पुस्तिका की सील तब तक न खोलें, जब तक आपको ऐसा करने के लिए कहा न जाए

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उत्तर–पुस्तिका (ANSWER BOOK)

(जिन अभ्यर्थियों की उत्तर–पुस्तिका पर अनुक्रमांक, विषय, हस्ताक्षर तथा बाएँ हाथ के अंगूठे की छाप, जहाँ आवश्यक हो, नहीं होंगे उनका मूल्यांकन नहीं किया जाएगा तथा ऐसे अभ्यर्थियों को शून्य अंक दिए जाएँगें।) (Answer Books not bearing Roll No., Subject, Signature and Left-hand Thumb Impression, wherever required, will not be evaluated and such candidates shall be awarded zero mark.)	अनुक्रमांक Roll No. | | | | | | | | | | | विषय Subject ---------- हस्ताक्षर Signature ---------- बाएँ हाथ के अँगूठे की छाप Left-hand Thumb Impression |

भाषा : केवल एक पर निशान लगाएँ
Language : Tick only one

अंग्रेजी/ENGLISH	
हिन्दी/HINDI	

टिप्पणी : अभ्यर्थी प्रश्न–पत्र–सह–उत्तर–पुस्तिकाओं में उनके द्वारा भरे/दिए गए विवरण के लिए उत्तरदायी हैं।
Note : Candidates are responsible for particulars filled in/affixed by them in the Question Paper-cum-Answer Books.

निरीक्षक का पूरा नाम / Full Name of Invigilator	निरीक्षक के हस्ताक्षर / Signature of Invigilator

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प्रत्येक अभ्यर्थी को एक उत्तर–पुस्तिका मिलेगी, प्रत्येक में आवरण पृष्ठ सहित 32 पृष्ठ होंगे। यह उत्तर–पुस्तिका **यांत्रिकी अभियांत्रिकी** के लिए है। अभ्यर्थी इस उत्तर–पुस्तिका के ऊपरी हिस्से पर अपनी टिकट संख्या, अनुक्रमांक, विषय लिखें तथा हस्ताक्षर एवं बाएँ हाथ के अँगूठे का निशान लगाएँ। जिन अभ्यर्थियों की उत्तर–पुस्तिका के आवरण पृष्ठ पर अनुक्रमांक, विषय, हस्ताक्षर तथा बाएँ हाथ के अंगूठे का निशान नहीं भरे होंगे उन्हें जाँचा नहीं जाएगा व ऐसे अभ्यर्थियों को ''शून्य'' अंक दिया जाएगा।

अभ्यर्थियों को सख्त रूप से सलाह दी जाती है कि वे अपनी उत्तर–पुस्तिका के अंदर कोई व्यक्तिगत परिचय, उदाहरणार्थ, नाम, अनुक्रमांक, मोबाइल नम्बर, पता, आदि नहीं लिखें। अभ्यर्थियों द्वारा इस तरह का व्यक्तिगत विवरण लिखना गंभीरता से लिया जाएगा और ऐसी उत्तर–पुस्तिकाओं का मूल्यांकन नहीं किया जाएगा। कोई अतिरिक्त/अनुपूरक उत्तर–पुस्तिका नहीं दी जाएगी।

Each candidate will get one Answer Book, containing 32 pages including the cover pages. This Answer Book is for **MECHANICAL ENGINEERING.** Candidates are required to write their Ticket No., Roll Number, Subject and affix their signature and Left-hand Thumb Impression on the cover page of the Answer Book. Answer Book not bearing Candidates's Roll No., Subject, Signature and Left-hand Thumb Impression will not be evaluated and such candidates would be awarded "ZERO" mark.

Candidates are strictly advised not to write any personal identity, e.g., Name, Roll No., Mobile No., Address, etc. inside the Answer Book. Writing of such personal details by the candidates will be viewed seriously and such Answer Book SHALL NOT be evaluated.

No extra/supplementary Answer Book will be provided.

तालिका/TABLE

प्रश्न संख्या Question No.	अधिकतम अंक Maximum Marks	प्राप्तांक Marks Secured (परीक्षक द्वारा भरा जायेगा) (To be filled by Examiner)
1.	60	
2.	60	
3.	60	
4.	60	
5.	60	
6.	60	
जोड़ (अंकों में) Total (in figures)		

प्रश्न–पत्र - II (यांत्रिकी अभियांत्रिकी)
PAPER - II (MECHANICAL ENGG.)

FM + HM

Total Marks (in words)

Hundred	Ten	Unit

Note : Attempt any 5 (किन्ही 5 प्रश्नों को हल करें।)

परीक्षक के हस्ताक्षर / Signature of Examiner

इस पृष्ठ पर कुछ न लिखें।

DO NOT WRITE ANYTHING ON THIS PAGE.

रफ कार्य के लिए दाहिनी ओर मार्जिन का प्रयोग करें, यदि आवश्यक हो।

USE RIGHT HAND SIDE MARGIN FOR ROUGH WORK, IF NECESSARY.

1.(a) Define bulk modulus. Prove that bulk modulus for an ideal gas undergoing isothermal compression is P and for a ideal gas undergoing isentropic compression is γP.

आयतन मापांक को परिभाषित कीजिए। सिद्ध कीजिए कि समतापीय संपीडन से गुजरने वाली एक आदर्श गैस का आयतन मापांक P होता है और आईसेंट्रोपिक संपीडन से गुजरने वाली एक आदर्श गैस का आयतन मापांक γP होता है।

[15 Marks]

Sol.: **Bulk Modulus**

It is defined as a requirement of pressure to create unit volumetric strain.

$$K = \frac{\Delta P}{\varepsilon_V}$$

$$\text{where } \varepsilon_v = \frac{\Delta V}{V}$$

$$= \frac{-dP}{\left(\frac{dV}{V}\right)}$$

Note: (-ve) sign indicate that while increasing pressure volume decrease.

In tems of density bulk modulus is

$$K = \rho \frac{dP}{d\rho}$$

Higher the value of bulk modulus implies tough to compression of body.

For example:

Bulk modulus for water = 2×10^6 kPa

Bulk modulus for air = 101 kPa

For isothermal process (T = const.)

$$PV = mRT$$

$$PV = C \text{ (differenciating both side)}$$

$$PdV + VdP = 0$$

$$-\frac{dV}{V} = \frac{dP}{P}$$

We know

$$K = \frac{dP}{-\frac{dV}{V}} = \frac{dP}{\left[\frac{dP}{P}\right]}$$

$$K = P$$

For adiabalic process

A process in which heat transfer does not takes place for adiabolic procss.

$$PV^{\gamma} = C$$

Differentiating both side

$$\gamma PV^{\gamma-1}dV + VdP = 0$$

$$\gamma\, PV^{\gamma-1}\, dV = -V^{\gamma}dP$$

$$\gamma PdV = -VdP$$

$$-\frac{dV}{V} = \frac{dP}{P.\gamma}$$

$$K = -\frac{dP}{\frac{dV}{V}} \Rightarrow K = \gamma P$$

Solution End.

1.(b) Explain Newton's law of viscosity and also define absolute viscosity.

