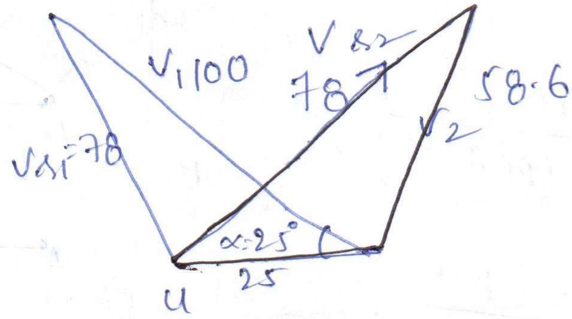
$\frac{Q-14}{16}$

Axial flow T. Turbine



$V_1 = 100$ m/sec
$u = 25$
$\alpha = 25°$
$V_{r1} = V_{r2}$
$V_{f1} = V_{f2}$

Sp work J/kg = ______ ?

$$RP = \frac{\rho Q [V_{w_1} + V_{w_2}] u}{\dot{m}}$$

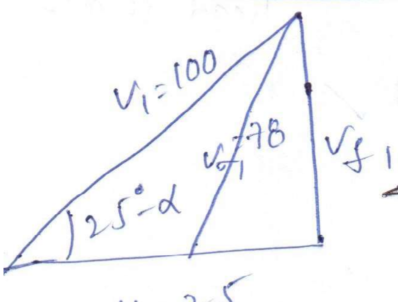
$$RP = \frac{J}{sec} \cdot \frac{kg}{kg}$$

$$\frac{J}{kg} = \frac{RP}{(kg/sec)\ \dot{m}}$$

Sp work J/kg =

$[V_{w_1} + V_{w_2}] u$

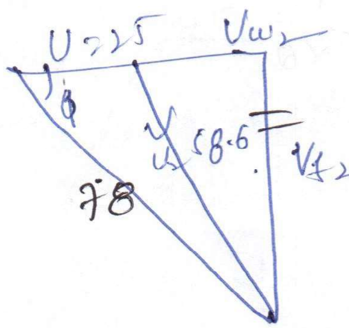
$$\boxed{V_{w_2} = \sqrt{V_2^2 - V_{f_2}^2}}$$



$V_{w_1} = V_1 \cos 25$

$V_{w_1} = 100 \times \cos 25$

$\boxed{V_{w_1} = 90.63 \text{ m/s}}$



$V_{f_2} = V_{f_1} = V_1 \sin\alpha$

$= 100 \sin 25$

$\boxed{V_{f_2} = 42.26 \text{ m/s}}$

$V_{f_2} = V_1 = V_1 \sin 25°$ $\Rightarrow V_{w_2} = \sqrt{58.6^2 - (100 \sin 25)^2}$

$= V_{w_2} = 40.5$ m/sec

$V_{w_2} = 40.7 \text{ m/s}$

$Sp.\ work = [V_{w_1} + V_{w_2}]\, u$

$= [90.03 + 40.5] \times 25$

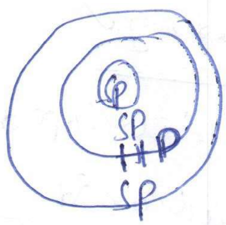
$= 3278 \text{ J/kg} \rightarrow$ ~~3027845~~ J/kg ✓

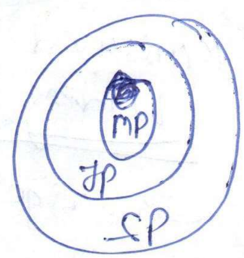
* Pump *

(1) Centrifugal pump :- (↔ Francis turbine)

→ (F T) $\approx$ (C.F pump)

Radial entry





IP = Impeller power

MP = manometric power

SP → Rating

→ $(R.P)_{R.T} = IP =$ Impeller power $= \rho Q[V_{w_2} u_2 - \underbrace{V_{w_1}}_{\to 0} u_1]$ $= \rho Q\, V_{w_2} u_2$

