Elementary Fluid Mechanics CEE 357-02
Fall 2019
Exam 1

Circle the correct answer

1. (**1pt**) A measure by which a physical variable is expressed quantitatively is a
(a) continuum
(b) unit
(c) dimension

2. (**1pt**) A newtonian fluid
(a) increases its resistance at a higher rate with increasing strain rates
(b) follows proportional resistance with increasing strain rate
(c) is less resistant at higher strain rates

3. (**1pt**) The limiting volume for defining the properties of a fluid is usually set to about ____________.

10^{-9} mm^3

Solve and show your work.

4. (**30 pts**) A compressed air tank has a volume of 0.84 ft^3. The tank is filled with air at gage pressure of 50 psi and a temperature of 70°F. The atmospheric pressure is 14.7 psi (abs).

Find: Determine the density of the air and the weight of air in the tank.

$$\rho = \frac{p}{RT} \qquad (5pts)$$

$$\rho = \frac{\left(50\frac{lb}{in^2} + 14.7\frac{lb}{in^2}\right) * (144\frac{in^2}{ft^2})}{\left(1716\frac{ft\ lb}{\text{slug°R}}\right)[(70+460)\text{°R}]} \qquad (5\ pts)$$

$$\rho = 0.0102\frac{slugs}{ft^3} \qquad (5pts)$$

Weight = $\rho\ g\ x\ volume$ $\qquad (5pts)$

$= 0.0102\frac{slugs}{ft^3}\ x\ \left(32.2\frac{ft}{s^2}\right) * (0.84\ \text{ft3}) \qquad (5pts)$

$=0.276\frac{slugs*ft}{s^2}$

Weight = 0.276 lb, since 1 slug*ft/s^2 (5 pts)

Circle the correct answer

5. (**1 pt**) ____________ is frequently used to measure atmospheric pressure, especially in forecasting weather.

(a) A barometer

(b) A manometer

(c) A piezometer

6. (**1 pt**) If a floating body is stable, that indicates that for small disturbances its metacentric height is _______.

(a) zero

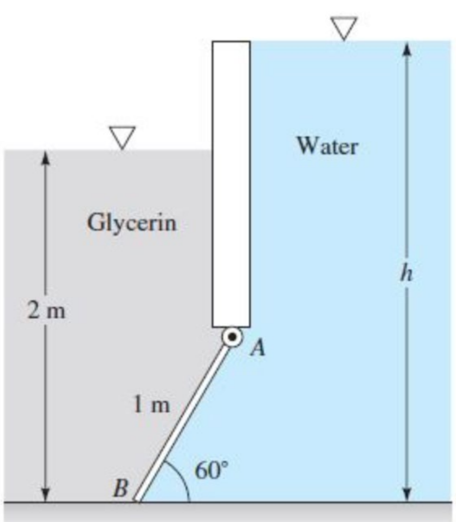
(b) positive

(c) negative

Solve and show your work.

7. Hydrostatic forces on plane surfaces. (**32 pts**)

Gate AB in the given image is a homogeneous mass of 930 kg, 1.2 m wide, hinged at A, and resting on a smooth bottom at B. All fluids are at 20°C. Let γ (glycerine) = 12360 N/m3. For what water depth h (in m) will the force at point B be zero?



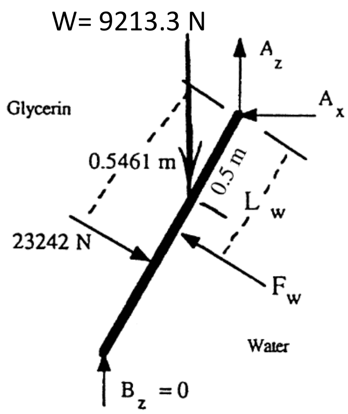
Assume AC (vertical distance of Gate AB) is equal to (AB)sinθ= (1m)(sin 60 degrees) = 0.86666

$Gate_{CG}$ = Vertical Projection Halfway point. = 0.866/ 2 = 0.433

CENTROID OF AB is 0.433 m vertically below A.
so h_{CG} = 2.0 m – 0.433 = 1.567 m below surface of water.
(5pts)

Let $\gamma_{glycerin}$ = 12360 N/m^3 for glycerin and 9790 N/m^3 for water.
The force is estimated by the relation:
$F_g = \gamma \, \bar{h} \, A$ = (12360) (1.567)(1*1.2) = 23242 N (5pts)

The line of action is given by $y_{CP,g} = -\frac{(1/12)(1.2)(1)^3 \sin 60°}{(1.567)(1.2)}$ = -0.0461 m (6pts)



$F_w = \gamma\, \bar{h}\, A = (9790)\,(h_{CG,w})(1*1.2)$

$$y_{CP,g} = -\frac{(1/12)(1.2)(1)^3 \sin 60°}{(h_{CG,w})(1.2)} = -\frac{0.0722}{h_{CG,w}} \qquad (5pts)$$

The weight of the gate, W= 930 (9.81) = 9213.3 N acts at the centroid, as shown above. The horizontal force at B equals zero. Sum moments counterclockwise about A to find the water depth.

