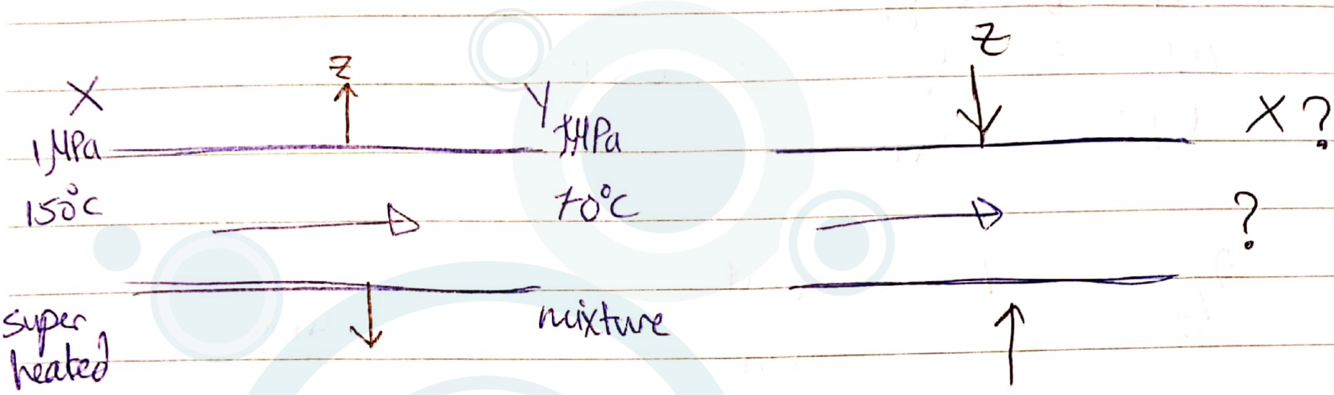
Ch: 7) second law of thermodynamics

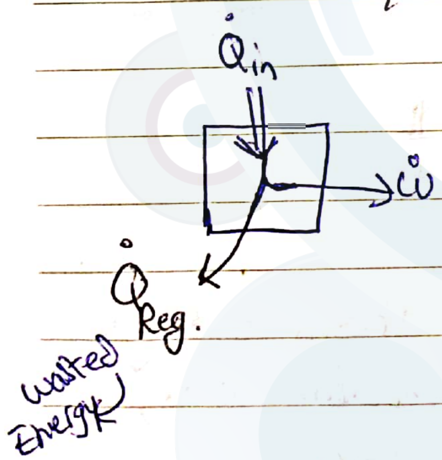


reversable process → ideal process
inreversable process → actual process

depends on the path → 2^{nd} law → manage paths of Energy

focusses on Losed Energy → friction
→ Q_{loss}

Heat Engine : any device you give it Energy & it gives you work.



you can't take work if and only if you get regection of heat.

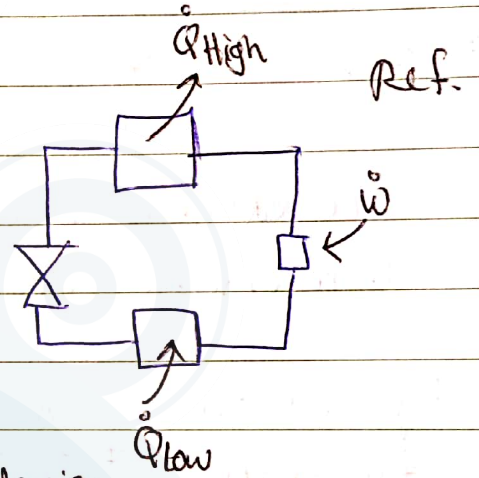
$\dot{Q}_{in} \neq \dot{W}$ impossible

$\dot{W} = \dot{Q}_{in} - \dot{Q}_{out}$ (KJ)