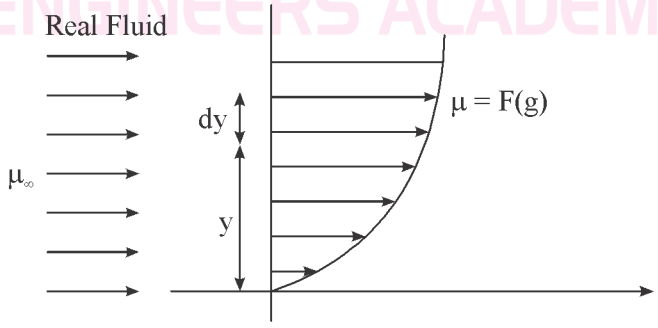
न्यूटन के श्यानता के नियम की व्याख्या कीजिये और निरपेक्ष श्यानता को भी परिभाषित कीजिये।

[10 Marks]

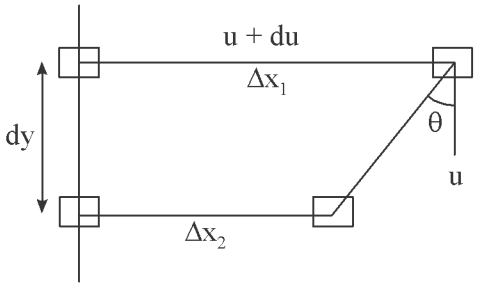
Sol.: **Newton's Law of Viscosity**

It states that the shear stress is directly proportional to the rate of change of angular deformation.

$$\tau \times \frac{d\theta}{dt}$$



At $y = 0$ $u = 0$ (No slip condition)



$$\tan\theta = \frac{\Delta x_1 - \Delta x_2}{dy}$$

$$= \frac{(\mu + du)dt - \mu dt}{dy}$$

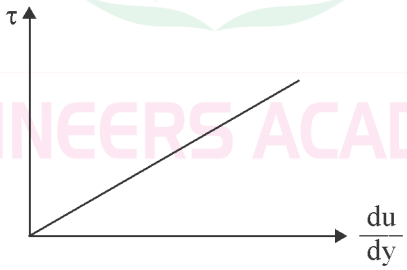
$$= \frac{du\,dt}{dy}$$

$$\frac{d\theta}{dt} = \frac{du}{dy}$$

θ is very small

$$\tau = \mu\frac{d\theta}{dt}$$

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



Where

τ = shear stress

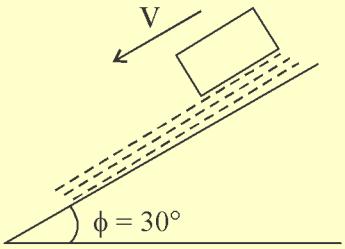
μ = cofficient of viscosity

$\frac{du}{dy}$ = Velocity gradient

Solution End.

1.(c) A 90 N rectangular solid block is slide down in 30° incline plane. The plane is lubricated with 3 mm thin film of oil of viscosity 8 poise and relative density 0.9. If the contact area between them are 0.3 m^2, then find the terminal velocity of the block.

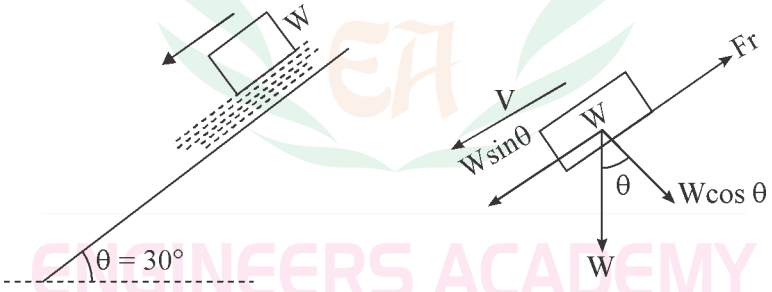
एक 90 N आयताकार ठोस ब्लॉक पाइप 30° आनत समतल में नीचे की ओर स्लाइड किया जाता है। तल को 8 पोइस की श्यानता और 0.9 सापेक्षिक घनत्व वाले तेल की 3 मिमी पतली फिल्म से लुब्रिकेट किया जाता है। यदि उनके बीच संपर्क क्षेत्र है 0.3 m^2, फिर ब्लॉक का टर्मिनल वेग क्या होगा?



[15 Marks]

Sol.: Given

$$W = 90\ N$$
$$\theta = 30°$$
$$\mu = 8\ Poise$$
$$h = 3\ mm$$
$$A = 0.3\ m^2$$



Apply H.S.L. in axial direction

$$F_{net} = ma$$
$$W\sin\theta - f_r = 0$$
$$W\sin\theta = \tau \times A$$
$$W\sin\theta = \frac{\mu V}{h} A$$
$$90\sin 30° = \frac{0.8 \times V}{3 \times 10^{-3}} \times 0.3$$
$$V = 0.5625\ m/s$$

Solution End.

1.(d) Three litre of petrol having weight 23.7 find
तीन लीटर पेट्रोल का वजन 23.7 है, तो ज्ञात कीजिये

(i) Density (घनत्व)

(ii) Specific weight (विशिष्ट भार)

(iii) Specific gravity (विशिष्ट गुरूत्व)

(iv) Specific volume (विशिष्ट आयतन)

[20 Marks]

Sol.: Given

$$\forall = 3L = 3 \times 10^{-3}\ m^3$$

$$W = 23.7\ N$$

We know

$$W = mg$$

$$23.7 = m \times 9.81$$

$$m = 2.416\ kg$$

(i) Density

$$\rho = \frac{m}{\forall}$$

$$\rho = \frac{2.416}{3 \times 10^{-3}} = 805.3\ kg/m^3$$

(ii) Specific weight

$$w = \rho g$$

$$w = 7900\ N/m^3$$

(iii) Specific gravity

$$S = \frac{\rho_{petrol}}{\rho_{water}}$$

$$S = \frac{805.3}{1000}$$

$$S = 0.8053$$

(iv) Specific Volume

$$v = \frac{1}{\rho}$$

$$= \frac{1}{805.3}$$

$$= 1.24 \times 10^{-3}\ m^3/kg$$

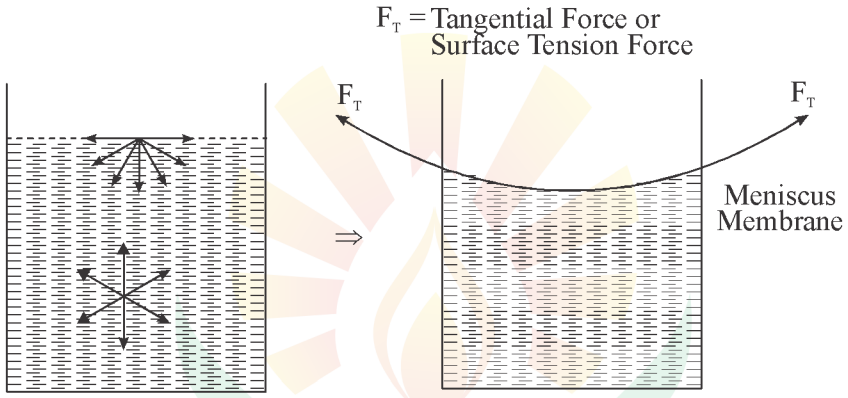
Solution End.

2. (a) Define surface tension. Prove that the relationship between surface tension and pressure inside a droplet of liquid in excess of outside pressure is given by $P = \frac{4\sigma}{d}$.