→ HP = manometric power $= \gamma Q H_m$

$\eta_{mech} = \dfrac{IP}{SP}$, $\eta_{mano} = \dfrac{MP}{I.P}$, $\eta_{vol} = \dfrac{Q}{Q + \Delta Q}$

$$\boxed{\eta_{mano} = \frac{gH_m}{V_{w_2} U_2}}$$

$$\boxed{\eta_{overall} = \eta_{mech} \times \eta_{mano} \times \eta_{vol}}$$

water exit whirl velocity is zero

$V_{w_2} = 0$

water enters without whirl velocity

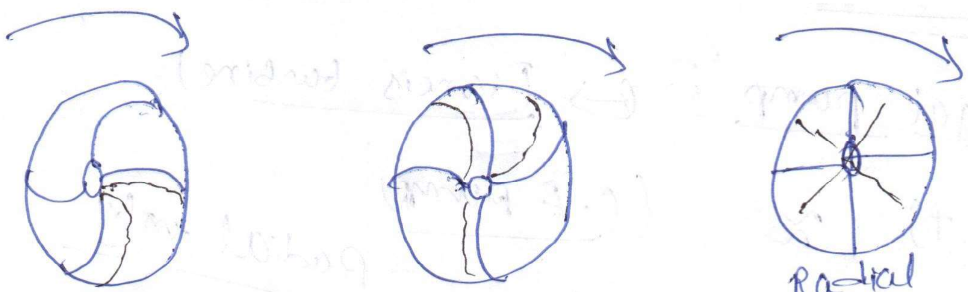
$V_{w_1} = 0$

→ manometric power $M \cdot P = \gamma Q H_m$

$$\eta_{mech} = \frac{IP}{S \cdot P}, \quad \eta_{mano} = \frac{MP}{IP}$$

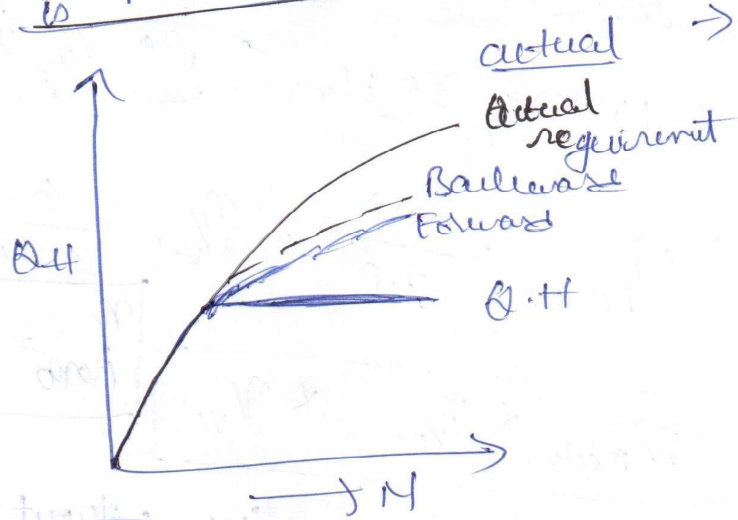
$$\eta_{vol} = \frac{Q - \Delta Q}{Q} \text{ (or) } \frac{Q}{Q + \Delta Q}$$

Types of blades in impeller :-



Forward blading ✓ | Backward blading ✓ | Radial blading ✓

Note: Through discharge & head developed will be maximum for forward blading, backward blading is most preferable



→ For Forward blading power required will be more when discharge & head will increase with slight high amt