Thermal effeciency :-

$$\eta_{th} = \frac{\dot{W}}{\dot{Q}_{in}} \quad ; \quad 0 < \eta < 1$$

$$\eta_{th} = 1 - \frac{Q_{out}}{Q_{in}}$$



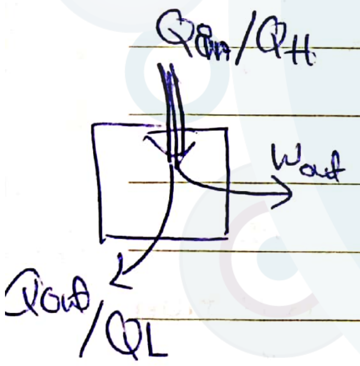
low $\xrightarrow[\text{work}]{\text{external}}$ High

One path for Energy

positive

Q_H : magnitude of $\dot{Q}$ between cyclic device and the high temp. medium at T_H

Q_L : magnitude of Q between cyclic device and the low temp. medium at T_L



$$\dot{W}_{net,out} = Q_H - Q_L$$

$$\eta_{th} = \frac{W_{out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

* Heat is always transferred from a high temp. medium to a low temp. medium one, and never the another way.

$\Rightarrow$ there will always be Waste Energy

Example 7-1) Net power Production of a Heat Engine

$\dot{Q}_{in} = P = 80$ MW

$\dot{Q}_{out} = 50$ MW

① $\dot{W}_{out}$? ② $\eta_{th} = ?$

$\dot{W}_{out} = 80 - 50 = 30$ MW

$$\eta_{th} = \frac{\dot{W}}{\dot{Q}_{in}} = \frac{30}{80} = 0.375$$

Example 7.2) Fuel consumption Rate of a car

$\dot{W} = 65$ hp

$\eta_{th} = 24\%$

Heating value = 19000 Btu/lbm

(19000 Btu of Energy is released for each lbm of fuel burned)

rate fuel consumption ?

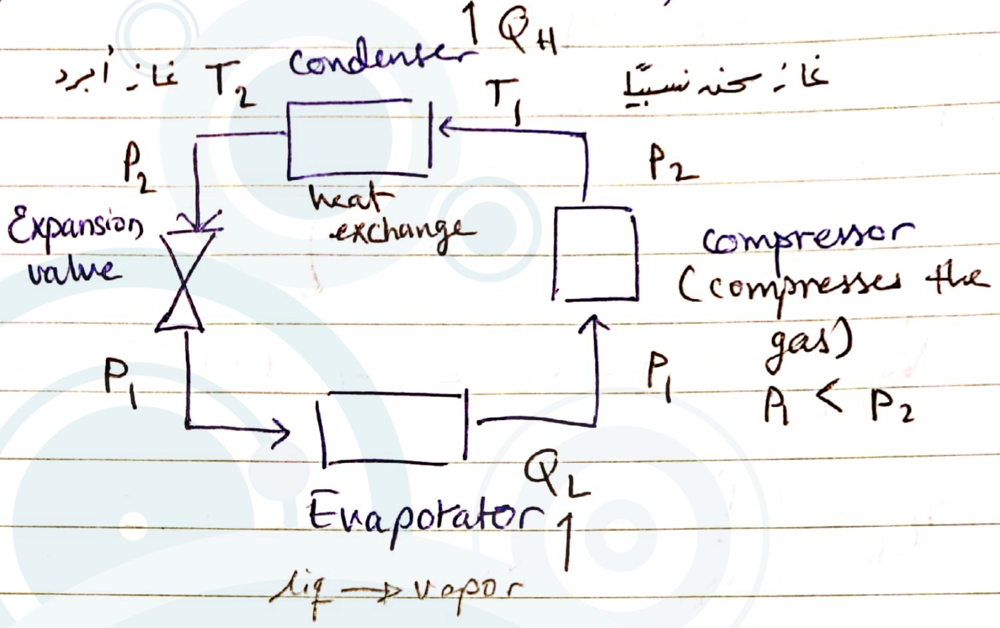
$$\dot{Q}_{in} = \frac{\dot{W}_{out}}{\eta_{th}} = 270.83 \text{ hp} * \frac{2545 \text{ Btu/h}}{1 \text{ hp}}$$

$$= 689\ 262.35 \text{ Btu/h}$$

$$\dot{m}_{fuel} = \frac{689\ 262.35 \text{ Btu/h}}{1900 \text{ Btu/lbm}} = 36.3 \text{ lbm/h}$$