पृष्ठ तनाव को परिभाषित कीजिए। सिद्ध कीजिए कि किसी द्रव की बूंद के भीतर बाह्य दाब के आधिक्य में पृष्ठ तनाव और दाब के बीच संबंध $P = \frac{4\sigma}{d}$ द्वारा दिया जाता है।

[20 Marks]

Sol.: **Surface tension**



It is defined as a tangential force acting on a per unit length of free surface of liquid Formula

$$\sigma = \frac{F_T}{l}$$

Unit: N/m or J/m^2

Dimensional formula [$M^1L^0T^{-2}$]

For circular Cross section

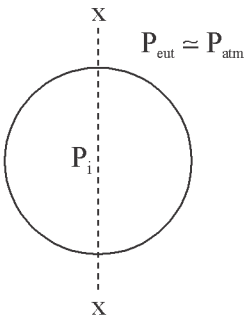
$$l = \pi d$$

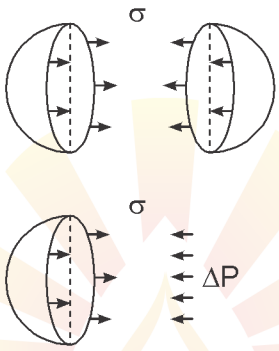
For rectangular cross section

$$l = 2(a+b)$$

- Surface tension occurs due to unbalance cohesive force. As temperature increase, cohesive force decrease, so surface tension also decrease.
- Surface tension is a property of liquid which tends to minimise the surface area of liquid.

Liquid droplet





$$P_i - P_{out} = \Delta P = \text{Excess Pressure}$$

under equilibrium condition

$$\text{Pressure force} = \text{surface tension force}$$

$$\Delta p.\frac{\pi}{4}(d^2) = \sigma.\pi d$$

$$\Delta p = \frac{4\sigma}{d}$$

Where

σ = Surface tension of liquid

d = Diameter of sphere

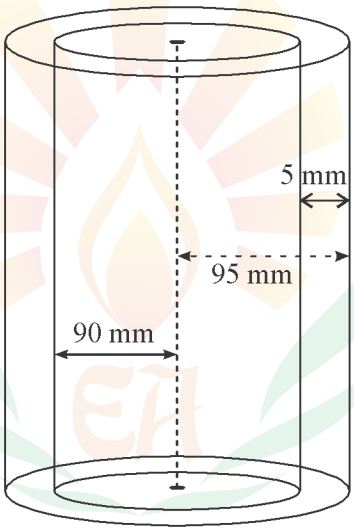
Solution End.

2.(b) A cylindrical shaft of 90 mm diameter, rotated about vertical axis inside a fixed cylindrical tube length 50 cm and 95 mm internal diameter. If the space between the tube & the shaft is filled by a lubricant of dynamic viscosity 2.0 poise determine the power required to overcome viscous resistance when the shaft is rotated at a speed of 240 rpm.

90 मिमी व्यास का एक बेलनाकार शाफ्ट, एक निश्चित बेलनाकार ट्यूब लंबाई 50 सेमी और 95 मिमी आंतरिक व्यास के अंदर ऊर्ध्वाधर अक्ष के परितः घुमाया जाता है। यदि ट्यूब और शाफ्ट के बीच की जगह को गतिशील श्यानता 2.0 पॉइज के स्नेहक द्वारा भरा जाता है, तो श्यान प्रतिरोध पर नियंत्रण पाने के लिए आवश्यक शक्ति का निर्धारण करें, जब शाफ्ट को 240 आरपीएम की गति से घुमाया जाता है।

[20 Marks]

Sol.:



Given

External dia. $D_o = 95$ mm

Internal dia. $D_i = 90$ mm

$$\text{Thickness (t)} = \frac{95 - 90}{2} = \frac{5}{2}\text{ mm} = 2.5\text{ mm}$$

$\mu = 2$ poise $= 0.2$ Pa.s

$N_S = 240$ rpm

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

$$\frac{F}{A} = \frac{\mu V}{Y}$$

$$\text{Power (P)} = F.V$$

$$P = \left(\frac{\mu V}{Y} A\right) \cdot V \qquad \ldots (1)$$

$$V = \omega r$$

$$V = \frac{2\pi N}{60} \times r_i$$

$$V = \frac{2 \times \pi \times 240}{60} \times 45 \times 10^{-3}$$

$$V = 1.1304 \text{ m/s}$$

$$A = \pi dL$$

$$= \pi \times 0.09 \times 0.5$$

$$A = 0.1413 \text{ m}^2$$

From equation (1)

$$P = \frac{0.2 \times 0.1413}{2.5 \times 10^{-3}} \times (1.1304)^2$$

$$= 14.44 \text{ W}$$

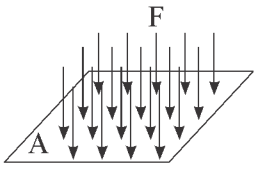
Solution End.

2. (c) Define pressure and what do you understand by hydrostatic law.
दाब को परिभाषित कीजिए और द्रवस्थैतिक नियम से आप क्या समझते हैं?

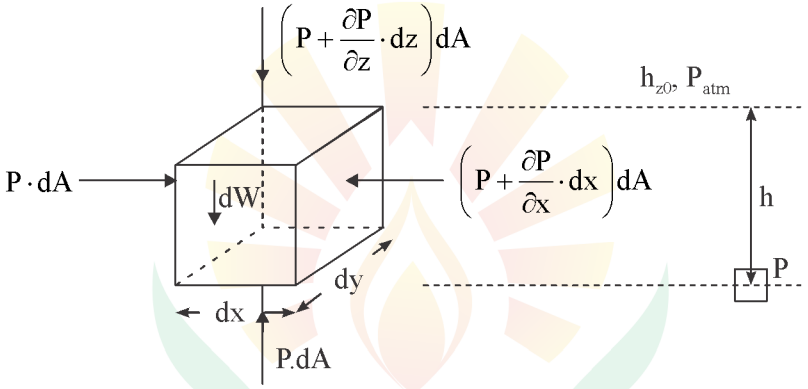
[10 Marks]

Sol.: **Pressure :** It is defined as force applied normal to the surface of an object per unit area over which that force is applied. The SI unit of pressure is the Pascal (Pa).

$$P = F/A$$



Hydrostatic law:



Apply Newton's 2nd Law in Z direction

$$F_{net} = ma$$

$$\Rightarrow PdA - \left(P+\frac{\partial P}{\partial z}\cdot dz\right)dA - dW = dm \times 0$$

$$\Rightarrow -\frac{\partial P}{\partial z}.dz.dA - (\rho d\forall).g = 0$$

$$\Rightarrow -\frac{\partial P}{\partial z}.dz.dx.dy - (\rho dx.dy.dz).g = 0$$

$$\Rightarrow -\frac{\partial P}{\partial z} = \rho g$$

$$\Rightarrow \frac{\partial P}{\partial z} = -\rho g$$

This is called as Hydrostatic law.

Solution End.

2. (d) A hydraulic press has a ram of 40 cm diameter and plunger of 5.5 cm diameter. Find the weight lifted by the hydraulic press when the force applied at the plunger is 500 N.

एक हाइड्रोलिक प्रेस में 40 सेमी व्यास का एक रैम और 5.50 सेमी व्यास का प्लंजर होता है। जब प्लंजर पर लगाया गया बल 500 N है तो हाइड्रोलिक प्रेस द्वारा उठाया गया वजन ज्ञात करें।

[10 Marks]

Sol.: Given

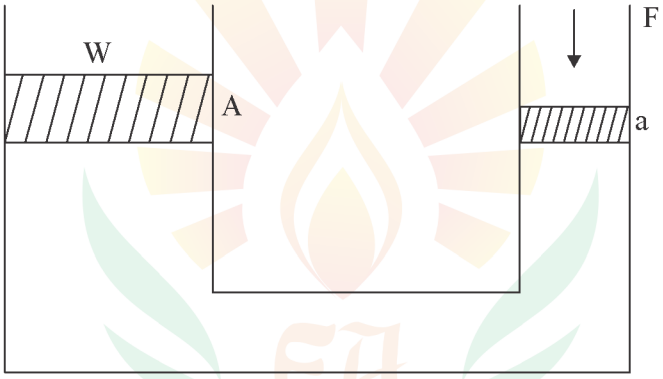
$$D = 40 \text{ cm},$$

$$F = 500 \text{ N},$$

$$d = 5.5 \text{ cm}$$

According to Pascal's Law :

Pressure at Ram & Plunger remains same.



