نموذج أسئلة و اجابة مادة ميكانيكا الموائع م ١١١١

تاريخ الامتحان السبت ١٤ يناير ٢٠١٧

استاذ المادة أ.د محمد عبد اللطيف الشرنوبى

Benha University
College of Engineering at Benha
Questions For Final Examination
Subject: Fluid Mechanics M1111 **January/14/2017**
First year Mech. **Time :180 min.**
Examiner:Dr.Mohamed Elsharnoby

Attempt all questions	**Number of questions = 5**	**Number of pages**

a) Define, give examples and draw the figure of shear stress vs. rate of shear strain $\delta u/\delta y$ for : Newtonian fluid, pseudo plastic, dilatant, plasic, bingham plastic, and ideal fluid. ***Give examples of Thixotropic*** and ***Rheopectic*** *fluids*.

b) What is the source of viscosity in liquids and gases and how does the temperature increase affect the viscosity in liquids and gases?

c) Derive an expression for the capillary height change h, as shown, in figure 1for a fluid of *surface* tension σ and contact angle θ between two parallel plates W apart. Evaluate h for water at 20°C if W = 0.5 mm, σ =0.0728 N/m and $\theta = 0^o$.

2-a) A shaft 70.0 mm in diameter is being pushed at a speed of 400 mm/sec through a bearing sleeve 70.2 mm in diameter and 250 mm long. The clearance, assumed uniform, is filled with oil at 20^oC with ν = 0.1 Stokes and SG = 0.9.

i) Find the force exerted by the oil on the shaft.

ii) If the shaft is fixed axially and rotated inside the sleeve at 2000 rpm, determine the torque and power required to rotate the shaft with that rpm.

b) Calculate the pressure, in kPa, at A, B, C, and D in Figure 2.

c) Gate ABC in Figure 3 is 2m square and hinged at B . Howlarge must h be for the gate to open?

3-a) A block of wood having a volume of o.o34 m^3 and weighing 300 N is suspended in water as shown in Figure 4. A wooden rod of length 3,4 m and cross section of $200mm^2$ is attached to the weight and also to the wall. If the rod weight is 16 N, what will angle θ be for equilibrium?

b) The coffee cup in figure 5 is placed on a turntable, and rotated about its central axis until a rigid-body mode occurs. The cup is initially filled with water up to a height of 7 cm. Find (*a*) the angular velocity which will cause the coffee to just reach the lip of the cup and (*b*) the gage pressure at point *A* for this condition.

c) Define center of Bouancy, Meta center, Metacentric radius and mention the conditions of stability of immersed and floatin bodies..

4-a)Define i) uniform flow ii) Streamline iii) Streakline iv) Potentail flow v) vorticity vi) circulation (give the mathematical expression) .

b) Given the velocity field **V = 13x^2 yi+18(yz+x)j+15k, find the vorticith and the angular velocity vector at (2,3,4).**

c) Assuming the container in Figure 6 is large and losses are negligible, drive an expression for the distance X where the free jet leaving horizontally will strike the floor, as a function of h and H. Sketch the three trajectories or h/H=0.25, 0.50, and 0.75

5-a)When the pump in Fig. 7 draws 220 m^3/hr of water from the reservoir, the total friction head loss head is 5 m. The flow discharges through a nozzle to the atmosphere Estimate the pump power in kW.

b) Deduce an expression for the discharge of water over a right-angled sharp edged V-notch, given that the coefficient of discharge is 0.61.A rectangular tank 16m by 6m has the same notch in one of its short vertical sides. Determine the time taken for the head, measured from the bottom of the notch, to fall from 15cm to 7.5cm.

