Quick Revision Formulae

For

Mechanical Engg.

* **Francis turbine**

- Area of flow $\boxed{A_{f1} = K\pi d_1 b_1}$
- Discharge through the runner $\boxed{Q = A_{f1} V_{f1}}$
- Hydraulic power $\boxed{H.P = \gamma Q H}$ kw
- Runner power when V_{ω_2} is in direction of u_2
  $$\boxed{R.P = \frac{\gamma Q}{g}\left[V_{\omega_1} u_1 - V_{\omega_2} u_2\right]}$$
- Runner power when V_{ω_2} is in opposite direct of u_2 $\boxed{R.P = \frac{\gamma Q}{g}\left[V_{\omega_1} u_1 + V_{\omega_2} u_2\right]}$
- Hydraulic efficiency $\boxed{\eta_h = \frac{R.P}{H.P} = \frac{V_{\omega_1} u_1}{gH}}$
- Mechanical efficiency $\boxed{\eta_{mech} = \frac{S.P}{R.P}}$
- Overall efficiency $\boxed{\eta_0 = \eta_h \times \eta_{mech}}$
- Volumetric efficiency $\boxed{\eta_{vol} = \frac{Q}{Q + \Delta Q}}$
  where ΔQ = leakage loss
  Q = discharge entering the turbine
- Degree of reaction (R) : $\boxed{R = 1 + \frac{V_2^2 - V_1^2}{2 V_{\omega_1} u_1}}$
- Efficiency of draft tube $\boxed{\eta_d = \frac{\left(\frac{V_2^2}{2g} - \frac{V_3^2}{2g}\right) - h_f}{\frac{V_2^2}{2g}}}$

* **Pelton wheel**

- Power available at inlet of vanes $= \frac{\gamma Q V_1^2}{2g}$
- Runner power $\boxed{R.P = \frac{\gamma Q}{g}\left[V_{\omega_1} - V_{\omega_2}\right] u}$
- $\boxed{(\eta_b)_{max} = \frac{1 + K\cos\phi}{2}}$
- Blade efficiency $\boxed{\eta_{blade} = \frac{V_1^2 - V_2^2}{V_1^2}}$

Specific speed of Turbine $\boxed{N_s = \frac{N\sqrt{P}}{H^{5/4}}}$

Fluid Mechanics

* **Model relationships for turbine** / Cp

Capacity or flow coeff.
$$\left(\frac{Q}{ND^3}\right)_p = \left(\frac{Q}{ND^3}\right)_m$$

Head coeff.
$$\left(\frac{gH}{N^2D^2}\right)_p = \left(\frac{gH}{N^2D^2}\right)_m$$

Power coeff.
$$\left(\frac{P}{N^3D^5}\right)_p = \left(\frac{P}{N^3D^5}\right)_M$$

* **Brayton cycle or Joule cycle:-** [Gas P.P]

$$\eta = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}}$$

$$T_2 = T_4 = \sqrt{T_{max} \cdot T_{min}}$$

$$(r_p)_{optimum} = \left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{2(\gamma-1)}}$$

$$(r_p)_{optimum} = \sqrt{(r_p)_{max}}$$

$$(r_p)_{max} = \left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{\gamma-1}}$$

$$\text{Back work Ratio} = \frac{W_C}{W_T}$$

$$\text{Work Ratio} = \frac{W_{net}}{W_T} = \frac{W_T - W_C}{W_T}$$

$$1 - \frac{W_C}{W_T}$$

* **Rankine vapour power cycle (or) steam power cycle**

* **Specific steam consumption** $SSC = \frac{3600}{W_{net}} \frac{kg}{kw.hr}$

KJ/kg

$$\eta_{ranking} = 1 - \frac{Q_{rej}}{Q_{in}} = 1 - \frac{T_1}{T_m} = \frac{W_{net}}{Q_S} = \frac{Q_S - Q_R}{Q_S} = 1 - \frac{Q_R}{Q_S}$$

* **For regeneration in Rankine cycle**

* $W_T = 1(h_{[illegible]} - h_{[illegible]}) + (1-y)(h_{[illegible]} - h_7)$
* $W_P = (1 - [illegible])(h_{[illegible]} - h_1) + 1(h_4 - h_{[illegible]})$
* $W_{[illegible]} = W_{[illegible]} - W_P$
* $Q_S = 1(h_5 - h_4)$
* **Applying conservation of energy for OFWH**

$(1 - [illegible])h_{[illegible]} + [illegible]h_{[illegible]} = 1 \times h_{[illegible]}$

- **Average skin friction coefficient**

  $(\bar{C}_{fx})$: $\boxed{\bar{C}_{fx} = 2C_{fx}}$

- **Average head transfer coefficient**

  $(\bar{h}_x)$: $\boxed{\bar{h}_x = 2h_x}$

- **Peclet No.** $\boxed{Pe_x = Re_x . Pr}$

For turbulent boundary layer

- $\boxed{C_{fx} = 0.0592\, Re_x^{-1/5}}$ $\left(\text{for } 5\times10^5 < Re_x < 10^7\right)$
- $\boxed{\bar{C}_{fL} = 0.074\, Re_L^{-1/5}}$
- $\boxed{\bar{N}_{uL} = 0.037\, Re_L^{4/5}\, Pr^{1/3}}$ $(0.6 < Pr < 60)$