$N \uparrow$ $Q, H \uparrow$

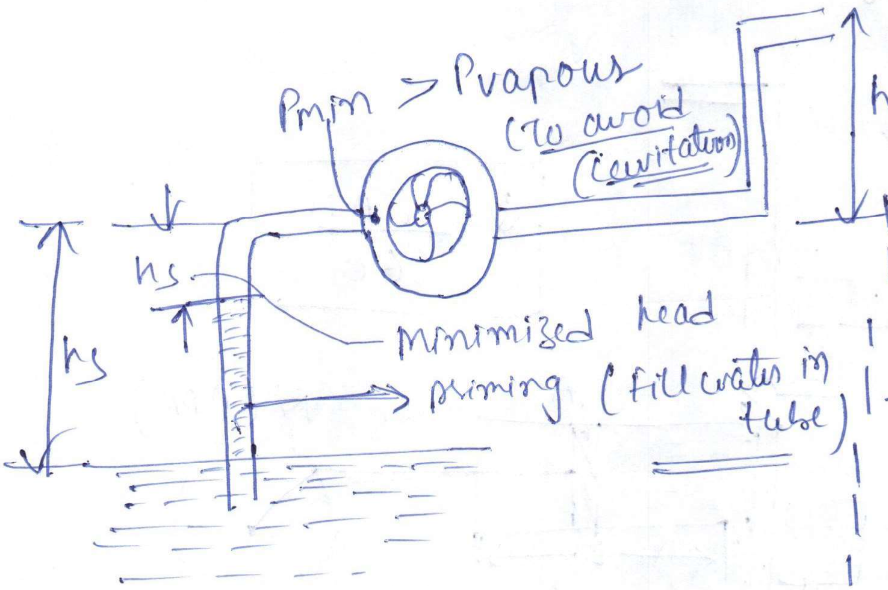
after some speed

$Q, H \longrightarrow$ asymptotes

Surging & stalling

Air compressor ✓

N.P.S.H (Net positive suction head):



→ During priming $h_s \downarrow$

→ To avoid cavitation

$P_{min} > P_{vapour}$

$\sigma > \sigma_c$

→ H_m = Failure head $= h_s + h_d + h_{fs} + h_{fd}$

→ σ_c = Critical σ
= cavitation coefficient

σ = Thomo number

$$\boxed{\sigma = \frac{NPSH}{H}} \rightarrow \boxed{NPSH = \frac{P_{atm}}{\rho g} - h_s - h_{fs} - \frac{P_{vapour}}{\rho g}} \;[\text{Abs.}] \quad > \sigma_c \cdot H$$

$$\rightarrow \boxed{NPSH = h_s + h_{fs} + \frac{P_{vapour}}{\rho g}} \longrightarrow [\text{suction}]$$

$\sigma = \sigma_c \Rightarrow \boxed{NPSH > \sigma_c \times H}$

$\frac{NPSH}{H} > \sigma_c$

→ To avoid cavitation ⇒ $P_{min} > P_{vapour}$

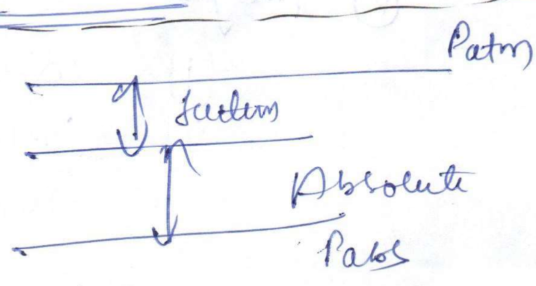
$\sigma > \sigma_c$

(10 units pressure / +ve head)