So, $$P_1 = P_2$$

$$\frac{W}{A} = \frac{F}{a}$$

$$\Rightarrow \frac{W}{D^2} = \frac{F}{d^2}$$

$$\Rightarrow \frac{W}{40^2} = \frac{500}{5.5^2}$$

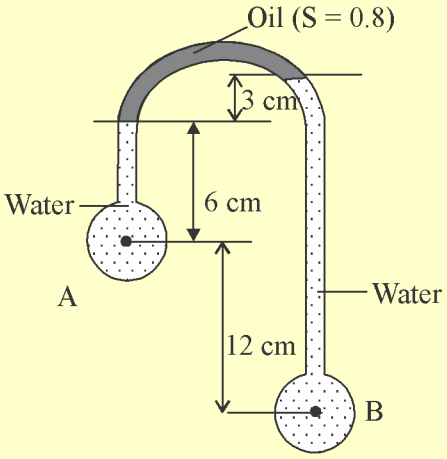
$$\Rightarrow W = 26446.3 \text{ N}$$

$$\Rightarrow W = 26.4463 \text{ kN}$$

Solution End.

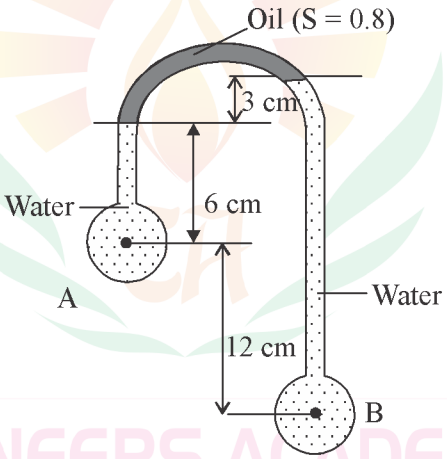
3.(a) For the given figure. Find the pressure difference between A & B.

दिए गए चित्र के लिए, A और B के बीच दाब अंतर ज्ञात कीजिये।



[10 Marks]

Sol.:



$$P_A - (10^3 \times g \times 0.06) - (800 \times g \times 0.03) + (10^3 \times g \times 0.21) = P_B$$

$$P_A - 600g - 240g + 2100g = P_B$$

$$P_A - P_B = 1260\ g$$

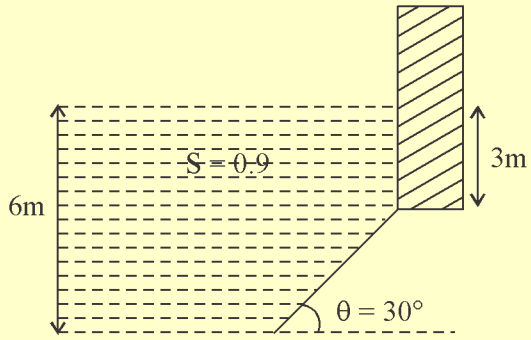
$$= 1260 \times 9.81$$

$$= 12360.6\ Pa.$$

Solution End.

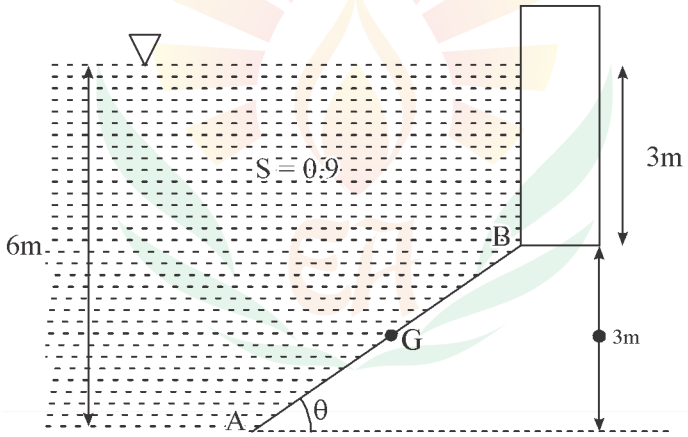
3.(b) Determine and locate total hydrostatic force (F) due to the oil on the plate inclined at 30° with the horizontal. The plate is hinged at its top edge and width is 2m inside the plane.

क्षैतिज के साथ 30° पर झुकी हुई प्लेट पर तेल के कारण कुल हाइड्रोस्टेटिक बल (F) का निर्धारण और स्थान का पता लगाएं। प्लेट शीर्ष किनारे पर टिका है और चौड़ाई प्लेन के अंदर 2m है।



[20 Marks]

Sol.:



$$\sin 30° = \frac{3}{AB}$$

$$AB = 6\ m$$

$$\bar{h} = 3 + \frac{3}{2} = 4.5\ m$$

$$F_P = \rho g \bar{h} A$$

$$= 900 \times 9.81 \times 4.5 \times (6 \times 2)$$

$$F_P = 476.76 \text{ kN}$$

$$h_{cp} = \frac{(I_{xx})_G \sin^2\theta}{A\bar{h}} + \bar{h}$$

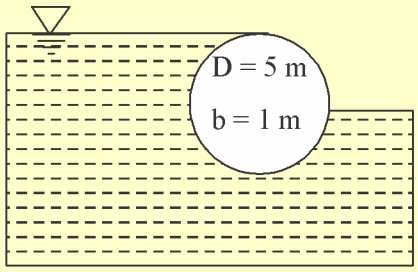
$$= \frac{\frac{2 \times 6^3}{12} \times \left(\frac{1}{2}\right)^2}{2 \times 6 \times 4.5} + 4.5$$

$$= 4.67 \text{ m}$$

Solution End.

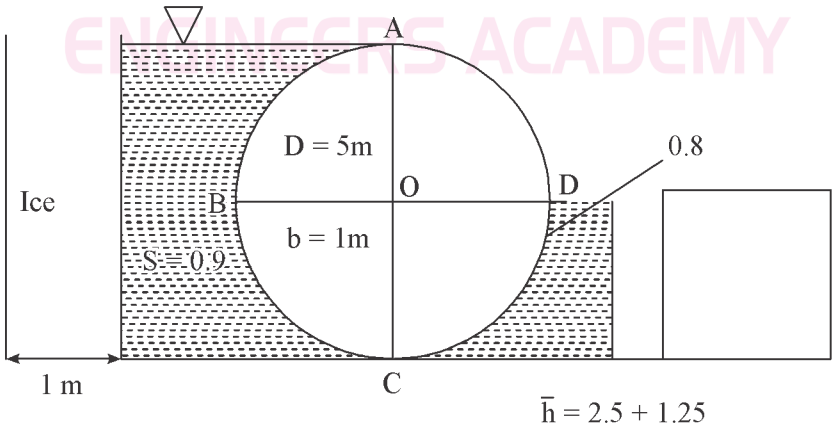
3.(c) For the given cylinder having diameter 5m and width 1m find the resultant hydrostatic pressure force.