* **Convection in pipes**

(i) constant heat flux at wall

$$\boxed{\frac{\bar{h}D}{K} = \bar{N}_{uD} = 4.364}$$

(ii)constant wall temperature $\boxed{\bar{N}_{uD} = 3.66}$

For turbulent flow

$\boxed{\bar{N}_{uD} = 0.023\, Re_D^{4/5}\, Pr^{1/3}}$ $\rightarrow$ **Dittus Boiller relation**

* **Natural convection**

- **Grashof''s number** $\boxed{Gr_L = \frac{g\beta L^3 (T_s - T_\infty)}{\upsilon^2}}$
- **Rayleigh number** $\boxed{Ra_L = Gr_L . Pr = \frac{g\beta L^3 (T_s - T_\infty)}{\upsilon^2}}$

* **Heat exchanger**

- **Logarithmic mean temperature difference (LMTD)**

$\boxed{Q = \dot{m}_h C_h \Delta T_h}$ $\boxed{Q = m_C C_C \left(T_{c,0} - T_{c,i}\right)}$

$$\boxed{Q = \frac{UA(\Delta T_1 - \Delta T_2)}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}}$$

* **Effectiveness**

* **NTU method :** $\boxed{NTU(N) = \frac{UA}{C_{min}}}$

- **For double pipe or parallel flow** $\boxed{\varepsilon = \dfrac{1-\exp\left[-N(1+C)\right]}{1+C}}$
- **Counter flow effectiveness** $\boxed{\varepsilon = \dfrac{1-\exp\left[-N(1-C)\right]}{1-C\exp\left[-N(1-C)\right]}}$
- $\boxed{\varepsilon = \dfrac{N}{1+N}}$ (if $C=1$)

* **Radiation**

- **Lambart's cosine law** $\boxed{E_b = \pi I_b = \sigma T^4}$
- **Plank's distribution law**

$$\boxed{E_{b\lambda} = \pi I_{b\lambda} = \frac{2\pi C_1}{\lambda^5\left[\exp\left(\dfrac{C_2}{\lambda T}\right)-1\right]}}$$

$C_1 = 6.625\times10^{-34}\ J.S$

$C_2 = 1.38049\times10\ J/mol.K$

- **Wein's formula** $\boxed{\dfrac{I_{b\lambda}}{T^5} = \dfrac{2C_1}{(\lambda T)^5 \exp\left(\dfrac{C_2}{\lambda T}\right)}}$
- **Rayleigh-Jean's formula** $\boxed{\dfrac{I_{b\lambda}}{T^5} = \dfrac{2C_1}{C_2}\dfrac{1}{(\lambda T)^4}}$
- **Wein's displacement law**

$\boxed{\lambda_{max} T = C_3}$ $C_3 = 0.289\times10^{-2}\,m.k$

- **Reciprocity theorem** $\boxed{A_1F_{12} = A_2F_{21}}$
- **Radiation exchange between small grey bodies**

$$\boxed{Q_{12} = \epsilon_1\epsilon_2 AF\sigma\left(T_1^4 - T_2^4\right)}$$

- **Radiation exchange between large parallel gray bodies**

$$\boxed{Q_{12} = \frac{A\sigma\left(T_1^4 - T_2^4\right)}{\dfrac{1}{\epsilon_1}+\dfrac{1}{\epsilon_2}-1}}$$

- **Radiation exchange between large gray concentric cylinders or sphere**

$$\boxed{Q_{12} = \frac{A_1\sigma\left(T_1^4 - T_2^4\right)}{\dfrac{1}{\epsilon_1}+\dfrac{A_1}{A_2}\left(\dfrac{1}{\epsilon_2}-1\right)}}$$

- **Exchange between a small gray body in a large gray enclosers**

$$\boxed{Q_{12} = \epsilon_1 A_1\sigma\left(T_1^4 - T_2^4\right)}$$

- **Radiosity** $\boxed{J = G\rho + \epsilon E_b}$
- **Critical radius of insulation**

For cylinder $\boxed{r_c = \dfrac{K_{ins}}{h}}$ **For sphere** $\boxed{r_c = \dfrac{2K_{ins}}{h}}$

- **Fourir's law** $\boxed{Q = -KA\frac{dT}{dx}}$
- **Newton's law of cooling** $\boxed{\frac{Q}{A} = q = h(T_S - T_\infty) = h.\Delta t}$
- **Stefan-Boltzmann law**