$\boxed{7\text{-}4}$ Refrigerators and Heat Pumps

$T_1 > T_2$



Coffecient of performance (COP_R)

- the object of a refrigerant is to remove Q_L from the Ref. space.

$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{Q_L}{W_{in}}$$

$$= \frac{\dot{Q}_L}{\dot{W}_{in}} > 1$$

$$= \frac{Q_L}{Q_H - Q_L}$$

$$= \frac{1}{\frac{Q_H}{Q_L} - 1}$$

* **Heat pump** → هدفها

بدنا نسخنه $\dot{Q}_H$

↓

Desired output → Q_H

$$COP_{HP} = \frac{\dot{Q}_H}{\dot{W}} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_L}$$

$$\boxed{COP_{HP} = COP_R + 1}$$

Ch:11) Fluid statics

* How we can calculate forces produced by liquids or gases in static

Force ← Pressure لحتى نعرف

* How we calculate / analysie the stability of the floating submerged bodes (ا غمور)

---

* Hydrostatic : deals with liquid fluid static
* Aerostatic : " " gas fluid static

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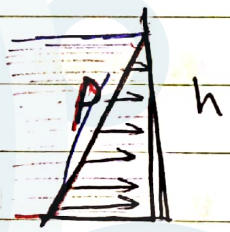
* Hydrostatic → Submerged surfaces

$p = p_{atm} + \rho g h$ (open to the atm) p is linearly with h



$p = p_o + \rho g h$ (evacuated or pressurized)

$p_{gage} = \rho g h = \rho g y \sin\theta$

For a flat surface (Free Surface)

① $F_R = (p_o + \rho g y_c \sin\theta) A = (p_o + \rho g h_c) A = p_{avg} A_c = p_c A$

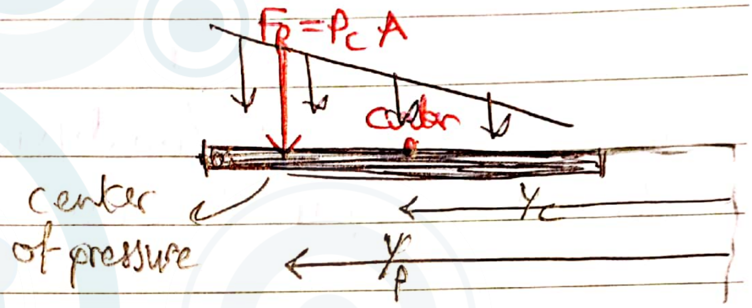
h_c → vertical distance to the centroid of area

h_c → centeroid of Area

p_c → center of pressure

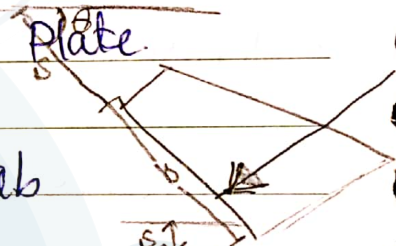
$\ast$ $h_p = y_p \sin\theta$; h_p : vertical distance of the center of pressure from the free surface

location: ② $y_p = y_c + \dfrac{I_{xxc}}{y_c A}$?

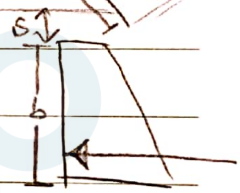


I_{xxc} : moment of Inertia

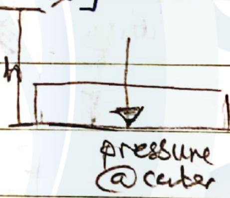
** Special case : Submerged Rectangular plate.



