Ryerson University
Department of Mechanical & Industrial Engineering

Midterm Exam
MEC516 Fluid Mechanics I

Date: Friday, October, 16, 2015 **Time:** 4:10-6:00 pm (1 hour, 50 minutes)

Examiner: Dr. D. Naylor

INSTRUCTIONS
1. This is a ***CLOSED BOOK TEST***. Materials allowed are limited to: pen, pencil, ruler, and a calculator. A personal equation sheet is NOT allowed.
2. Some helpful equations can be found on the last page of this exam paper.
3. Calculators must be non-communicating and must not be capable of storing formulae.
4. Cell phones, PDAs, etc. are NOT allowed. **Possession of a communication device will trigger charges of academic misconduct.**
5. Students are responsible for keeping track of the time. It is strongly recommended to bring a regular watch to the exam.
6. Answer all questions. The mark values are shown below.
7. A valid student identification card must be presented when attendance is taken.
8. In order to get maximum part marks use the symbols given in the problem statement. Also, be sure to give the proper units on intermediate results.
9. Missing units on final answers will be penalized.

Student Name (**PRINT PLEASE!**): SOLUTIONS & MARKING SCHEME.

Student Number: ____________

Section: ____________

Question	Mark
A1-A4	/12
B1	/10
B2	/8
B3	/10
Total	/40

PART A - MULTIPLE CHOICE QUESTIONS

Each of the questions below is followed by several suggested answers. ***On the exam paper, circle the ONE that is best.*** There is no penalty for incorrect answers.

Questions A1 to A4 are worth **3 marks** each.

A1. In this course, we will be assuming that fluids are "Newtonian". A fluid is considered to be Newtonian if:

(a) The fluid obeys Newton's first and second laws.
(b) The viscosity is not a function of temperature.
(c) The fluid cannot resist shear stress no matter how small.
(d) The viscosity is a function of the velocity gradient but constant over time.
(e) The local fluid shear stress is linearly proportional the local velocity gradient.

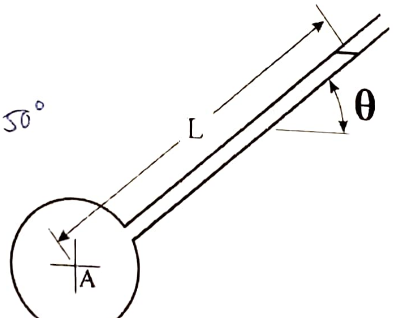
A2. Consider the inclined piezometer attached to a pipe as shown in the sketch below. The pipe is filled with water (ρ=998 kg/m^3). The inclined length of the water column is L=125 cm and the angle is θ=40 degrees. The gauge pressure in the pipe at point A is:

(a) 9.37 kPa (b) 7.87 kPa (c) 12.2 kPa (d) 6.29 kPa (e) 6.12 kPa

$P_A = \gamma L \cos(90-\theta)$

$= (9790\ N/m^3)\ 1.25m \cos 50°$

$= 7.87$ kPa



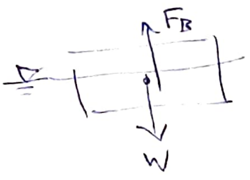
A3. An aluminum part with a volume of 0.12m^3 with a specific gravity of S.G.=2.8 rests on the bottom of an oil tank. The part is fully submerged in oil with specific gravity S.G.=0.85. What is the magnitude of the force exerted by the part on the bottom of the tank?

(a) 0.23 kN (b) 0.33 kN (c) 2.1 kN (d) 2.3 kN (e) 3.3 kN

$F = W - F_b = .12m^3\ 2.8(9790\ N/m^3) - 0.12(.85)9790 = 2.3kN$

A4. A block of wood (S.G.=0.6) floats on the surface of oil with 75 percent of its volume below the water line i.e., 75% submerged. What is the specific gravity (S.G.) the oil?

(a) 0.75 (b) 0.80 (c) 0.85 (d) 0.95 (e) 1.05



$W = F_B$

$\cancel{\forall_{wood}}\ \gamma_{wood} = 0.75 \cancel{\forall_{wood}}\ \gamma_{OIL}$

$\gamma_{OIL} = \dfrac{\gamma_{wood}}{0.75}$ $SG_O = \dfrac{SG_{wood}}{0.75} = \dfrac{0.6}{.75} = 0.80$

$\div \gamma_{water}$

B1. Consider flow at a mean velocity V in a round pipe with an inside diameter D and length L. The fluid has dynamic viscosity μ. For laminar fully developed flow in a round pipe, the pressure gradient along the length of the pipe can be expressed as:

$$\frac{dp}{dx} = \frac{-K\,\mu\,V}{D^2}$$

Using the **four primary dimensions M, L, T and θ**: MUST!

