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 a mixture that contains 30% water (ρ=998 kg/m^3) ***by mass***. The remainder is ethylene glycol (ρ=1260 kg/m^3). What is the density of the mixture? Let m = 1 kg.

(a) ρ= 1064 kg/m^3
(b) ρ= 1076 kg/m^3
(c) ρ= 1121 kg/m^3
(d) ρ= 1168 kg/m^3
(e) ρ= 1181 kg/m^3

$\rho = \frac{m}{V}$ $V_w = \frac{0.3\ kg}{998\ kg/m^3} = 3.00\times10^{-4}\ m^3$

$V_{EG} = \frac{0.7}{1260} = 5.55\times10^{-4}\ m^3$ $\rho = \frac{m}{V_{TOT}} = 1168\ kg/m^3$

A2. Using the nomenclature of Chapter 1, what are the ***dimensions*** of the term obtained by dividing dynamic viscosity (μ) by specific weight (γ)?

$\{\frac{\mu}{\gamma}\}$

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

$\frac{Ns}{m^2}\frac{m^3}{N} = s\,m = \{TL\}$

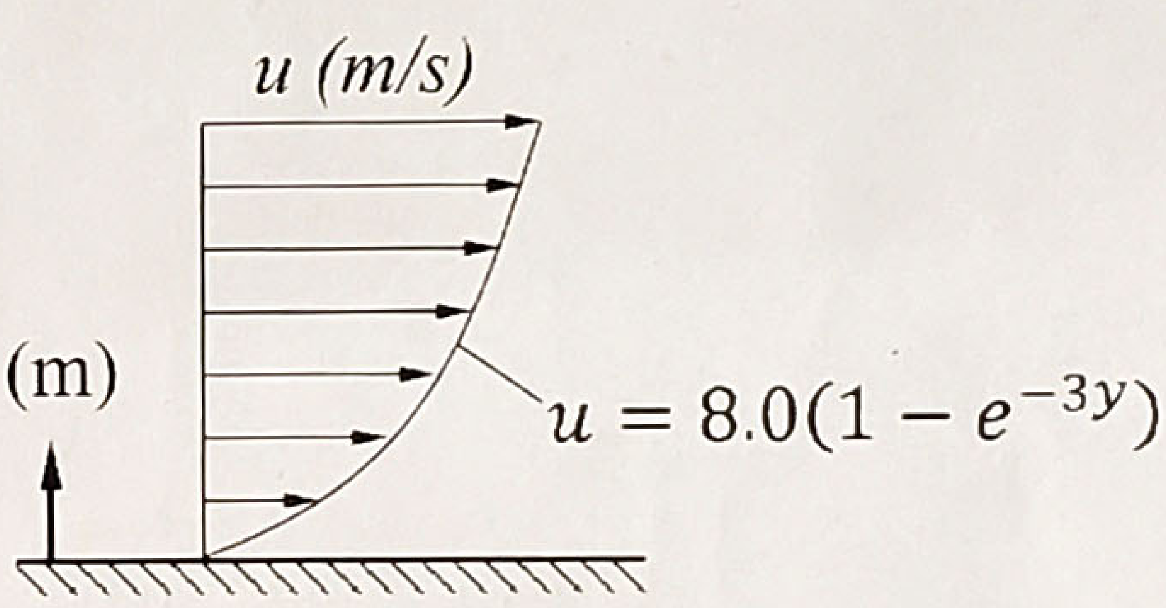
A3. Engine oil (S.G.=0.89) with a dynamic viscosity of μ=0.15 Ns/m^2 flows parallel to a surface, as shown in the sketch. The variation of the fluid velocity is: $u = 8.0(1 - e^{-3y})$ where u is the fluid velocity (in m/s), and y is the distance from the surface (in meters). The viscous shear stress (τ) at the surface is:

(a) 1.2 Pa
(b) 3.2 Pa
(c) 3.6 Pa
(d) 4.0 Pa
(e) 6.0 Pa

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

$\frac{du}{dy}\Big|_{y=0} = 24e^{-3y}\Big|_{y=0} = 24\frac{1}{s}$

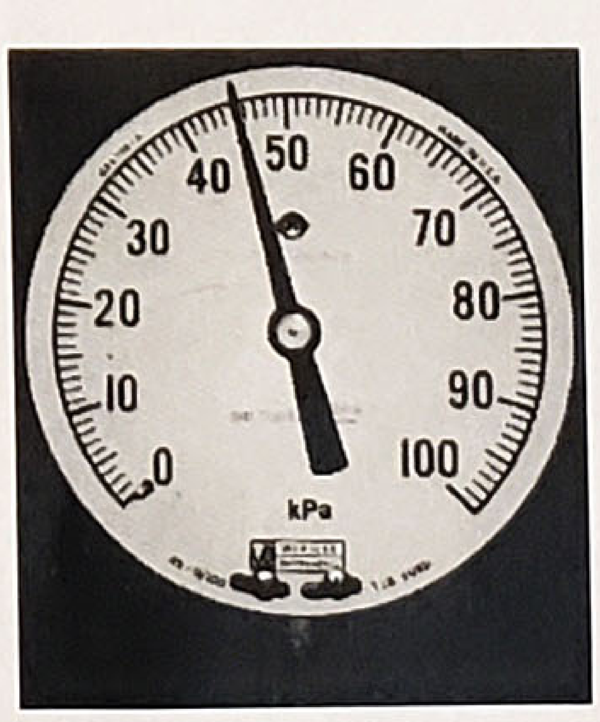
$\tau = 0.15\frac{Ns}{m^2}(24)\frac{1}{s} = 3.6\ \frac{N}{m^2}$



A4. Consider an air tank located in Denver Colorado (the "mile high city"). A Bourdon gauge on the air tank reads 45 kPa. The local atmospheric pressure in Denver is 87.0 kPa and the tank temperature is 18°C. The gas constant for air is R=287 J/(kg K). What is the density of the air in the tank?

(a) 0.54 kg/m^3
(b) 1.58 kg/m^3
(c) 1.75 kg/m^3
(d) 1.85 kg/m^3
(e) 2.71 kg/m^3

$\rho = \frac{P}{RT} = \frac{(87+45)\ kPa}{0.287\frac{kJ}{kg\,K}(18+273.15)K} = 1.58\ kg/m^3$