Tilted plate : $F_R = (P_0 + \rho g (s + b/2)\sin\theta)\, ab$



vertical plate : $F_R = [P_0 + \rho g (s + b/2) \cancel{\sin\theta}]\, ab$



Horizontal plate : $F_R = (P_0 + \rho g h)\, ab$

location: $y_p = s + \dfrac{b}{2} + \dfrac{b^2}{12[s + b/2 + P_0/(\rho g \sin\theta)]}$

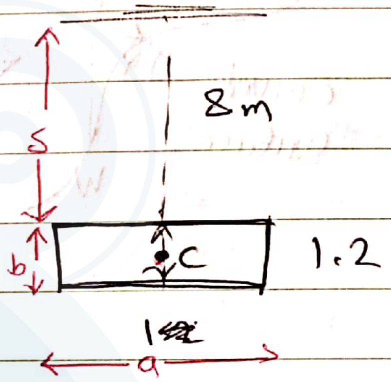
Example 11-1) p: 449

car — door → 1.2 m, 1 m; 8 m below the free surface

$\rho_{water} = 1000 \ kg/m^3$

① $F_R = ?$ ② $y_p = ?$

horizontal, door → vertical Rect. plate



$$F_R = (\cancel{P_0}^{\,0} + \rho g(s + b/2))ab$$

$$= 1000 * 9.81 (8 + 0.6) 1.2 (1)$$

$$= 101239.2 \ N$$

$$= 101 \ KN$$

y_p → directly under the the midpoint of the door

$$y_p = s + \frac{b}{2} = 8 + 0.6 = 8.6 \ m$$

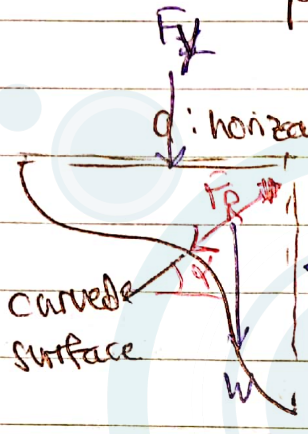
(or) (more accurately)

$$y_p = 8 + \frac{b}{2} + \frac{b^2}{12[s + b/2 + \cancel{0}]} = 8 + 0.6 + \frac{(1.2)^2}{12(8.6)}$$

$$= 8.614 \ m$$

** -- Curved Surfaces
↓
Projections

$W = \rho g V$



$F_H = F_x$

$F_V = F_y \pm W$

$F_R = \sqrt{F_H^2 + F_V^2}$

$\alpha = \tan^{-1}\left(\frac{F_V}{F_H}\right)$

* multilayered fluid → 2 fluids

differs ρ ← نحسب كل واحد لحال

لحاله بأسلوب

Example (1-2) p: 45)

① $F_H = \rho g h_c A$ $\quad h_c = 5 - 0.4 = 4.6 \text{ m}$

$= 1000 * 9.81 * 4.6 (0.8 * 1) = 36.1 \text{ KN}$

② $F_V = F_y - W$

$= 1000 * 9.81 * 5 (0.8) - \rho g V$

$= 39.2 - 1.3$

$= 37.9 \text{ KN}$

$W = \rho g V$

$= \frac{1000 * 9.81 * 1 (R^2 - \frac{R^2 \pi}{4})}{1000}$

$= 1.3 \text{ KN}$

③ $F_R = \sqrt{37.9^2 + 36.1^2} = 52.3 \text{ KN}$

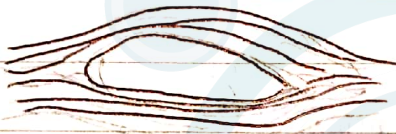
$\tan\theta \Rightarrow \theta = \tan^{-1}\frac{F_V}{F_H} = \quad \theta = 46.4°$

