Department of Mechanical Engineering
Assignment Problem Sheet 5 [Session 2015-16]
(Engineering Thermodynamics & Fluid Mechanics) MECH 1201

Properties of Fluid

1. The velocity distribution over a plate is given by $u(y) = \frac{2}{3}y - y^2$. If μ=0.863Pa-s, find the shear stress at $y = 0$ and $y =$ 0.15m. [Ans: 0.576 N/m^2, 0.317 N/m^2]

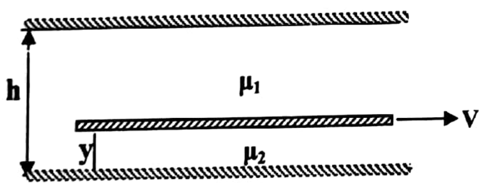
2. The velocity profile of a fluid over a plate is parabolic, with vertex 20cm from the plate, where the velocity is 120cm/s. Calculate the velocity gradients and shear stresses at a distance 0, 10, 20 cm from the plate, if the viscosity of the fluid is 8.5 Poise. [Ans: 12/s, 6/s, 0/s; 10.2N/m^2, 5.1 N/m^2, 0 N/m^2]

3. A circular disc of diameter **D** is slowly rotated in a liquid of viscosity μ at a height **h** from a fixed surface. Derive an expression for torque **T** necessary to maintain an angular velocity ω, of the disc. [Ans: $T = \frac{\pi\mu\omega D^4}{32h}$]

4. A space 25mm wide between two large plane surfaces is filled with glycerine. What force is required to drag a very thin plate 0.75m^2 in area between the surfaces at a speed of 0.5m/s,
   (i) if this plate remains equidistant from the two surfaces.
   (ii) if the plate is at a distance of 10mm from one of the surfaces.
   Take μ= 0.785 N-s/m^2. [Ans: (i) 47 N (ii) 49 N]

5. A vertical gap 23.5mm wide of infinite extent contains oil of specific gravity 0.95 and viscosity 2.45 N-s/m^2. A metal plate of dimensions (1.5m × 1.5m × 1.5mm), weighing 49N is to be lifted through the gap at a constant speed of 0.1m/s. Estimate the force required to lift the plate. (Assume, the plate at middle position in the gap) [Ans: F = 117.8 N]

6. A thin plate is placed between two flat surfaces, having a very narrow gap of height **h**, in such a way that the viscosity of liquids on the top and bottom of the plate are μ_1 and μ_2 respectively. Calculate the position of the thin plate such that drag force or viscous resistance to uniform motion of the thin plate is minimum. [Ans: $y = \frac{h}{1+\sqrt{\mu_1/\mu_2}}$]



7. A 90N rectangular solid block slides down a 30^0 inclined plane. The plane is lubricated by a 3 mm thick oil of viscosity 0.8 Pa-s. If the contact area is 0.3m^2, estimate the terminal velocity of the block. [Ans: 0.5625 m/s]

8. A 150mm diameter shaft rotates at 1500 r.p.m in a 200mm long journal bearing, with an internal bearing diameter 150.5mm. The uniform annular space between the shaft and the bearing is filled with oil of dynamic viscosity 0.8 Poise. Calculate the power required to rotate the shaft. [Ans: 4.186 kW]

9. A shaft 80mm diameter is being pushed through a bearing sleeve 80.2mm in diameter and 0.3m long. The clearance, assumed uniformed is filled with lubricating oil of viscosity 0.1 kg/m-s and specific gravity 0.9.
   (a) If the shaft moves axially at 0.8m/s, estimate the resistance force exerted by the oil on the shaft.
   (b) If the shaft is axially fixed, and rotated at 1800rpm, estimate the resisting torque exerted by the oil and the power required to rotate the shaft. [Ans. 60.32N, 22.74 N-m, 4.29kW]

10. A hydraulic ram of 200mm diameter and 1.2m long moves within a concentric cylinder 200.2mm diameter. The annular clearance is filled with oil of specific gravity 0.85 and kinematic viscosity 400mm^2/s. What is the viscous force resisting the motion when the ram moves at a speed of 120mm/s. [Ans: F=307.6 N]

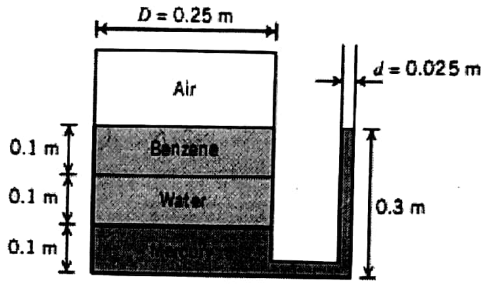
11. A vertical shaft has a hemispherical bottom of radius **R** which rotates inside a bearing of identical shape at its end. An oil film of thickness **h** and viscosity μ is maintained over the curved surface in the bearing. Estimate the viscous torque in the shaft when it rotates with an angular velocity ω. [Ans: T=$(4\pi\omega\mu R^4)/3h$]

12. An increase in pressure of a liquid from 8MPa to 17MPa results in 0.3% decrease in its volume. Determine the bulk modulus of elasticity and coefficient of compressibility of the liquid. [Ans: E = 3000MPa, β =0.33×10^{-9} m^2/N]