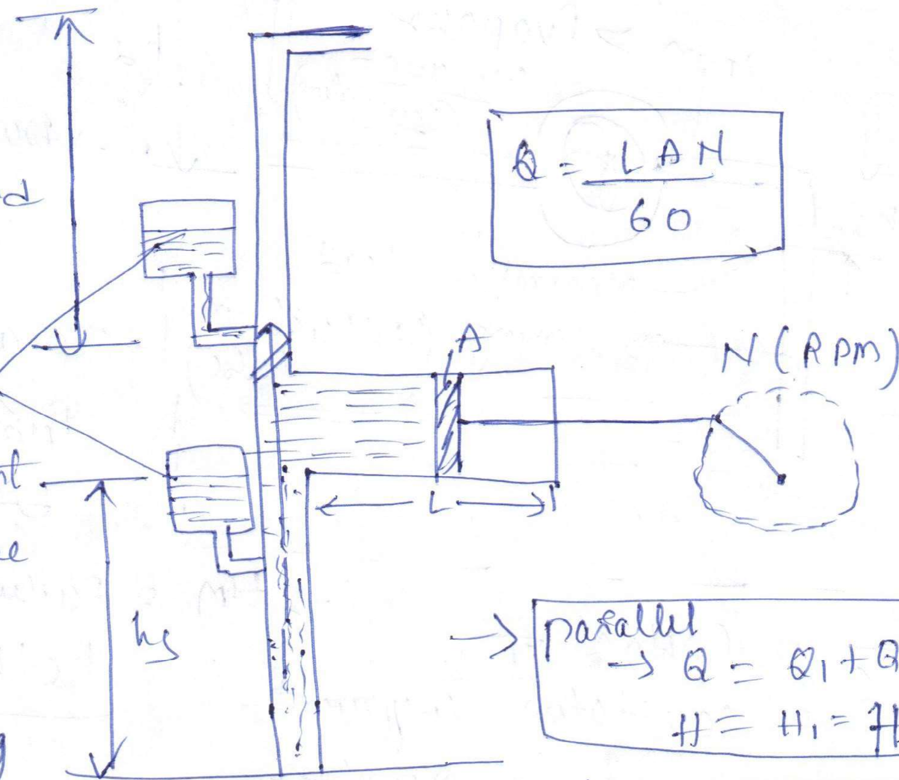
Create casing pump (−20)

A — 20 } −10
↓
B — 10 } 10
↓
C — 0 } 10
↓
D — (−10)

E
↑
(0)
(−10)



* Reciprocating pump :-



Air vessel
It acts
as damping agent
to reduce the
fluctuation in
pressure
like surging
tank

$$\boxed{Q = \frac{LAN}{60}}$$

→ parallel
→ $Q = Q_1 + Q_2$
$H = H_1 = H_2$

Series $H = H_1 + H_2$
$Q = Q_1 = Q_2$

$$Slip = \frac{Q_{Th} - Q_{act}}{Q_{th}} = 1 - \frac{Q_{act}}{Q_{th}}$$

$$\boxed{Slip = (1 - C_d)}$$

-ve slip
↳ $Q_{act} > Q_{th}$

→ $Q = \frac{LAN}{60}$

$$\frac{m^3}{sec} = \frac{vol}{stroke} \times \left(\frac{stroke}{rev}\right)\left(\frac{rev}{min}\right)\Big|_{60} = m^3/sec$$

Note :

① Negative slip ⇒ $Q_{act} > Q_{th}$ will be possible

(i) when pump running at high speed

(ii) suction head far greater than delivery head i.e $h_s >> h_d$

1) Unit quantity → unit speed $N_u = \frac{N}{\sqrt{H}}$, $Q_u = \frac{Q}{\sqrt{H}}$

Ist preference

$P_u = \frac{P}{H^{3/2}}$

Similarity

1) Geometric

2) Kinematic

3) Dynamic

(I) (2) Model study :-

(II)

$\frac{\sqrt{H}}{DN} = C$; $\frac{Q}{D^3 N} = C$; $\frac{P}{D^5 N^3} = C$

(3) Specific speed :- →

(N_s)

Turbine	Pump
$\frac{N\sqrt{P}}{H^{5/4}}$	$\frac{N\sqrt{Q}}{H^{3/4}}$

Gate

Q: If speed of centrifugal pump is double the pump will the power required to drive

→ $P \propto N^3$ ---- $\frac{P}{D^5 N^3} = C$

$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3 \Rightarrow P_2 = 8P_1$

$(D_1 = D_2 = D)$

geometric similarity

→ Sol.

	Case 1	Case 2
Speed	N	2N
Power	P	P_2

$\left[\frac{P}{\cancel{D^5} N^3}\right]_1 = \left[\frac{P}{\cancel{D^5} N^3}\right]_2$

Then using the formula

$\frac{P}{D^5 N^3} = C$

$P_2 = P_1 \left(\frac{N_2}{N_1}\right)^3$

$= P\left(\frac{2\cancel{N}}{\cancel{N}}\right)^3$

$P_2 = 8P$

Q-06

Q A model of turbine working under a head of 1/4th of that under which full scale turbine works. The dia of model is 1/2 of full scale. If N is RPM of model. RPM full scale will be

Sol:

$\frac{1}{4}$ th of Full scale

N — (RPM model) R.P.M$_{(F.S)}$ = ?

