Student Name: SOLUTION KEY Student Number:________________

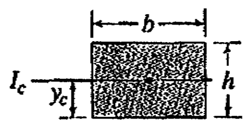
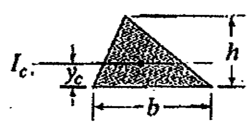
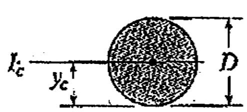
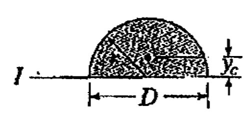
University of British Columbia | *Department of Civil Engineering*
Civil 215, Fluid Mechanics I | October 22, 2008
Time Limit: 2 hours

DO NOT OPEN EXAM UNTIL ASKED TO DO SO!

INSTRUCTIONS:

1. One sheet of paper with writing on one side and a calculator (any kind) allowed.
2. No talking.
3. Do NOT leave during the last 5 minutes of the exam.
4. No cell phones, laptop computers or PDAs.
5. Write solutions directly on the exam.
6. Sign your name and student number on the top of each page.
7. Use the backside of each page as scratch space.
8. Double-check your work, especially consistency of units.
9. Assume $\gamma_W = 9810\ \text{N/m}^3$.

TABLE A.7 **Properties of areas**

Shape	Sketch	Area	Location of centroid	I_c or $I = I_c + Ay_c^2$
Rectangle		bh	$y_c = \frac{h}{2}$	$I_c = \frac{bh^3}{12}$
Triangle		$\frac{bh}{2}$	$y_c = \frac{h}{3}$	$I_c = \frac{bh^3}{36}$
Circle		$\frac{\pi D^2}{4}$	$y_c = \frac{D}{2}$	$I_c = \frac{\pi D^4}{64}$
Semicircle		$\frac{\pi D^2}{8}$	$y_c = \frac{4r}{3\pi}$	$I = \frac{\pi D^4}{128}$

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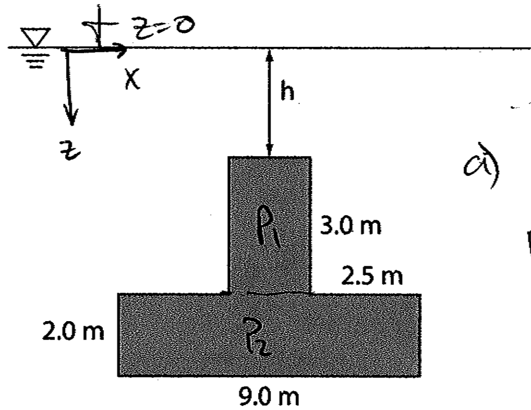
Question 1: (10 marks) A thin T-shaped plate (see below) is submerged in oil (s = 0.86) and lies in a vertical plane. Find the magnitude and depth of the centre of the hydrostatic force acting on one side of the plate if the top of the plate is located 1 m below the surface (h = 1 m).



Divide the problem into 2 panels. (P_1 and P_2):

a) Look at force on P_1:

$$F_1 = s \cdot \gamma_w \cdot h \cdot A + \tfrac{1}{2} \cdot s \cdot \gamma_w \cdot 3.0 \cdot A$$

$$= 0.86 \cdot 9810 \cdot 1(3 \cdot 4) + \tfrac{1}{2} \cdot 0.86 \cdot 9810 \cdot 3 \cdot (3 \cdot 4)$$

$$= 101239.2 + 151858.8$$

$$\boxed{= 253098 \text{ N}} \quad (253.098 \text{ kN})$$

Look at force on panel P_2:

$$F_2 = s \cdot \gamma_w \cdot (1+3) \cdot A + \tfrac{1}{2} \cdot s \cdot \gamma_w \cdot 2 \cdot A$$

$$= 0.86 \cdot 9810 \cdot (4) \cdot 2 \cdot 9 + \tfrac{1}{2} \cdot 0.86 \cdot 9810 \cdot 2 \cdot 2 \cdot 9$$