18.5.2020

ch:12) Bernoulli & Energy Equations

Fluid Dynamics
- Bernoulli Equation
- Energy Equation

* Bernoulli equation   اذا بدنا ندرس حركة مائع كل نقطة



velocity → acceleration

$$\frac{\partial d}{\partial t} \rightarrow \frac{\partial v}{\partial t}$$

Steady state flow
$\frac{\partial}{\partial t} = 0$
there's no change with time

$$\frac{\partial v}{\partial d}$$

velocity changes with respect to displacement

* $$\frac{P_1}{\rho} + \frac{V_1^2}{2} + g z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + g z_2$$

$$\underbrace{P}_{\text{Static pressure}} + \underbrace{\rho \frac{V^2}{2}}_{\text{Dynamic pressure}} + \underbrace{\rho g z}_{\text{hydrostatic pressure}} = \text{const.}$$

(depends on the level selected)

* $$P_{stag} = \overset{\text{static}}{P} + \overset{\text{Dynamic}}{\rho \frac{v^2}{2}}$$ [Stagnation pressure]

↳ when $v=0$, P is max.

$$\underset{\text{fluid velocity}}{v} = \sqrt{\frac{2(P_{stag} - P)}{\rho}}$$ → $P = \rho g h = \rho g y \sin\theta$

* Energy Equation

الطاقة اللي مشيتها من ال pump

الطاقة اللي كان بقدر يمشيها لولا turbine

$$\frac{P_1}{\rho_1 g} + \frac{V_1^2}{2g} + z_1 + h_{pump} = \frac{P_2}{\rho_2 g} + \frac{V_2^2}{2g} + z_2 + h_{turbine} + h_L$$

الطاقة اللي كان بقدر يمشيها لولا ال friction

$$\dot m\left(\frac{P_1}{\rho_1 \cancel{g}} + \frac{V_1^2}{2\cancel{g}} + gz_1\right) + \dot W_{pump} = \dot m\left(\frac{P_2}{\rho_2 g} + \frac{V_2^2}{2g} + z_2\right) + \dot W_{turbine} + E_{mech.loss}$$

(height loss)

$$\dot W = h * g * \dot m$$

* Kinetic Energy correction factor (α)

$$\frac{\alpha V_1^2}{2} \quad ; \quad \frac{\alpha V_2^2}{2}$$

$$\dot V = VA = m/s * m^2 = m^3/s = \frac{L}{s}$$

$$\dot V = \frac{V}{\Delta t} = \frac{L}{s}$$

1

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Ch:14) Internal flow

* $\dot{m} = \rho V_{avg} A_c = \int_{A_c} \rho\, u(r)\, dA_c$

  $= \rho \dot{V}$

* $V_{avg} = \frac{2}{R^2} \int_0^R u(r)\, r\, dr$

* Laminar & Turbulent Flows

  Laminar → Smooth; Turbulent → fluctuating

  $Re \leq 2300$ transition $Re \geq 4000$

  $2300 \leq Re \leq 400$

* $Re = \frac{\rho V_{avg} D}{\mu} = \frac{V_{avg} \cdot D}{\nu} = \frac{\text{Inertial forces}}{\text{Viscous forces}}$

  ν → viscosity

(Reynolds #)

circular: D = the same diameter of the cylinder

non circular:

square: $D_h = \frac{4a^2}{4a} = a$

rectangle: $D_h = \frac{2ab}{a+b}$

In general: $D_h = \frac{4A_c}{P}$

A_c → الداخلي

P → المحيط [illegible]

* laminar flow

Velocity Profile function

(1) $u(r) = 2V_{avg}\left(1 - \frac{r^2}{R^2}\right)$

variable

inner radius

$= u_{max}\left(1 - \frac{r^2}{R^2}\right)$

we use it to find

$\dot{m}$

V_{avg}.