*** * * GOOD LUCK * * ***

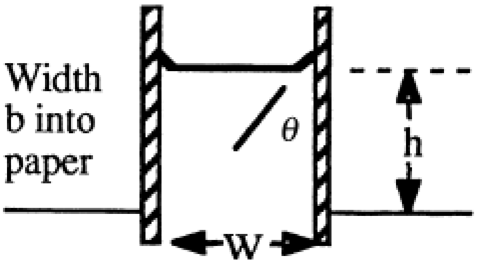


Figure 1

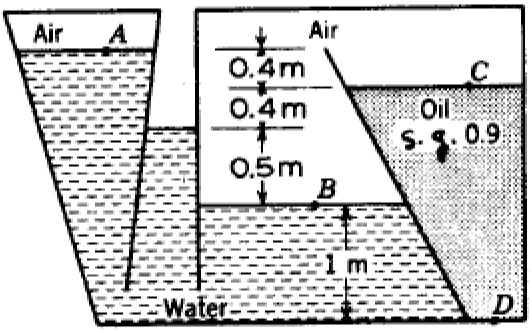


Figure 2

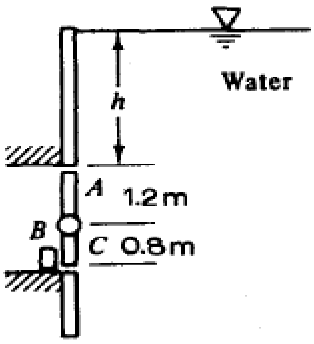


Figure 3

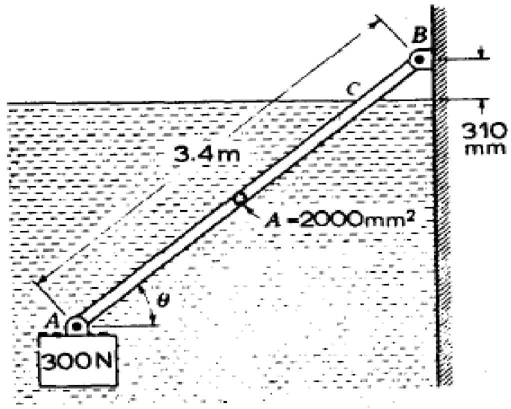


Figure 4

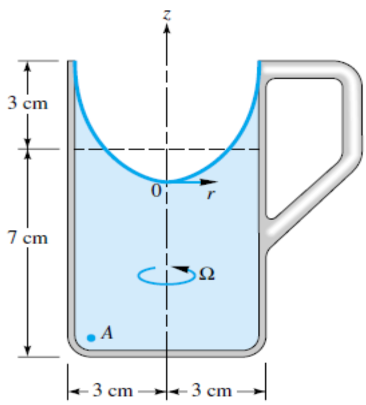


Figure 5

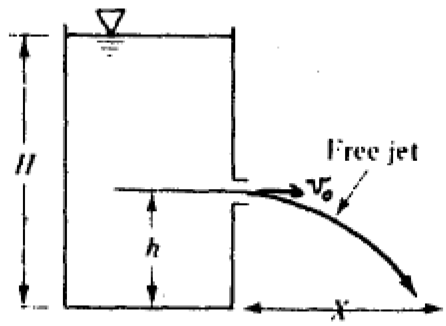


Figure 6

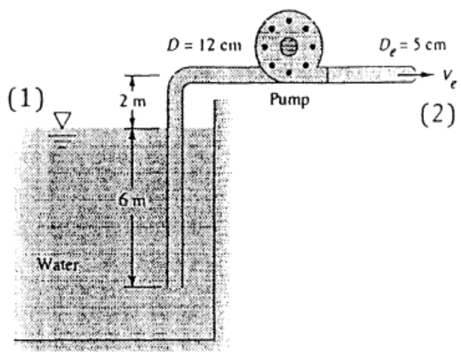


Figure 7

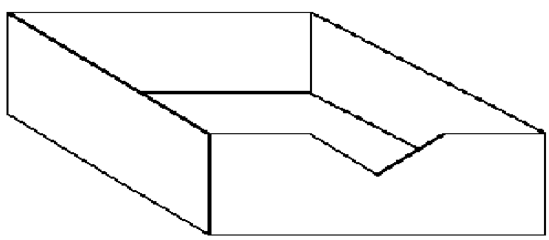


Figure 8

College of Engineering at Benha
Department of Mechanical Eng.
Subject: **Fluid Mechanics** 1111مادة ميكانيا الموائع كود م

