MODEL ANSWER

EXAMINATION : IV-sem/MECH/2019(S)(New)(80)

SUBJECT : FMHM

SUBJECT CODE : MET-404

BRANCH : MECH. ENGG.

No.1 (2×10)

(a) Specific gravity :- It is the ratio of the weight density or density of a fluid to the weight density of a standard fluid. Standard fluids are air (gas), water (liquid). It is a unit less quantity.

(b) Archimedes Principle :-
When a body is submerged either fully or partially then it is acted upon by a force of buoyancy vertically upward which is equal to the weight of liquid displaced by the body. $F_B = W \Rightarrow \rho_{body} \times V = \rho_{fluid} \times \forall$

(c) Continuity equation for one-dimensional flow :-
According the principle of mass conservation for a steady, one-dimensional flow, with one inlet and one outlet, This equation is termed as continuity equation and given by :- $\boxed{\rho A_1 V_1 = \rho A_2 V_2}$

ρ = density of fluid
A_1 and A_2 are cross-sectional area at inlet and outlet
V_1 and V_2 velocity of flow at inlet and outlet.

(d) Slip of a Pump :-
It is defined as the difference between the theoritical discharge and actual discharge of the pump.

$\therefore$ Slip = $Q_{th} - Q_{act}$ or % slip = $\left(1 - \frac{Q_{act}}{Q_{th}}\right) \times 100$
$= (1 - C_d) \times 100$

(e) (i) Example of Impulse turbine - Pelton wheel
(ii) Example of Reaction turbine - Francis Turbine

No. 1

(f) Hydraulic Gradient Line (HGL) :-

It is the line representing the difference between the total head available to the fluid and the velocity head,

$\therefore$ $HGL = TEL - \frac{v^2}{2g}$ or $HGL = \frac{p}{w} + z$

$\Rightarrow$ HGL = pressure head + datum head

(g) function of venturimeter :-

It is a device used for measuring the rate of a flow of a fluid flowing through a pipe. It consists of three parts : (a) A converging part (b) Throat and (c) a diverging part. It is based on the principle of Bernoulli's equation.

(h) Difference between laminar and turbulent flow :-

→ Laminar flow is the flow in which the fluid particles move along a well-defined paths or stream line and all the stream lines are straight and parallel. Thus the particles move in layers gliding smoothly over adjacent layer. This type of flow is also called stream-line flow or viscous flow.

→ Turbulent flow is the flow in which the fluid particles move in a zig-zag way. Due to this zig-zag motion, eddies formation takes place which are responsible for high energy loss.

(i) Cavitation :- It is the phenomenon in which rapid changes of pressure in a liquid lead to the formation of small vapour-filled cavities in places where the pressure is relatively low.

(j) Kinematic viscosity :- $\nu = \frac{\text{dynamic viscosity } (\mu)}{\text{Mass density } (\rho)}$

Its SI unit is m^2/s

CGS unit is cm^2/s or stoke.

1 stoke = 1 cm^2/s = 10^{-4} m^2/s

No. 2 (a) Absolute Pressure is defined as the pressure measured with reference to absolute vaccum pressure.

Gauge Pressure is defined as the pressure which is measured with the help of a pressure-measuring instrument, in which the atmospheric pressure is taken as datum. The atmospheric pressure on this scale is zero.

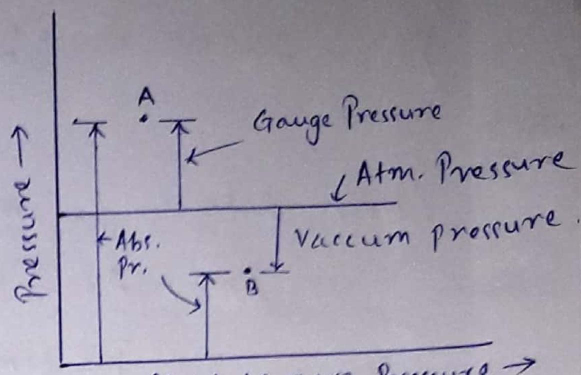


fig (1)

Vaccum Pressure is defined as the the pressure below the atmospheric pressure.