Fluid Statics

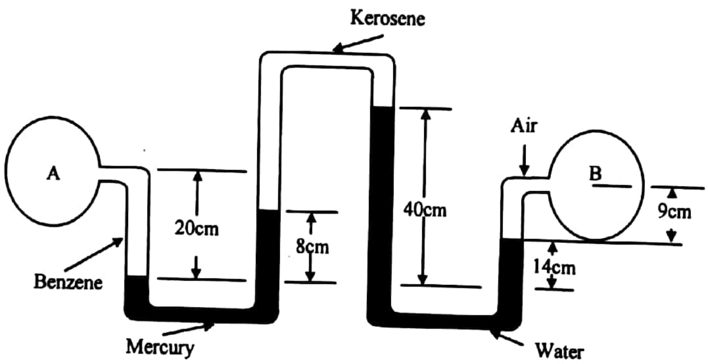
1. An open tank contains water upto a depth of 1.5m and above it an oil of relative density 0.8 for a depth of 2m. Find the gauge pressure (i) at the interface of two liquids (ii) at the bottom of the tank.
[Ans: (i) $1.57 N/cm^2$ (ii) $3.04 N/cm^2$]

2. Consider a tank containing mercury, water, benzene, and air as shown. Find the air pressure (gauge) in the tank. If an opening is made at the top of the tank, find the equilibrium level of the mercury in the manometer attached as shown. Specific gravity of Benzene =0.879, Specific gravity of Mercury =13.55
[Ans: p= 24.7 kPa(gauge), h= 0.116 m]



3. A differential U-tube mercury manometer is used to measure the pressure difference between points 1 and 2 in a pipeline, conveying water. The point 1 is 0.5m lower than the point 2. The difference in the level of manometric fluid (mercury) on the two limbs is 0.8m. Calculate the pressure difference between points 1 and 2. Assume, density of water is $1000 kg/m^3$, Specific gravity of mercury is 13.6 [Ans: 103.79 kPa]

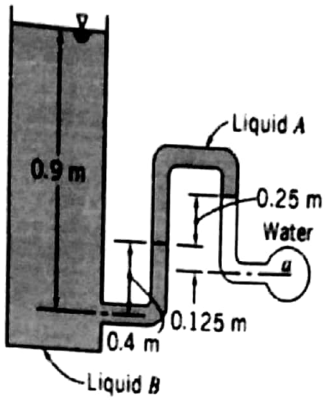
4. Determine the pressure difference between points A and B. Specific gravities of benzene, kerosene and air are 0.88, 0.82 and 1.2×10^{-3} respectively. Consider air as incompressible fluid.



[Ans: 8.97 kPa]

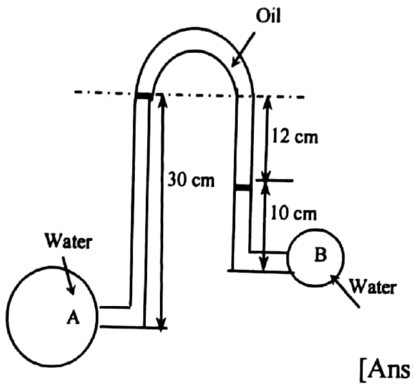
5. A simple U-tube manometer containing mercury is connected to a pipe in which a fluid of specific gravity 0.9 and having vacuum pressure, is flowing. The other end of the manometer is open to atmosphere. Find the vacuum pressure in pipe, if the difference in mercury level in the two limbs is 50 cm and height of fluid in the left limb from the centre of pipe is 10 cm below. [Ans: 67.6 kPa (vacuum)]

6. Determine the gauge pressure in kPa at point '***a***', if liquid A has SG = 1.20 and liquid B has SG = 0.75. The liquid surrounding point '***a***' is water, and the tank on the left is open to the atmosphere.



[Ans: P_a (gauge) = 4.414 kPa]

7. Water is flowing through two different pipes to which an inverted differential manometer having an oil of sp. gr. 0.9 is connected? The pressure head in the pipe A is 2.5 m of water. Find the pressure in pipe B for the manometer readings as shown in figure below.

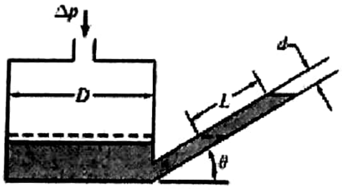


[Ans: P_B = 23.622kPa = 2.41m of water]

8. A U-Tube manometer is used to measure the pressure of water in a pipeline. which is in excess of atmospheric pressure. The right limb of the manometer contains mercury and is open to atmosphere. The contact between water and mercury is in the left limb. (i) Determine the pressure of water in the main line, if the difference in level of mercury in the limbs of U-tube and the free surface of mercury is in level with the centre of pipe.
(ii) If the pressure of water in pipeline is reduced to 9810N/m^2, calculate the new difference in the level of mercury. Sketch the arrangements in both cases. [Ans: (i) 12.361 kN/m^2, (ii) 8.016 cm]

9. Two small vessels are connected to a U-tube manometer containing mercury (relative density 13.56) and the connecting tubes are filled with oil (relative density 0.82). The vessel at the higher pressure is 2m lower in elevation than the other. What is the pressure difference between the vessels when the steady difference between mercury meniscus is 225mm? What is the difference of piezometric head? If an inverted U-tube manometer containing a liquid of relative density of 0.74 were used instead, what would be the manometer reading for the same pressure difference? [Ans: 44.2kPa, 3.496m, 35.83m]

10. The inclined-tube manometer shown has D =76 mm and d=8 mm, and is filled with Meriam red oil. Compute the angle θ, that will give a 15-cm oil deflection along the inclined tube for an applied pressure of 25 mm of water (gauge). Specific gravity of Meriam red oil=0.827.



[Ans: $\theta = 10.97^0$]