Model Answer of the Final Exam
Date of the Exam Jan./14/2017

نموذج أسئلة و اجابة مادة ميكانيكا الموائع م ١١١١

تاريخ الامتحان السبت ١٤ يناير ٢٠١٧

استاذ المادة أ.د محمد عبد اللطيف الشرنوبى

Elaborated by: Dr. Mohamed Elsharnoby

1-a) The relationship between shear stress and the velocity gradient (rate of shear strain) in the fluid. These relationships can be seen in the graph below for several categories

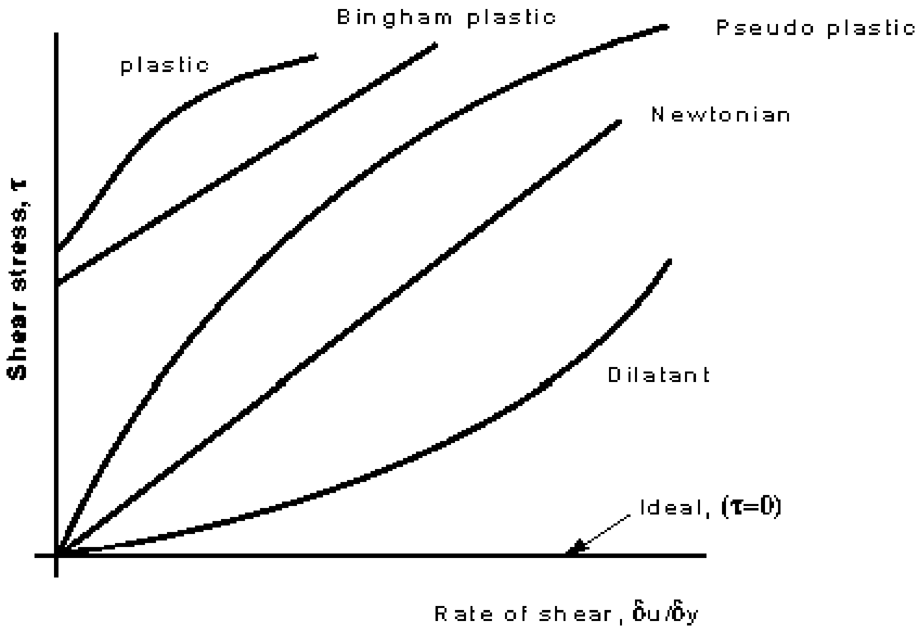


Figure 3 Shear stress vs. Rate of shear strain δu/δy

Newtonian fluids:

Fluids which obey the Newton's law of viscosity are called as Newtonian fluids. Newton's law of viscosity is given by

$\tau = \mu\, du/dy$, where τ = shear stress and μ = viscosity of fluid

du/dy = shear rate, rate of strain or velocity gradient

All gases and most liquids which have simpler molecular formula and low molecular weight such as water, benzene, ethyl alcohol, CCl_4, hexane and most solutions of simple molecules are Newtonian fluids.

Properties are independent of time under shear.

Bingham-plastic: Resist a small shear stress but flow easily under larger shear stresses. e.g. tooth-paste, jellies, and some slurries.

Pseudo-plastic:

Most non-Newtonian fluids fall into this group . No minimum shear stress necessary and the viscosity decreases with rate of shear, e.g. polymer solutions, blood, colloidal substances like clay, milk and cement.. Pseudo plastic fluids are also called as Shear thinning fluids. At low shear rates (du/dy) the shear thinning fluid is more viscous than the Newtonian fluid, and at high shear rates it is less viscous.

o ***Dilatant fluids***: Viscosity increases with increasing velocity gradient. They are uncommon, but suspensions of starch and sand behave in this way. Dilatant fluids are also called as shear thickening fluids. *;* Viscosity increases with rate of shear e.g. quicksand.

o ***Thixotropic*** *fluids* e.g. thixotropic jelly paints.