$\boxed{Q = \sigma A T_1^4}$ $\quad \sigma = 5.67\times10^{-8}\,w/m^2k^4$

- $\boxed{Q = UA\ \Delta T}$ **U = over all heat transfer coefficient**

$$\boxed{U = \frac{1}{\frac{1}{h_A} + \frac{1}{k} + \frac{1}{h_B}}}$$

- **General 3-D heat conduction equation**

$$\boxed{\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q}{k} = \frac{\rho C_P}{K}.\frac{\partial T}{\partial t} = \frac{1}{\alpha}\frac{\partial T}{\partial t}}$$

- α**= thermal diffusivity** $= \frac{K}{\rho C_P}\left(m^2/\sec\right)$
- **Heat conduction through plane wall** $\boxed{Q = \frac{KA\ \Delta T}{L}}$
- **For cylinder** $\boxed{\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) = 0}$
- **For sphere** $\boxed{\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right) = 0}$
- **Radial heat conduction through cylindrical system**

$$\boxed{Q = \frac{2\pi KL(T_i - T_o)}{\ln\left(\frac{r_o}{r_i}\right)}}$$

- **For sphere** $\boxed{Q = \frac{4\pi K r_i r_o (T_i - T_o)}{r_o - r_i}}$
- **System with variable thermal conductivity**

$\boxed{K_m = k(1 + \beta T_m)}$

- **Plane wall with internal heat generation**

$\boxed{\frac{d^2T}{dx^2} + \frac{q}{k} = 0}$ $\boxed{T_w = T_\infty + \frac{qL}{2h}}$

- **Biot no.** $\boxed{Bi = \frac{hL}{K}}$ $\boxed{T_{max} = T_w + \frac{qL^2}{8K}}$

*** FINS**

Long fins: $\boxed{\frac{T - T_\infty}{T_0 - T_\infty} = e^{-mx}}$, $m = \sqrt{\frac{hp}{kA}}$

$$Q = \sqrt{hpkA}\,\theta_0 = \sqrt{hpkA}.(T_0 - T_\infty)$$

- **Fin with insulated end:**

$$\frac{T - T_\infty}{T_0 - T_\infty} = \frac{\cosh[m(L-x)]}{\cosh(mL)}$$

$$Q = \sqrt{hpkA}\,(T_0 - T_\infty)\tanh(mL)$$

- **Fin with convection off the end:**

$$Q = \sqrt{hpkA}\,(T_0 - T_\infty)\frac{\tanh(mL) + \frac{h}{mk}}{1 + [\tanh(mL)]\frac{h}{mk}}$$

- **Efficiency of fins** $(\eta_{fin}) = \frac{Q_{fin}}{Q_{max}}$

$$Q_{max} = hPL\theta_0$$

- **Effectiveness of fins (E)** $E = \frac{Q_{with\ fin}}{Q_{without\ fin}}$
- **Skin friction coefficient** (C_f): $C_f = \frac{\tau_s}{\frac{1}{2}\rho u_\infty^2}$
- **Prandtle No.** (P_r): $P_r = \frac{\upsilon}{\alpha} = \frac{\mu C_p}{K}$
- **Friction factor for laminar flow** $f = \frac{64}{Re}$
- **Darcy-weisbach equation**

$$h_L = \frac{fLu_m^2}{2gD}$$

- **Bulk mean temperature** $T_b = \frac{2}{u_m R^2}\int_0^R u.T.r.dr$
- **Mean velocity** $(u_m) = u_m = \frac{2}{R^2}\int_0^R u.r.dr$

* **Forced convection system**
  Exact laminar boundary layer solution

- **Boundary layer thickness**

(δ) $\delta = \frac{5.0}{\sqrt{u_\infty / vx}} = \frac{5x}{\sqrt{Re_x}}$

- **Skin friction coefficient** $C_{fx} = \frac{\tau_s}{\frac{1}{2}\rho u_\infty^2} = \frac{0.664}{\sqrt{Re_x}}$

* Otto cycle :

- $$R_k = \frac{V_C + V_S}{V_C} = \frac{V_1}{V_2}$$

R_k = C.R (Compression Ratio)

- $$\eta = 1 - \frac{1}{(R_K)^{\gamma-1}}$$

- **Mean effective pressure**

$$P_{mean} = \frac{\eta(\Delta P)}{(\gamma-1)(R_k-1)}$$

* Diesel cycle:

$$R_c = \text{cut off ratio} = \frac{V_3}{V_2}$$

- $$\eta = 1 - \frac{1}{(R_k)^{\gamma-1}\,\gamma}\left[\frac{R_c^{\gamma}-1}{R_c-1}\right]$$

* Performance parameters

1. Indicated power $IP = \dfrac{P_{imep} \times L \times A \times K \times n}{60}$

2. Brake power

$$B.P = \frac{P_{b.mep} \times L \times A \times k \times n}{60} \quad \text{or} \quad BP = \frac{2\pi NT}{60}$$

3. Friction power $F.P = IP - BP$

4. Mechanical efficiency $\eta_m = \dfrac{BP}{IP}$

5. Indicated thermal efficiency (η_{ith})

$$\eta_{ith} = \frac{IP}{m_f \times CV}$$

6. **Brake thermal efficiency** $\boxed{\eta_{b\,th} = \frac{BP}{m_f \times CV}}$