(2) $Re = \frac{V_{avg} \cdot D}{\nu} = \frac{\rho}{\mu} V_{avg} \cdot D$

friction factor $f = \frac{64}{Re} = \frac{64 \cdot \mu}{V_{avg} \cdot D \rho}$ laminar

Head loss $h_L = f \frac{L V_{avg}^2}{2g D} = \frac{\Delta P_L}{\rho g}$

$\Delta P = \rho g h$

$\Delta P_L = \rho g h_L$

Energy Eq'n

length of the pipe

pressure loss (3) $\Delta P_L = f \frac{L}{D} \frac{\rho V_{avg}^2}{2}$

(4) $V_{avg} = \frac{\Delta P D^2}{32 \mu L}$

$\dot{V} = V_{avg} A_c = \frac{\Delta P \pi D^4}{128 \mu L}$

In Horizontal pipe

(5) $\dot{W}_{pump} = \dot{V} \Delta P_L = \dot{V} \rho g h_L = \dot{m} g h_L$

** special case ≡ Inclined pipe (effect of gravity) θ

θ ↗ +ve uphill, ↘ −ve downhill

$$V_{avg} = \frac{(\Delta P - \rho g L \sin\theta) D^2}{32 \mu L}$$

$\Delta z = z_2 - z_1 = L \sin\theta$

$$\dot{V} = \frac{(\Delta P - \rho g (L\sin\theta)) \pi D^2}{128 \mu L}$$

** Flow in Non circular pipe → $D_h = \frac{4 A_c}{P}$ (A_c → inner Area, P → inner circumference)

a/b or θ → f

** check page 538

* Turbulent Flow

1. plastic cast iron ... كلا قطيع نوع الماسورة أو حجر معامل ... table 14-2 p: 543 roughness

✓ 2. $Re = ✓$ Turbulent

$$f \Rightarrow \frac{1}{\sqrt{f}} \simeq -1.8 \log\left[\frac{6.9}{Re} + \left(\frac{\varepsilon/D}{3.7}\right)^{1.11}\right]$$

$h_L = ✓$

3. $\Delta P_L = ✓$ ع معادلات بأربع مجاهيل

4. ✓ منقدر نستخدم بداله

5. ✓

$$h_L = 1.07 \frac{\dot{V}^2 L}{g D^5} \left\{ \ln\left(\frac{\varepsilon}{3.7D} + 4.62\left(\frac{\nu D}{\dot{V}}\right)^{0.9}\right)\right\}^{-2}$$

$$\dot{V} = -0.965 \left(\frac{g D^5 h_L}{L}\right)^{0.5} \ln\left[\frac{\varepsilon}{3.7D} + \left(\frac{3.17 \nu^2 L}{g D^3 h_L}\right)^{0.5}\right]$$

check page 545

$$D = 0.66\left[\varepsilon^{1.25}\left(\frac{L\dot{V}^2}{g h_L}\right)^{4.75} + \nu \dot{V}^{9.4}\left(\frac{L}{g h_L}\right)^{5.2}\right]^{0.04}$$

value

bends

exits

inlets

* **Minor losses**

contractions

expansions

tees

elbows

$$h_L = K_L \frac{V^2}{2g} = f \frac{L_{equiv}}{D} \frac{V^2}{2g}$$

$$L_{equiv} = \frac{D}{f} K_L$$ check p: 552

$$h_{L,total} = h_{L,major} + h_{L,minor}$$

laminar

turbulent [illegible]

$$h_{L,tot.} = \left(f \frac{\Sigma L}{D} + \Sigma K_L\right) \frac{V^2}{2g}$$

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Heat Transfer

انتقال طاقة (ي آثار حرارة

ch:16) mechanism of heat transfer

- Conduction
- Convection
- Radiation

Conduction

in Solids

gases & liq. → bounded

عندهم كابلاه قدرة تحرك

$$\dot{Q}_{cond.} = KA \frac{T_1 - T_2}{\Delta x}$$ (Fourier's law of Heat conduction)

$$= -KA \frac{\Delta T}{\Delta x} = -KA \frac{dT}{dx}$$

K: thermal conductivity

table 16-1
p: 628

$$\text{Thermal diffusivity} = \alpha = \frac{\text{Heat conduction}}{\text{Heat storage}} = \frac{K}{\rho C_p}$$