(a) Derive or state the dimensions of each variable (p, x, D, V, μ). **(4 marks)**
(b) Determine the dimensions of the constant K. **(6 marks)**

(a)

$$\{P\} = \left\{\frac{F}{A}\right\} = \left\{\frac{ML/T^2}{L^2}\right\} = \left\{\frac{M}{T^2 L}\right\}$$ 2

$\{x\} = \{L\}$ $\{D\} = \{L\}$ $\{V\} = \{L/T\}$ ½

$$\{\mu\} = \left\{\frac{\tau}{du/dy}\right\} = \left\{\frac{F/A}{du/dy}\right\} = \frac{\left\{\frac{M\cancel{L}}{T^2 L^{\cancel{2}}}\right\}}{\left\{\frac{\cancel{L}}{T\cancel{L}}\right\}} = \left\{\frac{M}{TL}\right\}$$ 1½

(b)

$$K = -\frac{dp}{dx}\,\frac{D^2}{\mu V} \qquad \{K\} = \left\{\frac{dp}{dx}\right\}\frac{\{D^2\}}{\{\mu\}\{V\}}$$

$$\{K\} = \left\{\frac{\cancel{M}}{\cancel{T^2}\cancel{L^2}}\right\}\frac{\{\cancel{L^2}\}}{\left\{\frac{\cancel{M}}{\cancel{LT}}\right\}\left\{\frac{\cancel{L}}{\cancel{T}}\right\}} = \{-\}$$ 6

K IS DIMENSIONLESS

(NOTE: DIMENSIONS DON'T HAVE A SIGN.
THIS WAS A COMMON ERROR)

2. A mercury manometer is connected from Tank A to Tank B as shown in the sketch below. A Bourdon pressure gauge on tank A indicates that the pressure in the air is 120 kPa. Tank A contains oil ($SG_o = 0.9$) and Tank B contains water ($\rho = 998\ kg/m^3$). The local atmospheric pressure is 98 kPa.

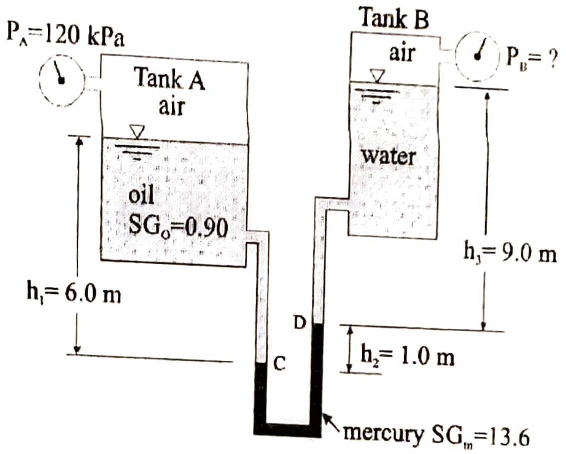
(a) Calculate the reading on the Bourdon pressure gage in Tank B for the manometer configuration shown below.

(b) The temperature in Tank A is 20 °C. Calculate the density of the air in Tank A. The gas constant for air is R = 287 J/kgK.

$\gamma_o = SG_o \gamma_w = 8811\ N/m^3$

$\gamma_w = 9790\ N/m^3$

$\gamma_m = SG_m \gamma_w = 133144\ N/m^3$



(a) $P_A + \gamma_o h_1 - \gamma_m h_2 - \gamma_w h_3 = P_B$

$P_B = 120 \times 10^3\ N/m^2 + 8811\ N/m^3 (6m) - 133144\ N/m^3 (1m)$

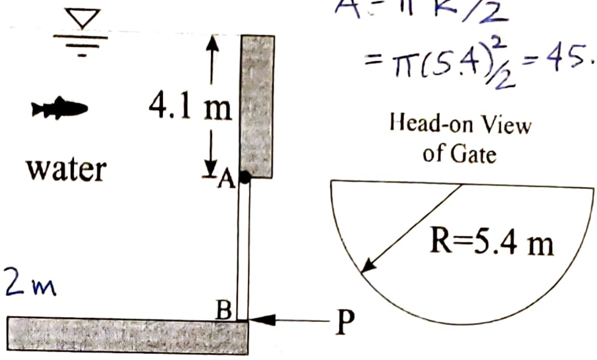
$- 9790\ N/m^3 (9m) = -48388\ N/m^2 = -48.4\ kPa$ ANS/

(b) $\rho = \dfrac{P_A}{RT}$ $\qquad P_A = 120 + 98 = 218\ kPa$ (a)