व्यास 5m और चौड़ाई 1m वाले दिए गए बेलन के लिए परिणामी जलस्थैतिक दाब बल ज्ञात कीजिए।



[15 Marks]

Sol.:



$\bar{h} = 2.5 + 1.25$

Find the resultant horizontal and vertical force for the given figure.

$$F_{H_1} = \rho g A \bar{h}$$

$$= 900 \times 9.81 \times 5 \times 1 \times 2.5$$

$$= 110.3625\ \text{kN}$$

$$F_{H_2} = \rho g A \bar{h}$$

$$= 800 \times 9.81 \times 2.5 \times 1 \times 3.75$$

$$= 73.575\ \text{kN}$$

$$\text{Net } F_H = F_{H_1} - F_{H_2}$$

$$= 110.3625 - 73.575$$

$$= 36.7875\ \text{kN}$$

$$F_{V_1} = \rho g \forall$$

$$= 900 \times 9.8 \times \frac{\pi}{8} \times 5^2$$

$$= 86.634\ \text{kN}$$

$$F_{V_2} = 800 \times 9.81 \times \frac{\pi}{16} \times 5^2$$

$$= 38.504\ \text{kN}$$

$$F_{net} = F_{V_1} + F_{V_2}$$

$$= 86.634 + 38.504$$

$$= 125.138\ \text{kN}$$

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

$$= \sqrt{36.7875^2 + 125.138^2}$$

$$F_R = 130.43\ \text{kN}$$

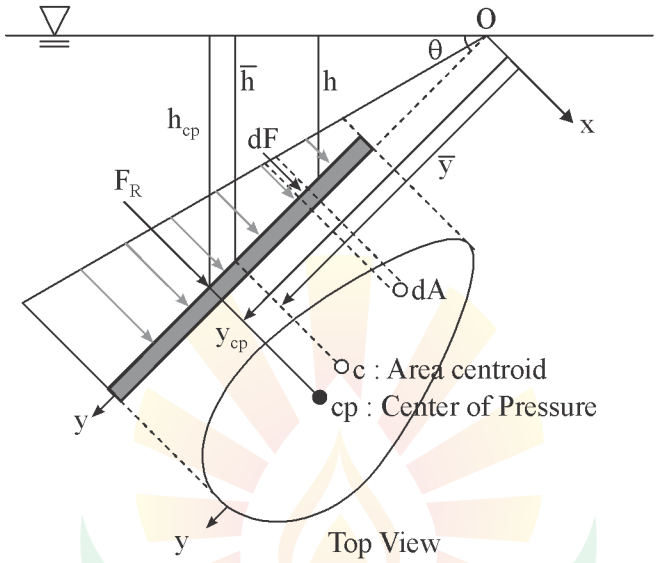
Solution End.

3.(d) Prove that centre of pressure of a completely submerged plane surface is always below the centre of gravity of submerged surface.

सिद्ध कीजिए कि एक पूर्ण जलमग्न समतल सतह का दाब केंद्र सदैव जलमग्न सतह के गुरुत्व केंद्र से नीचे होता है।

[15 Marks]

Sol.:



Pressure on element = ρgh

Pressure force on element = (ρgh) dA

Total force on body

$$\int dF = \int \rho gh\, dA$$

$$F = \rho g \int h\, dA$$

$$= \rho g \int y \sin\theta\, dA$$

$$= \rho g \sin\theta \int y\, dA$$

$$= \rho g \sin\theta\, \bar{y} A$$

$$\because \bar{y} = \frac{\int y\, dA}{A}$$

$$h = y \sin\theta$$

$$\bar{h} = \bar{y} \sin\theta$$

$$F = \rho g A \bar{h}$$

Centre of Pressure (c.p)

It is defined as point on which total pressure force is acting

Taking moment about = O

$$\text{Taking moment} = \int \text{moment of element}$$

$$F_p \times y_{cp} = \int dF.y$$

$$\rho g A \bar{h} \times \frac{h_{cp}}{\sin\theta} = \int \rho g h dA.y$$

$$\bar{h} A \times \frac{h_{cp}}{\sin\theta} = \int y \sin\theta dA.y$$

$$h_{cp} = \frac{\sin^2\theta \int y^2 dA}{A\bar{h}}$$

$$h_{cp} = \frac{I_{XX_0} \sin^2\theta}{A\bar{h}}$$

$$(I_{xx})_0 = (I_{xx})_G + Ay^2$$

$$h_{cp} = \frac{\left[(I_{xx})_G + A\bar{y}^2\right]\sin^2\theta}{A\bar{h}}$$

$$= \frac{(I_{x_x})_G \sin^2\theta}{A\bar{h}} + \frac{A\bar{y}^2 \sin^2\theta}{A\bar{h}} \qquad \left[\bar{y}^2 \sin^2\theta = \bar{h}^2\right]$$

$$h_{cp} = \bar{h} + \frac{(I_{xx})_G \sin^2\theta}{A\bar{h}}$$

Where

h_{cp} = Centre of pressure location

$\bar{h}$ = Centre of gravity location

$$h_{cp} - \bar{h} = \frac{(I_{xx})_G \sin^2\theta}{A\bar{h}}$$

$$h_{cp} - \bar{h} > 0$$

Solution End.

4.(a) For 2-D flow the velocity component is given as $u = \frac{u_0 x}{L}$ and $V = \frac{u_0 y}{L}$. where u_0 is constant. It is found that the total acceleration at x = L, y = L is 10 m/s^2. If L = 0.2, then find the magnitude of u_0.

2-D प्रवाह के लिए, वेग घटक को $u = \frac{u_0 x}{L}$ और $V = \frac{u_0 y}{L}$ के रूप में दिया जाता है, जहां u_0 नियत है। यह पाया गया है कि x = L, y = L पर कुल त्वरण 10 m/s^2 है। यदि L = 0.2 मीटर हो, तो u_0 का परिमाण ज्ञात कीजिए।

[20 Marks]

Sol.: Given

$$u = \frac{u_0 x}{L}, v = \frac{-v_0 y}{L}$$

We know

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t}$$

For 2-D steady flow

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}$$

$$a_x = \frac{u_0 x}{L}.\left(\frac{u_0}{L}\right) + 0$$

$$a_x = \frac{u_0^2}{L^2}.x$$

We know

$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + \frac{\partial v}{\partial t}$$

$$a_y = 0 - \frac{u_0 y}{L}\left(\frac{-u_0}{L}\right)$$

$$a_y = \frac{u_0^2}{L^2}.y$$

$$\bar{a} = a_x\hat{i} + a_y\hat{j}$$

$$|\bar{a}| = \sqrt{a_x^2 + a_y^2}$$

$$= \sqrt{\left[\left(\frac{u_0}{L}\right)^2 x + \left[\left(\frac{u_0}{L}\right)^2 y\right]\right]^2}$$

$$|\bar{a}| = \frac{u_0^2}{L^2} \cdot \sqrt{x^2 + y^2}$$

at $x = L, y = L, |\bar{a}| = 10$

$$10 = \frac{u_0^2}{L^2} \cdot \sqrt{L^2 + L^2}$$

$$10 = \frac{u_0^2 \sqrt{2}}{L}$$

$$10 = \frac{u_0^2 \sqrt{2}}{0.2}$$

$$u_0 = 1.189 \text{ unit}$$

Solution End.

4.(b) If velocity potential for 2-D flow is given by $\phi = x^2 - y^2 + 3xy$. Calculate the flow rate between the streamline passing through the point (1, 1) & (2, 2).