7. **Relative efficiency** $(\eta_{rel.}) = \frac{\text{Acutal thermal } \eta}{\eta_{air\ standard}}$

8. **Volumetric efficiency**

$$\boxed{\eta_{vol} = \frac{\text{Volume of change acutally inducted}}{V_S}}$$

9. **Indicated specific fuel consumption**

$$\boxed{(ISFC) = \frac{\dot{m}_f}{SP}}$$

10. **Brake specific fuel consumption**

$$\boxed{BSFC = \frac{\dot{m}_f}{BP}}$$

11. **Specific power output:**

$$\boxed{Ps = \frac{B.P}{A}}$$

* **Comparison of factors controlling the knocking for S.I & C.I engines**

Factors	S.I Engine	C.I Engine
(1) SIT	High	Low
(2) Delay period	High	Low
(3) R_k	Low	High
(4) inlet temperature & pressure	Low	High
(5) combustion wall temperature	Low	High
(6) rpm (N)	High	Low
(7) cylinder size	Small	Large

- **Length of open belt drive (O.B.D**

$$= 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_2 - D_1)^2}{4C}$$

- **Length of cross belt driven (C.B.D)**

$$= 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_2 + D_1)^2}{4C}$$

- **Velocity ratio**

$$\boxed{V.R = \frac{N_2}{N_1} = \left(\frac{D_1 + t}{D_2 + t}\right)\left(1 - \frac{S}{100}\right)}$$

- **Ratio of belt tension** $\boxed{\frac{T_1}{T_2} = e^{\mu\theta}}$

- **Maximum tensile strength of belt**

$$\boxed{T_{max} = b.t.\sigma_{per}}$$

- **Power transmission capacity of belt drive**

$$\boxed{P.T.C = (T_1 - T_2)v}$$

- **Centrifugal tension** $\boxed{T_c = \frac{T_{max}}{3}}$

- **Initial tension** $\boxed{T_0 = \frac{T_1 + T_2 + 2T_c}{2}}$

- **Number of 'V' belts** $\boxed{n = \frac{P_{total}}{P_{each}}} \times K_a$

- **Buckingham dynamic load**

$$\boxed{F_d = F_t + \frac{20.67v[bc + F_t]}{20.67v + \sqrt{bc + F_t}}} \qquad \boxed{c = \frac{e}{K\left[\frac{1}{E_1} + \frac{1}{E_2}\right]}}$$

- **Soderberg equation** $\boxed{\frac{1}{FOS} = \frac{\sigma_m}{\sigma_{yt}} + \frac{K_f\sigma_v}{\sigma_e}}$

- **Goodman equation** $\boxed{\frac{1}{FOS} = \frac{K_t\sigma_m}{\sigma_{ut}} + \frac{K_f\sigma_v}{\sigma_e}}$

- **Notch sensitivity index** $\boxed{q = \frac{K_f - 1}{K_t - 1}}$

- **Unwin's formula** $\boxed{d = 6\sqrt{t}}$

- **Area of transverse fillet weld**

  $\boxed{A_{T.F.W} = h\ell_e}$, $\boxed{h = \dfrac{t}{\cos\theta + \sin\theta}}$

- $\boxed{\text{Strength of T.F.W} = 0.832t\,\ell_e\tau_{per}}$

- **Strength of parallel fillet weld**

  $= 0.707t\,\ell_e\tau_{Per}$

- **Strength of Butt weld** $= h\ell(\sigma_t)_{per}$

- **Frictional torque of thrust bearing by uniform pressure theory**

  $$\boxed{(T_f)_{UPT} = \frac{2}{3}\mu\omega\left(\frac{R_0^3 - R_i^3}{R_0^2 - R_i^2}\right)}$$

- **Frictional torque of thrust bearing by uniform wear theory**

  $$\boxed{(T_f)_{UWT} = \mu\omega\left(\frac{R_0 + R_i}{2}\right)}$$

- **Power less** $\boxed{P_{loss} = T_f.\omega}$

* T_f **equations for flat pivot bearing**

$$\boxed{(T_f)_{UPT} = \frac{2}{3}\mu WR} \qquad \boxed{(T_f)_{UWT} = \frac{1}{2}\mu WR}$$

- **Bearing pressure** $\boxed{p_{ind} = \dfrac{W}{LD}}$

- **Strength of bearing** $= p_{per} \times L \times D$

- **Bearing characteristic number** $= \dfrac{zn}{p}$

- **Mc-Kee's equation**

  $$\boxed{\mu = \frac{33}{10^8}\left[\left(\frac{zn'}{p'}\right)\left(\frac{D}{C}\right)\right] + K}$$

- **Somer field No.** $\boxed{S = \left(\dfrac{zn}{p}\right)\left(\dfrac{D}{C}\right)^2}$ rps

- **Petroff's equation for μ** $\boxed{\mu = 2\pi^2\left(\dfrac{zn}{p}\right)\left(\dfrac{D}{C}\right)}$

- **Life of bearing** $\boxed{L_{90} = \left(\dfrac{C}{P_e}\right)^k}$ (Million rev.)

