RYERSON UNIVERSITY

Department of Mechanical and Industrial Engineering

FLUID MECHANICS I – BME516 / MEC516

MIDTERM EXAM

DATE: Wednesday, October 10, 2018

TIME: 8:10 - 9:55 am

EXAMINER: Dr. D. Naylor

DURATION: 105 minutes

INSTRUCTIONS:

1. This is a CLOSED BOOK EXAM. Permitted aids are: one 8.5 inch × 14 inch (legal size) personal equation (aid) sheet, both sides; non-communicating electronic calculator; and drawing and writing instruments (i.e., ruler, pens and pencils).
2. A table of centroids and second moments of area is included with this exam paper. A basic formula sheet is also included with this exam paper.
3. Prohibited items include: textbooks, class notes, cell-phones and other wireless devices, laptop computers, etc. **Possession of a communication device will trigger charges of academic misconduct.**
4. A valid student identification card must be presented when attendance is taken.
5. Answer all questions. Marks are indicated beside each question and in the table below.
6. To get full marks you must clearly show the formulas, methods and numbers used to solve the problem.
7. **For maximum part marks use the symbols given in the problem statement.** Also, be sure to give the proper units on all intermediate results.
8. Marks will be deducted for incorrect or missing units.

Student Name (Please Print): SOLUTIONS

Student Number: ______________________ Section Number: __________

Question	Mark
A1-A5	/10
Q1	/5
Q2	/5
Q3	/10
Q4	/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 *A5* are worth **2 marks** each.

A1. Consider the following parameters: V is velocity, D is diameter, ρ is density, μ is dynamic viscosity. Which group of parameters is ***dimensionless***?

(a) $\rho V D^{-1} \mu$
(b) $\rho^{-1} V D \mu$
✓ (c) $\rho V D \mu^{-1}$
(d) $\rho V D^{-1} \mu^{-1}$

$Re = \frac{\rho V D}{\mu}$

$\left(\frac{M}{L^3}\right)\left(\frac{L}{T}\right)L\left(\frac{LT}{M}\right) = M^0 L^0 T^0$ DIMESIONLESS (REYNOLDS NUMBER)

A2. A Bourdon gauge on an air tank reads 20.2 lb/in² when the local atmospheric pressure is 14.9 lb/in². A weather system causes the local atmospheric pressure to decrease to 14.4 lb/in². If there has been no air discharge and the tank temperature is unchanged, what will the Bourdon gauge read?

(a) 14.4 lb/in²
✓ (b) 20.7 lb/in²
(c) 19.7 lb/in²
(d) 20.2 lb/in²

$P_{abs} = P_g + P_{atm}$ 20.2 psi + 14.9 psi = P_g + 14.4 psi

P_g = 20.7 psi

A3. In the lecture/video demonstration, a mason jar partly filled with hot water (at about 60°C) was made to boil by placing an ice cube on the metal lid. Why does the liquid water boil?

(a) The liquid water boils to replace the latent heat that is transferred from the vapour to the lid, in order to re-establish thermal equilibrium.
(b) The cold lid increases the pressure in the vapour due to the cooling effect of the ice, disturbing the equilibrium.
✓ (c) Condensation on the lid causes the pressure to decrease below the vapour pressure corresponding to the liquid temperature.
(d) The ice cube produces the required temperature difference between the vapour and liquid to produce boiling in the liquid.