قديش بتنتشر الحرارة على قديش المادة بتخزن حرارة

table
16-4
p: 632

Convection → gas, liq. → motion
→ solid surface with motionary fluid

velocity vs. حركة السريان/التحفيز → حركة

(free) Natural convection
force convection

Force معدل انتقال الحرارة اكبر

$$\dot{Q}_{conv} = h A_s (T_s - T_\infty)$$

[Newton's law of cooling]

h: convection coeff → Table 16-5 p:635

A_s: Surface Area

T_s: surface

T_∞: fluid

convection, conduction → T ⇒ K طبعا or C°

$$W = VI = \dot{Q}$$

داكا موجود

* **Radiation** (electromagnatic waves)

photons

ماكانه
ما في إله

combined heat transfer → Radiation + convection

$\Rightarrow \dot{Q}_{rad} = \varepsilon \sigma A_s (T_s^4 - T_\infty^4)$ W

emissivity

Stefen-boltzman coeff.

kelvin

$\Rightarrow \dot{Q}_{absorbed} = \alpha \, \dot{Q}_{inicide}$ W

absorptivity

$\Rightarrow$ combined heat transfer → تعرّض إل fluid

$\dot{Q}_{tot} = \dot{Q}_{conv} + \dot{Q}_{rad}$

$= h_{combined} A_s (T_s - T_\infty)$ kelvin

$h_{combined} = h_{conv} + h_{rad} = h_{conv} + \varepsilon \sigma (T_s + T_{surr})(T_s^2 + T_{surr}^2)$

ch:17) Steady heat conduction

Thermal Resistance

convection

radiation

$R_{wall,cond}$ R_{conv} R_{rad}

$R_{cond.} = \frac{L}{KA}$ $R_{conv} = \frac{1}{hA}$ $R_{rad} = \frac{1}{h_{rad} A_s}$

$Q_{cond} = \frac{T_1 - T_2}{R_{wall}}$; $Q_{conv} = \frac{T_s - T_\infty}{R_{conv}}$; $Q_{rad} = \frac{T_s - T_{surr}}{R_{rad}}$

$Q_{tot} = h_{combined} A_s (T_s - T_\infty)$

On Series $\rightarrow$ $R_{tot} = R_1 + R_2 + \dots$

$$\dot{Q} = \frac{T_{\infty 1} - T_{\infty 2}}{R_{tot}} = UA\,\Delta T$$

U → over-all heat transfer

on Parallel $\rightarrow R_{tot} \rightarrow \frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

$$R_{tot} = \frac{R_1 R_2}{R_1 + R_2}$$

$$\dot{Q} = \frac{T_{\infty 1} - T_{\infty 2}}{R_{tot}}$$

ch: 8) Transient Heat Conduction

lumped system analysis

هنا بقدر اتعامل حرارياً مع الأجسام كأنها كتلة واحدة

One unit

single temp.

$m \quad V \quad \rho \quad T_i$

$T = T(t)$

$\dot{Q} = h A_s (T_\infty - T(t))$

$$\frac{T(t) - T_\infty}{T_i - T_\infty} = e^{-bt}$$

$$b = \frac{h A_s}{\rho V C_p}$$

convection coeff (h)

Volume (V)

exponential relation between temp of the body & surr. temp.

* $\dot{Q}(t) = hA_s\,(T(t) - T_\infty)$

cooling rate

* $Q = mC_p\,[T(t) - T_\infty]$

total amount of heat after certain temp.

* $Q_{max} = mC_p\,[T_\infty - T_i]$

اول خطوة بدنا

$Bi = \dfrac{h\,L_c}{K}$ $\qquad Bi \leq 0.1$

Biot no.

$L_c = \dfrac{V}{A_s}$

characteristics length