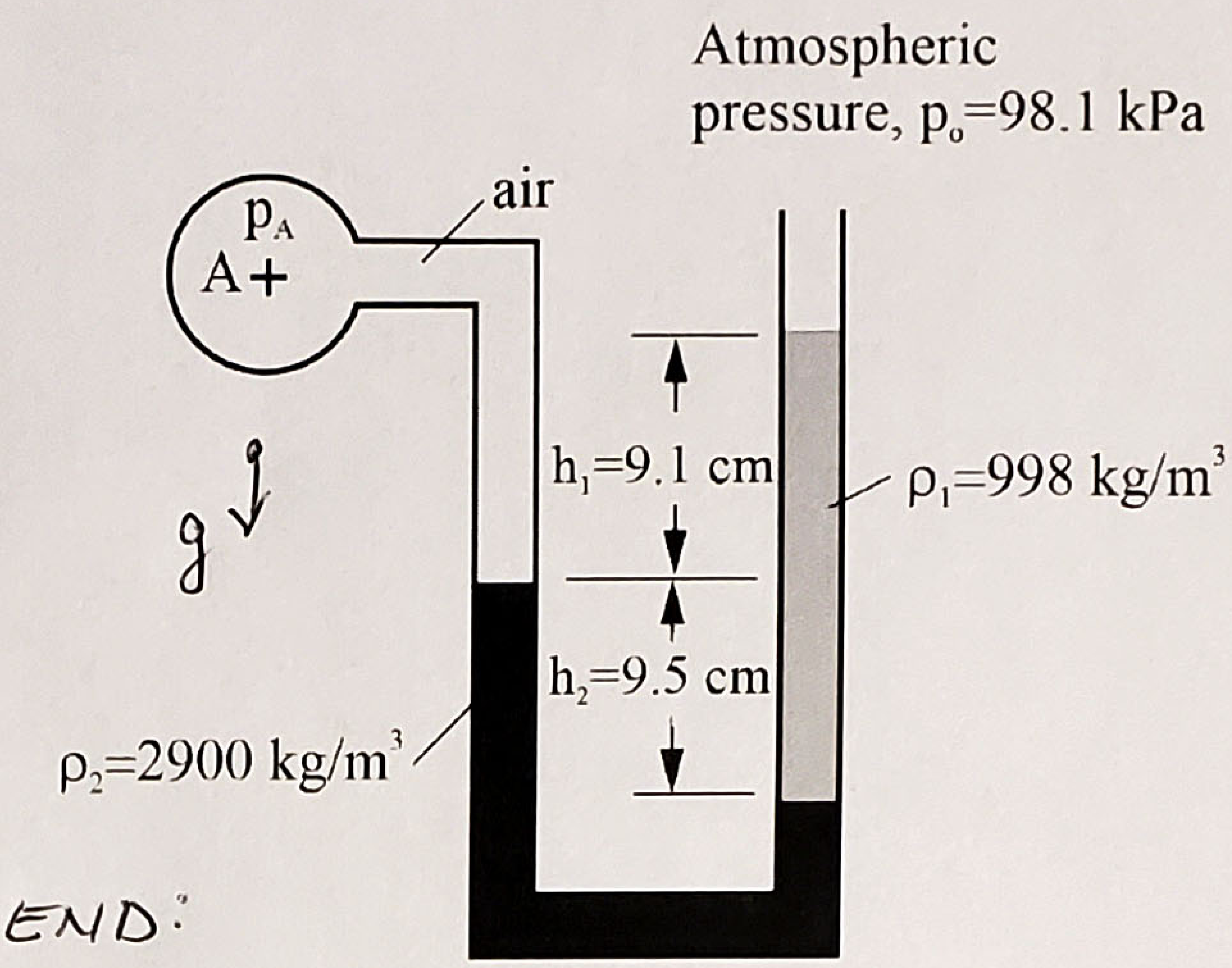


A5. Consider a solid cube of material (with no internal cavities or voids) placed into a container with liquid. Which **one** of the following statements related to buoyancy is ***false***?

(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's weight. ✓
(d) If the cube sinks, the fully submerged cube displaces its weight in liquid. X
(e) If the cube floats, the cube displaces its weight in liquid. ✓

Q1. Consider the manometer with two liquids shown below.

(a) Obtain an expression for the **gauge pressure** at point A in terms of the variables shown in the sketch: The absolute pressure at point A is p_A. The local atmospheric pressure is p_o. The manometer liquid heights are h_1 and h_2. The liquid densities are ρ_1 and ρ_2.
Your answer must be in symbolic form. No numerical values! *(6 marks)*



STARTING AT THE OPEN END:

$$p_o + \rho_1 g h_1 + \rho_1 g h_2 - \rho_2 g h_2 = p_A$$

$$p_A - p_o = \rho_1 g (h_1 + h_2) - \rho_2 g h_2$$ ANS

(b) Use the values shown in the figure to calculate the **absolute pressure** at point A (p_A). *(4 marks)*

$$p_A = p_o + \rho_1 g (h_1 + h_2) - \rho_2 g h_2$$

$$= 98.1 \times 10^3 \text{ Pa} + 998 \frac{kg}{m^3} (9.806 \frac{m}{s^2})(0.186 m) - 2900 \frac{kg}{m^3} (9.806 \frac{m}{s})0.095 m$$