Rheopectic *fluids*:. e.g. gypsum suspension in water.

1-b) <u>Causes of Viscosity in Fluids</u>

<u>Viscosity in Gasses</u>

The molecules of gasses are only weakly kept in position by molecular cohesion (as they are so far apart). As adjacent layers move by each other there is a continuous exchange of molecules. Molecules of a slower layer move to faster layers causing a drag, while molecules moving the other way exert an acceleration force. Mathematical considerations of this momentum exchange can lead to Newton law of viscosity.

If temperature of a gas increases the momentum exchange between layers will increase thus increasing viscosity.

Viscosity will also change with pressure - but under normal conditions this change is negligible in gasses.

Viscosity of gases increases with increase in temperature.

<u>Viscosity in Liquids</u>

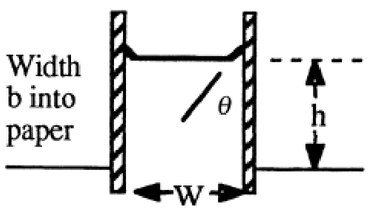
There is some molecular interchange between adjacent layers in liquids - but as the molecules are so much closer than in gasses the cohesive forces hold the molecules in place much more rigidly. This cohesion plays an important roll in the viscosity of liquids.

Increasing the temperature of a fluid reduces the cohesive forces and increases the molecular interchange. Reducing cohesive forces reduces shear stress, while increasing molecular interchange increases shear stress. Because of this complex interrelation the effect of temperature on viscosity has something of the form:

$$\mu_T = \mu_0 (1 + AT + BT)$$

1-c)

Solution: With *b* the width of the plates into the paper, the capillary forces on each wall together balance the weight of water held above the reservoir free surface:



$$\rho g W h b = 2(Y b \cos\theta), \quad \text{or:} \quad h \approx \frac{2Y\cos\theta}{\rho g W} \quad Ans.$$

For water at 20°C, $Y \approx 0.0728$ N/m, $\rho g \approx 9790$ N/m³, and $\theta \approx 0°$. Thus, for W = 0.5 mm,

$$h = \frac{2(0.0728\text{ N/m})\cos 0°}{(9790\text{ N/m}^3)(0.0005\text{ m})} \approx 0.030\text{ m} \approx \mathbf{30\ mm} \quad Ans.$$

2-a)i

$$F = \tau A \qquad \tau = \mu\,(dv/dr) \qquad \mu = \rho\nu = [(0.9)(998)](0.005) = 4.49\text{ kg/(m}\cdot\text{s)}$$

$$dr = (0.0702 - 0.0700)/2 = 0.0001\text{ m} \qquad \tau = (4.49)(0.4/0.0001) = 17\,960\text{ N/m}^2$$

$$A = (\pi)(7.00/100)(25/100) = 0.05498\text{ m}^2 \qquad F = (17\,960)(0.05498) = 987\text{ N}$$

(ii)

$$T = \tau A r \qquad \tau = \mu\,(dv/dr)$$

$$v = r\omega = [(7.00/2)/100][(2000)(2\pi/60)] = 7.330\text{ m/s} \qquad dr = 0.0001\text{ m}$$

$$\tau = (4.49)(7.330/0.0001) = 329.1\times10^3\text{ N/m}^2 \qquad A = (\pi)(7.00/100)(\tfrac{25}{100}) = 0.05498\text{ m}^2$$

$$T = (329.1\times10^3)(0.05498)[(7.00/2)/100] = 633\text{ N}\cdot\text{m}$$

$$P = \omega T = [(2000)(2\pi/60)](633) = 132.6\times10^3\text{ W} \quad \text{or} \quad 132.6\text{ kW}$$

2=b

$p_A = -(0.4+0.4)(9.790) = -7.832$ kPa; $p_B = (0.5)(9.790) = 4.895$ kPa. Neglecting air, $p_C = p_B = 4.895$ kPa; $p_D = 4.895 + (0.9)(9.790)(1+0.5+0.4) = 21.636$ kPa.

