# CE 3305 – Fluid Mechanics Exam 1

## Purpose

Demonstrate ability to apply fluid mechanics and **problem solving principles** covering topics such as: Fluid properties, viscosity, vapor pressure, fluid statics and pressure.

## Instructions

1. Put your name on each sheet you submit.
2. Begin each problem on a separate page.
3. Use the problem solving protocol in the class notes.
4. Label answers, be sure to include units.

## Allowed Resources

1. Your notes
2. The textbook
3. The mighty Internet
4. **You may not communicate with other people during the exam**

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ANY PAGE MISSING NAME (-1) PT.

RAW PTS — Use these

p1 24 ~ 29 pts
p2 26 ~ 31 pts
p3 33 ~ 40 pts
83

GRADE USING RAW PTS. AS SHOWN; ADD BELOW

p1 +5
p2 +5
p3 +7

24 pts – problem 1

 Name: NAME (+1) P. olar Bear

1. Argon gas is used as a sheilding gas for welding for fabrication of metal objects. A 200-liter tank has an empty ~~weight~~ mass of 50 kg.

   Determine:

   (a) The total weight of the 200-liter tank of argon at a pressure of 3,500 psia at a temperature of 313$^o$K.

   (b) The argon pressure if the tank is submersed in the North Sea to repair an underwater pipeline, where the ambient water temperature is 6$^o$C

   (c) The additional ballast (~~weight~~ mass) required for the tank to be neutrally bouyant in seawater ($\rho_{sw} = 1025 \frac{kg}{m^3}$)

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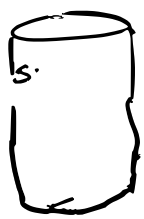
SKETCH (+1) FOR "SKETCH"



200L  $p = 3500$ psia
$m_T = 50$ kg  $T = 313K$
$m_g = ?$

KNOWNS (+3) FOR "KNOWN" SECTION + 2 KNOWN VALUES

$V = 200L$
$m_T = 50$ kg (given)

UNKOWNS (+4) FOR "UNKNOWN" SECTION + 3 UNKNOWNS (BALLAST)

$m_g = ?$  $m_B = ?$ so. $W_T + W_G + W_B = F_B$

$p(@T = 6°C)$

## GOVERNING EQUATIONS

(+4) "GOVERN..." SECTI AND ID NEEDED VALUES

P.O.B

$$p\forall = \frac{m_g}{M} R T$$

$M_{argon} = 39.96$ (IUPAC website)

$$R = 0.0821 \frac{L \cdot atm}{K \cdot mol}$$

## SOLUTION

+

(a)

$\forall = 200L$

$T = 313K$

$$p = 3500 psia * \frac{1 atm}{14.75 psia} = 237.28 atm$$

$M = 39.96$

Solve for $m$

(+1) Formula & algebra

$$m_g = \frac{p\forall M}{RT} = \frac{(237.28 atm)(200L)(39.96 g/mol)}{0.0821 \frac{L \cdot atm}{K \cdot mol} 313K}$$

$$m_g = 73,797.9 g$$

$$= 73.8 kg$$

$$W_{TOTAL} = m_g g + m_T g = (73.8 kg + 50 kg) 9.8 m/s^2$$

$$= (123.797 kg)(9.8 m/s^2) = 1213.22 N$$

(+2) value & units

b) T reduced to 6°C = 279K P.O.B

$$p = \frac{73.8 \cdot 10^3\ g}{39.96\ g}\left(0.0821\ \frac{L \cdot atm}{K \cdot mol}\right)(279K) \Big/ 200L$$

$$= 211.52\ atm\ \frac{14.75\ psia}{1\ atm} = \underline{\underline{3119.84\ psia}}$$

(+3) value & unit, must identify absolute or gage

c) Neutral Bouyant Mass

(+1) Formula

$$F_B = W_{TOTAL} = W_{TANK} + W_{BALLAST}$$

$$F_B = \left(1025\ \frac{kg}{m^3}\right)\left(9.8\ m/s^2\right)(200L)\left(\frac{1\ m^3}{1000L}\right)$$

(+1) arithmetic

$$F_B = 2009N$$

$$W_T = 1213.22N$$

∴ Need 795.78N of ballast

$$m_{BALLAST} = \frac{795.78N}{9.8\ m/s^2} = \underline{\underline{81.2\ kg}}$$

(+2) value & unit

DISCUSSION (+1) "ANY DISCUSSION" even just the word!