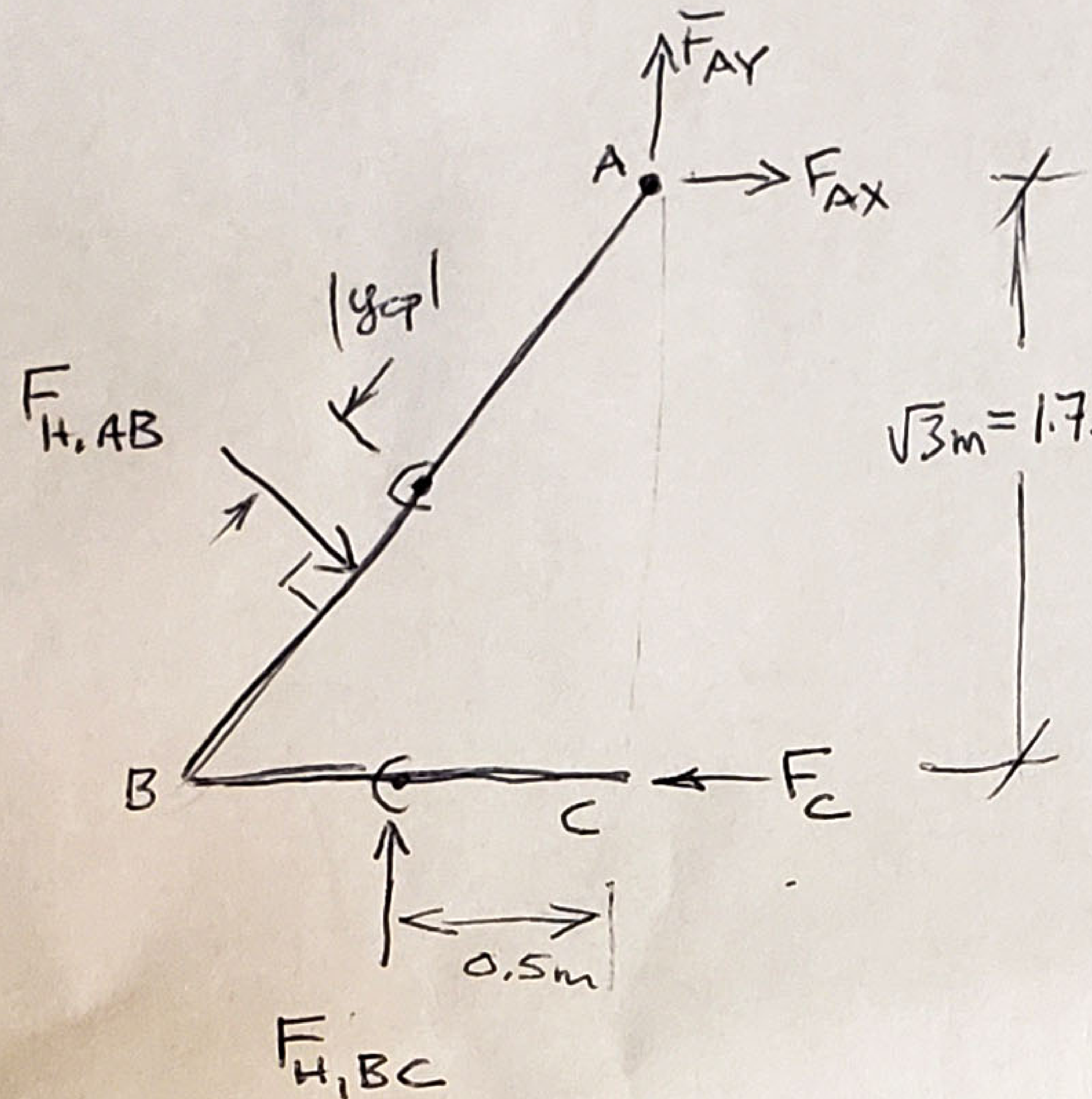
$$= 98.1 \text{ kPa} + 1.82 \text{ kPa} - 2.70 \text{ kPa}$$

