Benha University
College of Engineering at Benha
Questions For Corrective Final Examination
Subject: Fluid Mechanics M 201 **May 24/ 2016**
Second year Mech. **Time :180 min.**
Examiner:Dr.Mohamed Elsharnoby

Attempt all questions	**Number of questions = 5**	**Number of pages = 2**

1-a) Define and find the dimensions and units of the following:
i) Vapor pressure ii) Compressibility of the fluid iii) viscosity iv) surface tension coefficient.
v) specific weight and specific volume.
b) -A disk of radius R rotates at an angular velocity inside a disk-shaped container filled with oil of viscosity μ, as shown in Fig. 1. Assuming a linear velocity profile and neglecting shear stress on the outer disk edges, derive a formula for the viscous torque on the disk.

c) -The uniform 5-m-long round wooden rod in Fig. 2 is tied to the bottom by a string. Determine (a) the tension in the string and (b) the specific gravity of the wood. Is it possible for the given information to determine the inclination angle θ? Explain.
2-a) In Figure 3, At 20°C gage A reads 350 kPa absolute. What is the height h of the water in cm? What should gage B read in kPa absolute?

b) A rectangular gate (6m x 4m) is hinged at A and supported by a stopper as shown in Figure 4. Find the reaction at the hinge neglecting the weight of the gate.
c) State the conditions of stability of immersed and floating bodies.
3-a)Define : i) Steady flow ii) potential flow iii) ideal fluid iv) Streamline, streak line, time lines and path line.

b) A velocity flow field is given as : $\vec{V} = (x^2 - y^2)i - 2xyj$

i) Determine acceleration of particle at the point (2,4). ii) Does this flow represent a physical flow?. iii) Determine the vorticity at the point (x,y) .iv) Determine the equation of stream line passing through the point (1,2).

c) State the assumptions for derivation the Bernoulli equation.

4-a) A closed tank has an orifice 0.025m diameter in one of its vertical sides (figure 5). The tank contains oil to a depth of 0.66 m above the center of the orifice and the pressure in the air space above the oil is maintained at 13780 N/m^2 above atmospheric. Determine : i)the discharge from the orifice. (Coefficient of discharge of the orifice is 0.61, relative density of oil is 0.9), ii) the time to empty the tank if the pressure is kept constant inside the tank.

b) A Venturi meter with an entrance diameter of 0.3m and a throat diameter of 0.2m is used to measure the volume of gas flowing through a pipe. The discharge coefficient of the meter is 0.96. Assuming the specific weight of the gas to be constant at 19.62 N/m^3, calculate the volume flowing when the pressure difference between the entrance and the throat is measured as 0.06m on a water U-tube manometer (figure 6).

5 a) Water flows steadily through a reducing pipe bend, as in **Fig.7.** Known conditions are p_1 = 350 kPa, D = 25 cm, V = 2.2 m/sec , p = 120 kPa, and D = 8 cm. Neglecting bend and water weight, estimate the total force which must be resisted by the flange bolts.

b) For the piping system shown in **Fig.8**, determine the elevation of water surface in the downstream reservoir if the discharge through the system is 0.15 m^3/s and the pump develops 40 horsepower to the system. Carefully sketch the HGl and the EGL showing relative magnitudes and slopes.

