THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
2023 ACADEMIC YEAR TERM 1
TEST
CEE 3311–FLUID MECHANICS

INSTRUCTIONS
1. Attempt all questions
2. Questions do not carry equal marks
3. If you fail to answer part of a question, assume a value and use it in the subsequent calculations

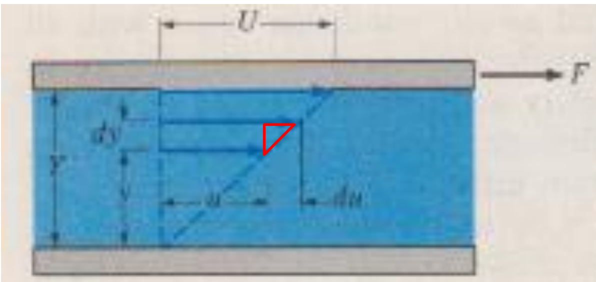
TIME: TWO (2) HOURS **CLOSED BOOK TEST**

Question 1

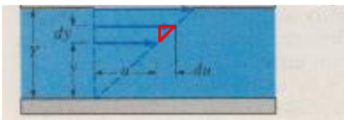
a) Derive Newton's Equation of Viscosity. (6 marks)

$F \alpha \frac{AU}{Y}$

- From similar triangles in Fig, U/Y can be replaced by velocity gradient $\frac{du}{dy}$ (with v=0 at bottom and v=U at the top)



$$F \alpha \frac{AU}{Y} \Rightarrow \frac{F}{A} \alpha \frac{U}{Y}$$



If a constant of proportionality μ(mu) is now introduced, $\frac{F}{A} = \mu \frac{U}{Y}$

the shearing stress τ (tau) between any **two thin sheets** of fluid may be expressed by

$$\tau = \frac{F}{A} = \mu \frac{U}{Y} = \mu \frac{du}{dy}$$ Newton's Equation of Viscosity

$\mu = \tau / du/dy$ is called absolute viscosity, dynamic viscosity, coefficient of viscosity or simply the viscosity of the fluid

b) Briefly explain what happens during cavitation when bubbles enter the higher pressure regions. (4 marks)

The bubbles collapse (*implosion*) upon entering the higher pressure regions, and this collapse produces *local pressure spikes*

c) Briefly explain the summation of forces for the fluid at rest. (3 marks)

Because the fluid is at *rest*, the element *is in equilibrium* and the *summation of forces* acting on the element in any direction must be *zero*.

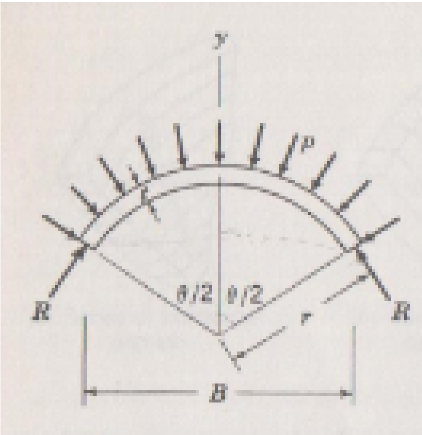
d) This shows that for an incompressible fluid at rest, at any point in the fluid the sum of the elevation z and the pressure head p/ γ is *equal* to the sum of these two quantities *at any other point*. What is the significance of this statement? (3 marks)

The significance of this statement is that, in a fluid at rest, with an *increase in elevation there is a decrease in pressure head, and vice versa*.

e) Distinguish between the U-tube manometer used to measure small pressure and large pressure. (3 marks)

Manometer used to measure relatively large pressures uses a fluid with specific weight or density which is quite large

f) Draw a free body diagram of an arch rib only for the Kariba Dam and show the forces. (4 marks)



g) What two parameters need to be calculated in the design of devices and objects that are submerged? (2 marks)

The magnitudes and locations of forces

Question 2

a) Give two applications of hydrometers. (3 marks)

   i) the amount of antifreeze in the radiator of an automobile
   ii) the charge in a battery since the density of water changes when subjected to an electrical charge

b) Prove the Law of Buoyancy. (7 marks)

- To prove the law of buoyancy, consider the submerged body (Fig 5.1 a). In part (b) a cylindrical free-body diagram is shown that includes the submerged body with weight W and liquid having a weight F_W; the cross sectional area A is the maximum cross sectional area of the body.