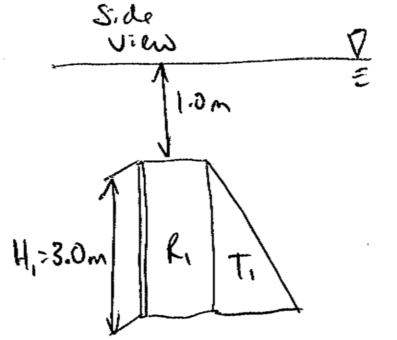
$$= 607435.2 + 151858.8$$

$$\boxed{= 759294 \text{ N}} \quad (759.294 \text{ kN})$$

Total Force $= F_1 + F_2$ $\boxed{= 1012392 \text{ N}}$ (1012.392 kN)

b) Find the resulting location for each panel and then combine. (Top panel first)

Side View



where R and T stand for rectangle and triangle.

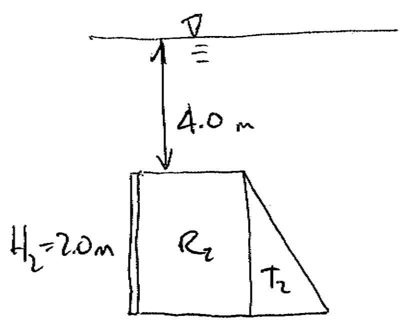
$$y_{PR_1} = d_1 + H_1/2 = 1.0 + 1.5 = 2.5 \text{ m}$$

$$y_{PT_1} = d_1 + \tfrac{2}{3} \cdot H_1 = 1.0 + 2.0 = 3.0 \text{ m.}$$

$$\therefore F_1 \cdot y_{P1} = F_{R1} \cdot y_{PR1} + F_{T1} \cdot y_{PT1}$$

$$\therefore \underline{y_{P1} = 2.8\,m}$$

Location : (For Bottom Panel)



$$y_{PR2} = d_2 + H_2/2 = 5.0\,m$$

$$y_{PT2} = d_2 + \tfrac{2}{3} \cdot H_2 = 4.0 + 1.33 = 5.33\,m$$

$$\therefore F_2 \cdot y_{P2} = F_{R2} \cdot y_{PR2} + F_{T2} \cdot y_{PT2}$$

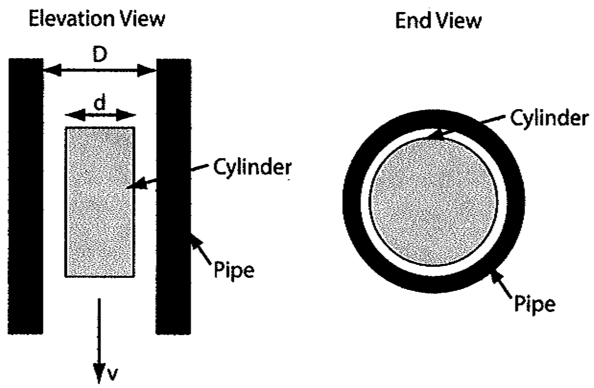
$$\therefore \underline{y_{P2} = 5.066\,m}$$

$$\therefore y_P = \frac{F_1 \cdot y_{P1} + F_2 \cdot y_{P2}}{F_{TOT}}$$

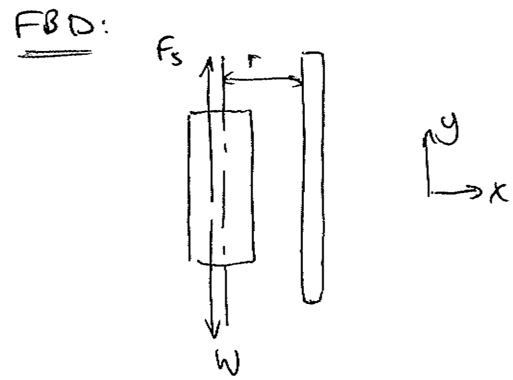
$$\boxed{\therefore y_P = \cancel{4.56}\,m \quad \text{and} \quad x_P = 0}$$

4.50 m

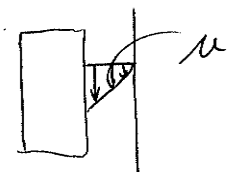
Question 2: (6 marks) A solid cylinder (as shown) with a weight of 30 N, diameter *d* of 100 mm and length *l* of 300 mm is sliding at a velocity of 0.2 m s^{-1} down an oil filled pipe at a steady rate. Using this information, and the fact that the internal diameter of the pipe is 100.2 mm, derive a formula for the steady rate of descent of the cylinder and then determine the viscosity of the oil. Assume a linear variation in the fluid velocity in the space between the cylinder and the pipe.