The relationship between the absolute pressure, gauge pressure and vaccum pressure are shown in the fig. (1).

$$\therefore \boxed{P_{abs} = P_{atm} + P_{gauge}}$$

or

$$\boxed{P_{vaccum} = P_{atm} - P_{abs.}}$$

→ The atmospheric pressure at sea level at 15°C is 101.3 KN/m² or 10.13 N/cm² in SI unit. In MKS unit $P_{atm} = 1.033$ kgf/cm²

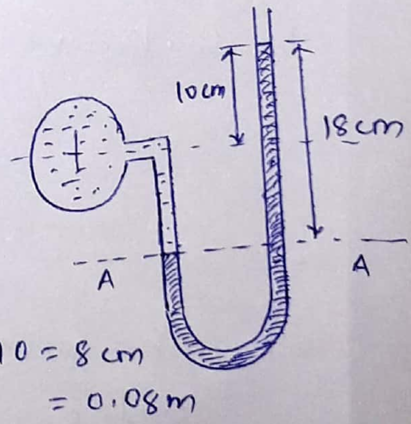
→ The atmospheric pressure head is 760 mm of mercury or 10.33 m of water.

(b) $S_1 = 0.8$

$\rho_1 = S_1 \times 1000 = 0.8 \times 1000 = 800$ kg/m³

$S_2 = 13.6$

$\rho_2 = 13.6 \times 1000 = 13600$ kg/m³



Difference of mercury level $= h_2 = 18$ cm $= 0.18$ m

Height of fluid from A-A, $h_1 = 18 - 10 = 8$ cm $= 0.08$ m

Equating pressure above A-A,

$$P + \rho_1 g h_1 = \rho_2 g h_2$$

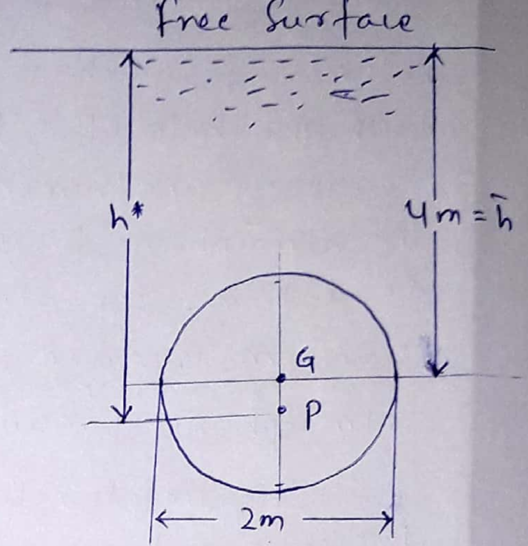
$$\Rightarrow P = \rho_2 g h_2 - \rho_1 g h_1 \Rightarrow P = 13600 \times 9.81 \times 0.2 - 800 \times 9.81 \times 0.08$$

$\Rightarrow P = 26683 - 627.84$

$\Rightarrow P = 26055.16 \text{ N/m}^2 = 2.605 \text{ N/cm}^2$ (Ans)

No.2

(c) Given data : $d = 2m$



$\therefore$ Area $A = \frac{\pi}{4} d^2 = 3.14 \text{ m}^2$

$\bar{h} = 4m$

The total pressure $F = \rho g A \bar{h}$

$\Rightarrow F = 1000 \times 9.81 \times 3.14 \times 4$

$\Rightarrow F = 123213.6 \text{ N}$

Position of center of pressure :

$$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$$

$$\Rightarrow h^* = \frac{(\pi d^4/64)}{(\frac{\pi}{4}d^2)\bar{h}} + \bar{h}$$

$$\Rightarrow h^* = \frac{0.785}{12.56} + 4 = 0.0625 + 4$$

$$= 4.0625 \text{ m}$$

(d) Hydraulic Coefficients :-

1. Coefficient of velocity (C_v)
2. Coefficient of contraction (C_c)
3. Coefficient of discharge (C_d)

1. Coefficient of velocity $C_v = \frac{\text{Actual velocity of jet at vena-contracta}}{\text{Theoretical velocity}}$

$$\Rightarrow \boxed{C_v = \frac{V}{\sqrt{2gH}}}$$, V = actual velocity, $\sqrt{2gH}$ = theoretical velocity

The value of C_v varies from 0.95 to 0.99 for diff. orifices, depending upon the shape, size of the orifice and on the head under which flow takes place. Generally $C_v = 0.98$ (for sharp-edged orifice)

2. Coefficient of Contraction $\boxed{C_c = \frac{a_c}{a}}$

Here, a_c = area of jet at vena-contracta

a = area of orifice

The value of C_c varies from 0.61 to 0.69 depending on shape and size of the orifice and head of liquid. But generally $C_c = 0.64$.

