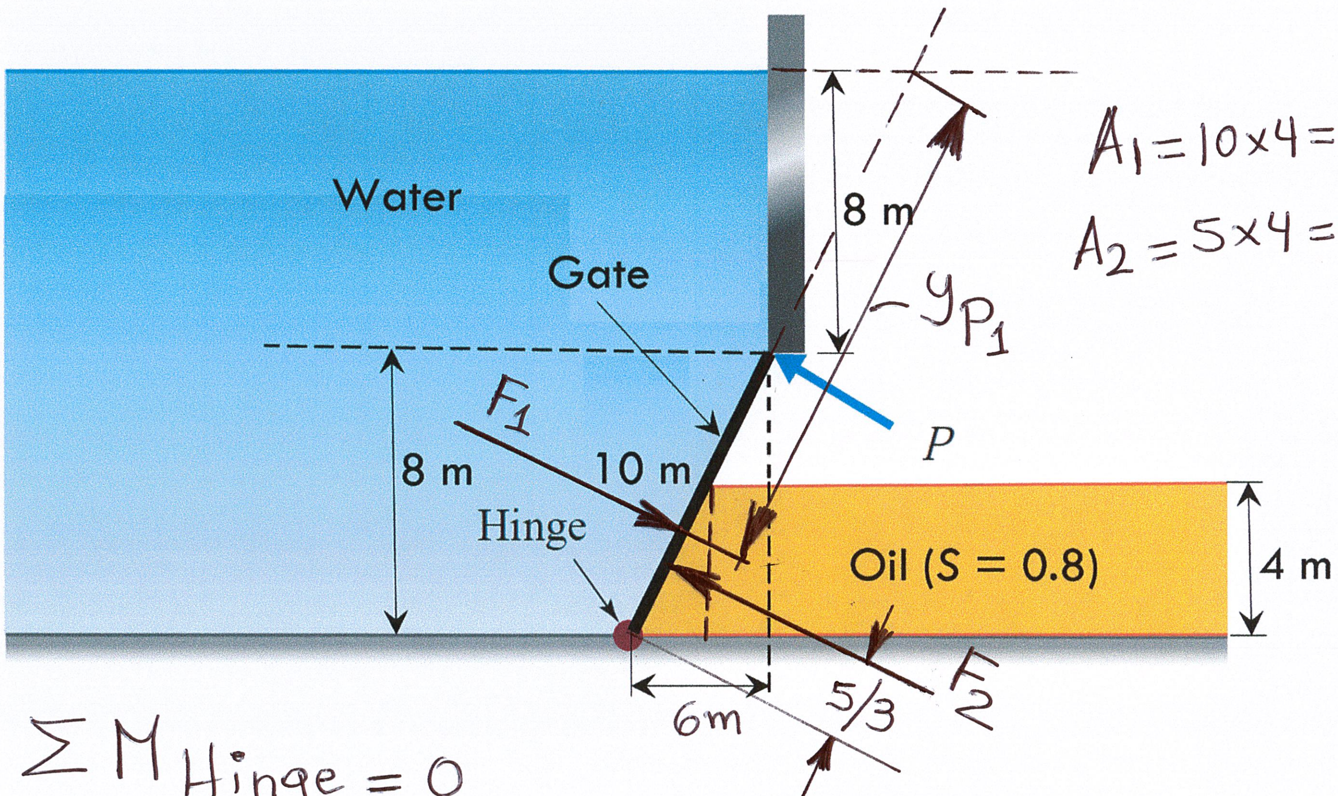
Florida International University
CWR 3201 Fluid Mechanics, Fall 2021
Mid-term # 1

Instructor: Arturo S. Leon, Ph.D., P.E., D.WRE

Student Name: Arturo Leon **Panther ID:** ____________

✓ **You will have 50 minutes to complete the exam. The exam is closed book and closed notes. Only one page (front and back) with handwritten equations are allowed**

1. **(35 points)** Determine the force "*P*" needed to hold the 4-m wide gate in the position shown below.