GOOD LUCK

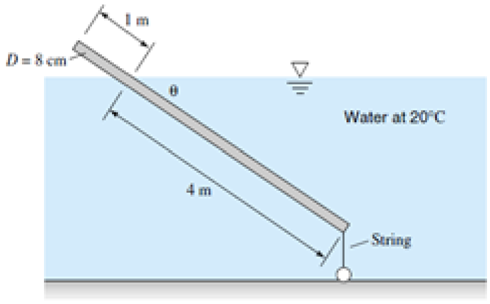


Figure 2

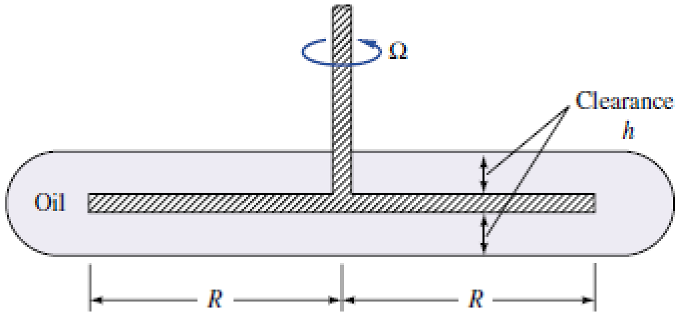


Figure 1

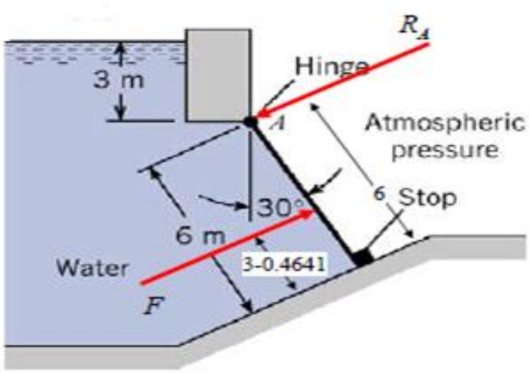


Figure 3

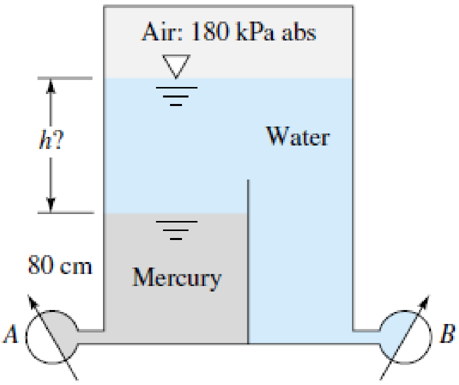


Figure 4

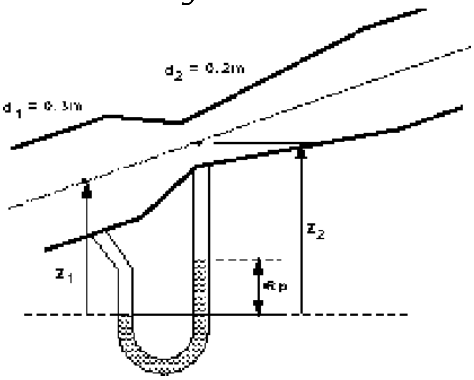


Figure 5

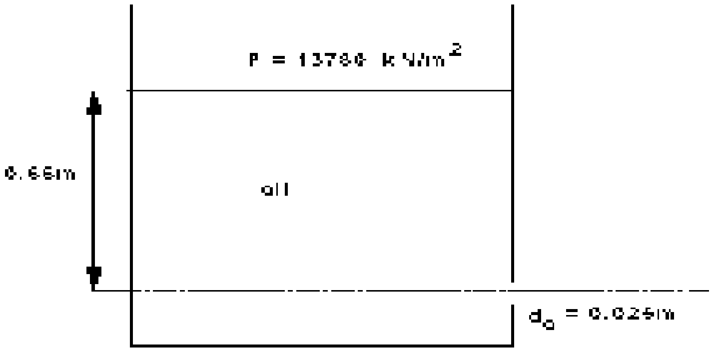


Figure 6

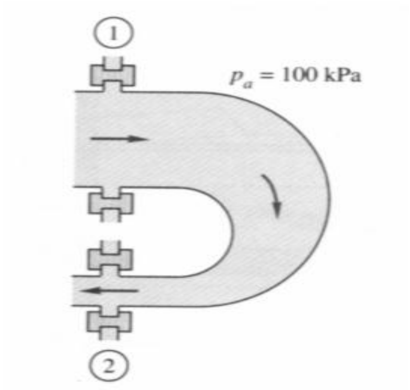


Figure 7

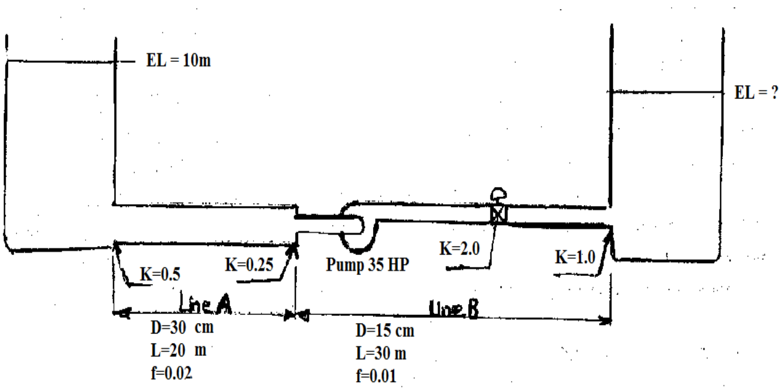


Figure 8

Benha University   **College of Engineering at Banha**

Benha Higher Institute of Technology
Department of Mechanical Eng.
Subject: Fluid Mechanics
Model Answer of the Final Exam   **Date: May/24/2016**

اجابة امتحان   ميكانيكا الموائع م 201

الدكتور محمد عبد اللطيف الشرنوبي

Elaborated by: Dr. Mohamed Elsharnoby

Q#1 Q#1 a- i) **Vapor pressure**: Pressure at which liquid boils, or pressure of vapor above liquid at equilibrium state.

Dimensions: $ML^{-1}T^{-2}$ **Units:** Pa, N/m^2, bar, psi

ii) Compressibility of the fluid: It is the volumetric strain per unit pressure change.

