RYERSON UNIVERSITY

Department of Mechanical and Industrial Engineering

FLUID MECHANICS I – BME516/MEC516

MIDTERM EXAM

DATE: Thursday, October 11, 2018

TIME: 12:10 - 1:55pm

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: __________

Please Check One: ☐ Online Course

☐ Face-to-Face Lecture Course

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.

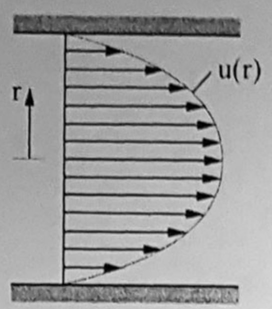
A1. Using the nomenclature of Chapter 1, what are the ***dimensions*** of the term created by dividing dynamic viscosity (μ) by fluid density (ρ)?

$$\frac{\mu}{\rho}$$

(a) $L^2T^{-1}M^{-1}$
(b) LTM^{-1}
(c) L^2T
(d) L^2T^{-1}
(e) $L^{-2}T$

A2. The sketch below shows the fluid velocity distribution in a round pipe for laminar flow. The fluid velocity (u) at the pipe wall is zero because of the:

(a) fluid surface tension.
(b) capillary effect.
(c) no-slip condition.
(d) impermeability condition.
(e) surface roughness of the pipe wall.



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?

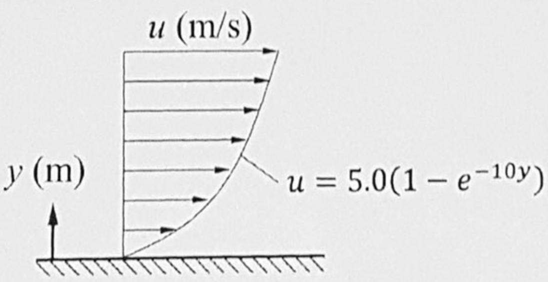
(a) The liquid water boils to replace the latent heat that is transferred from the vapour to the lid, in order to re-establish thermal equilibrium.
(b) The cold lid increases the pressure in the vapour due to the cooling effect of the ice, disturbing the equilibrium.
(c) Condensation on the lid causes 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. Engine oil with a dynamic viscosity of μ=0.12 Ns/m^2 flows parallel to a surface, as shown in the sketch. The variation of the fluid velocity (u) with distance from the surface (y) is: $u = 5.0(1 - e^{-10y})$ m/s. The viscous shear stress (τ) at the surface is:

(a) 0 N/m^2
(b) 0.60 N/m^2
(c) 6.0 N/m^2
(d) 7.5 N/m^2
(e) 50 N/m^2

$\frac{du}{dy}\Big|_{y=0} = 50\,\frac{1}{s}$

$\tau_w = \mu \frac{du}{dy}\Big|_{y=0} = 6.0$

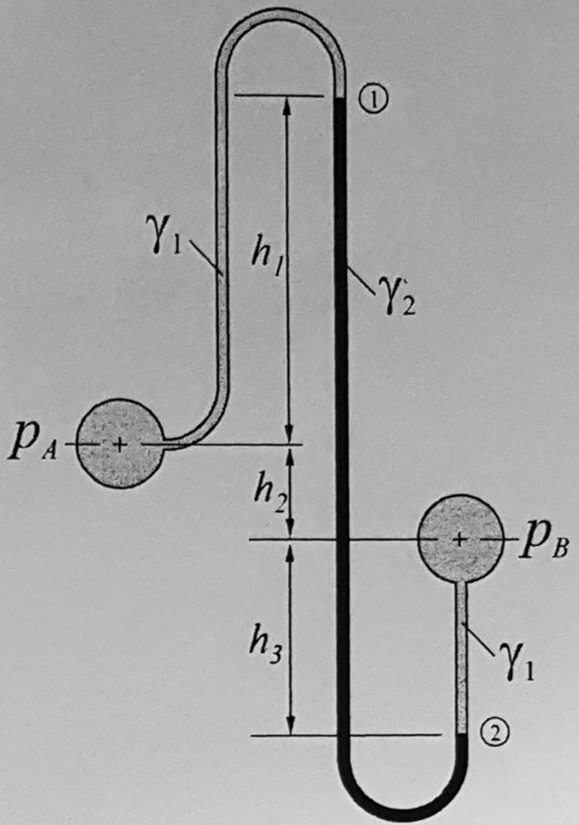


A5. Consider a solid cube of material (with no internal cavities or voids) placed into a container with liquid. Which **one** of the following statements related to buoyancy is ***false***?

(a) The cube will float if the liquid has a higher specific gravity than the cube material.
(b) If the cube sinks, the fully submerged cube displaces its volume in liquid.
(c) If the cube floats, the buoyancy force equals the cube weight.
(d) If the cube sinks, the fully submerged cube displaces its weight in liquid.
(e) If the cube floats, the cube displaces its weight in liquid.

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 two fluids (γ_1, γ_2).