यदि 2-D प्रवाह के लिए वेग क्षमता $\phi = x^2 - y^2 + 3xy$ द्वारा दी गई है, तो बिंदु (1, 1) और (2, 2) से गुजरने वाली स्ट्रीमलाइन के बीच की प्रवाह दर की गणना करें।

[15 Marks]

Sol.: Given

$$\phi = x^2 - y^2 + 3xy$$

We know

$$\frac{\partial \psi}{\partial y} = \frac{\partial \phi}{\partial x}$$

$$\frac{\partial \psi}{\partial y} = 2x + 3y$$

$$\int \partial \psi = \int (2x + 3y) \partial y$$

$$\psi = 2xy + \frac{3}{2} y^2 + f(x) \quad \ldots (1)$$

We know

$$\frac{\partial \psi}{\partial x} = -\frac{\partial \phi}{\partial y}$$

$$= -(-2y + 3x)$$

$$\int \partial \psi = \int (2y - 3x)\partial x$$

$$\psi = 2xy - \frac{3}{2}x^2 + f(y) \quad \ldots (2)$$

From equation (1) and (2)

$$\psi = 2xy + \frac{3}{2}y^2 - \frac{3}{2}x^2$$

$$\psi_{(1,1)} = 2.1.1 + \frac{3}{2}(1^2 - 1^2)$$

$$\psi_{(1,1)} = 2$$

$$\psi_{(2,2)} = 2.2.2 + \frac{3}{2}(2^2 - 2^2)$$

$$\psi_{(2,2)} = 8$$

We know

$$Q = |\psi_1 - \psi_2|$$

$$= 6 \text{ unit}$$

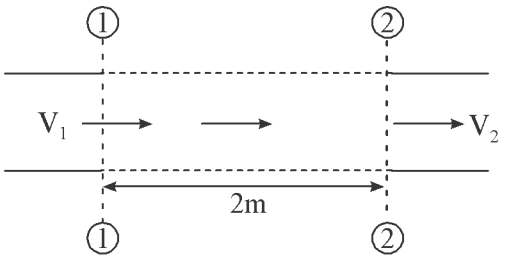
Solution End.

4. (c) A circular pipe of 10 cm diameter has 2 m length which is porous. In this porous section the velocity of exit is known to be constant. If the velocity at the inlet and outlet of the porous section are 2 m/s and 1.2 m/s respectively. Find the average velocity of this emitted discharge.

10 सेमी व्यास के एक गोलाकार पाइप की लंबाई 2 मिमी है, जो पोरस है। इस पोरस खंड में निकास का वेग स्थिर माना जाता है। यदि पोरस खंड के प्रवेश और निकास का वेग क्रमशः 2 मीटर प्रति सेकंड और 1.2 मीटर प्रति सेकंड है। इस उत्सर्जित निर्वहन का औसत वेग ज्ञात कीजिए।

[15 Marks]

Sol.: Given



$$d = 10 \text{ cm}$$
$$V_1 = 2 \text{ m/s}$$
$$V_2 = 12 \text{ m/s}$$
$$L = 2 \text{ m}$$

Emitted discharge

$$Q_e = Q_1 - Q_2$$
$$= A_1V_1 - A_2V_2$$
$$= A(V_1 - V_2)$$
$$= \frac{\pi}{4} \times 0.1^2(2 - 1.2)$$
$$Q_e = 6.28 \times 10^{-3} \text{ m}^3/\text{s}$$

Emitted discharge = Emitted area × Emitted velocity

$$Q_e = \pi dL \times V_e$$
$$6.28 \times 10^{-3} \text{ m}^3/\text{s} = \pi \times 0.1 \times 2 \times V_e$$
$$V_e = 0.01 \text{ m/s}$$

Solution End.

4. (d) Define (परिभाषित कीजिये)

1. Steady and unsteady flow (स्थिर और अस्थिर प्रवाह)
2. Laminar and turbulent flow (लेमिनार और विक्षुब्द प्रवाह)

[10 Marks]

Sol.: **Steady and unsteady flow**

A steady flow is one in which all conditions at any point in a stream remain constant with respect to time. This is the definition for the ideal case. True study flow is present only in Laminar flow. In the turbulent flow, there are continual fluctuations in velocity. Pressure also fluctuate at every point. But if this rate of change of pressure and velocity are equal on both sides of a constant average value, the flow is steady flow.

A flow in which quantity of liquid flowing per second is not constant, is called unsteady flow. Unsteady flow is transient phenomenon. It may be in time become steady or zero flow. For example when a value is closed at the discharge end of the pipeline.

Laminar and turbulent flow

In laminar flow, fluid flow in very organised manner in form layer with sliding over each other. Normally it occurs at low velocity. It is also known as viscons flow.

In turbulent flow, fluid flow in very disorganised manner with rapid intermixing to each other in zig-zag path. Normally it occurs at high velocity.

When fluid flow through circular pipe

$$Re < 2000, \text{Laminar flow}$$

$$2000 < Re < 4000, \text{Transition flow}$$

$$Re > 4000, \text{Turbulent flow}$$

When fluid flow over a flat plate -

$$Re < 5 \times 10^5, \text{Laminar Flow}$$

$$5 \times 10^5 < Re < 2 \times 10^7, \text{Transition flow}$$

$$Re > 2 \times 10^7, \text{Turbulent flow}$$

Solution End.

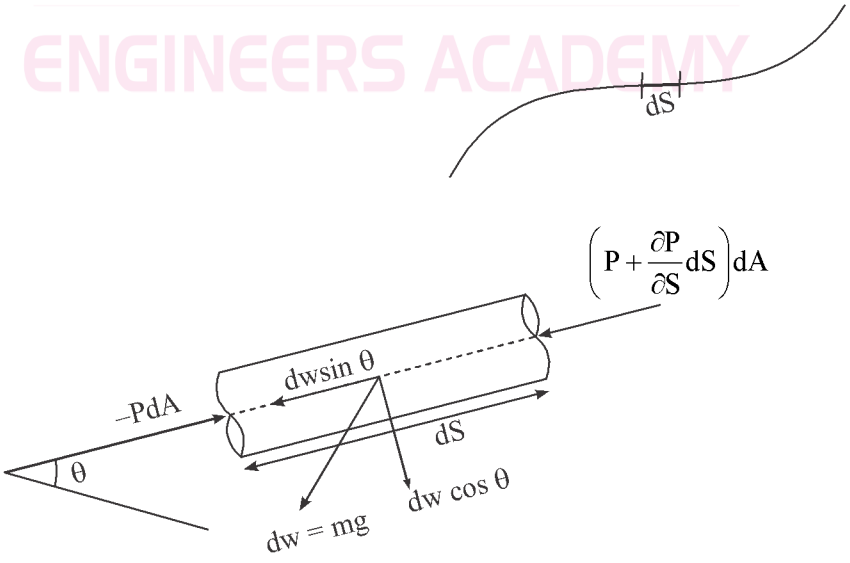
5. (a) Explain Euler's equation with assumptions.
यूलर समीकरण को परिकल्पनाओ के साथ व्याख्या कीजिये

[15 Marks]

Sol.: Euler's equation for a steady flow of an ideal fluid along a streamine is a relation between the velocity, pressure, and density of a moving fluid. It is based on Newton's second law of motion. The integration of the equation gives Bernoulli's equation in the form of energy per unit weight of the following fluid.