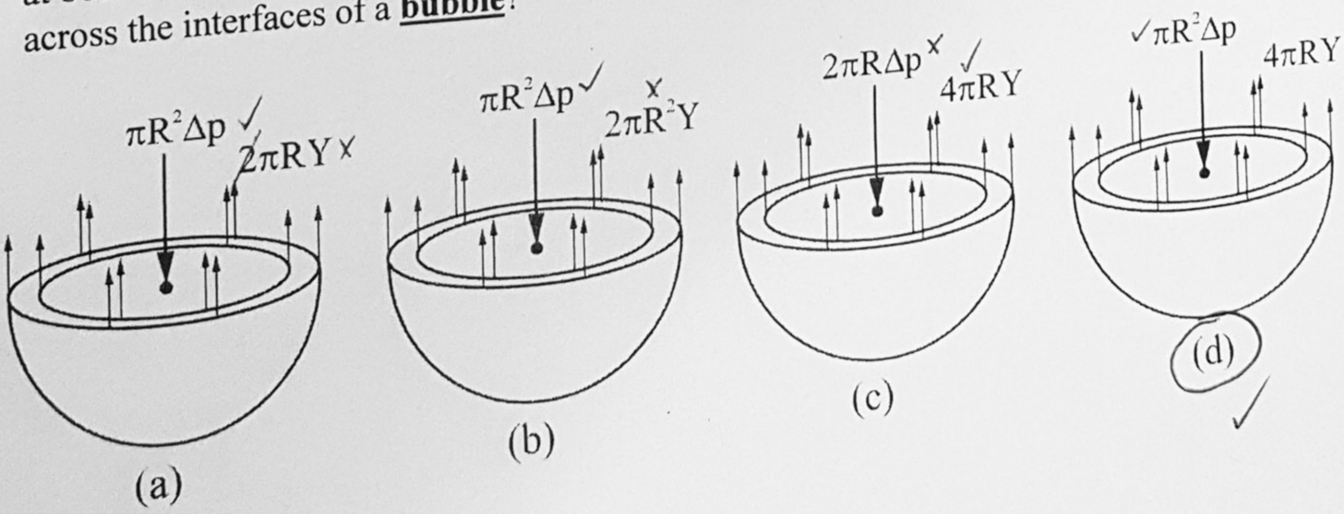
A4. A solid steel part has a mass of 25 kg and a volume of 3.2x10⁻³ m³. The part is quenched in an oil bath with specific gravity SG_{oil} =0.94. The steel part rests on the bottom of the tank, fully submerged. The force that the part exerts on the bottom of the tank is:

✓ (a) 216 N
(b) 221 N
(c) 230 N
(d) 235 N
(e) 240 N

$F_B = \gamma_f \forall$ $W = mg$

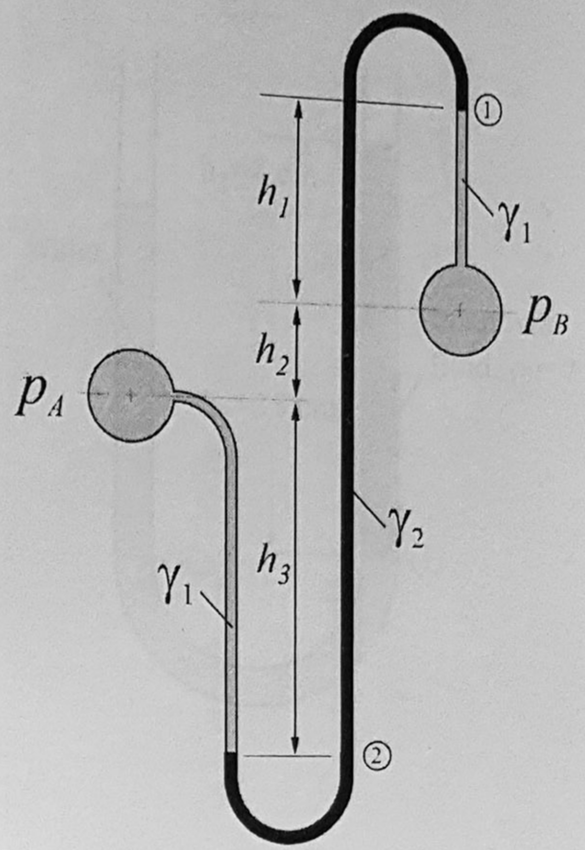
$F = mg - \gamma_f \forall$
$= 25\,kg\,(9.81\,m/s^2) - 940\,kg/m^3\,(9.81\,m/s^2)(3.2\times10^{-3}\,m^3)$
$= 245.25\,N - 29.51\,N = 216\,N$

A5. A bubble has **two** liquid-vapour interfaces at almost the same radius (R). Surface tension (Y) acts at both interfaces. Which free body diagram is correct for calculating the pressure difference (Δp) across the interfaces of a **bubble**?