(5 marks)



$= P_1$

$= P_2$

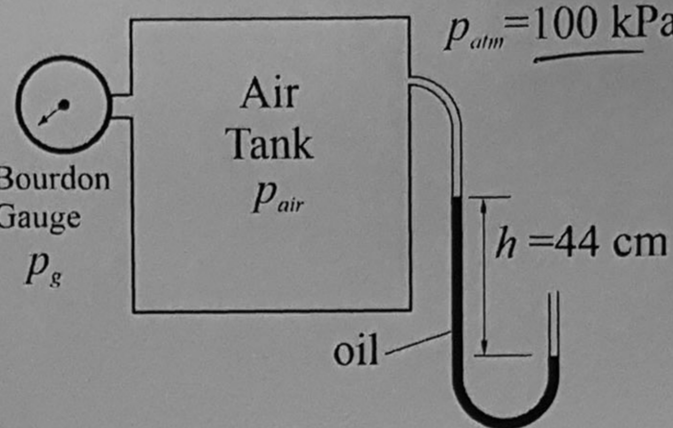
$$P_B + \gamma_1 h_3 - \gamma_2 (h_1 + h_2 + h_3) + \gamma_1 h_1 = P_A$$

$$P_A - P_B = \gamma_1 (h_1 + h_3) - \gamma_2 (h_1 + h_2 + h_3)$$

Q2. A manometer with oil (ρ_{oil}=927 kg/m^3) as the gauge fluid is attached to an air tank. Local atmospheric pressure is p_{atm}=100 kPa. The gas constant for air is R=287 J/kgK. The air temperature is 20°C.

(a) Calculate the pressure reading on the Bourdon gauge (p_g). *(3 marks)*
(b) Calculate the density (ρ) of the air in the tank. *(2 marks)*

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



(a) $$P_{atm} - \gamma_{oil} h = P_{air}$$

GAUGE PRESS. $$P_{air} - P_{atm} = -\gamma_{oil} h = -\rho_{oil} g h = P_g$$

$$P_g = -927 \frac{kg}{m^3} (9.81 \frac{m}{s^2})\, 0.44 m = -4001 \text{ Pa}$$

$$= -4.00 \text{ kPa}$$ ANS

(b) $$P_{air} = P_{atm} - \gamma_{oil} h = P_{atm} + P_{gauge}$$

$$= 100 \text{ kPa} - 4 \text{ kPa} = 96 \text{ kPa}$$

$$\rho = \frac{P_{air}}{RT} = \frac{96 \times 10^3 \frac{N}{m^2}}{287 \frac{N\text{-}m}{kg K} (20+273) K} = 1.14 \ kg/m^3$$ ANS

293K

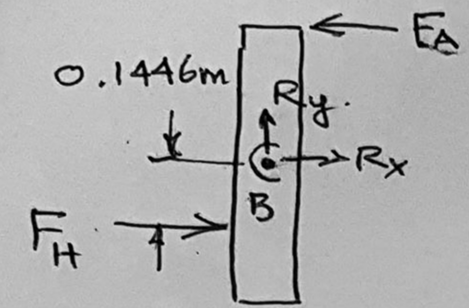
$\gamma_w = \rho g = 9790\ N/m^3$

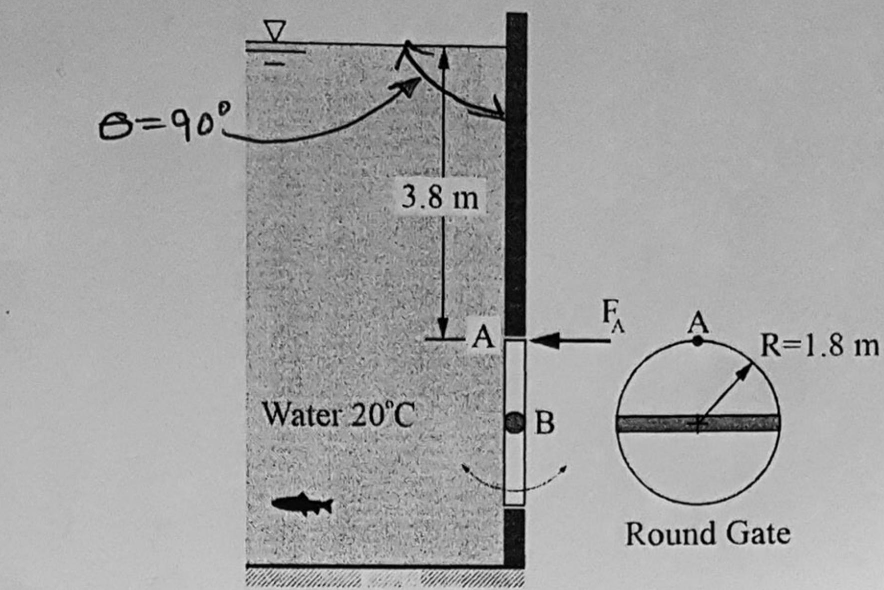
Q3. Water (ρ=998 kg/m³) is contained by a circular gate with a radius of R=1.8m. The gate can rotate about a hinge at point B. The top of the gate (point A) is located at a depth of 3.8 m. Calculate the force (F_A) applied normal to the top edge of the gate (point A) required to keep the gate from opening.