- $(COP)_{ref} = \frac{R.E}{W_{in}}$
- **Unit of refrigeration = TR,** $\boxed{1TR = 3.5\ KJ/sec}$
- **Volumetric efficiency of a reciprocating compressor**

$$\eta_{vol} = \frac{\text{Actual volume}}{\text{Swept volume}} = \frac{\dot{m}v_1}{\frac{\pi}{4}D^2LNK} \qquad \boxed{\eta_{vol} = 1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}},\ \boxed{C = \frac{V_C}{V_S}}$$

- **V-C cycle** $\boxed{COP = \frac{R.E}{W_{in}} = \frac{h_1 - h_3}{h_2 - h_1}}$
- **Refrigeration capacity** $= \dot{m}(h_1 - h_2)\,kw$
- **Power input** $(P_{in}) = \dot{m}(h_2 - h_1)\,kw$
- **Gas refrigeration cycle** $w_{in} = w_C - w_E = (h_2 - h_1) - (h_3 - h_4)$ $R.E. = h_1 - h_4$
- $\boxed{COP = \frac{1}{(r_P)^{\frac{\gamma-1}{\gamma}} - 1}}$
- **V-A refrigeration cycle** $\boxed{COP = \left(\frac{T_G - T_O}{T_G}\right)\left(\frac{T_R}{T_O - T_R}\right)}$
- **Heat rejection ratio or factor** $\boxed{HRR = \frac{Q_C}{R.E} = \frac{1}{COP} + 1}$
- **Specific humidity or humidity ratio** $\boxed{\omega = 0.622\left(\frac{P_V}{P - P_V}\right)}$
- **Relative humidity** $\boxed{\phi = \frac{m_V}{m_{VS}} = \frac{P_V}{P_{VS}}}$
- **Degree of saturation** $\boxed{\mu = \frac{\omega}{\omega s} = \phi\left(\frac{P - P_{VS}}{P - P_V}\right)}$
- **Enthalpy of moist air** $\boxed{hm = \left[C_{Pa}t + \omega(2500 + 1.88t)\frac{KJ}{kg - k}\right]}$
- **Apjohn's formula** $\boxed{P_V = P_{V'} - \frac{1.8P(t - t')}{2700}}$ $t' = WBT$, $t = DBT$
- **Sensible heat factors** $\boxed{SHF = \frac{SH}{SH + LH}}$
- **Room sensible heat factor** $\boxed{RSHF = \frac{RSH}{RTH}}$
- $\boxed{RLH = RTH - RSH}$
- $\boxed{SH = 0.024 \times cmm(\Delta t)}\,kw$ **cmm = volume flow rate of air in** m^3/min
- $\boxed{LH = 50 \times cmm(\Delta\omega)}$
- $\text{Number of air changes} = \frac{\text{volume flow rate of air}\,(m^3/hr)}{\text{volume of room}\,(m^3)}$
- **Bypass factor** $\boxed{BPF = \frac{t_s - t_2}{t_s - t_1}}$
- $\boxed{\eta = 1 - BPF}$, $\boxed{\eta = \frac{t_2 - t_1}{t_s - t_1}}$

- **Normal stress when** σ_x, σ_y & τ_{xy} are given

$$\sigma_n = \frac{1}{2}(\sigma_x + \sigma_y) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta + \tau_{xy}\sin 2\theta$$

- $$\tau_s = -\left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\theta + \tau_{xy}\cos 2\theta$$
- **Location of principal plane**

$$\text{Tan}2\theta = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

- $$\sigma_{1/2} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$
- **Absolute**

$$\tau_{max} = \text{larger of} \left[\left|\frac{\sigma_1 - \sigma_2}{2}\right|, \left|\frac{\sigma_2 - \sigma_3}{2}\right|, \left|\frac{\sigma_3 - \sigma_1}{2}\right|\right]$$

- **Shear strain** $\gamma_{xy} = 2\tau_{xy}$
- **Maximum shear stress**

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$$

- **Centre of Mohr's circle** $= \left(\frac{\sigma_x + \sigma_y}{2}, 0\right)$
- **Radius of Mohr's circle**

$$= \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

- **Relationship between** $\sigma_{1,2,3}$ & $\epsilon_{1,2,3}$

$$\epsilon_1 = \frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E} - \mu\frac{\sigma_3}{E}, \quad \epsilon_2 = \frac{\sigma_2}{E} - \mu\frac{\sigma_3}{E} - \mu\frac{\sigma_1}{E},$$

$$\epsilon_3 = \frac{\sigma_3}{E} - \mu\frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E}$$

