frac{\partial\rho}{\partial t} + \frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w) = 0$$

- Euler's equation of motion along a streamline is given by

$$\frac{dP}{\rho} + VdV + gdz = 0$$

which is valid for steady and inviscid flow.

- Bernoulli's equation along a streamline is given by

$$\frac{P}{\rho}+\frac{V^2}{2}+gz=\text{constant}$$

- Discharge by Venturimeter is given by

$$Q=\frac{C_d A_1 A_2}{\sqrt{A_1^2-A_2^2}}\sqrt{2gh\left(\frac{\rho_m}{\rho_w}-1\right)}$$

where A_1 and A_2 are the cross-sectional areas of the venturimeter at its inlet and throat respectively. ρ_m and ρ_w are the density of the manometric fluid and the working fluid respectively. h is the difference in height of the manometric fluid in the two limbs of the manometer, and C_d is the coefficient of discharge of the venturimeter.

- Volume flow rate by orificemeter is given by

$$Q=\frac{C_v C_C A_o A_1}{\sqrt{A_1^2-C_C^2 A_o^2}}\sqrt{2g\left[\frac{(P_1-P_2)}{\rho g}+(z_1-z_2)\right]}$$

where C_c is the coefficient of contraction, C_v is the coefficient of velocity, and A_o is the area of orifice.

- The velocity measured by Pitot tube is given by

$$V=C\sqrt{2gh}$$

where C is the coefficient of Pitot tube and h is the difference in stagnation and static pressure head.

- The velocity measured by Pitot - static tube is given by

$$V=C\sqrt{2g\frac{\Delta P}{\rho}}$$