FBD:



assume linear shear profile:



shear on inner cylinder:

$\tau = \mu \cdot du/dr$ where $du/dr = V/\left(\frac{D-d}{2}\right)$

$\therefore \tau = 2\mu \cdot V/(D-d)$

and shear force $= \tau \cdot A$ where $A = l \cdot \pi \cdot d$

since we know $\Sigma F_y = 0$ then $\tau \cdot A = W$:

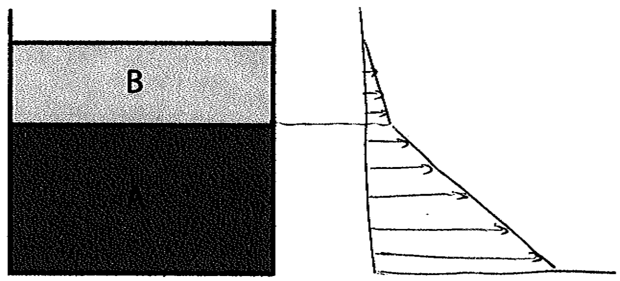
$$\frac{2 \cdot \mu \cdot V}{(D-d)} \cdot l \cdot \pi \cdot d = 30$$

$$\mu = 30 \cdot (D-d) / 2 \cdot V \cdot l \cdot \pi \cdot d$$

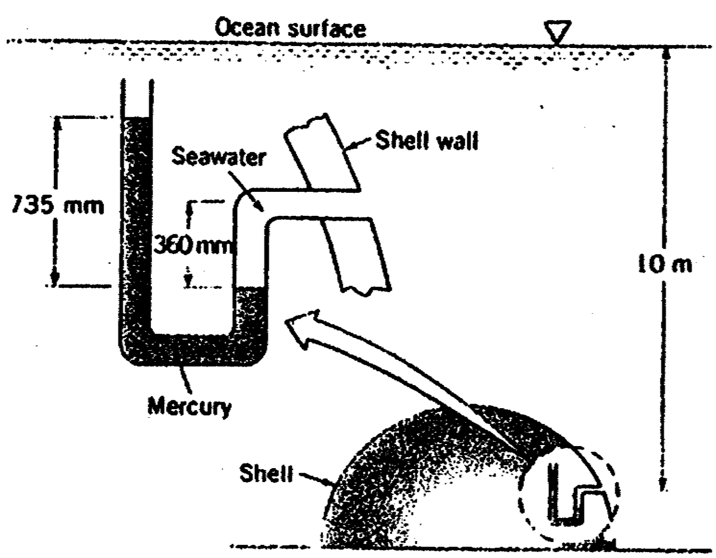
$$\mu = 30 \cdot 2 \times 10^{-4} / 2 \cdot 0.2 \cdot 0.3 \cdot \pi \cdot 0.1$$

$$\boxed{\mu = 1.59 \times 10^{-1} \ N \cdot s/m^2}$$

Question 3: (2 marks) The reservoir shown below contains two immiscible fluids of specific weights γ_A and γ_B, respectively, one above the other (i.e. $\gamma_A > \gamma_B$). Sketch the gage pressure distribution along a vertical line through the two liquids.



Question 4: (6 marks) An air-filled, hemispherical shell is attached to the ocean floor at a depth of 10 m. A mercury barometer located inside the shell reads 765 mm Hg, and a mercury U-tube manometer designed to give outside water pressure indicates a differential reading of 735 mm Hg as illustrated. Based on these data, what is the atmospheric pressure at the ocean surface? Assume that the specific gravity of seawater is 1.03 and of mercury is 13.6.