- **Volumetric strain of rectangular bar**

$$\epsilon_v = \left(\frac{\sigma_x + \sigma_y + \sigma_z}{E}\right)(1 - 2\mu)$$

- **Volumetric strain of cylindrical bar**

$$\epsilon_v = \epsilon_l + 2\epsilon_D$$

- **Volumetric strain of spherical bar**

$$\epsilon_v = 3\epsilon_D$$

* Relationship between elastic constant

$\boxed{E = 3K(1-2\mu)}$, $\boxed{E = 2G(1+\mu)}$, $\boxed{E = \frac{9K}{3K+G}}$

$\boxed{\mu = \frac{1}{m} = \frac{3K-2G}{6K+2G}}$

- Axial elongation of the Prismatic bar

$\boxed{\Delta = \frac{PL}{AE}}$

* Deflection in Non-prismatic Bars

1. Stepped Bar $\boxed{\Delta = \frac{PL_1}{A_1E} + \frac{PL_2}{A_2E}}$

2. Circular tapering Bar $\boxed{\Delta = \frac{4PL}{\pi E D_1 D_2}}$

* Deflection of composit Bar

$\boxed{\Delta_1 = \Delta_2 = \Delta = \frac{PL}{A_1E + A_2E}}$

* Deflection due to self weight of bar

(1) prismatic Bar $\boxed{\Delta = \frac{WL}{2AE}}$

(2) conical Bar $\boxed{\Delta = \frac{WL}{6AE}}$

- Maximum stain energy in elastic region $= \frac{(\sigma_{EL})^2}{2E} \times \text{volume}$ or $= \frac{1}{2} P_{EL}.\delta_{EL}$

- Thermal expansion $\boxed{\delta_{thermal} = \alpha.\Delta T.L}$

- Thermal strain $\boxed{\epsilon_{thermal} = \pm\alpha.\Delta T}$

- Thermal stress $\boxed{\sigma_{thermal} = \pm\alpha.\Delta T.E}$

- In case of pure bending

$\boxed{(\sigma_b)_{max} = \frac{M}{Z} = \frac{32M}{\pi D^3}}$, $\boxed{Z = \frac{\pi}{32} D^3}$

- In case of pure torsion

$\boxed{\tau_{max} = \frac{T}{Z_p} = \frac{16T}{\pi D^3}}$, $\boxed{Z_p = \frac{\pi}{16} D^3}$

- Bending equation $\boxed{\frac{\sigma_b}{y} = \frac{M}{I} = \frac{E}{R}}$

- $$\frac{\sigma_{Top}}{\sigma_{Bottom}} = \frac{\epsilon_{Top}}{\epsilon_{Bottom}} = -\frac{y_{Top}}{y_{Bottom}}$$
- **Pure torsion equation for circular shaft** $$\frac{T_R}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$$

* **Combined Bending & Torsion**

$$\sigma_1 / \sigma_2 = \frac{16}{\pi D^3}\left[M \pm \sqrt{M^2 + T^2}\right]$$

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{16}{\pi D^3}\left[\sqrt{M^2 + T^2}\right]$$

- **Equivalent moment**

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

- **Equivalent torque** $$T_e = \sqrt{M^2 + T^2}$$
- **Strain energy stored due to torsion in shaft**

$$u = \frac{T^2 L}{2GI_P}$$

- **Strain energy stored due to torsion in hollow shaft**

$$u_{hollow} = \frac{\tau_{max}}{4G}\left(\frac{R_0^2 + R_i^2}{R_0^2}\right)$$

- $$u = \frac{\tau_{max}^2}{4G}, \quad \tau = \frac{r}{R}.\tau_{max}$$

* **Shear stress distribution in Beams**

(1)In rectangular section

$$q = \frac{6S}{bd^3}\left(\frac{d^2}{4} - y^2\right)$$

where S = shear force

$$q_{max} = \frac{3}{2}\frac{S}{bd}, \quad q_{avg} = \frac{S}{bd}$$

(2)In circular Beam

(2) In circular Beam

$$q = \frac{4}{3}\frac{S}{\pi R^4}\left(R^2 - y^2\right) \qquad q_{max} = \frac{4}{3}\frac{S}{\pi R^2}$$

(3) In triangular section

$$q_{max} = \frac{3S}{bh},\quad q_{avg} = \frac{2S}{bh},\quad q_{N.A} = \frac{4}{3}q_{avg}$$

(4) In Diamond section

$$q_{max} = \frac{9}{4}\frac{S}{h^2},\quad q_{avg} = \frac{2S}{h^2},\quad q_{N.A} = q_{avg}$$

(5) In I-section

$$q_{max} = \frac{S}{8I}\frac{B}{b}\left(b^2 - d^2\right) + \frac{S}{8I}d^2$$

* **Thin cylindrical pressure vessels**

$$\sigma_h = \frac{pD}{2t},\quad \sigma_L = \frac{pD}{4t},\quad \tau_{max} = \frac{pD}{8t}$$

$$\epsilon_h = \frac{pD}{4tE}(2-\mu),\quad \epsilon_L = \frac{pD}{4tE}(1-2\mu),\quad \epsilon_V = \frac{pD}{4tE}(5-4\mu)$$