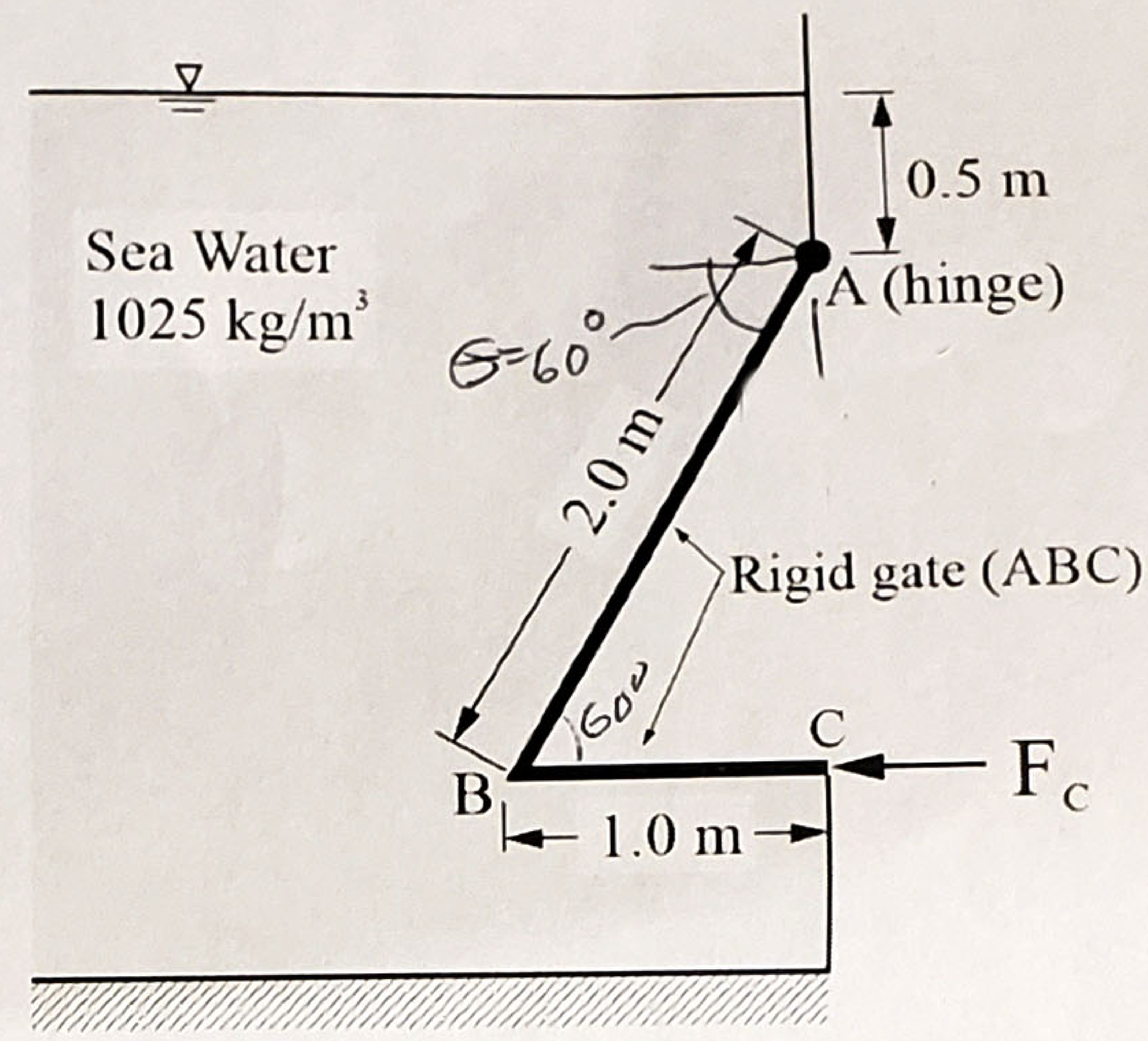
$$= 97.2 \text{ kPa}$$ ANS

Q2. Sea water (ρ=1025 kg/m^3) is contained behind a rigid gate shown in the sketch below. The rigid gate (ABC) rotates about a hinge at point A. The width of the gate is 3.0 m (into the page). The weight of the gate is negligible.

(a) Draw a separate fully labelled free body diagram of the gate (ABC). Do not draw on the problem sketch. ***(2 marks)***

(b) Calculate the horizontal force (F_C) applied at point C required to keep the gate in place. Clearly indicate both the magnitude and direction of the force F_C. ***(8 marks)***





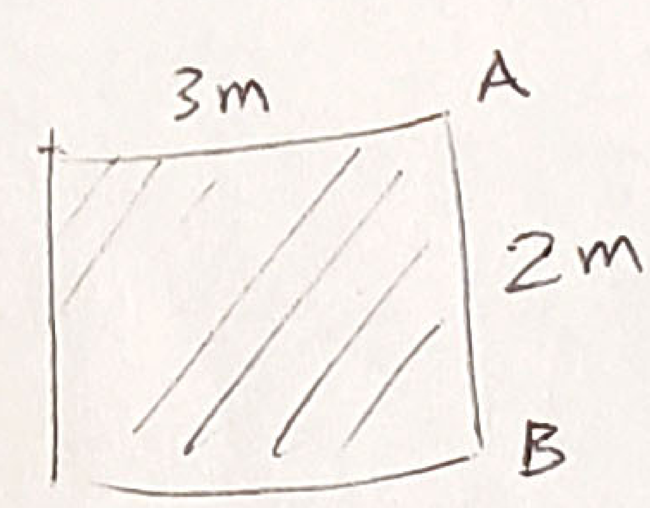
$$F_{H,AB} = \gamma h_{c,AB} A_{AB} = \underbrace{1025\frac{kg}{m^3}\left(9.806\frac{m}{s^2}\right)}_{10050\, N/m^3}\underbrace{\left(0.5+\frac{\sqrt{3}}{2}\right)m}_{1.3660m}\left(6m^2\right) =$$