Application of IGL and definition of bouyant force.

~ 26 pts

 Name: P. Olar Bear

2. The figure below is a schematic of a sliding plate viscometer used to measure the viscosity of a fluid. The top plate is moving to the right with a constant velocity in response to a force of 3 Newtons.

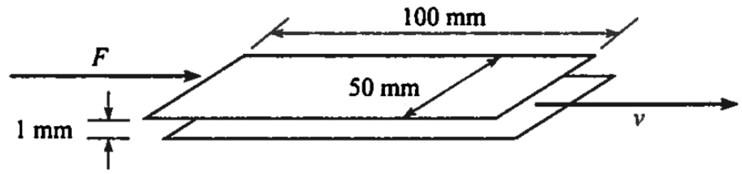



Figure 1:

Determine:

(a) The speed of the plate if the viscosity is $\mu = 5 \times 10^{-2}\ \frac{N \cdot s}{m^2}$

(b) The speed of the plate if the viscosity is $\mu = 7 \times 10^{-2}\ \frac{N \cdot s}{m^2}$

(c) The viscosity if the speed of the plate is 10.001 $\frac{m}{s}$

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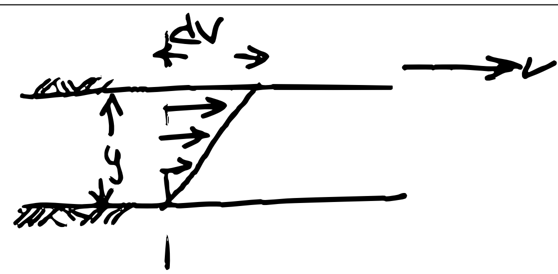
SKETCH




(+3) sketch i.d. y axis i.d. velocity profile

KNOWN

$\mu = 5 \cdot 10^{-2} \frac{Ns}{m^2}$ ; $7 \cdot 10^{-2} \frac{Ns}{m^2}$ (given)

$y = 0.001\,m$ (given); $F = 3N$ (given)

$A = 50 \times 100\ mm^2 \cdot \frac{1\,m^2}{(1000m)^2} = 0.005\,m^2$

(+6) known + 5 values

## UNKNOWNS

dV (Top plate velocity) — (+2) "UNKNOWN" +1 velocity seek

## GOVERNING EQUATIONS

(+3) – Defn $\tau$ force, Defn $\tau$ slope du/dy

Defn. Viscosity $\tau = \mu \frac{dV}{dy}$ $\tau = F/A$

## SOLUTION

$$\tau = \frac{F}{A} = \frac{3N}{0.005m^2} = 600 N/m^2$$ (+2) value + UNIT

$$\tau = \mu \frac{dV}{dy}; \quad dV = \frac{\tau\, dy}{\mu}$$

a) $$dv = \frac{(600 N/m^2)(0.001 m)}{5 \cdot 10^{-2} \frac{N \cdot s}{m^2}}$$ (+1) arithmetic

$$= 1.2 \cdot 10^{1} m/s = \underline{\underline{12 m/s}}$$ (+2) value & unit

b) $$dv = \frac{(600 N/m^2)(0.001 m)}{7 \cdot 10^{-2} \frac{N \cdot s}{m^2}}$$ (+1) arithmetic

$$= \underline{\underline{8.57 m/s}}$$ (+2) value & unit

c)

c) VISCOSITY TO PRODUCE

$dV = 10.001$ m/s

$$\mu = \tau \frac{dy}{dV}$$

$$\mu = \left(\frac{600 N}{m^2}\right) \frac{(0.001 m)}{(10.001 m/s)}$$

(+1) arithmetic

$$= 5.99 \cdot 10^{-2} \frac{N \cdot s}{m^2}$$

(+2) value & unit

DISCUSSION:

- VARIOUS APPLICATION DEFN. VISCOSITY. NEED SHEAR STRESS AND IMPLICIT ASSUME LINEAR VELOCITY PROFILE IN FLUID

(+1) word "discussion"

ANY discussion as EC, but rest needs to be right.