Q1. Two water pipes are connected by a manometer, as shown in the sketch. Obtain an expression for the pressure difference between the two pipes $(p_A - p_B)$ in terms of the manometer heights (h_1, h_2, h_3) and the specific weights of the fluids (γ_1, γ_2).

(5 marks)



STARTING AT B:

$$\underbrace{\underbrace{p_B - \gamma_1 h_1}_{=p_1} + \gamma_2 (h_1 + h_2 + h_3)}_{=p_2} - \gamma_1 h_3 = p_A$$

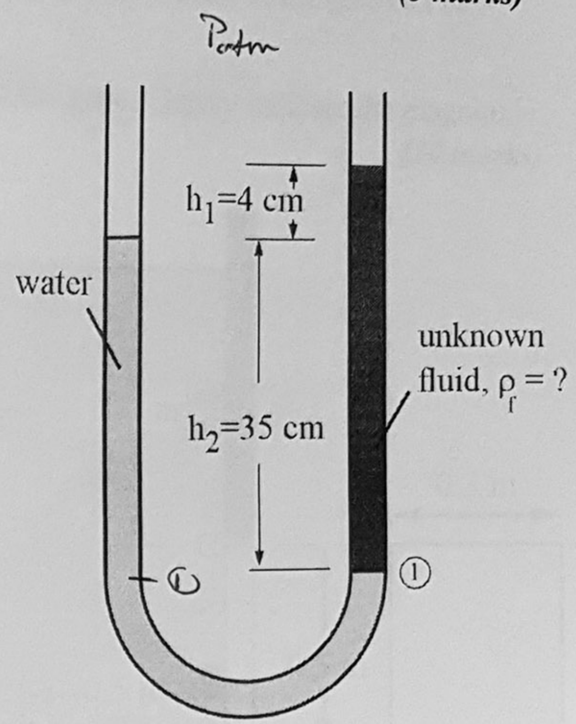
$$\boxed{p_A - p_B = \gamma_2 (h_1 + h_2 + h_3) - \gamma_1 (h_1 + h_3)}$$

ANS.

Q2. A U-tube manometer is open to the atmosphere at both ends. It contains water (ρ_w=998 kg/m^3) and an unknown fluid. Calculate the density (ρ_f) of the unknown fluid on the right side.

Work in symbolic form. Substitute numerical values at the end!

(5 marks)



$$\gamma = \rho g$$

$$P_1 = P_{atm} + \gamma_w h_2 = P_{atm} + \gamma_f (h_1 + h_2)$$

$$\gamma_f = \rho_f g = \frac{\rho_w g h_2}{(h_1 + h_2)}$$

$$\rho_f = \rho_w \left(\frac{h_2}{h_1 + h_2}\right)$$

$$\rho_w = 998 \frac{kg}{m^3} \left(\frac{35}{35+4}\right) = 896 \, kg/m^3 \quad ANS/$$

Q3. Water (ρ=998 kg/m^3) is contained by an L-shaped gate with dimensions shown in the sketch. The gate can rotate about a hinge at point B. The top edge of the gate is located 0.75m from the free surface. The depth of the gate is 0.3m (into the page). Calculate the force (F_A) applied normal to the lower left side of the gate (point A) required to keep the gate from opening. The weight of the gate can be neglected.

Draw a separate and fully labelled free body diagram of the gate. Clearly indicate the magnitude and direction of force F_A.