Dimensions: $M^{-1}LT^{2}$ **Units:** Pa^{-1}

iii) Dynamic viscosity coefficient: It measures the resistance of the fluid to flow under the effect of shear force.

Dimensions: $ML^{-1}T^{-1}$ **Units:** Kg/m.s, Pa.s, poise,..

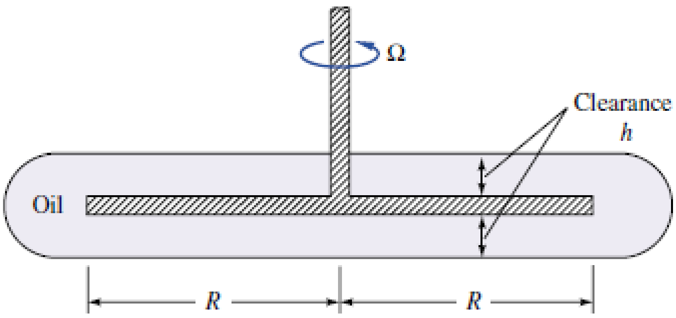
iv) Specific weight: It is the weight per unit volume.

Dimensions: $ML^{-2}T^{-2}$ **Units:** N/m^3

v) Surface tension Coefficient is the work should be done to bring enough molecules to form unit surface area

Dimensions $M\ T^{-2}$ **Units:** J/m^2

b)



We find first the viscous torque (T) required:

$$dT = \tau dA.r = \mu \frac{du}{dy} 2\pi r dr.r = 2\pi\mu \frac{\Omega r}{h} r^2 dr$$

$$T = \frac{2\pi\mu\Omega}{h}\int_0^R r^3 dr = \frac{\pi\mu\Omega R^4}{2h}$$

$$T = 0.1822 N.m$$

$$power = T.\Omega = 1.4577 watt$$

1-c)

The weight of the rod is acting at the middle of the rod (C.G).

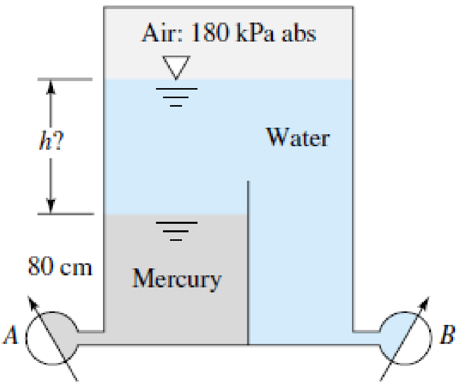
The up thrust R is acting upward at the middle of the immersed portion of the rod. Assume the tension T in the string.