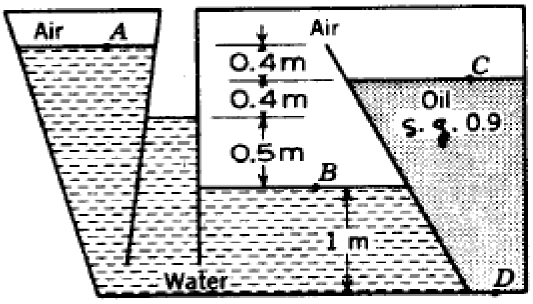


Figure 2

2-c

The gate will open when resultant force F acts above point B—i.e., when $|y_{cp}| < 0.2$ m. that y_{cp} is the distance between F and the centroid of gate ABC.)

$$y_{cp} = \frac{-I_{xx}\sin\theta}{h_{cg}A} = \frac{-[(2)(2)^3/12](\sin 90°)}{(h+1.0)[(2)(2)]} = \frac{-1.333}{4h+4}$$

For $|y_{cp}| < 0.2$, $1.333/(4h+4) < 0.2$, $h > 0.666$ m. (Note that this result is independent of fluid weight.)

as shown in Figure 3

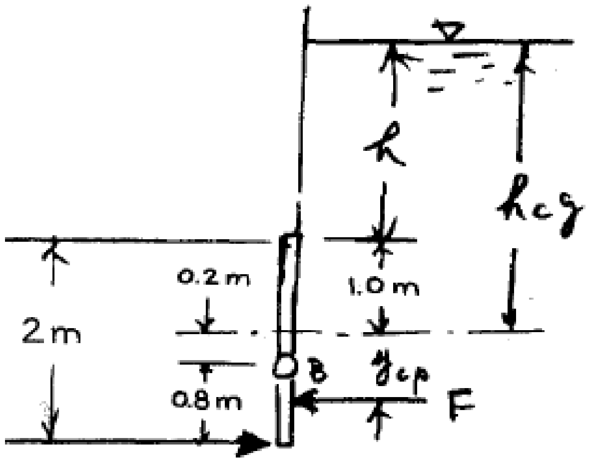


Figure 3

3-a

$$(F_b)_{block} = [(9.79)(1000)](0.034) = 333\text{ N} \qquad (F_b)_{rod} = [(9.79)(1000)][(AC)(2000/10^6)] = 19.58AC\text{ N}$$

$$\sum M_B = 0$$

$$333(3.4\cos\theta) + (19.58AC)[(AC/2) + (\tfrac{310}{1000})/\sin\theta](\cos\theta) - 300(3.4\cos\theta) - (16)(3.4/2)(\cos\theta) = 0$$

$$AC = 3.4 - (\tfrac{310}{1000})/\sin\theta$$

$$333(3.4\cos\theta) + 19.58[3.4 - (\tfrac{310}{1000})/\sin\theta] \times \{[3.4 - (\tfrac{310}{1000})/\sin\theta]/2 + (\tfrac{310}{1000})/\sin\theta\}(\cos\theta) - 300(3.4\cos\theta) - (16)(3.4/2)(\cos\theta) = 0$$

$$4.341 = [3.4 - (\tfrac{310}{1000})/\sin\theta][1.700 + (\tfrac{310}{1000})/(2\sin\theta)] \qquad 4.341 = 5.780 - 0.048/\sin^2\theta$$