* **Thin spherical pressure vessels**

$$\sigma_h = \sigma_L = \frac{pD}{4t} \text{ or } \sigma_1 = \sigma_2 = \frac{pD}{4t}$$

- **Euler's Buckling load** $P_e = \dfrac{n^2\pi^2 E.I}{L_e^2}$

- **End condition of columns**

  1. If both end are hinged $L_e = L$
  2. If one end is fixed & other is hinged

     $L_e = L/\sqrt{2}$
  3. If both end are fixed $L_e = \dfrac{L}{2}$
  4. If one end is fixed and other is free

     $L_e = 2L$

- **Stiffness of spring** $K = \dfrac{P}{\Delta} = \dfrac{Gd^4}{64R^3 n}$

Thermodynamics

- Temperature Kelvin = °C + 273.15
- Non flow work or closed system work in various processes

  1. Constant pressure or Isobaric process $w = \int p dv$
  2. Constant volume Process $w = \int p dv = 0$
  3. Isothermal process $\boxed{w = pv \ln\left(\frac{P_1}{P_2}\right)}$
  4. Adiabatic process $\boxed{w = \frac{P_1V_1 - P_2V_2}{\gamma - 1}}$
  5. Polytrophic process $\boxed{w = \frac{P_1V_1 - P_2V_2}{n - 1}}$

- Slope of isothermal line on P-V diagram $= -\frac{P}{V}$
- Slope of adiabatic curves on P-V diagram $= \gamma\left(-\frac{P}{V}\right)$
- For adiabatic process of an ideal gas

  1. $P_1V_1^{\gamma} = P_2V_2^{\gamma}$ 2. $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$
  3. $\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \frac{T_2}{T_1}$

- Open system work in various process

  1. Constant pressure process $\boxed{w = -\int v dp = 0}$
  2. Const. volume process $\boxed{w = (P_1 - P_2)V}$
  3. Isothermal process work $\boxed{w = P_1V_1 \ln\frac{V_2}{V_1}}$
  4. Adiabatic open system work
  $\boxed{w = \frac{\gamma}{\gamma - 1}(P_1V_1 - P_2V_2)}$
  5. Polytropic open system work
  $\boxed{w = \frac{n}{n-1}(P_2V_2 - P_1V_1)}$

- $\boxed{\gamma = \frac{C_P}{C_V}}$, $\boxed{C_P > C_V}$, $\boxed{\gamma > 1}$, $\boxed{C_P - C_V = R}$, $\boxed{C_V = \frac{R}{\gamma - 1}}$, $\boxed{C_P = \frac{\gamma R}{\gamma - 1}}$
- 1st law of thermodynamics $\boxed{\delta Q = dE + \delta w}$
- II law of thermodynamics

  1. Kelvin plank statement $\boxed{\eta_{HE} = \frac{Q_1 - Q_2}{Q_1}}$
  2. Clausius statement

  $\boxed{(COP)_{H.P} = \frac{Q_1}{Q_1 - Q_2}}$ $\boxed{(COP)_{HP} - (COP)_{HE} = 1}$

Thermodynamics

- **Steady flow energy equation**
  $\boxed{h_1 + \frac{\bar{V}_1^2}{2} + gz_1 + \frac{Q}{m} = h_2 + \frac{\bar{V}_2^2}{2} + gz_2 + \frac{w}{m}}$
- **For unsteady state** 1. $\left(\frac{dm}{dt}\right)_{cv} = m_i - m_e$
  2. $\left(\frac{dv}{dt}\right)_{cv} = \dot{m}_i h_i + \dot{Q} + m_e h_e - w_{cv}$
- **Clausius inequality** $\boxed{\oint \frac{dQ}{T} \le 0}$
- **Entropy** $\boxed{\frac{dQ}{T} \ge ds}$ • **Enthalpy** $\boxed{H = U + PV}$ **joule**
- **Specific enthalpy** $\boxed{h = \frac{H}{m}}\ \frac{KJ}{kg}$
- **Available energy (AE) = Q_1 – unavailable energy (UE)**
- $\boxed{\uparrow UE = T_0 Q_1 \left(\frac{T_1 - T_2}{T_1 T_2}\right)}$
- **Availability in closed system**
- $\boxed{w_{max} = (U_1 - U_0) - T_0(S_1 - S_0)}$, $\boxed{\text{useful work} \quad w_{max} - P_0(\Delta v)}$
- **Maximum work = change in availability**
- **Availability in open system**
  $\boxed{w_{max} = (h_1 - h_2) - T_0(S_1 - S_2)}$
- **Irreversibility** $\boxed{I = T_0 (\Delta S)_{universe}}$
- **Gibbs function** $\boxed{G = H - TS}$
- **Helmholtz function** $\boxed{F = U - TS}$
- **Maxwell equations**
  1. $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$ 2. $\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$
  3. $\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$ 4. $\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$
- $\boxed{Tds = du + pdv}$, $\boxed{Tds = dh - vdp}$
- $\boxed{Tds = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dv}$, $\boxed{Tds = C_P dT - T\left(\frac{\partial V}{\partial T}\right)_P dp}$
- $\boxed{C_P - C_V = -T\left(\frac{\partial V}{\partial T}\right)_P^2 \left(\frac{\partial P}{\partial V}\right)_T}$
- **Coefficient of volume expansivit** $\boxed{\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P}$
- **Isothermal Bulk modulus** $\boxed{K_T = -V\left(\frac{\partial P}{\partial V}\right)_T}$
- **Isothermal compressibility** $\boxed{\frac{1}{K_T} = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T}$
- $\boxed{C_P - C_V = T\beta^2 V K_T}$