$\rho = \dfrac{218 \times 10^3\ N/m^2}{287\ \frac{N\,m}{kg\,K} (20+273) K} = 2.59\ kg/m^3$ ANS/

B3. A semi-circular gate with radius R=5.4 m is hinged along the edge at point A. The water has a density of 998 kg/m³. Calculate the required force (P) applied at point B to hold the gate stationary. **(10 marks)**

$$A = \pi R^2/2$$
$$= \pi (5.4)^2/2 = 45.80 m^2$$



$$F_h = \gamma_w h_{CG} A$$

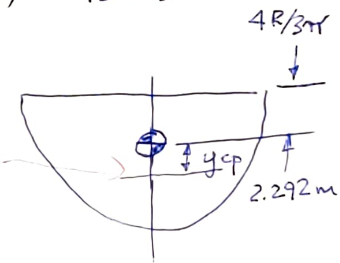
$$h_{CG} = 4.1 m + \frac{4R}{3\pi}$$
$$= 4.1 m + 2.292 m = 6.392 m$$

$$F_h = (9790 N/m^3)\, 6.392 m\, (45.80 m^2) = 2866 kN \rightarrow$$ 4

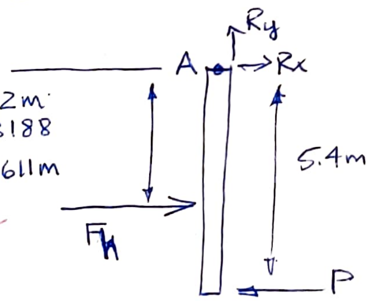
$$y_{cp} = \frac{-I_{xx} \sin\theta}{h_{CG} A}$$

$$I_{xx} = 0.10976 R^4$$
$$= 0.10976 (5.4)^4 = 93.33 m^4$$ 1/2

$$y_{pc} = \frac{-93.33 m^4 (\sin 90^\circ)}{6.392 m (45.80) m^2} = -0.3188 m$$



FBD



2.292m
+0.3188
= 2.611m

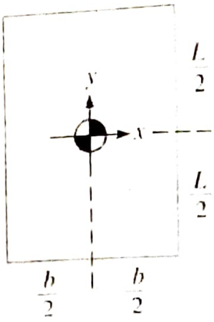
2

$$\Sigma M_A = 0$$

$$F_h (2.611) m = P (5.4 m)$$

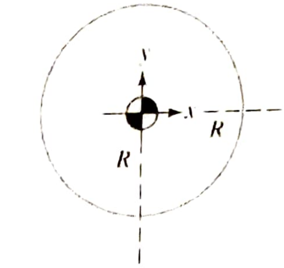
1

$$P = 2866 kN \frac{(2.611)}{5.4} = 1390 kN$$ 3



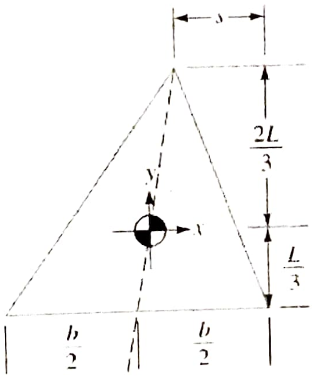
(a)

$$A = bL \qquad I_{xx} = \frac{bL^3}{12} \qquad I_{xy} = 0$$



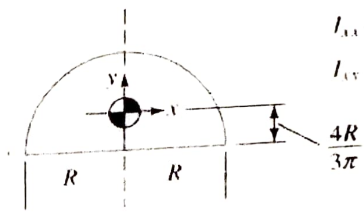
(b)

$$A = \pi R^2 \qquad I_{xx} = \frac{\pi R^4}{4} \qquad I_{xy} = 0$$



(c)

$$A = \frac{bL}{2} \qquad I_{xx} = \frac{bL^3}{36} \qquad I_{xy} = \frac{b(b-2s)L^2}{72}$$



(d)

$$A = \frac{\pi R^2}{2} \qquad I_{xx} = 0.10976R^4 \qquad I_{xy} = 0$$

Ideal gas equation of state: $p = \rho RT$

Hydrostatic Pressure: $\frac{dp}{dz} = -\gamma$

Fluid shear stress: $\tau = \frac{F}{A} = \mu\frac{du}{dy}$

Hydrostatic forces on plane surfaces:

$$F = \gamma\, h_{CG}A \qquad y_{CP} = -\frac{I_{xx}\sin\theta}{h_{CG}\,A} \qquad x_{CP} = -\frac{I_{xy}\sin\theta}{h_{CG}\,A}$$

Buoyancy force: $F_B = \gamma\forall_{displaced}$