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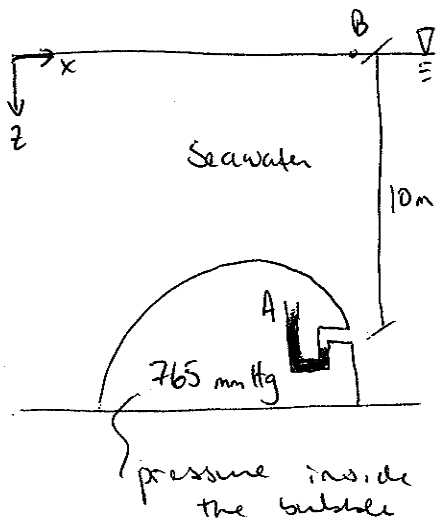
Sketch problem:



$$P_A + \gamma_w \cdot S \cdot 0.735 - \gamma_{sw} \cdot 10 - \gamma_{sw} \cdot 0.36 = P_B$$

$$101991.6 + 13.6 \cdot 9810 \cdot 0.735 - 1.03 \cdot 9810 \cdot 10.36 = P_B$$

$$\therefore P_B = 101991.6 + 98060.76 - 104680.548$$

$$= \underline{\underline{95371.8 \text{ Pa}}}$$

$$\boxed{\therefore P_B = 95.37 \text{ kPa}}$$

Convert pressure inside bubble:

$$\frac{760 \text{ mm Hg}}{765 \text{ mm Hg}} = \frac{101325 \text{ Pa}}{x}$$

$$x = 101991.6 \text{ Pa}$$

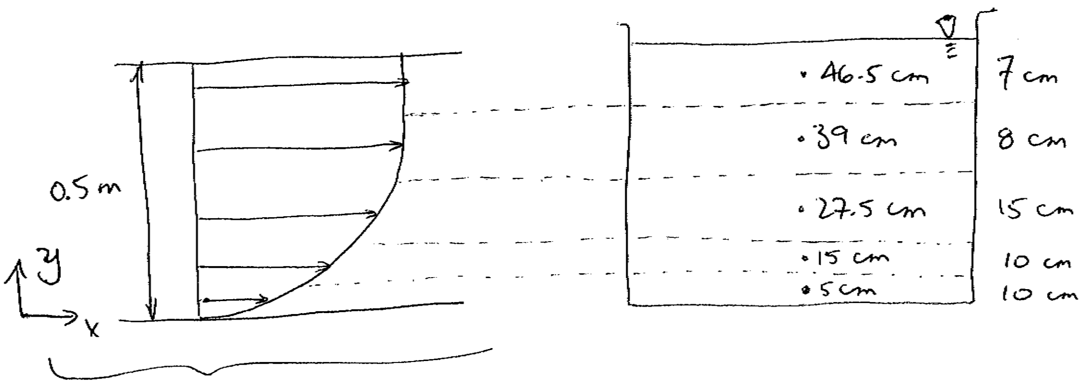
Convert this back to mm Hg:

$$\frac{95371.8}{101325} = \frac{x}{760}$$

$$x = 715.3 \text{ mm Hg}$$

$\therefore$ Atmospheric pressure is 715.3 mmHg.

Question 5: (6 marks) Acid mine drainage (AMD), sometimes known as acid rock drainage (ARD), results from rainwater reacting with sulfate to generate sulfuric acid which corrodes downstream. This water is often collected in concrete channels before being treated. As an entry-level engineer your job is to determine the volumetric flow by making velocity measurements in the channel. The total width of the channel is 1.0 m and the total depth is 0.5 m. Determine what the design flowrate (generally during peak storm events) of the measured velocities are 0.1, 0.18, 0.23, 0.28 and 0.3 m s^{-1} at 0.1, 0.3, 0.55, 0.78 and 0.93 fraction of the total depth respectively.



Need to show profile.

$$Q = \Sigma V_i \cdot A_i$$

$$= 0.1 \cdot 0.1 \cdot 1 + 0.18 \cdot 0.1 \cdot 1 + 0.23 \cdot 0.15 \cdot 1 + 0.28 \cdot 0.08 \cdot 1 + 0.3 \cdot 0.07 \cdot 1$$

$$= 0.01 + 0.018 + 0.0345 + 0.0224 + 0.021$$

$$= 0.1059 \ m^3/s$$

$$\therefore Q = 0.1059 \ m^3/s.$$