From the equilibrium of forces R = W_{rod} + T $\rightarrow W_{rod} = \rho_{rod} V_{rod} g, R = \rho_{water} x0.8V_{rod} g$. Assume that the rod is making an angle θ with the horizontal and taking the moment about the lower end of the rod we get

$$\rightarrow W_{rod} x2.5\cos\theta = Rx2\cos\theta \rightarrow \rightarrow 2.5\rho_{rod} V_{rod} g = 2\rho_{water} x0.8V_{rod} g \rightarrow \frac{\rho_{rod}}{\rho_{water}} = 0.64$$

The tension in the string T = R- Word = $\frac{\pi}{4}(0.08)^2 x4x1000x9.81 - \frac{\pi}{4}(0.08)^2 x5x640x9.81 = 39.448N$

2-a



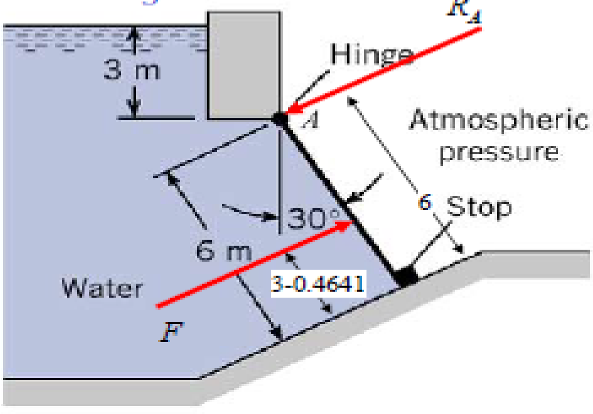
350x1000 = 180x1000 + 9810xh + 0.8x13.6x9810

h = 6.449 m

P_B = 251.115 kPa

2-b)

A rectangular gate (6m × 4m) is hinged at A and supported by a stopper as shown. Find the reaction at the hinge neglecting the weight of the gate



$$F = \bar{p}A = (\gamma \bar{y} \sin\alpha)A$$
$$= 9810 * (3 + 3\cos 30) * (4 * 6)$$
$$= 1{,}318{,}000\, N$$

$$y_{cp} - \bar{y} = \frac{\bar{I}}{\bar{y}A} = \frac{4 * 6^3 / 12}{(6.464 * 24)}$$
$$= 0.4641\, m$$

$$\Sigma M = 0$$
$$= 6R_A - (3 - 0.4641)F$$
$$R_A = \frac{3 - 0.4641}{6} F$$
$$= (0.42265)1318\, kN$$
$$R_A = 557.05\, kN$$

2-c)

i) Condition of stability of immersed body

The center of buoyancy B should be above the center of gravity CG

ii) Condition of stability of floating body

Meta center M should be above the center of gravity CG

3-a)

b-i) **Steady flow** is the flow whose properties are independent on time.
ii) **Potential flow** is the flow which has zero vorticity.
iii) **Ideal flow** is the non-viscous flow; of the flow which has zero viscosity equal zero.
iv) **Streamline** - An imaginary line in the flow that is everywhere parallel to the local velocity vectors.

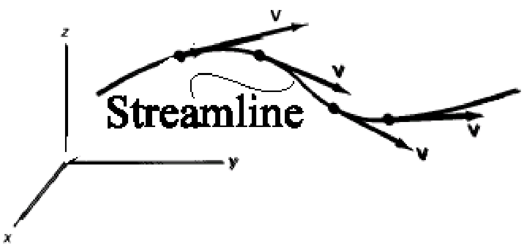


Figure 4

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.
A timeline is a set of fluid particles that form a line segment at a given instant of time.
A pathline is the actual path traversed by a given (marked) fluid particle.