$N \rightarrow N/2$

$2N \rightarrow 4N$

	F.S (1)	Model (2)
Head	4H	H
Dia	2D	D
R.P.M	(m)?	N

$$\Rightarrow \frac{\sqrt{4H}}{2DN_1} = \frac{\sqrt{H}}{D \cdot N}$$

$$N_1 = N$$

$$\boxed{\left(\frac{\sqrt{H}}{DN}\right)_{FS} = \left(\frac{\sqrt{H}}{DN}\right)_{mod}}$$

Q-10

A turbine working under ~~load~~ head of 40m was developing a power of 100kw If the head reduced to 20m the power developed in kw

Sol.

	1	2
H(m)	40	20
P(kw)	1000	P_2 ?

$$\boxed{P_u = \left[\frac{P}{H^{3/2}}\right]}$$

$$\left[\frac{P}{H^{3/2}}\right]_1 = \left[\frac{P}{H^{3/2}}\right]_2$$

$$\rightarrow P_2 = 1000 \times \left(\frac{20}{40}\right)^{3/2}$$

$$= \frac{1000}{2^{1.5}} \approx \underline{\underline{354 \text{ kw}}} \quad 354 \text{ kw}$$

Q-05 A turbine working under head of 40 m when running at 1000 r.p.m was developed 300 kw for initial testing a 1:4 scale model of turbine working under head of 10 m can develop power of P_2?

Sol.

	FS	model
Head. H —	40	10
power (P) —	300	P_2 ?
→ ~~R.P.M (N)~~ —	1000	—
→ 1:4 scale (D) —	4D	D

unless the dynamic & kinematic ratio is mentioned the given ratio must be taken as geometric ratio.

P, H, D (power, head diameter)

$$\frac{\sqrt{H}}{DN} = C \longrightarrow \sqrt{H} \propto DN$$

$$\therefore \frac{P}{D^5 N^3} = C \Rightarrow \frac{P}{D^2 (DN)^3} = C$$

$$\boxed{\frac{P}{D^2 \times H^{3/2}} = C} \Rightarrow \left[\frac{P}{D^2 \times H^{3/2}}\right]_{FS} = \left[\frac{P}{D^2 \times H^{3/2}}\right]_{model}$$

$$\frac{300}{(40)^2(40)^{3/2}} = \frac{P_2}{(D)^2 \times (4)^{3/2}}$$

$$P_2 = \frac{300}{16 \times 4^{1.5}} = \underline{2.34 \text{ kW}}$$

Gate
ES

Given

Failure head $= 40 m$ — (H)

Atm. pressure head $= 10.5 m$ —— $\left(\frac{P_{atm}}{\rho g}\right)$

vapour pressure head $= 2.5 \rightarrow \left(\frac{P_{vapour}}{\rho g}\right)$

cavitation coefficient $= 0.15$ (σ_c)

More height at which turbomachine can set above tail race level?

Sol.

$$NPSH = \left(\frac{P_{atm}}{\rho g}\right) - \left(H_s + \cancel{h_{fs}}^{0} + \frac{P_{vapour}}{\rho g}\right)$$

$$\sigma_c \times H < NPSH$$

$$\sigma_c \cdot H < NPSH$$

$\rightarrow \sigma_c \cdot H < 10.5 - 2.5 - H_s$

$\rightarrow 10.5 - h_s - 2.5 > 0.15 \times 40$

$h_s < 2 m$ ✓

When $\downarrow V \cdot Q \uparrow$

$$z + \frac{P}{\rho g} + \frac{V^2}{2g} = C$$

when $V \downarrow \frac{V^2}{2g} \downarrow \frac{P}{\rho g} \uparrow$

At exit of turbine

$P < P_{atm}$

Hence draft tube used to increase pressure energy

* Run away speed :- of turbine.