~33pts



3. A large atmospheric tank used for quenching rocket motors is filled with a Class A auto-foaming fire supressant liquid (specific weight 7595 N/m$^3$). The supressant is restrained by a circular gate as shown.[1]

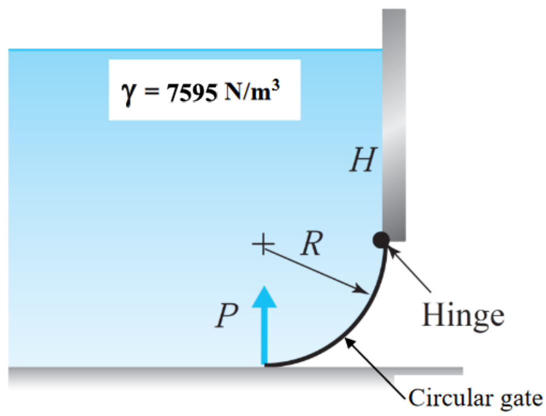



Figure 2:

The dimensions of interest are: R = 1.5 m, H = 6 m, Gate width (into the plane of the image) b = 3 m.

Determine:

(a) The liquid pressure at the hinge.

(b) The liquid pressure at the bottom of the gate

(c) The horizontal and vertical force of the liquid acting on the circular gate

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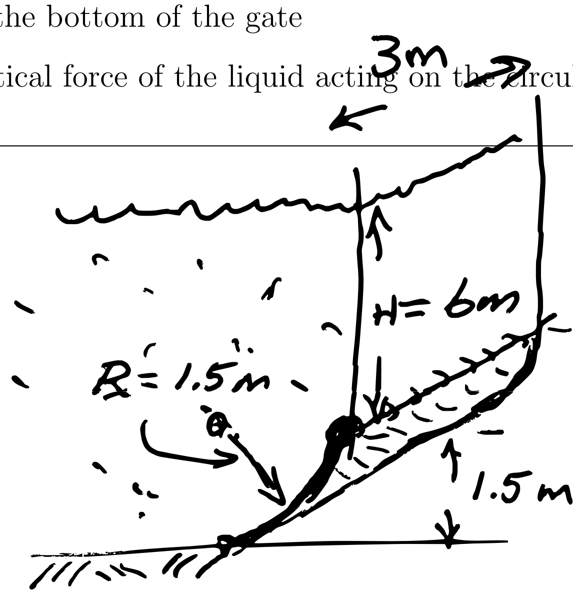
SKETCH




+3
Dimensions & sketch

[1] When a rocket motor quench is needed, the gate is lifted and the suppressant rapidly flows over the test area.

Name

## KNOWN

$H = 6m$ $\quad W = 3m$

$R = 1.5m$

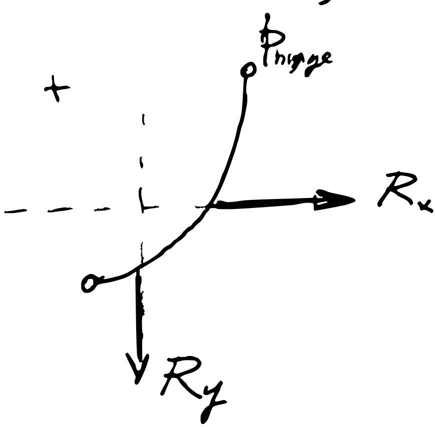
$\gamma = 7595 \frac{N}{m^3}$

(+5) "KNOWN" + 4 knowns.

## UNKNOWN

$p_{@HINGE}$, $R_x$, $R_y$ (and line of action)

(+3) "UNKNOWN" + 3 SOUGHT VALUES DRAWING OPTIONAL

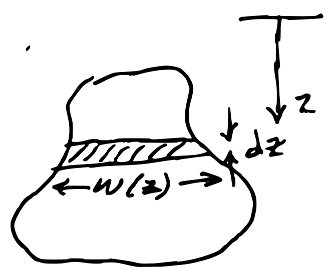



## GOVERNING EQUATION

$p = p_0 + \rho g h$ (HYDROSTATIC EQUATION)