$$\sin^2\theta = 0.033357 \qquad \sin\theta = 0.18264 \qquad \theta = 10.5°$$

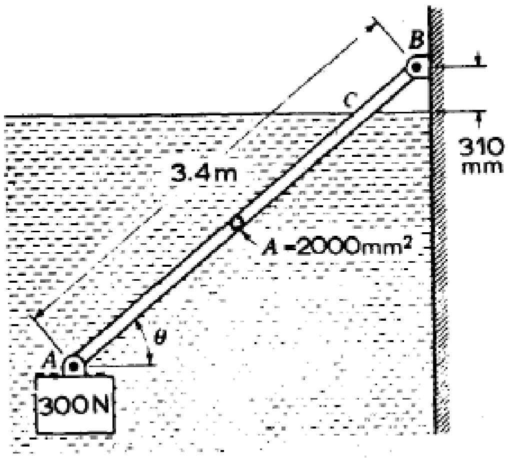


Figure 4

3-b) Solution

Part i) The cup contains 7 cm of coffee. The remaining distance of 3 cm up to the lip must equal the distance *h*/2 in next figure.. Thus

$$\frac{h}{2} = 0.03\text{ m} = \frac{\Omega^2 R^2}{4g} = \frac{\Omega^2 (0.03\text{ m})^2}{4(9.81\text{ m/s}^2)}$$

Solving we obtain

$$\Omega^2 = 1308 \qquad \text{or} \qquad \Omega = 36.2\text{ rad/s} = 345\text{ r/min}$$

To compute the pressure, it is convenient to put the origin of coordinates *r* and *z* at the bottom of the free-surface depression, as shown in Fig.5. The gage pressure here is p_o=0, and point *A* is at (*r*, *z*)= (3 cm, _4 cm). We can then evaluate

$$p_A = 0 - (1010\ kg/m^3)(9.81\ m/s^2)(-0.04\ m)$$
$$+ \tfrac{1}{2}(1010\ kg/m^3)(0.03\ m)^2(1308\ rad^2/s^2)$$
$$= 396\ N/m^2 + 594\ N/m^2 = 990\ Pa$$

This is about 43 percent greater than the still-water pressure $p_A = 694$ Pa.

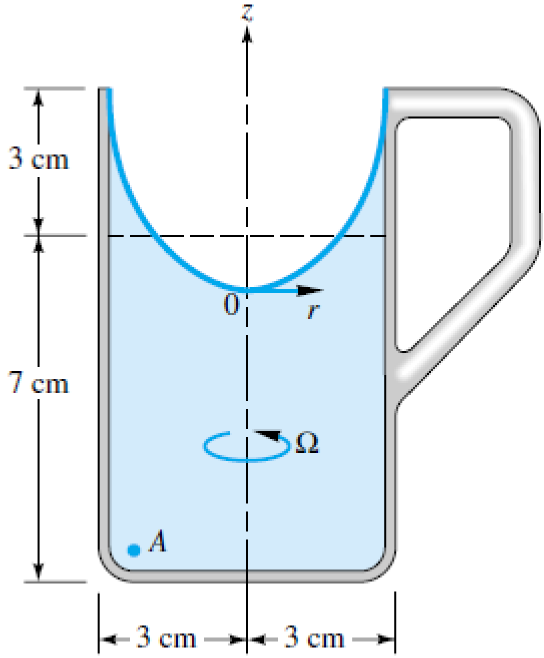


Figure 5

3-c) Center of Bouncy is the point of action of the up thrust acting on the floating or immersed bodies..
A vertical line drawn upward from *B*_ intersects the line of symmetry at a point *M*, called the *metacente*

The *metacentric height* $\overline{MG}$ is the distance between metacenter (M) and center of mass (G).

The *metacentric radius* $\overline{MB}$ is the distance between meta center (M) and center of Bouyancy (B).

Condition of stability:

(i) For immersed bodies the center of bouyancy (B) should be above center of gravity (G).
(ii) For floating bodies the Metacenter (M) should be above center of gravity(G).

4-a)i- **Uniform flow** is the flow whose velocity is the same at all points in the flow field (Velocity is independent on position).

ii) **Streamline** - An imaginary line in the flow that is everywhere parallel to the local velocity vectors.