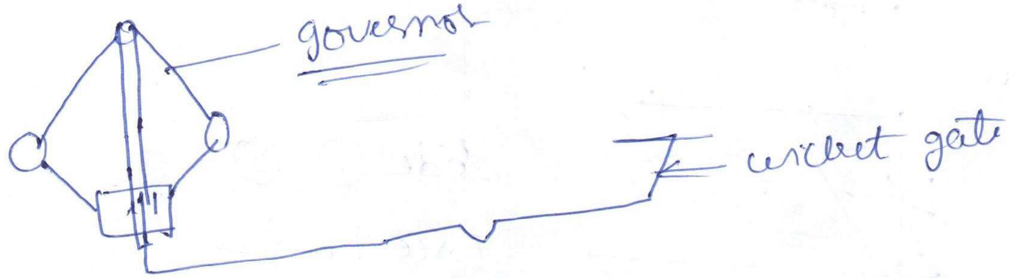
→ Run away speed of a turbine is a max.m speed that a turbine can experience under no load condition with wicket gate wide open (Maximum mass flow)

→ It is a structural integrity test in which governor is not present

$\frac{Q \uparrow}{Load \downarrow}$

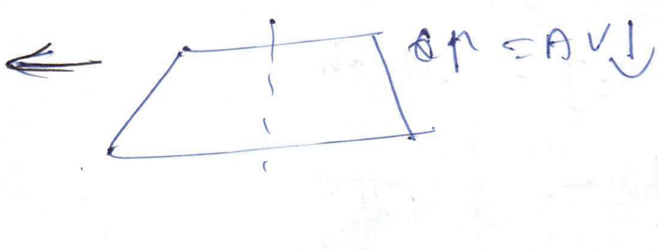
It does not happen in reality

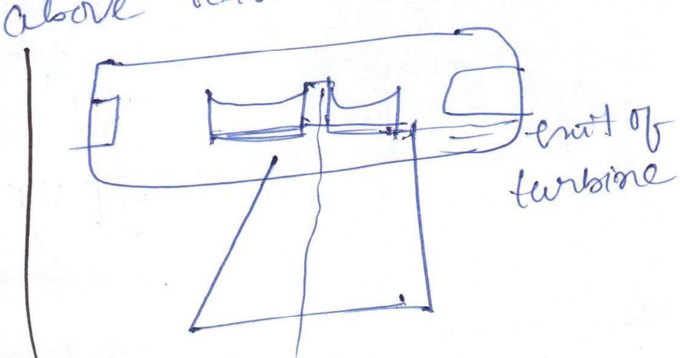
→ In actual when maximum velocity & noload condn occurs, governor will act & gate will get be closed ; so no load & wide open gate will not happen simultaneous



✪ Draft tube :-

Draft tube is required at exit of reaction turbine to convert large portion of its K.E going as waste into useful pressure energy, Hence makes it possible to erect (install) the turbomachine above tail race level



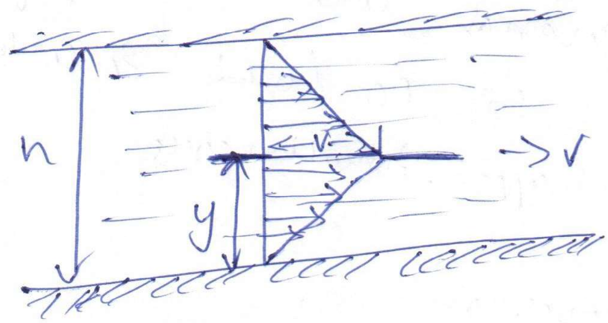


1) Through a very narrow gap of height 'h' a thin plate of large extent is pulled at a velocity 'V' on the one side of viscosity μ and on other side oil viscosity μ_2

calculate the position of the plate so that

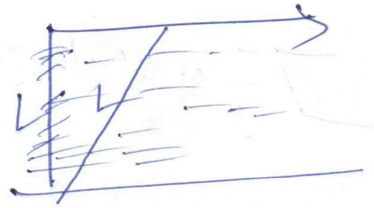
Sol: (i) The shear force on two sides of plate is equal ① $F_1 = F_2$