- **Grubler's equation** $\boxed{F = 3(l-1) - 2j - h}$
- **Grashof's law** $\boxed{(S + l) < (p + q)}$
- **Number of instantaneous centre** $= {}^{l}C_2$ $\boxed{\text{No. of I.C.} = \frac{l(l-1)}{2}}$
- **Linear velocity of instantaneous centre**

$$\boxed{V_{I_{mn}} = \omega_m (I_{mn} I_{lm}) = \omega_n (I_{mn} I_{ln})}$$

- **Coriolis acceleration** $\boxed{a = 2V\omega}$
- **Minimum number of teeth of gear to avoid interference**

$$\boxed{T_{min} = \frac{2A_W}{\left\{\sqrt{1 + \frac{1}{G}\left(\frac{1}{G} + 2\right)\sin^2\phi} - 1\right\}}}$$

- **Minimum number of teeth of pinion to avoid interference**

$$\boxed{t_{min} = \frac{2A_P}{\sqrt{1 + G(G + 2)\sin^2\phi} - 1}}$$

- **Speed ratio or velocity ratio** $= \frac{\omega_{\text{main driver}}}{\omega_{\text{main driven}}}$
- **Train value** $= \frac{1}{\text{Velocity Ratio}}$
- **For watt governor** $\boxed{N^2 = \frac{895}{h}}$
- **Porter governor**

$$\boxed{N^2 = \frac{895}{h}\left[\frac{2mg + (Mg \pm f)(1 + K)}{2mg}\right]} \quad \text{where} \quad \boxed{K = \frac{\tan\beta}{\tan\theta}}$$

- **Proell governor** $\boxed{N^2 = \frac{895}{h}\left(\frac{a}{e}\right)\left[\frac{2mg + (Mg \pm f)(1 + K)}{2mg}\right]}$
- **Stiffness of Hartnell governor** $\boxed{S = 2\left(\frac{F_2 - F_1}{r_2 - r_1}\right)\left(\frac{a}{b}\right)^2}$
- **For Wilson Hartnell governor** $\boxed{\frac{F_2 - F_1}{r_2 - r_1} = 4s + \frac{S_a}{2}\left(\frac{b}{a} \cdot \frac{y}{x}\right)^2}$
- $\boxed{\text{Sensitivity of governor} = \frac{N_{mean}}{N_1 - N_2}}$

- **Velocity of piston** $v = r\omega\left[\sin\theta + \frac{\sin 2\theta}{2\sqrt{n^2 - \sin^2\theta}}\right]$
- **Acceleration of piston** $a = r\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$
- **Velocity of connecting rod** $\omega_{C.R} = \frac{\omega\cos\theta}{\sqrt{n^2 - \sin^2\theta}}$
- **Acceleration of connecting rod**

  $$\alpha_{C.R} = -\omega^2\sin\theta\left[\frac{n^2-1}{\left(n^2 - \sin^2\theta\right)^{3/2}}\right]$$
- **Fluctuation of speed** $= \omega_{max} - \omega_{min}$
- **Coefficient of fluctuation of speed** for fly wheel :

  $$\boxed{C_S = \frac{N_{max} - N_{min}}{N}} \qquad N = \frac{N_{max} + N_{min}}{2}$$
- **Fluctuation of energy** $e = E_{max} - E_{min}$
- **Coefficient of fluctuation of energy** for fly wheel $\boxed{C_E = \frac{E_{max} - E_{min}}{W_{cycle}}}$

  $$\boxed{\Delta E = I\omega^2 C_S}$$
- **Natural frequency of spring**

  $$\omega_n = \sqrt{\frac{K}{m}}\ \text{rad/sec} \ \& \ F_n = \frac{1}{2\pi}\sqrt{\frac{K}{m}}\ \text{Hz}$$
- **Damping factor** $\xi = \frac{C}{C_c}$
- **Critical damping constant** $C_c = 2m\omega_n$
- **Logarithm decrement** $= \frac{2\pi\xi}{\sqrt{1-\xi^2}}$
- **Transmeability** $= \frac{\sqrt{1 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}{\sqrt{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$
- **Damped frequency** $\omega_d = \omega_n\sqrt{1-\xi^2}$