3. Coefficient of discharge $\boxed{C_d = \frac{Q}{Q_{th}}}$

$$\Rightarrow C_d = \frac{\text{Actual velocity} \times \text{Actual area}}{\text{Theoritical velocity} \times \text{Theoretical area}}$$

$$\Rightarrow \boxed{C_d = C_v \times C_c}$$

The value of C_d varies from 0.61 to 0.65 (orifice)

and $C_d = 0.98$ (for venturimeter)

No.2 (e) Darcy's formula for head loss due to friction :-

$$\boxed{h_f = \frac{4fLV^2}{d \times 2g}}$$

Here, h_f = loss of head due to friction

L = length of the pipe

V = mean velocity of flow

d = diameter of pipe

f = Coeff. of friction or friction factor $= \frac{16}{Re}$ for $Re < 2000$ (viscous flow)

$= \frac{0.079}{Re^{1/4}}$ $4000 < Re < 10^6$

Chezy's formula for head loss due to friction in pipes :-

$$\boxed{h_f = \frac{f'}{\rho g} \times \frac{P}{A} \times L \times V^2}$$

Here, $V = C\sqrt{mi}$

If $\frac{A}{P} = \frac{\text{Area of flow}}{\text{Perimeter(wetted)}} = m$ = hydraulic mean depth

$i = \frac{h_f}{L}$ = Loss of head per unit length of pipe

$C = \sqrt{\frac{\rho g}{f'}}$ = Chezy's constant.

No. 2 (f) Given $d = 120\,mm = 0.12\,m$

$H = 90\,m$

$C_v = 0.95$

$\therefore$ Area of nozzle $= a = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (0.12)^2 = 0.0113\,m^2$

Now, theoretical velocity of jet of water :-

$$V_{th} = \sqrt{2gH} = \sqrt{2 \times 9.81 \times 90} = 42.02\,m/s$$

But $C_v = \frac{V_{act.}}{V_{th}} \Rightarrow V_{act.} = C_v \times V_{th}$

$\Rightarrow V_{act.} = 0.95 \times 42.02$

$= 39.92\,m/s$

$\therefore$ force on the fixed vertical plate is given by :-

$$F = \rho a (V_{act.})^2$$

$\Rightarrow F = 1000 \times 0.0113 \times (39.92)^2$

$= 18008.07\,N$

$\approx 18\,KN$

No. 4 Given data :- $S_o = 0.9$ = Sp. gr. of oil

$S_h = 13.6$ = Sp. gr. of mercury

$C_d = 0.98$

Reading of differential manometer $x = 22\,cm$

$\therefore$ diff. of pressure head $h = x\left[\frac{S_h}{S_o} - 1\right]$

$\Rightarrow h = 22\left(\frac{13.6}{0.9} - 1\right)$ cm of oil

$\Rightarrow h = 310.44$ cm of oil

dia. at inlet $d_1 = 15\,cm$, $a_1 = \frac{\pi}{4} d_1^2 = 176.625\,cm^2$

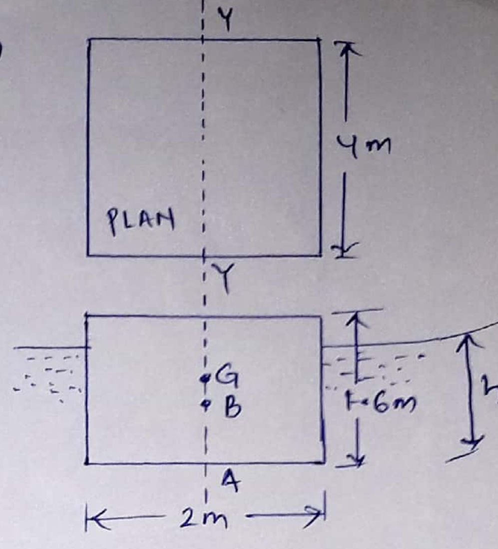
$d_2 = 8\,cm$, $a_2 = \frac{\pi}{4} d_2^2 = 50.24\,cm^2$

$\therefore$ discharge $Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh} = 5018.65\,cm^3/s$

$\Rightarrow Q = 0.98 \times \frac{(176.625)(50.24)}{\sqrt{(176.625)^2 - (50.24)^2}} \times \sqrt{2 \times 9.81 \times 310.44} = 50.18$ lps

No. 6 ans

Given data :- dimension of block $= 4m \times 2m \times 1.6m$



Let, h = depth of immersion

S = Sp. gr. of wood $= 0.8$

$\therefore$ weight of the wooden block

$= 0.8 \times 1000 \times 9.81 \times$ Volume

$= 0.8 \times 1000 \times 9.81 \times 4 \times 2 \times 1.6$

$W_1 = 100454.4$ N

weight of water displaced = weight density of water $\times$ Volume of block submerged