(ii) The pull required to drag the plate is minimum



$$\boxed{F = \frac{\mu A V}{y}}$$

①



side	①	②
Force	F_1	F_2
viscosity	μ_1	μ_2
Area	$A_1 = A_2 = A$	
vel	$V_1 = V_2 = V$	
D/S	$(h-y)$	y

① $F_1 = F_2 \Rightarrow \dfrac{\mu_1 A V}{(h-y)} = \dfrac{\mu_2 A V}{y}$

$$\mu_1 y = \mu_2 [h-y]$$

$$y[\mu_1 + \mu_2] = \mu_2 h$$

$$y = \frac{\mu_2 h}{[\mu_1 + \mu_2]}$$

(2) ~~pull~~ pull

$$\rightarrow \frac{dP}{dy} = 0, \quad \frac{d}{dy}\left[\frac{\mu_1 AV}{(h-y)} + \frac{\mu_2 AV}{y}\right] = 0$$

$$\rightarrow \mu_1 \cancel{AV} - \frac{1}{(h-y)^2}(-1) + \mu_2 \cancel{AV}\left(-\frac{1}{y^2}\right) = 0$$

$$\sqrt{\frac{\mu_1}{(h-y)^2} = \frac{\mu_2}{y^2}} \Rightarrow \frac{\sqrt{\mu_1}}{(h-y)} = \frac{\sqrt{\mu_2}}{y}$$

$$\sqrt{\mu_1} \cdot y = \sqrt{\mu_2}\,[h-y]$$

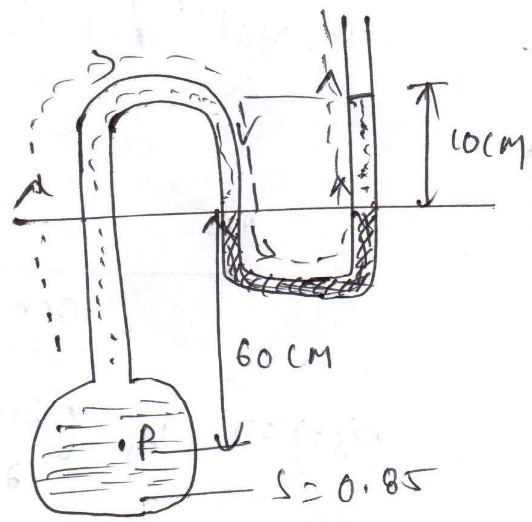
$$\sqrt{\mu_1} \cdot y + \sqrt{\mu_2} \cdot y = \sqrt{\mu_2} \cdot h$$

$$\boxed{y = \frac{\sqrt{\mu_2} \cdot h}{\sqrt{\mu_1} + \sqrt{\mu_2}}} = y = \frac{\sqrt{\mu_2} \cdot h}{\cancel{\sqrt{\mu_2}}\left[1 + \frac{\sqrt{\mu_1}}{\sqrt{\mu_2}}\right]} = y = \frac{h}{\left[1 + \frac{\sqrt{\mu_1}}{\sqrt{\mu_2}}\right]}$$

P-43

(6)

$$P - 0.85\,\rho_w \cdot g \cdot 0.6 - \rho_{Hg}\, g \cdot 0.1 = 0$$



$$\rightarrow P - 0.85\,\rho_w \cdot g \cdot 0.6 - \rho_{Hg} \cdot g \cdot 0.1$$

$$P = (\quad) + (\quad) = 18.3\,\text{kPa}$$

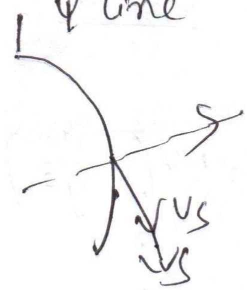
Put

$$h = \frac{P}{\rho \cdot g}$$

$$= \frac{1.8 \times 10^3}{10^3 \times 9.81} = \underline{2.0}$$

P63 23/7/17

8)