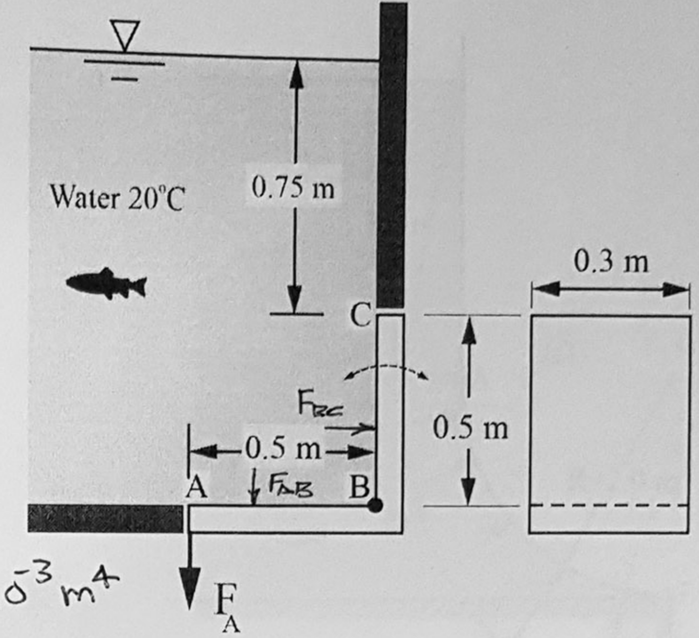
(10 marks)

F_{BC}:

$F_{BC} = \gamma h_{CG} A_{BC}$

$A_{BC} = 0.5(0.3) = 0.15 m^2$

$h_{CG} = 0.75 + 0.25 = 1 m$



$F_{BC} = 9790 \frac{N}{m^3} (1m)(0.15 m^2)$

$F_{BC} = 1468.5 N \rightarrow$

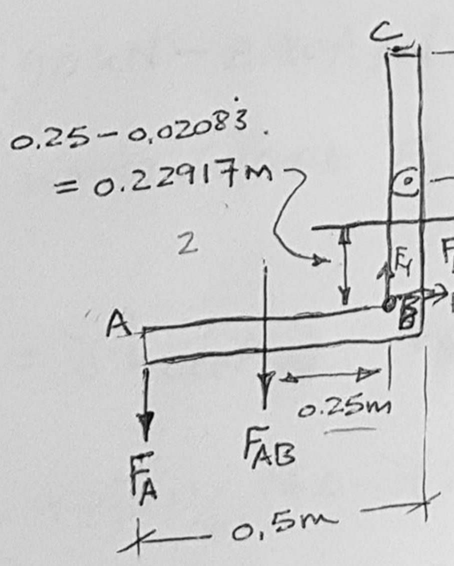
$I_{xx} = \frac{bh^3}{12} = \frac{0.3(0.5)^3 m^4}{12} = 3.125 \times 10^{-3} m^4$

$y_{cp} = \frac{-I_{xx}\sin\theta}{h_{CG} A_{BC}} = \frac{3.125 \times 10^{-3} m^4}{1m (0.15 m^2)} = -0.0208\dot{3} m$

F_{AB}: $F_{AB} = \gamma h A_{AB} = 9790 N/m^3 (1.25m)(0.15m^2) = 1835.6 N \downarrow$

F.B.D.

$\Sigma M_B = 0$ (+↻)



$F_A(0.5m) + F_{AB}(0.25) = F_{BC}(0.2292)$

$F_A = \frac{F_{BC}(0.2292) - F_{AB}(0.25)}{0.5m} = \frac{1468(0.2292) - 1836(0.25) Nm}{0.5 m}$