$A_1 = 10 \times 4 = 40\ m^2$

$A_2 = 5 \times 4 = 20\ m^2$

$\Sigma M_{Hinge} = 0$

$P(10) + F_2\left(\frac{5}{3}\right) = F_1(20 - y_{P_1}) \quad \ldots (1)$

$F_1 = \gamma_w \bar{h}_1 A_1 = 1000 \times 9.8 \times \left(8 + \frac{8}{2}\right) \times 40 = 4704\ kN$

$F_2 = S\gamma_w \bar{h}_2 A_2 = 0.8 \times 1000 \times 9.8 \times \left(\frac{4}{2}\right) \times 20 = 313.6\ kN$

$$* \; y_{p_1} = \bar{y}_1 + \frac{\bar{I}_1}{A_1 \bar{y}_1}$$

$$\bar{y}_1 = 10 + \frac{10}{2} = 15\,m$$

$$\bar{I}_1 = \frac{4 \times 10^3}{12}$$

$$y_{p_1} = 15 + \frac{4 \times 10^3}{12 \times 40 \times 15}$$

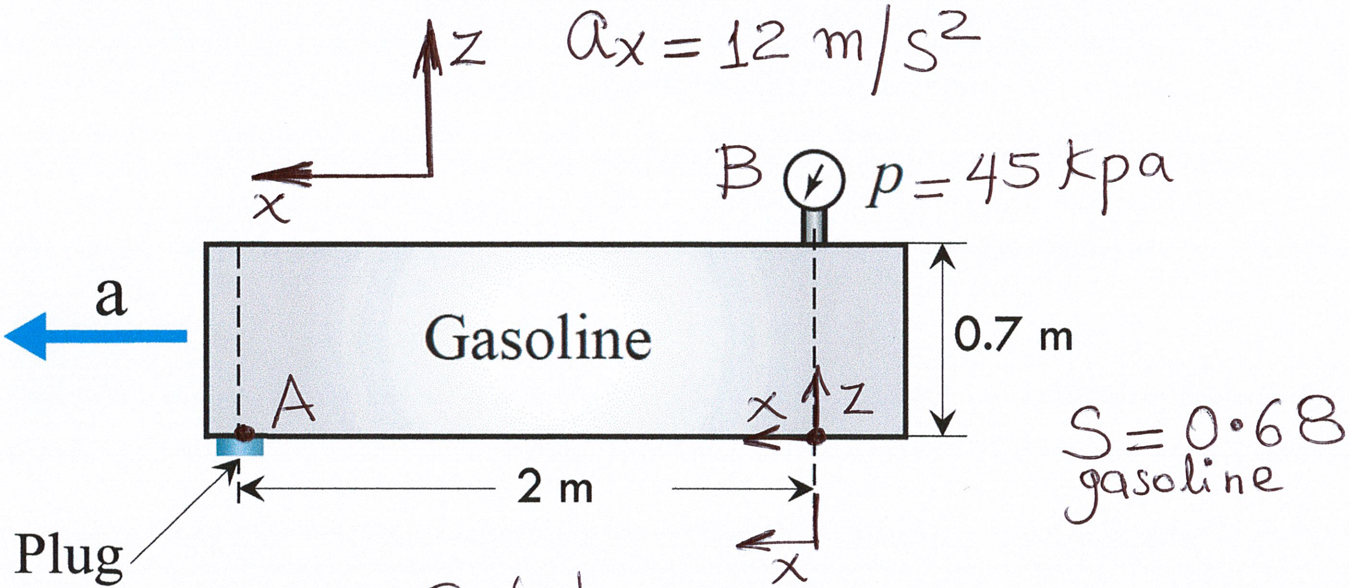
$$\boxed{y_{p_1} = 15.56}$$

In ①

$$P(10) + 313.6\,KN \left(\frac{5}{3}\right) = 4704\,(20 - 15.56)$$

$$\therefore \; \boxed{P = 2036.3\ KN}$$

2. **(30 points)** The gasoline tank below, with an initial pressure of $p = 45$ kPa, is accelerated to the left at a rate of 12 m/s^2. What is the force on the 3-cm-diameter plug show below? The density of gasoline is 680 kg/m^3 ($S = 0.68$).