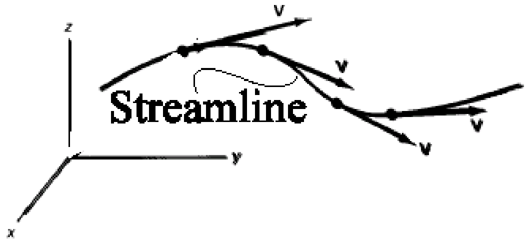


Figure 6

(iii)**Streakline** - An instantaneous line composed of all particles originating from a given point in the flow field; or is the locus of particles which have earlier passed through a prescribed point in space.

iv) **Potential flow** is the flow which has zero vorticity.

Potential flow: Flow whose vorticity equal zero or Curl **V** = 0, where the vector operation ($\nabla \times \mathbf{V}$) is referred to as the curl of the velocity vector **V**. The vorticity vector, ζ, is defined as twice the rotation vector:

$$\zeta = 2\boldsymbol{\omega} = \nabla \times \mathbf{V}$$

v) Circulation is defined as the line integral around the curve of the arc length **ds** times the tangential component of velocity. Shear stress for the element is thus given by

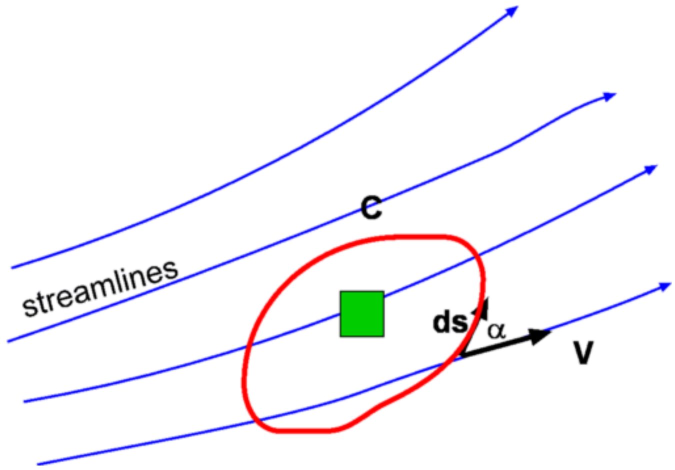


Figure 7: Definition of Circulation

Figure 7: Definition of Circulation

$$\Gamma = \oint_C \vec{V}.ds = \oint_C V\ cos\alpha\ ds = \oint_C (udx + vdy + wdz)$$

4-b)

$$\omega_x = \frac{1}{2}\left(\frac{\partial V_z}{\partial y} - \frac{\partial V_y}{\partial z}\right) = \tfrac{1}{2}(0 - 18y) = -9y \qquad \omega_y = \frac{1}{2}\left(\frac{\partial V_x}{\partial z} - \frac{\partial V_z}{\partial x}\right) = \tfrac{1}{2}(0 - 0) = 0$$

$$\omega_z = \frac{1}{2}\left(\frac{\partial V_y}{\partial x} - \frac{\partial V_x}{\partial y}\right) = \tfrac{1}{2}(18 - 13x^2) = 9 - 6.5x^2 \qquad \boldsymbol{\omega} = -9y\mathbf{i} + 0\mathbf{j} + (9 - 6.5x^2)\mathbf{k}$$

At point (2, 3, 4) m, $\boldsymbol{\omega} = (-9)(3)\mathbf{i} + [9 - (6.5)(2)^2]\mathbf{k} = -27\mathbf{i} - 17\mathbf{k}$ rad/s.

4-c

$$v_0 = \sqrt{2g(H-h)} \qquad h = gt^2/2 \qquad t = \sqrt{2h/g} \qquad X = v_0 t = \sqrt{2g(H-h)}\sqrt{2h/g} = 2\sqrt{h(H-h)}$$

For $h/H = 0.25$, or $h = 0.25H$, $X = 2\sqrt{(0.25H)(H - 0.25H)} = 0.866H$. For $h/H = 0.50$, or $h = 0.50H$, $X = 2\sqrt{(0.50H)(H - 0.50H)} = H$. For $h/H = 0.75$, or $h = 0.75H$, $X = 2\sqrt{(0.75H)(H - 0.75)} = 0.866H$. These three trajectories are sketched in Fig. 8 .