Note that body is not moving but stationary at that position

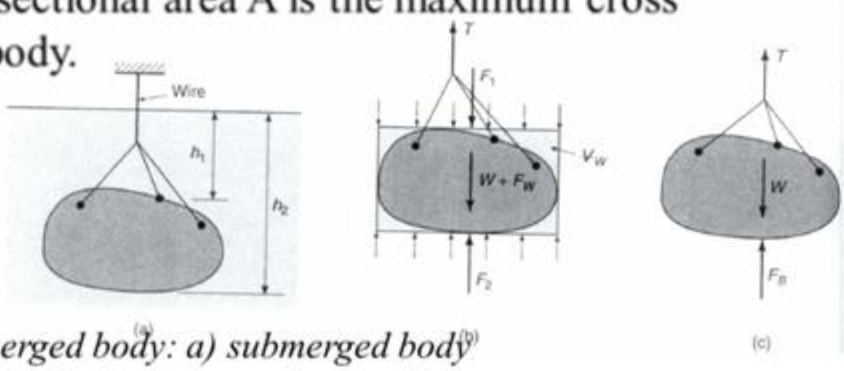


Fig 5.1 Forces on a submerged body: a) submerged body b) free-body diagram c) free-body diagram showing F_B

- From the diagram we see that the resultant vertical force acting on the free-body diagram due to the water only (do not include W as it is supported by wire, force T) is equal to
- $\sum F = F_2 - F_1 - F_W$
- This resultant force is by definition the buoyant force F_B. It can be expressed $F_B = p_2 A - p_1 A - \gamma V_W = \gamma h_2 A - \gamma h_1 A - \gamma V_W$

$$F_B = \gamma\,(h_2 A - h_1 A - V_W)$$ **Computed using forces**

- Where V_W is the liquid volume included in the free-body diagram. Recognising that the volume of the submerged body is

$$V_B = (h_2 - h_1)A - V_W)$$

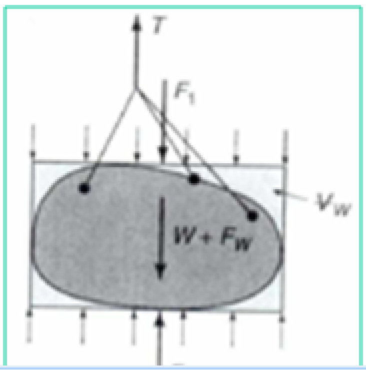
Computed using volume (geometry
Right handside equal to term in brackets of above eqn of F_B. Theref
put V_B into eqn of F_B.

We see that $F_B = \gamma\,(h_2 A - h_1 A - V_W) = \gamma V_B$

$$= \gamma V_{displaced\ liquid}$$

thereby proving the law of buoyancy.

Archimedes' principle is: There is a buoyancy force on an object equal to the weight of displaced liquid.



c) Distinguish between the Lagrangian and Eulerian descriptions of motion. (3 marks)
Lagrangian – in the study of particle mechanics, where attention is focused on an individual particle, the particle is observed as a function of time while in Eulerian a point is identified in space and then the velocity of particles passing the point is observed

d) Briefly explain what happens to the water level in the pitot tube when the velocity of water in the river reduces. (2 marks)

The water level in the pitot tube will also reduce

e) Explain the type of acceleration which occurs when there is incompressible fluid flow. (3 marks)

With incompressible fluid flow, there is convective acceleration wherever the effective flow area changes along the flow path resulting in increase/decrease of velocity

f) State the assumptions in the Bernoulli equation. (4 marks)