It is based on the following assumptions:

- The fluid is inviscid (i.e. the frictional losses are zero).
- The fluid is homogeneous and incompressible (i.e. mass density of the fluid is constant).
- The flow is steady, continous and along the streamline.
- Velocity of the flow is uniform over the section.
- Only gravity and pressure forces are considered.



$$\Sigma F_{net} = ma$$

$$pdA - \left(p + \frac{\partial p}{\partial s}ds\right)dA - \rho g \partial A \partial s \sin\theta = ma$$

$$-\frac{\partial p}{\partial s}dsdA - \rho g \partial A \partial s \sin\theta = \rho g dAds\left[v\frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}\right]$$

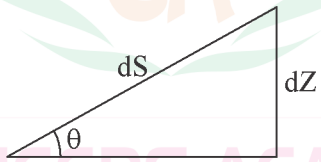
$$\frac{\partial p}{\partial s} + \rho g \sin\theta + \rho\left[v\frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}\right] = 0$$

$$\partial p + \rho g \sin\theta ds + \rho\left[v\frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}\right]ds = 0$$

$$\partial p + \rho g dz + \rho\left[v\frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}\right]ds = 0$$

$$\frac{\partial v}{\partial t} = \frac{\partial v}{\partial s}ds + \frac{\partial v}{\partial t}dt$$

$$a = v\frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}$$



For steady condition

$$\frac{\partial v}{\partial t} = 0$$

$$\partial P + \rho g dz + \rho v \partial v = 0$$

... Euler's equation

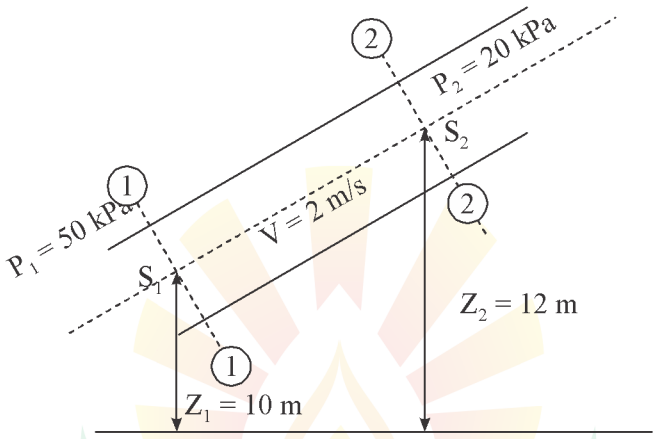
Solution End.

5.(b) A smooth pipe of 200 mm diameter carry water. The pressure in the pipe at section S_1 (10 m elevation) is 50 kPa. At section S_2 (12 m elevation) the pressure is 20 kPa and velocity 2 m/s. Find the direction of flow and head loss between them.

200 मिमी व्यास का चिकना पाइप पानी ले जाता है। सेक्शन S_1 (10 मीटर ऊंचाई) पर पाइप में दबाव 50 किलो पास्कल है। सेक्शन S_2 (12 मीटर ऊंचाई) पर दबाव 20 किलो पास्कल और वेग 2 मीटर प्रति सेकंड है। उनके बीच प्रवाह की दिशा और शीर्ष हानि ज्ञात कीजिए।

[15 Marks]

Sol.:



Given $P_1 = 50$ kPa, $P_2 = 20$ kPa

$z_1 = 10$ m, $z_2 = 12$ m

$v = 2$ m/s, $d = 200$ mm

energy at sections, S_1

$$e_1 = \frac{P_1}{\rho g} + z_1 + \frac{V_1^2}{2g}$$

$$= \frac{50 \times 10^3}{10^3 \times 9.81} + 10 + \frac{2^2}{2 \times 9.81}$$

$$e_1 = 15.30 \text{ m}$$

energy at section S_2

$$e_2 = \frac{P_2}{\rho g} + z_2 + \frac{V_2^2}{2g}$$

$$= \frac{20 \times 10^3}{10^3 \times 9.81} + 12 + \frac{2^2}{2 \times 9.81}$$

$$= 14.24 \text{ m}$$

Since energy at section S_1 is greater than at section S_2. So direction of flow must be from S_1 to S_2 & head loss

$$h_L = e_1 - e_2$$

$$= 1.06 \text{ m}$$

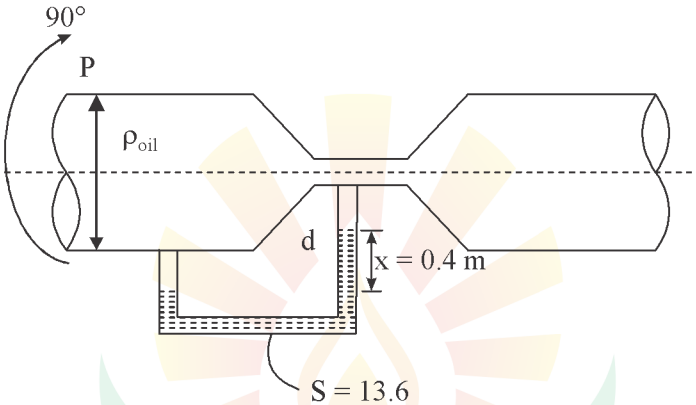
Solution End.

5. (c) A vertical venturimeter 40 cm × 20 cm is provided in a vertical pipe to measure the flow of oil of relative density 0.8. The difference in the elevation of the throat section and the pipe is 0.5 m. The direction of flow of oil being vertically upwards. The oil-mercury differential gauge shown deflection of mercury (S = 13.6) equal to 40 cm. Determine the discharge of oil flowing in the pipe.

सापेक्ष घनत्व 0.8 के तेल के प्रवाह को मापने के लिए लंबवत पाइप में लंबवत वेन्च्यूरीमीटर 40 cm × 20 cm प्रदान किया जाता है। गले के खंड और पाइप की ऊंचाई में अंतर 0.5 मीटर है। तेल के प्रवाह की दिशा लंबवत ऊपर की ओर हो रही है। तेल–पारा अंतर गेज ने पारा (S = 13.6) का विक्षेपण 40 सेमी के बराबर दिखाया। पाइप में बहने वाले तेल के निर्वहन का निर्धारण करें।

[15 Marks]

Sol.:



$D = 40\ cm = 0.4\ m$

$d = 20\ cm = 0.2\ m$

$x = 90\ cm = 0.9\ m$

$S_{oil} = 0.8$

$\rho_{oil} = 800\ kg/m^3$

$S_{Hg} = 13.6$

$\rho_{Hg} = 13600$

$$h = x\left[\frac{\rho_{Hg}}{\rho_{oil}} - 1\right]$$

$$= 0.4\left[\frac{13600}{800} - 1\right]$$

$h = 6.4\ m$

$$a_1 = \frac{\pi}{4}(0.4)^2$$

$$= 0.1256\ m^2$$

$$Q = \frac{a_1 a_2\sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$

$$= \frac{a_1\sqrt{2gh}}{\sqrt{\left(\frac{D}{d}\right)^4 - 1}}$$

$$= \frac{0.1256 \times \sqrt{2 \times 9.81 \times 6.4}}{\sqrt{\left(\frac{0.4}{0.2}\right)^4 - 1}}$$

$$Q = 0.363 \text{ m}^3/\text{s}$$

Solution End.

5.(d) In a pitot static tube the stagnation pressure is 3.0 kPa and static pressure is –3.0 kPa. The fluid is air (ρ_{air} = 1.2. kg/m^3). Calculate the velocity of flow. Assume C_v = 0.98.

एक पिटोट स्टेटिक ट्यूब में स्टेगनेशं का दबाव 3.0 किलो पास्कल है और स्थिर दबाव –3 किलो पास्कल है, द्रव हवा है (ρ_{air} = 1.2. kg/m^3)। प्रवाह के वेग की गणना करें। C_v = 0.98 मान लें।

[15 Marks]

Sol.: Given

$$C_V = 0.98,\ P_{stag} = 3\text{kPa},\ P_{stat} = -3\text{kPa},\ \rho_{air} = 1.2 \text{ kg/m}^3$$

$$V = C_V\sqrt{2g\left[h_{stag} - h_{stat}\right]}$$

$$= C_V\sqrt{2g\left[\frac{P_{stag}}{\rho g} - \frac{P_{stat}}{\rho g}\right]}$$

$$= C_V\sqrt{2g\left[\frac{3\times10^3}{1.2g} - \frac{(-3\times10^3)}{1.2g}\right]}$$

$$V = 0.98\sqrt{\frac{2}{1.2}\times6\times10^3}$$

$$V = 98 \text{ m/s}$$

Solution End.