$$= 82.38\ kN \searrow$$

$$F_{H,BC} = \gamma h_{c,BC} A_{BC} = 10050\, N/m^3 \underbrace{\left(0.5+\sqrt{3}\right)m}_{2.232m}\ 3m^2$$

$$= 67.30\ kN \uparrow$$

$$I_{xx} = \frac{bh^3}{12} = \frac{3(2)^3}{12} = 2.0 m^4$$



$$y_{cp} = -\frac{I_{xx}\sin\theta}{h_{c,AB} A} = -\frac{2.0m^4 \sin 60°}{1.3660m\ 6m^2}$$

$$= -0.2113\ m$$

$$\Sigma M_A = 0 \qquad F_c(1.732m) + 67.3(0.5m) = 82.38kN(1.2113m)$$

$$F_c = 38.2\ kN \leftarrow$$

ANS

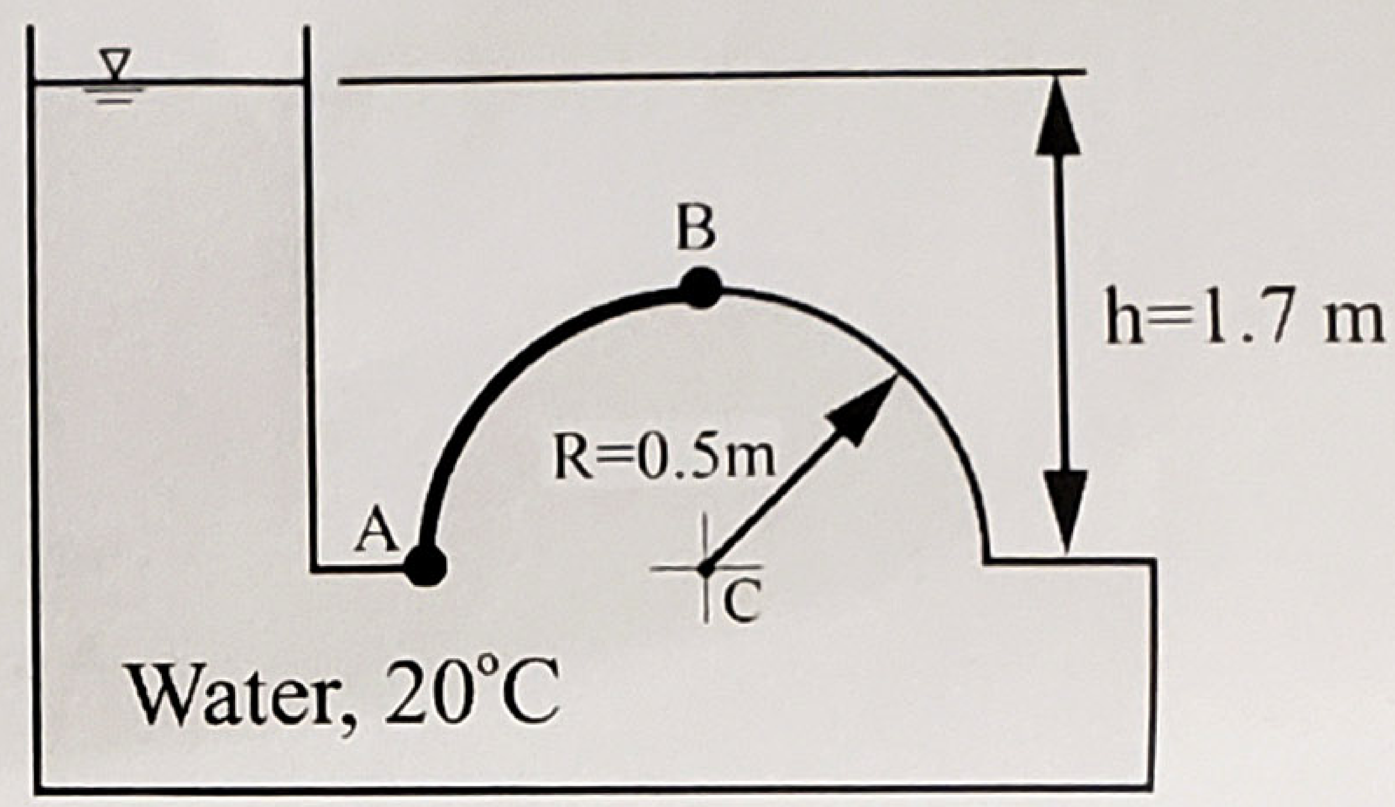
Q3. Water (ρ=998 kg/m^3) is contained in a tank shown in the sketch below. The curved section of the tank (AB) is a quarter circle with radius R=0.5m.