$V = f[s, n, t]$

$\rightarrow 0$ steam

$$a_s = V_s \cdot \frac{\partial V_s}{\partial s} + \cancel{V_n \cdot \frac{\partial V_s}{\partial n}} + \frac{\partial V_s}{\partial t} = 0$$

$\rightarrow V_s/R$

$$a_n = V_s \cancel{\frac{\partial V_n}{\partial s}} + V \cdot \frac{\partial V_n}{\partial n} + \frac{\partial V_n}{\partial t}$$

ψ line ⇒ $a_s = V_s \left(\frac{\partial V_s}{\partial s}\right)$ $\qquad a_n = \frac{V_s^2}{R}$

Q

$V_s = 3$ m/sec

$R = 9$ m

$\frac{\partial V_s}{\partial s} = \frac{1}{3}$ m/sec/m

$a_s = V_s \frac{\partial V_s}{\partial s}$

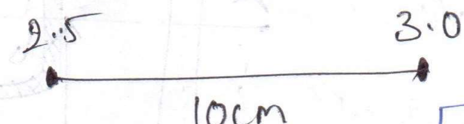
$= 3\left(\frac{1}{3}\right)$

$a_s = 1$ m/sec²

$a_n = \frac{V_s^2}{R} = \frac{3^2}{9} = 1$ m/sec²

$a_{total} = ?\ \sqrt{a_s^2 + a_n^2} \rightarrow \sqrt{1^2 + 1^2} = \sqrt{2}$ m/sec²

(9)



$a_s = ?$

$v^2 - u^2 = 2as$

$a = \frac{v^2 - u^2}{2s} = \left(\frac{v+u}{2}\right)\left(\frac{v-u}{s}\right)$

$= 13.75$

$a_s = ? \Rightarrow V_s \left(\frac{\partial V_s}{\partial s}\right)$

$= \left(\frac{2.5 + 3.0}{2}\right)\left(\frac{3.0 - 2.5}{0.1}\right)$

$a_s = 13.75$ m/sec²

(10)

(Q) $V_s = 3\sin\theta$

$R = 30m \rightarrow \theta = 45^0$

$\rightarrow \alpha_s = ? \Rightarrow \alpha_s = V_s \cdot \frac{\partial V_s}{\partial s}$

$ds = R d\theta$

$= 3\sin\theta \cdot \frac{\partial}{\partial s}[3\sin\theta]$

$\Rightarrow ds = R d\theta$

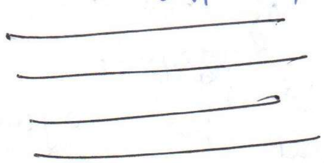
$= \frac{3}{R}\sin\theta \frac{\partial}{\partial\theta}[3\sin\theta]$

$= \frac{3}{R} \cdot \sin\theta \cdot 3\cos\theta \Rightarrow \frac{\cancel{3}}{\cancel{3}0}\sin 45 \times 3 \cdot \cos 45$

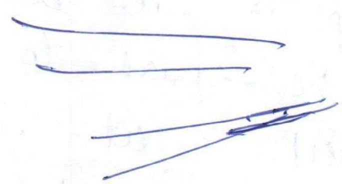
$= \frac{1}{\sqrt{2}} \times 3 \times \frac{1}{\sqrt{2}} \Rightarrow \alpha_s = 1.5 m/s^2$

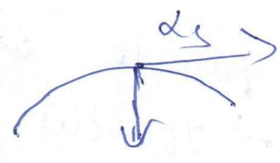
Flow lines

$\alpha_n = 0, \alpha_s = 0$

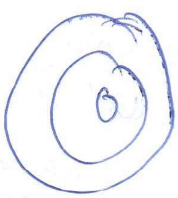


$\alpha_n = 0, \alpha_s \neq 0$

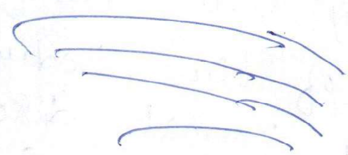




$\alpha_n = 0$



$\alpha_n \neq 0, \alpha_s = 0$



$\alpha_n \neq 0, \alpha_s \neq 0$