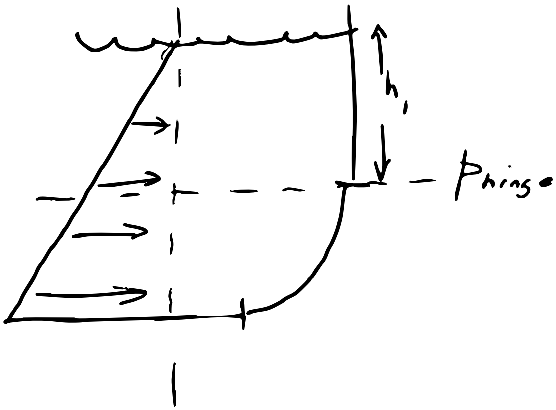
$F_V = \rho g \forall_{above\ surface}$

$F_H = \int_{z_1}^{z_2} p(z)\, w(z)\, dz$




(+7) "GOVERNING ...." AND THREE PRINCIPLES, NARRATIVE OK; DRAWING OPTIONAL

SOLUTION




FORMULA & ARITHMETIC (+2)

$$p_{hinge} = p_0 + \rho g h_1$$

$$p_{hinge} = p_0 + 7595 \frac{N}{m^3} \cdot 6m$$

$$p_{hinge} = 0 + 45570 \frac{N}{m^2} \sim 45.5 \text{ kPa}$$

VALUE & UNIT (+2)

$$p_{bottom} = p_{hinge} + \rho g R$$

FORMULA & ARITHMETIC (+2)

$$= 45570 \frac{N}{m^2} + 7595(1.5)$$

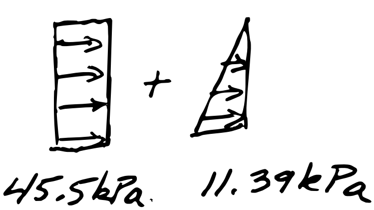
$$= 45570 + 11392.5 \frac{N}{m^2}$$

$$= 56962.5 \text{ Pa}$$

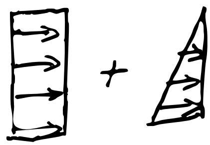
$$\sim 56.9 \text{ kPa}$$

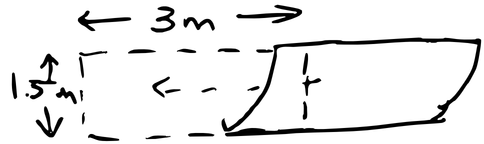
VALUE & UNIT (+2)

Applied Pressure



## Applied Pressure




$F_H = pA = 45570(1.5)(3) + 11392.5(1.5)(3)(\frac{1}{2})$

↑ TRIANGLE PRESSURE PRISM

FORMULA & ARITHMETIC +3

OK IF USE $F = \gamma \bar{h} A$

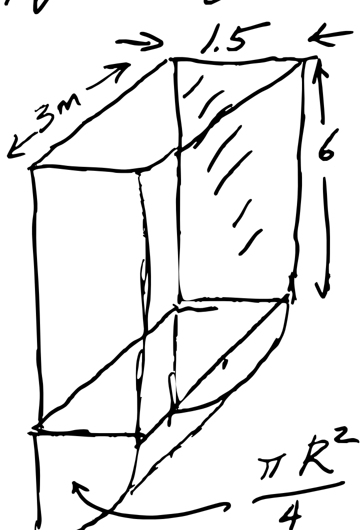
$= 205065\text{N} + 25633.125\text{N}$

$= 230698.13\text{N}$

$\sim 230.7\text{kN}$

+2 VALUE & UNIT

$F_V$ = weight of water over gate




$\forall = (3)(1.5)(6) + (3)(\frac{\pi}{4})(1.5)^2$

$= 32.301 \text{ m}^3$

FORMULA & ARITHMETIC +3

SKETCH OPTIONAL

$F_V = 7595\frac{\text{N}}{\text{m}^3}\, 32.301\text{m}^3 = 245,329.42\text{N}$

$\sim 245\text{kN}$

+2 VALUE + UNIT

SOLUTION SUMMARY

a) PRESSURE AT HINGE

$p_H = 45.5$ kPa

b) PRESSURE AT BOTTOM

$p_B = 56.9$ kPa

c) $F_H = 230.7$ kN

d) $F_V = 245$ kN

DISCUSSION

i) Applied hydrostatic eqn. for pressures. defn of force as $p * A'$ for forces

ii) LINE OF ACTION NOT EXPLICITLY REQUESTED!