6.(a) Derive the expression for specific speeds and explain its significance.
विशिष्ट गति के लिए व्यंजक व्युत्पन्न कीजिए तथा इसके महत्व को समझाइए।

[15 Marks]

Sol.: **Specific speed:**

It is define as a speed of geometrical similar turbine which works under unit head and produce unit power output.

We know that $u = K_u\sqrt{2gH}$

$$u \propto \sqrt{H} \quad \ldots (1)$$

We know $u = \frac{\pi DN}{60}$ ... (2)

$$u \propto DN$$

From equation (1) and (2)

$$DN \propto \sqrt{H}$$

$$D \propto \frac{\sqrt{H}}{N} \quad \ldots(3)$$

From, $Q = AV$

$$Q \propto D^2\sqrt{H}$$

From equation (3) $Q \propto \frac{H}{N^2}\sqrt{H}$ ... (4)

We know $P = \rho gQH$

$$P \propto QH$$

$$P \propto \frac{H}{N^2}\sqrt{H}.H$$

$$P = K\frac{H^{5/2}}{N^2} \quad \ldots (5)$$

$$\frac{PN^2}{H^{5/2}} = K$$

If, $P = 1, H = 1$

$$N = N_s$$

$$N_s^2 = K$$

$$N_s^2 = \frac{PN^2}{H^{5/2}}$$

$$N_s = \frac{N\sqrt{p}}{H^{5/4}}$$

If $Q = 1, H = 1$

$$N = N_s$$

$$Q = \frac{KH^{3/2}}{N^2}$$

$$1 = \frac{K}{N_s^2}$$

$$N_s^2 = K$$

$$N_s^2 = \frac{N^2Q}{H^{3/2}}$$

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

$N_S < 60 \rightarrow$ Pelton turbine

$60 < N_s < 300 \rightarrow$ Francis turbine

$N_s > 300 \rightarrow$ Kaplan turbine

N = Speed in r.p.m

P = Shaft power in kW

H = Positive net head in m

Solution End.

6.(b) For a pelton wheel net head is 32 m, discharge of nozzle is 0.18 m^3/s, area of nozzle jet is 7500 mm^2. The shaft power is 44 kW and mechanical efficiency is 94%. Find.

एक पेल्टन व्हील के लिए नेट हेड 32 मीटर, नोजल का डिस्चार्ज 0.18 m^3/s है, नोजल जेट का क्षेत्रफल 7500 mm^2 है। शाट की शक्ति 44 kW और यांत्रिक दक्षता 94% है। ज्ञात करे–

(i) Power at outlet of nozzle (नोजल के आउटलेट पर शक्ति)

(ii) Runner Power (रनर शक्ति)

(iii) Frictional power loss. (घर्षण शक्ति ह्रास)

[15 Marks]

Sol.: Calculate the power lost.

(1) In the nozzle $V = \frac{Q}{A} = \frac{0.18}{7500 \times 10^{-6}} = 24$ m/s

Nozzle outlet $= \frac{1}{2}\dot{m}v_1^2 = \frac{1}{2}\rho Q v_1^2 = \frac{1}{2} \times 10^3 \times 0.18 \times 24^2$

$= 51.84$ kW

W.P. $= \rho g Q H$

$= 9.81 \times 10^3 \times 0.18 \times 32 = 56.50$ kW

$$\eta_{mech} = \frac{\text{Shaft power}}{\text{R.P}}$$

$$\text{R.P} = \frac{44}{0.94} = 46.80 \text{ kW}$$

Power loss

$$\text{F.P} = \text{R.P} - \text{S.P}$$
$$= 46.80 - 44$$
$$= 2.8 \text{ kW}$$

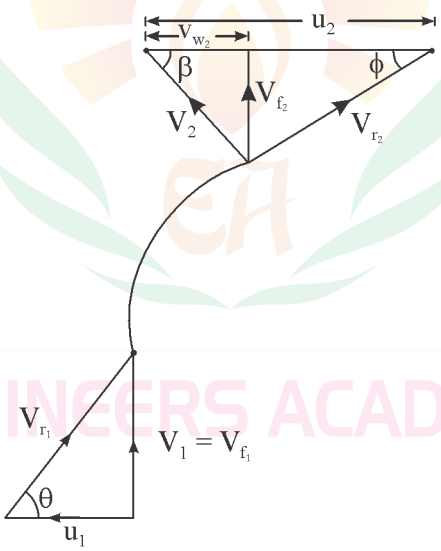
Solution End.

6. (c) A centrifugal pump discharge 0.2 m^3/s of water at a head of 25 m when running at 1400 rpm. The manometric efficiency is 80%. If the impeller has an outer diameter of 30 cm and width of 5 cm. Determine the impeller power and vane angle at outlet.

केन्द्रापसारक पंप 1400 rpm पर चलने पर 25 m के शीर्ष 0.2 m^3/s पानी का निर्वहन करता है। मोनोमेट्रिक दक्षता 80% है। यदि इम्पेलर का बाहरी व्यास 30 cm और चौड़ाई 5 cm है। आउटलेट पर इम्पेलर शक्ति और फलक कोण निर्धारित करें।

[15 Marks]

Sol.:



Given

$$Q = 0.2 \text{ m}^2/\text{s}$$
$$H = 25\text{m}$$
$$N = 1400 \text{ rpm}$$
$$\eta_{mano} = 80\%$$
$$D_2 = 30 \text{ cm}$$
$$B_2 = 5 \text{ cm}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.3 \times 1400}{60} = 21.98 \text{ m/s}$$

$$V_{r_1} = V_{r_2}$$

$$\theta = \pi d_2 B_2 V_{f_2}$$

$$0.2 = \pi \times 0.3 \times 0.05 \times V_{f_2}$$

$$V_{f_2} = 4.246 \text{ m/s}$$

$$\eta_{mano} = \frac{gH}{u_2 V_{w2}}$$

$$0.8 = \frac{9.81 \times 25}{21.98 \times V_{w_2}}$$

$$V_{w2} = 13.97 \text{ m/s}$$

$$\tan\phi = \frac{V_{f2}}{u_2 - V_{w2}} = \frac{4.246}{21.98 - 13.94}$$

$$\phi = 27.80°$$

Solution End.

6. (d) A pelton wheel has a single jet rotates at 600 rpm. The velocity of the jet from the nozzle is 100 m/s. If the ratio of the vane velocity to jet velocity is 0.44. What is the diameter of the pelton wheel.

एक पेल्टन व्हील में 600 rpm पर सिंगल जेट रोटेट होता है। नोजल से जेट का वेग 100 m/s है। यदि जेट वेग और वेन वेग का अनुपात 0.44 है, तो पेल्टन व्हील का व्यास कितना होता है?

[15 Marks]

Sol.:

$$N = 600 \text{ rpm}$$

$$V_1 = 100 \text{ m/s}$$

$$K_u = 0.44$$

$$u = K_u . V_1$$

$$u = 0.44 \times 100$$

$$u = 44 \text{ m/s}$$

We know $$u = \frac{\pi DN}{60}$$

$$44 = \frac{\pi \times D \times 600}{60}$$

$$D = 1.40 \text{ m}$$

Solution End.