$$\sum M_A = 0 = (23242)(0.5461) + (9213.3)(\cos 60)(0.5) - (9790)(h_{CG,w})(1.2\times 1)(0.5 + 0.0722/h_{CG,w})$$

$$(9790)(h_{CG,w})(1.2\times 1)(0.5 + 0.0722/h_{CG,w}) = 14995.8$$

$$(11748)(h_{CG,w})(0.5 + 0.0722/h_{CG,w}) = 14995.8 \qquad (5pts)$$

$$(11748)(h_{CG,w})(0.5 + 0.0722/h_{CG,w}) = 14995.8$$

$$(5872 h_{CG,w} + 848.2) = 14995.8$$

$$(h_{CG,w}) = 14995.8/5874 = 2.408\ m$$

Solve for $h_{CG,w} = 2.408m$, $or \quad h = h_{CG,w} + 0.433 = 2.84\ m$, When h = 2.84m, the force at point B will be zero. (6pts)

Circle the correct answer

8. The conversion of a system analysis to a control volume analysis through mathematical interpretation focusing on a specific region rather than individual masses is referred to as?

(a) Reynolds Number

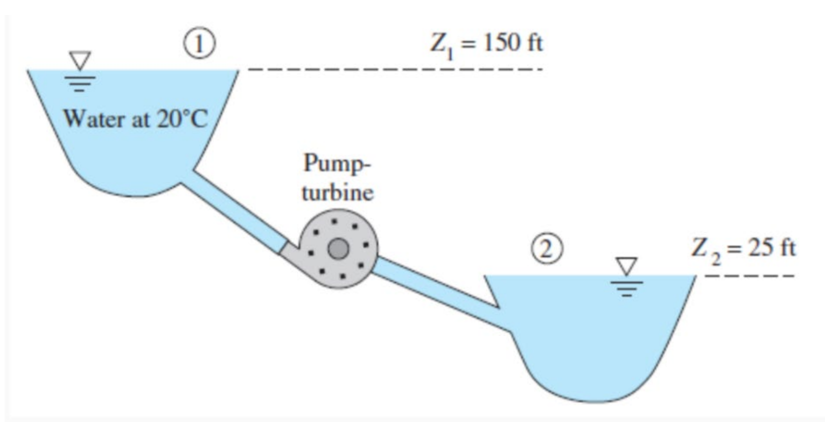
(b) Reynolds transport theorem

(c) Manning's Equation

Solve and show your work.

9. Energy **(32 Pts)**

The pump-turbine system in the figure given below draws water from the upper reservoir in the daytime to produce power for a city. At night, it pumps water from lower to upper reservoirs to restore the situation. For a design flow rate of 24600 gal/min in either direction, the friction head loss is 17 ft. Estimate the power (a) extracted by the turbine and (b) delivered by the pump.



Solution (a) with turbine, "1" is upstream:

$$\frac{p_1}{\rho g}+\frac{{V_1}^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{{V_2}^2}{2g}+z_2+h_f+h_t \qquad (5pts)$$

Or: $$0+0+150=0+0+25+17+h_t \qquad (5pts)$$

24600 gal/min = 24600 gal/min (6.3090 E-5 $m^3s^{-1}/(gal*min^{-1})$)(35.314 ft^3/s)= 54.8078 ft^3/s

Solve for P (Power)

P = $\gamma Q h_t=(62.4)(54.8)(108)=369{,}308\ \frac{ft\cdot lbf}{s}=671.5\ hp \qquad (6pts)$

Solution (b) with pump, "1" is downstream:

$$\frac{p_1}{\rho g}+\frac{{V_1}^2}{2g}+z_1+h_p=\frac{p_2}{\rho g}+\frac{{V_2}^2}{2g}+z_2+h_f \qquad (5pts)$$

Or: $$0+0+25\ +h_p=0+0+150+17 \qquad (5pts)$$

Solve for P (Power)

P = $\gamma Q h_p=(62.4)(54.8)(142)=485{,}572\ \frac{ft\cdot lbf}{s}=882.85\ hp \qquad (6pts)$

--------------BONUS----------------------

Bonus (2 points): If there is a control volume with an area (A_1, with a diameter of 10 cm, 78.54 cm^2, .007854 cm^2) for the inlet and an area (A_2, with a diameter of 20 cm, 314.16 cm^2, 0.031 m^2) for the outlet and the velocity of the inlet is 2 m/s, find the velocity of the outlet for an incompressible fluid at steady state. The person would have to assume that dm/dt = 0

Q1=Q2
(0.007854*2)= (0.031 *V_2)
V2= 0.50 m/s

Bonus (2 points): Find the absolute pressure 60 m below a salt-water lake in SI units (Pa), where the mean atmospheric pressure is 1 atm.

P = pa -gamma *z
P = 101,300 Pa – (10,060 N/m2)*(-60)
P= 704,900 Pa

Bonus (2 points): You are pouring cooking oil and water into a pot at the same time. You notice that the oil is coming out of the bottle much slower than the water. Does this mean that the oil has a higher or lower viscosity than the water?
Higher