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

(10 marks)

FREE BODY DIAGRAM





$F_H = \gamma_w h_{CG} A$ $\qquad h_{CG} = 3.8m + 1.8m = 5.6m$

$A = \pi R^2 = \pi(1.8)^2 = 10.18\ m^2$

$F_H = (9790\ N/m^3)\ 5.6m\ (10.18\ m^2) = 558\ kN \rightarrow$

$y_{cp} = \dfrac{-I_{xx} \sin\theta}{h_{CG} A}$ $\qquad I_{xx} = \dfrac{\pi R^4}{4} = \dfrac{\pi(1.8)^4}{4} = 8.245\ m^4$

$y_{cp} = \dfrac{-8.245\ m^4 (\sin 90°)}{5.6m\ (10.18\ m^4)} = -0.1446m$

$\Sigma M_B = 0 \qquad F_H(-y_{cp}) + F_A(R) = 0$

$F_A = \dfrac{-F_H(-y_{cp})}{R} = \dfrac{-558kN\ (0.1446m)}{1.8m}$

$F_A = -44.8kN$

i.e. $F_A = 44.8kN \rightarrow$

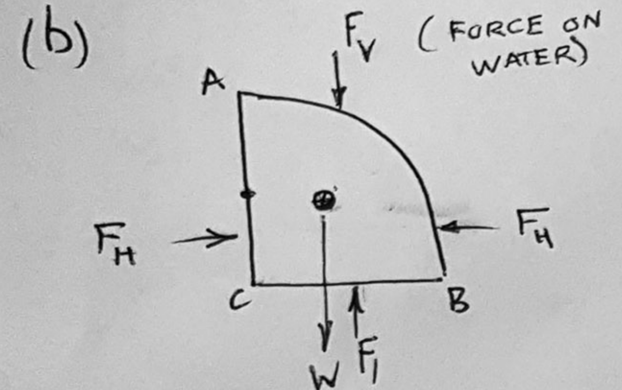
Q4. Water (ρ=998 kg/m³) is contained behind the structure shown in the sketch below. The curved section of the structure (AB) is a quarter circle with radius R=2.0 m.

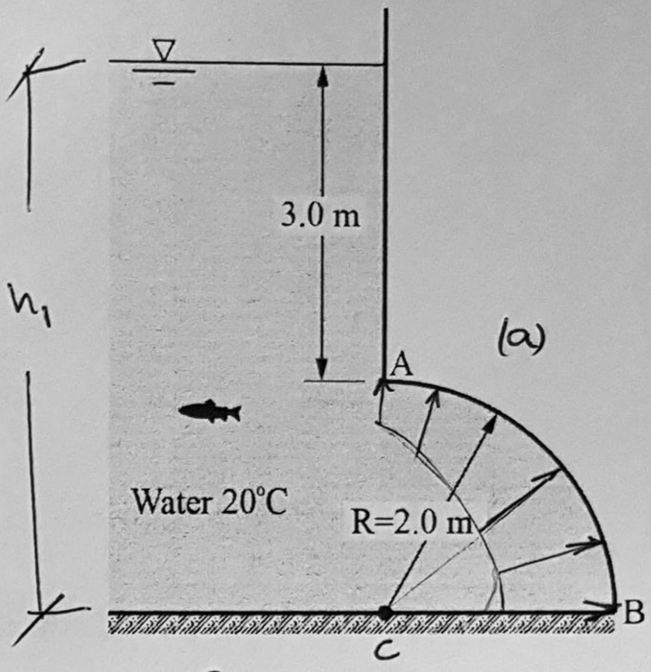
(a) Sketch the hydrostatic pressure distribution on curved surface AB. *(2 marks)*

(b) Calculate the magnitude and direction of the 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). (Line of action is **not** needed.) *(2 marks)*

(b)





F.B.D. (FORCES ON WATER)

$\uparrow +$

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

$F_V = F_1 - W$

$\forall = \pi\, m^3$

$W = \gamma \forall = 9790 \frac{N}{m^3} \left(\frac{\pi (2m)^2}{4}\right) 1m = 30.756\ kN \downarrow$

$F_1 = \gamma h_1 A_{CB} = 9790 \frac{N}{m^3} (5m)\, 2m^2 = 97.9\ kN \uparrow$

$F_V = 97.9\ kN - 30.756\ kN = 67.1\ kN$

∴ VERTICAL FORCE ON GATE $67.1\ kN \uparrow$ ANS.

(c) $F_h = \gamma h_{CG} A_{AC} \quad h_{CG} = 3.0 + \frac{R}{2} = 4m$

$F_h = 9790\, N/m^3 (4m)\, 2m (1m) = 78.3\ kN \rightarrow$ ANS