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

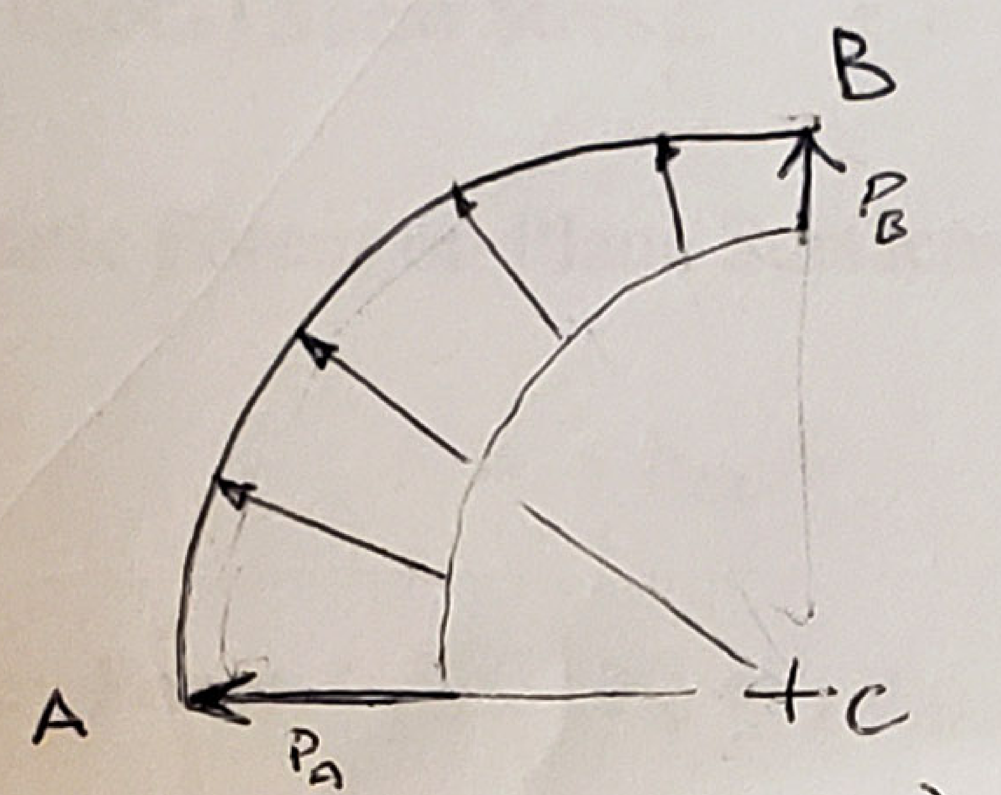
(b) Calculate the magnitude and direction of the **vertical** hydrostatic force on surface AB per unit width (into the page). ***Draw and fully label*** the appropriate free body diagram. *(6 marks)*

(c) Calculate the magnitude and direction of the **horizontal** hydrostatic force on surface AB per unit width (into the page). *(2 marks)*

Note: The lines of action of the forces in parts (b) and (c) are <u>not</u> required.