$F_A = -245 N$ ie. $F_A = 245 N \uparrow$ ANS/

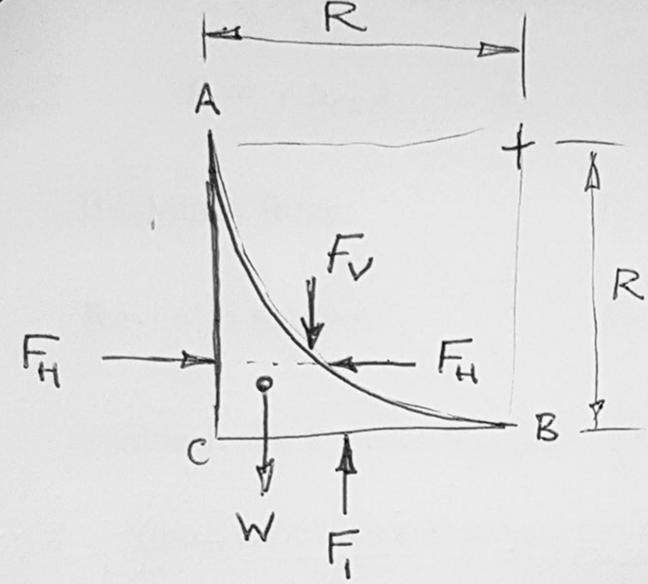
Q4. Water (ρ=998 kg/m³) is contained behind the structure shown in the sketch below. The curved section of the structure (AB) is a quarter circle with radius R=2.0m.

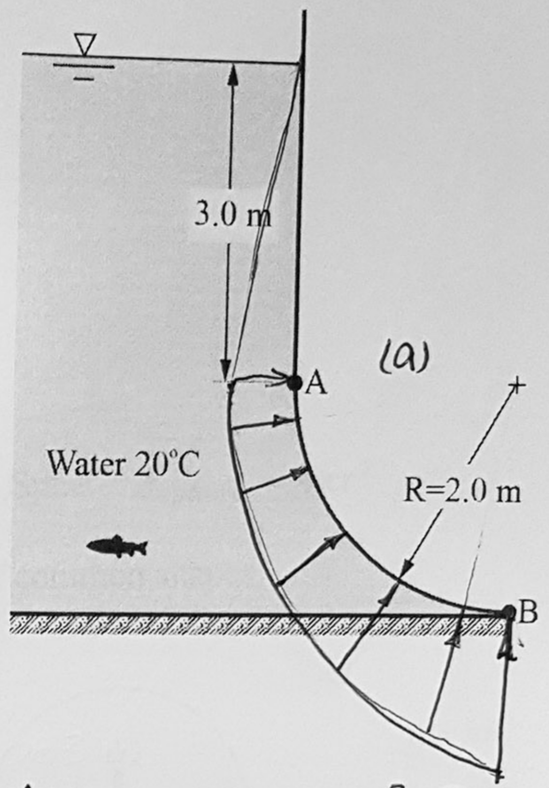
(a) Sketch the hydrostatic pressure distribution on the curved surface AB. **(2 marks)**

(b) Calculate the magnitude and direction of vertical hydrostatic force on surface AB per unit depth (into the page). ***Draw and fully label*** the appropriate free body diagram. **(6 marks)**

(c) Calculate the *magnitude and direction* of the horizontal hydrostatic force on surface AB per unit depth (into the page). The line of action is **not** needed. **(2 marks)**

(b)





$\Sigma F_z = 0 \qquad F_V = F_1 - W$

$W = \gamma \forall \qquad \forall = \left[R^2 - \frac{\pi R^2}{4}\right] 1m = (4-\pi) 1m^3 = 0.8584\ m^3$

$W = 9790\ N/m^3\ (0.8584\ m^3) = 8.404\ kN \downarrow$

$F_1 = \gamma h A_{BC} = 9790\ N/m^3 (5m)\ 2m^2 = 97.90\ kN \uparrow$

$F_V = 97.90\ kN - 8.404\ kN = 89.5\ kN \downarrow$ FORCE ON WATER

FORCE OF WATER ON GATE $F_V = 89.5\ kN \uparrow$ ANS/

(c) $F_H = \gamma h_{CG} A_{BC} \qquad h_{CG} = 4.0\ m \quad A_{BC} = 2m^2$

$F_H = 9790\ N/m^3 (4.0m)(2m^2) = 78.3\ kN \rightarrow$ ANS/