$= 1000 \times 9.81 \times 4 \times 2 \times h$ N

$W_2 = 78480\,h$ N

For equilibrium, $W_1 = W_2$

$\Rightarrow 100454.4 = 78480\,h$

$\Rightarrow h = \dfrac{100454.4}{78480} = 1.28$ m

Distance of Centre of Buoyancy from bottom :

$AB = \dfrac{h}{2} = \dfrac{1.28}{2} = 0.64$ m

and $AG = \dfrac{1.6}{2} = 0.8$ m

$\therefore BG = AG - AB = 0.8 - 0.64 = 0.16$ m

The meta-centric height is given by :-

$GM = \dfrac{I}{\forall} - BG$, $I = \dfrac{1}{12} \times 4 \times 2^3$

$= 2.66\ m^4$

$= \dfrac{2.66}{10.24} - 0.16$

$\forall = 4 \times 2 \times h$

$= 4 \times 2 \times 1.28 = 10.24\ m^3$

$= 0.259 - 0.16$

$= 0.0997$ m (Ans)

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FLUID MECHANICS AND HYDRAULIC MACHINES

(Code : MET-404)

Full Marks : 80 *Time* : 3 hours

Answer any **five** questions including **Q. Nos. 1 & 2**

Figures in the right-hand margin indicate marks

1. Answer *all* the questions in brief : 2 × 10

(*a*) Define specific gravity and state its unit.

(*b*) State Archimedi's principle.

(*c*) Write down continuity equation for one dimensional flow.

(*d*) What do you mean by slip of a pump ?

(*e*) Give one example from each of the following water turbine :

(*i*) Impulse turbine

(*ii*) Reaction turbine.

(*f*) Define Hydraulic gradient line.

(*g*) What is the function of venturimeter ?

(*h*) What is the difference between laminar and turbulent flow ?

(*i*) What is Cavitation ?

(*j*) What is Kinematic Viscosity and state its unit ?

2. Answer any *six* : 5 × 6

(*a*) Explain Absolute pressure, Gauge Pressure, Vacuum Pressure and their relationship through a plot.

(*b*) A simple U-tube manometer containing mercury, the right limb is open to atmosphere and left limb is connected to a pipe in which a fluid of specific gravity 0·8 is flowing. The center of pipe is 10 cm below the level of mercury in right limb. Find the pressure of fluid in pipe if difference of mercury level in two limbs is 18 cm.

(*c*) Determine the total pressure and position of centre of pressure on a circular plate of diameter 2 m which is placed vertically in water in such a way that the centre of the plate is 4 m below the free surface of water. Find the position of center of pressure also.

(*d*) Explain Hydraulic co-efficients.

(*e*) Write down the formula for head loss due to friction using Darcy's formula and Chezy's formula with its proper notation.

(*Turn Over*)

Mech (New)

(*f*) Water is flowing through a pipe at the end of which a nozzle is fitted. The diameter of nozzle is 120 mm and head of water at the centre of nozzle is 90 m. Find the force exerted by the jet of water on a fixed vertical plate. Take co-efficient of velocity is given as 0·95.

(*g*) What is a Hydraulic turbine and classify it ?

(*h*) A single acting reciprocating pump running at 60 rpm delivers 0·015 m^3/sec of water. The diameter of the piston is 200 mm and stroke length 400 mm. Determine theoritical discharge of the pump, co-efficient of discharge and slip of the pump.

3. Explain the construction and working principle of a centrifugal pump with neat sketch. 10

4. An oil of sp. gr. 0·9 flowing through a venturimeter having inlet diameter 15 cm and throat diameter 8 cm. The oil-mercury differential manometer shows a reading of 22 cm. Calculate the discharge of oil through the horizontal venturimeter. Take $c_d = 0{\cdot}98$. 10

5. A pelton wheel has a mean bucket speed of 10 m/sec with a jet of water flowing at rate of 800 lit./sec under a head of 40 meters. The bucket deflect the jet through an angle of 160°. Calculate the power given by water to the runner and hydraulic efficiency of the turbine. Assume co-efficient of velocity as 0·98. 10

6. A block of wood of specific gravity 0·8 floats in water. Determine the metacentric height of block if its size is 4 m × 2 m × 1·6 m. 10

7. Draw the layout of a hydro-electric power plant and mention its features. 10