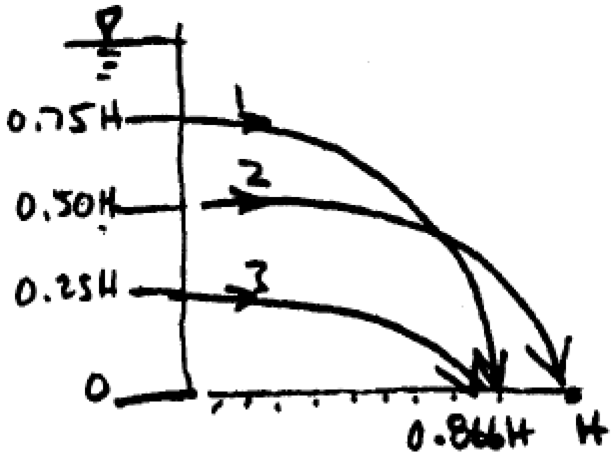


Figure 8

5-a)

Solution: Let "1" be at the reservoir surface and "2" be at the nozzle exit, as shown. We need to know the exit velocity:

As shown in Figure 8

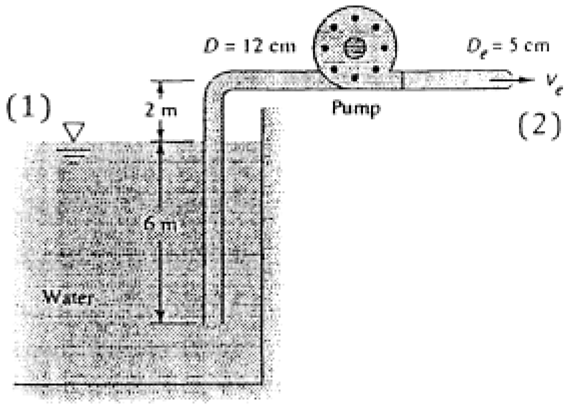


Figure 9

$$V_2 = Q/A_2 = \frac{220/3600}{\pi(0.025)^2} = 31.12\ \frac{m}{s}, \quad \text{while } V_1 \approx 0 \text{ (reservoir surface)}$$

Now apply the steady flow energy equation from (1) to (2):

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_f - h_p,$$

or: $0 + 0 + 0 = 0 + (31.12)^2/[2(9.81)] + 2 + 5 - h_p$, solve for $h_p \approx 56.4$ m.

The pump power $P = \rho Q h_p = (998)(9.81)(220/3600)(56.4)$

$= 33700\ W = \mathbf{33.7\ kW}$ *Ans.*

5-bFrom your notes you can derive:

$$Q = \frac{8}{15} C_d \tan\frac{\theta}{2} \sqrt{2g} H^{5/2}$$

, For this weir the equation simplifies to

$$Q = 1.44 H^{5/2}$$

, Write the equation for the discharge in terms of the surface height change:

$$Q\,\delta t = -A\,\delta h$$

$$\delta t = -\frac{A}{Q}\delta h$$

Integrating between h_1 and h_2, to give the time to change surface level

$$T = -\int_{h_1}^{h_2} \frac{A}{Q}\,dh$$

$$= -\frac{16 \times 6}{1.44}\int_{h_1}^{h_2} \frac{1}{h^{5/2}}\,dh$$

$$= \frac{2}{3} \times 66.67 \left[h^{-3/2}\right]_{h_1}^{h_2}$$

$h_1 = 0.15m$, $h_2 = 0.075m$

$$T = 44.44\left[0.075^{-3/2} - 0.15^{-3/2}\right]$$

$$= 1399\ \text{sec}$$