- Inviscid fluid (no shear stresses-no friction). An inviscid flow is the flow of an ideal fluid
- Steady flow ($\partial V/_{dt} = 0$)
- Along a streamline ($a_s = V\frac{\partial V}{\partial s}$)
- Constant density $\left(\partial\rho/_{\partial s} = 0\right)$

g) Given the equation $\lim_{\Delta t \to 0} \frac{N_{2,t+\Delta t} - N_{2,t}}{\Delta t}$ in derivation of the control volume equation, state what happens to region 2 as Δt approaches zero. (3 marks)

Region 2 approaches that of the control volume

Question 3

A cube of wood (s.g. = 0.60) has 22.5cm sides. Compute the magnitude and direction of the force F required to hold the wood completely submerged in water.

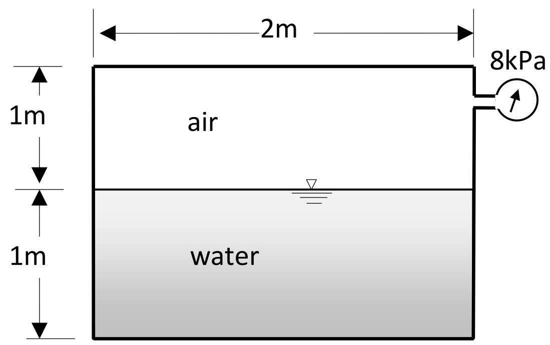
6.8 A cube of wood (s.g. = 0.60) has 9-in sides. Compute the magnitude and direction of the force F required to hold the wood completely submerged in water.

Since s.g.$_{\text{wood}}$ = 0.60, it is evident that the wood will float in water. Therefore, a force F acting downward will be required to hold the wood in equilibrium and completely submerged. The forces acting on the wood are essentially the same as those shown acting on the concrete cube in Fig. 6-2a: $\sum F_y = 0$, $F + W - F_b = 0$, $F + [(0.60)(62.4)][(\frac{9}{12})(\frac{9}{12})(\frac{9}{12})] - 62.4[(\frac{9}{12})(\frac{9}{12})(\frac{9}{12})] = 0$, $F = 10.5$ lb (downward).

Question 4

The cubic tank shown is half full of water. Find

a) The pressure on the bottom of the tank
b) The force exerted by the fluids on a tank wall
c) The location of the center of pressure.



Question 5

A gas flows through a square conduit. At one point along the conduit, the conduit sides are 0.120m, the velocity is 17.55m/s and the gas' mass density is (for its particular pressure and temperature) 1.1kg/m^3. At a second point, the conduit sides are 0.240m and the velocity is 12.02m/s. Find

a) the mass flow rate of the gas
b) the gas' mass density at the second point.

7.16. A gas flows through a square conduit. At one point along the conduit, the conduit sides are 0.100 m, the velocity is 7.55 m/s, and the gas's mass density is (for its particular pressure and temperature) 1.09 kg/m³. At a second point, the conduit sides are 0.250 m and the velocity is 2.02 m/s. Find the mass flow rate of the gas and the gas's mass density at the second point.

Solution:

$$M = \rho_1 A_1 V_1 = (1.09)[(0.100)(0.100)](7.55) = 0.0823 \text{ kg/s}$$

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$0.0823 = (\rho_2)[(0.250)(0.250)](2.02)$$

$$\rho_2 = 0.652 \text{ kg/m}^3$$

USEFUL HINTS

$$\mathrm{Re} = \frac{vD}{\upsilon}$$

$$\frac{dN_{sys}}{dt} = \frac{d}{dt}\int_{cv} \eta\, \rho\, dV + \int_{cs} \eta\, \rho\, (\vec{v}\, d\vec{A})$$

$$\bar{y} = \frac{1}{A}\int_{A} y\,dA$$

$$I_x = \int_{A} y^2\,dA$$

$$I_x = \bar{I} + A\bar{y}^2 \qquad F\alpha\frac{AU}{Y}$$

END OF TEST