3-b) c)) i-

$$\vec{V} = (x^2 - y^2)i - 2xyj$$
$$\vec{V} = ui + vj \rightarrow\rightarrow u = x^2 - y^2, v = -2xy$$
$$\text{the acceleration } \vec{a} = a_x i + a_y j$$
$$a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} \rightarrow\rightarrow a_x = (x^2 - y^2)(2x) + -2xy(\text{-}2y) = 2x^3 + 2xy^2$$
$$a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} \rightarrow\rightarrow a_y = (x^2 - y^2)(\text{-}2y) + -2xy(\text{-}2x) = 2y^3 + 2yx^2$$
$$a_x = 80, a_y = 160 \rightarrow \vec{a} = 80i + 160j$$

ii) The flow will represent a physical flow if $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$, for this flow we have $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 2x - 2x = 0$

$\therefore$ The flow is a physical flow.

iii) The vorticity is given by : $\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = -2y + 2y = 0$

iv) $u = x^2 - y^2 = \frac{\partial \psi}{\partial y} \rightarrow \psi = x^2 y - \frac{y^3}{3} + f(x)$

$$v = -2xy = -\frac{\partial \psi}{\partial x} \rightarrow \psi = x^2 y + g(y)$$
$$\therefore \psi = x^2 y - \frac{y^3}{3}$$

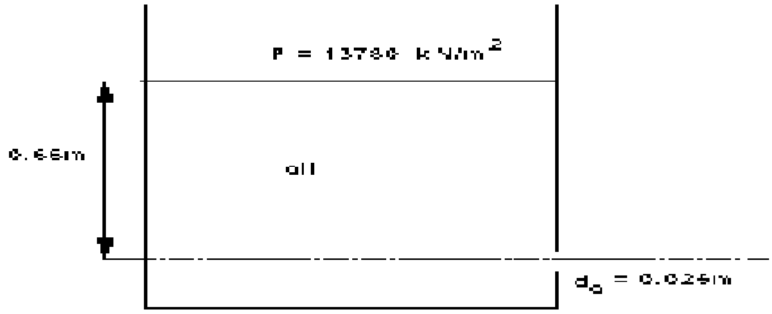
The equation of the streamline passing through the point (1,2) is given by: $3x^2 y - y^3 = -2$

3-c

Assumptions for derivation of Bernoulli equation

1- Steady flow
2- Flow along streamline
3- Ideal (non-viscous) flow
4- Incompressible flow
5- No shaft work
6- No heat transfer.

4-a)



From the question

$$\sigma = 0.9 = \frac{\rho_o}{\rho_w}$$
$$\rho_o = 900$$
$$C_d = 0.61$$

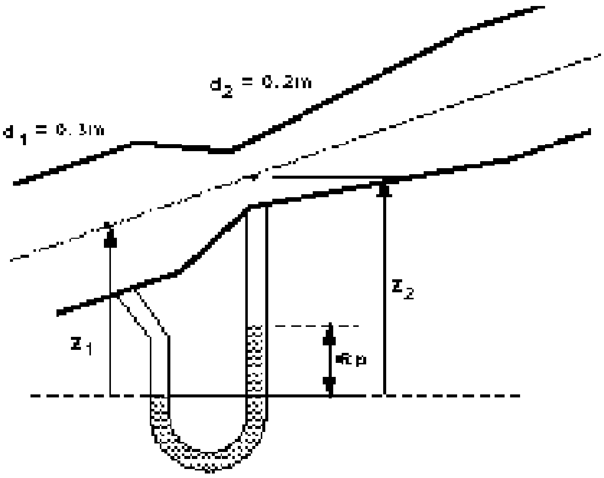
Apply Bernoulli,

$$\frac{p_1}{\rho g} + \frac{u_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{u_2^2}{2g} + z_2$$