Solution

$$dp = -\rho a_x dx - \rho(\cancel{a_z}^{\,0} + g)\,dz$$

$$P_A - P_B = -\rho a_x (X_A - X_B) - \rho g (Z_A - Z_B)$$

$$P_A - 45{,}000 = -680(12)[2-0] - 680 \times 9.8(0 - 0.7)$$

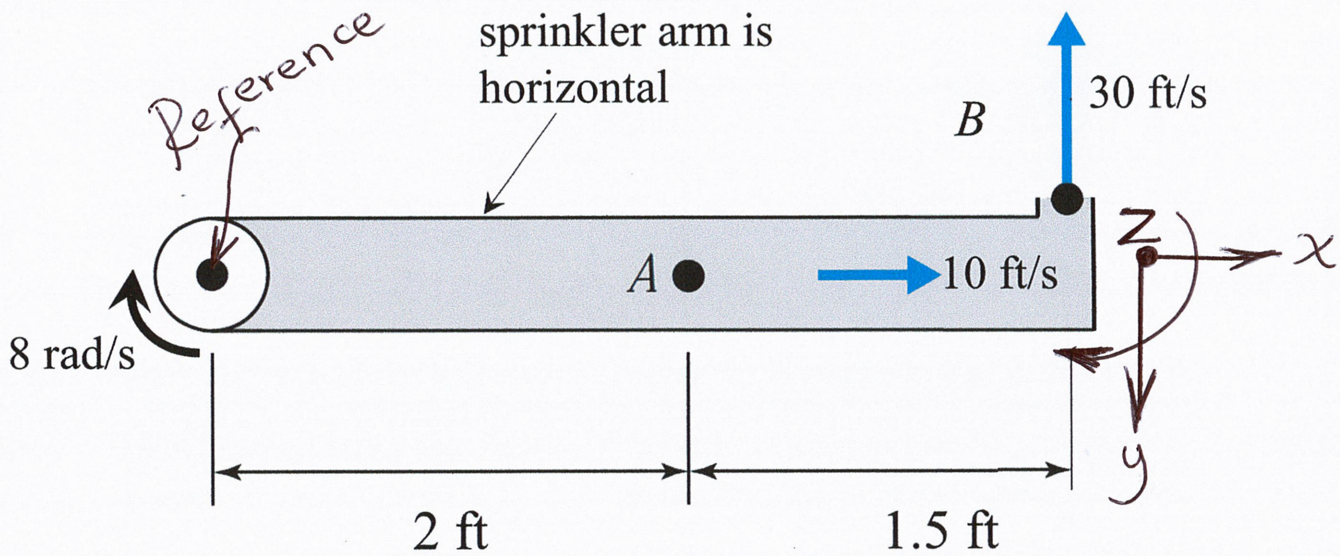
$$P_A = 33{,}344.8 \text{ Pa}$$ ← This is the pressure at the plug.

* Force at plug = P_A * Area

$$F = 33344.8 \times \pi \times \frac{0.03^2}{4} = 23.6 \text{ N}$$

3. **(35 points)** For the flow shown below, relative to a fixed reference frame, find the acceleration of a fluid particle at Point A. **The sprinkler arm is horizontal**. **Hint:** Make sure your coordinate system follows the **right-hand rule**.

PLAN VIEW of SPRINKLER



$\Omega_Z = 8\hat{k}$

$\vec{r}_A = 2\hat{i}$, $\vec{V}_A = 10\hat{i}\ \frac{ft}{s}$

$$\vec{A} = \vec{a} + \cancelto{0}{\frac{d^2\vec{S}}{dt^2}} + 2\vec{\Omega}\times\vec{V} + \vec{\Omega}\times(\vec{\Omega}\times\vec{r}) + \cancelto{0}{\frac{d\vec{\Omega}}{dt}\times\vec{r}} \quad \ldots (1)$$

(Reference frame is not accelerating)

$$\vec{a}_A = \cancelto{0}{\frac{\partial \vec{V}_A}{\partial t}} + u\cancelto{0}{\frac{\partial \vec{V}_A}{\partial x}} + v\cancelto{0}{\frac{\partial \vec{V}_A}{\partial y}} + w\cancelto{0}{\frac{\partial \vec{V}_A}{\partial z}} = 0$$

In (1)

$$\vec{A} = 0 + 2\vec{\Omega}\times\vec{V} + \vec{\Omega}\times(\vec{\Omega}\times\vec{r})$$

$$A = 2(8\hat{k} \times 10\hat{i}) + 8\hat{k} \times (8\hat{k} \times 2\hat{i})$$

$\hat{i}\ \hat{j}\ \hat{k}\ \hat{i}\ \hat{j}$

$\ominus\ \oplus$

$$A = 160\hat{j} + 8\hat{k} \times 16\hat{j}$$

$$A = 160\hat{j} - 128\hat{i}$$