(a)

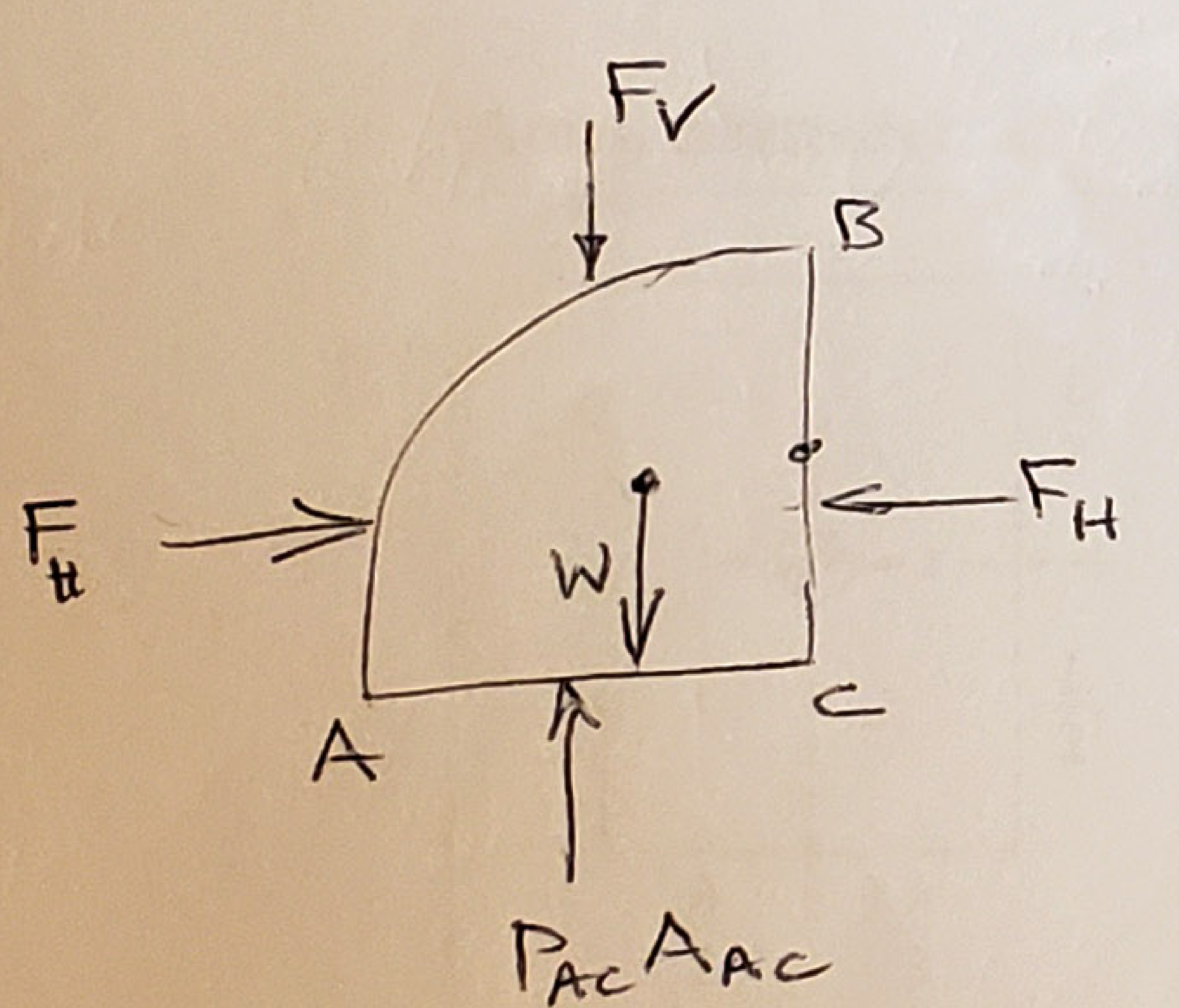


$P_A > P_B$ $(P_B \neq 0)$

P vectors ⊥ar

$\left(\therefore \ \overleftarrow{F_H} \quad F_V \uparrow \quad \text{FORCES ON GATE AB} \right)$

(b)



$$F_V = P_{AC}A_{AC} - W = \gamma h_{AC} A_{AC} - W$$

$$W = \gamma V = 9790 \, \frac{N}{m^3} \left(\frac{\pi (0.5)^2}{4} \right) m^3$$

$$= 1922 \text{ N} \downarrow$$

$$F_V = \underbrace{(9790 \, N/m^3)(1.7m)(0.5m^2)}_{8321.5N} - 1922 N = 6400 N \uparrow$$

1.45 m

(c) $F_H = \gamma h_{c,BC} A_{BC} = (9790 \, N/m^3)(1.7 - 0.25)m \, (0.5m^2)$

$= 7100 \text{ N} \leftarrow$