Take atmospheric pressure as 0,

$$\frac{13780}{\rho_o g} + 0.61 = \frac{u_2^2}{2g}$$
$$u_2 = 6.53 m/s$$
$$Q = 0.61 \times 6.53 \times \pi \left(\frac{0.025}{2}\right)^2 = 0.00195 m^3/s$$

4-b)



What we know from the question:

$$\rho_g g = 19.62\ N/m^2$$
$$C_d = 0.96$$
$$d_1 = 0.3m$$
$$d_2 = 0.2m$$

Calculate Q.

$$u_1 = Q/0.0707 \qquad\qquad u_2 = Q/0.0314$$

For the manometer:

$$p_1 + \rho_g g z = p_2 + \rho_g g\left(z_2 - R_p\right) + \rho_w g R_p$$
$$p_1 - p_2 = 19.62\left(z_2 - z_1\right) + 587.423 \qquad <----(1)$$

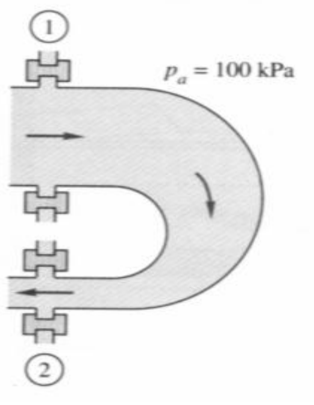
For the Venturimeter

$$\frac{p_1}{\rho_g g} + \frac{u_1^2}{2g} + z_1 = \frac{p_2}{\rho_g g} + \frac{u_2^2}{2g} + z_2$$
$$p_1 - p_2 = 19.62\left(z_2 - z_1\right) + 0.803u_2^2 \qquad <----(2)$$

Combining (1) and (2)

$$0.803u_2^2 = 587.423$$
$$u_{2_{ideal}} = 27.047\ m/s$$
$$Q_{ideal} = 27.047 \times \pi\left(\frac{0.2}{2}\right)^2 = 0.85m^3/s$$
$$Q = C_d Q_{idea} = 0.96 \times 0.85 = 0.816m^3/s$$

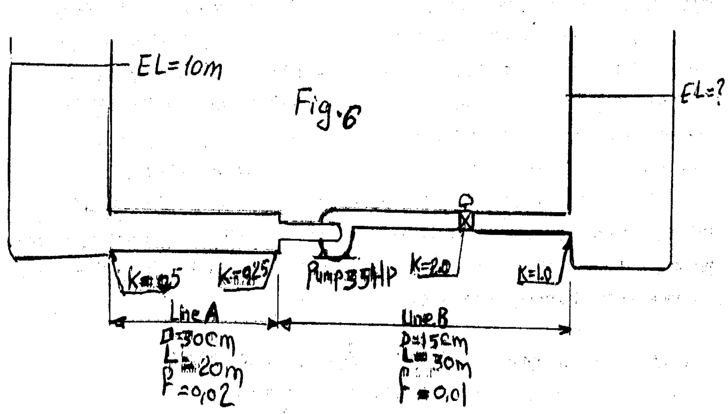
5-a)



$$\mathrm{Q} = \mathrm{A}_1\mathrm{V}_1 = A_2V_2 \quad \rightarrow \mathrm{V}_2 = \frac{A_1}{A_2}V_1 = 21.48m/\sec$$

$$\dot{\mathrm{m}} = \rho \mathrm{A}_1\mathrm{V}_1 = 107kg/\sec \quad -F_{bolt} + P_{1g}A_1 + P_{2g}A_2 = \dot{m}(-21.48 - 2.2) \rightarrow F_{bolt} = 14.9287kN$$

5-b)



The velocity in pipe 1 u_1 = 2.122 m/sec , u_2 = 8.488 m/sec

H_{f1} = 0.02x20/0.3x(2.122)^2 /2g = 0.306 m

h_{in}= 0.267755 m

h_{cont}= 0.133877 m

H_{f2} = 0.01x30/0.15x(8.488)^2 /2g = 7.344 m

H_{out}= 3.672 m

H_{valve}= 7.344 m

Hp = 20m

El= 10.94 m