University of Khenchela
Faculty of Science and Technology
Department of Mechanical Engineering
Level : L2 GM

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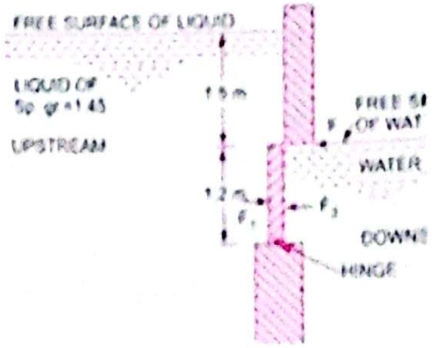
Exam: Fluid mechanics

Exercise 1

A vertical sluice gate is used to cover an opening in a dam. The opening is 2 m wide and 1.2 m high. On the upstream of the gate, the liquid of SG = 1.45, lies upto a hight of 1.5 m above the top of the gate, whereas on the downstream side the water is available upto a height touching the top of the gate. Find the force acting horizontally at the top of the gate which is capable of opening it. Assume that the gate is hinged at the bottom.



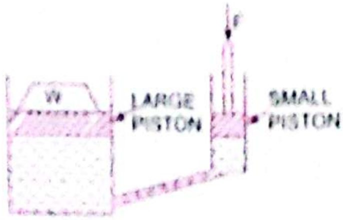
Exercise 2

The diameters of a small piston and large piston of a hydraulic jack are 3 cm and 10 cm respectively. A force of 80 N is applied on the small piston. Find the load lifted by the large piston when:

(a) The pistons are at the same level.

(b) Small piston is 40 cm above the large piston.

The density of the liquid in the jack is given as 1000 kg/m^3



Exercise 3

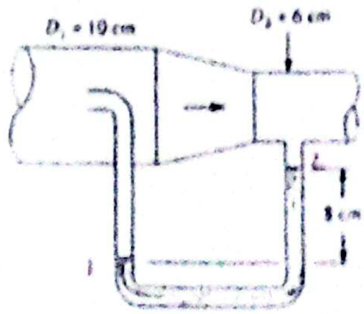
In Figure the flowing fluid is CO_2 at 20°C. Neglect losses.

If P_1 = 170 kPa and the manometer fluid is oil (SG = 0.827), estimate :

(a) pressure P_2

(b) the gas flow rate in m^3/h.

The density of CO_2 is : ρ_{CO2} = 3.07 kg/m^3



Exam correction : Fluid Mechanics.

Exercise 1: (7pts)

First we should calculate F_1 : the force exerted by the fluid of SG = 1,45 on the gate, and F_2 : the force exerted by water on the gate: $\rho_1 = 1,45 \times 1000\ kg/m^3$ (0,5)

(1) $F_1 = \rho_1 g \cdot h_{c_1} \cdot A = 1,45 \times 1000 \times \left(1,5 + \frac{1,2}{2}\right) \cdot (1,2 \times 2) \times 9,81$

$F_1 \simeq 71691,5\ N$ (0,5)

$F_2 = \rho_2 g\, h_{c_2} \cdot A = 1000 \times 9,81 \times \frac{1,2}{2} \times 2,4 = 14126,4\ N$ (0,5)

- Position of centre of pressure of the force F_1.

$y_1 = y_{c_1} + \frac{I_{xx,c_1}}{y_{c_1} \cdot A}$ (1) ; $I_{xx,c_1} = \frac{2 \times 1,2^3}{12} = 0,288\ m^4$ (0,5)

$y_1 = 2,1 + \frac{0,288}{2,1 \times 2,4} = 2,157\ m$ (0,5)

- Position of centre of pressure of the force F_2:

$y_2 = 0,6 + \frac{0,288}{2,4 \times 0,6} = 0,8\ m$ (0,5)

taking the moment of F_1, F_2 and F about the hinge, we get:

$F \times 1,2 + F_2(1,2 - y_2) - F_1(2,7 - y_1) = 0$ (1)

$F \simeq \frac{71691,5 \times 0,543 - 14126,4 \times 0,4}{1,2}$

$F \simeq 27731,4\ N$ (1)

Exercice 2 (7 pts)

(a) When the pistons are at the same level:

Pressure intensity on small piston $= \frac{F}{a}$ (0,5)

$a = \frac{\pi}{4} d^2 = \frac{\pi}{4}(3)^2 = 7,068 \text{ cm}^2$ (0,5)

$\frac{F}{a} = \frac{80}{7,068}$, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(10)^2 = 78,54 \text{ cm}^2$ (0,5)

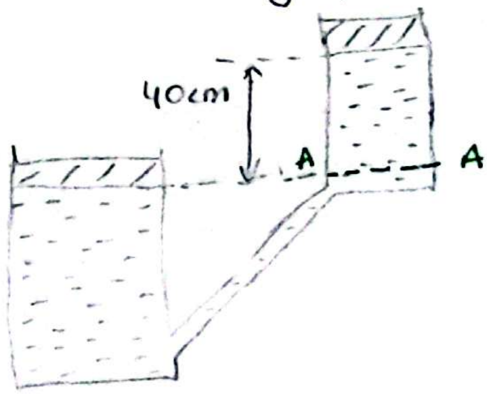
This is transmitted equally on the large piston, so the pressure intensity on the large piston $= \frac{80}{7,068}$. (0,5)

And the Force (load) on the large piston = Pressure × Area.

$= \frac{80}{7,068} \cdot \frac{\pi}{4}(10)^2$ (0,5)

$W = 888,96 \text{ N}$ (1)

(b) When the small piston is 40 cm above the large piston:



Pressure intensity at section AA = (0,5)

$= \frac{F}{a}$ + Pressure intensity due to height of 40 cm of liquid (1)

$= \frac{80}{7,068} + \frac{\rho g h}{10^4} = \frac{80}{7,068} + \frac{1000 \times 9,81 \times 0,4}{10^4}$

$= 11,7124 \text{ N/cm}^2$ (0,5)

Force on the large piston (load) = Pressure × Area (0,5)

$= 11,71 \times 78,54$

$W = 919,7 \text{ N}$ (1)

Exercise (6pts)

(a) $P_2 = P_1 - \rho_{oil} \cdot g \cdot h$ (1)

$= 170000 - 827 \times 9{,}81 \times 0{,}08 \Rightarrow \boxed{P_2 \simeq 169350{,}9\,Pa.}$ (1)

(b) using Bernoulli to find V_2:

$$P_1 + \frac{1}{2}\rho_{CO_2} V_1^2 + \cancel{g}y_1 = P_2 + \frac{1}{2}\rho_{CO_2} V_2^2 + \cancel{g}y_2 .$$ (0,5)

$$\Rightarrow P_1 - P_2 = \frac{1}{2}\rho_{CO_2}(V_2^2 - V_1^2) = \frac{1}{2}\rho_{CO_2} V_2^2 \left(1 - \frac{V_1^2}{V_2}\right) \ldots (1)$$ (0,5)

and using mass continuity équation:

(0,5) $A_1 V_1 = A_2 V_2 \Rightarrow V_1 = \frac{A_2}{A_1} V_2 = \frac{\pi D_2^2 \cdot 4}{4 \pi D_1^2} V_2$ (0,5)

$$V_1 = \left(\frac{D_2}{D_1}\right)^2 V_2 = \left(\frac{6}{10}\right)^2 V_2 = 0{,}36 V_2 . \Rightarrow \frac{V_1}{V_2} = 0{,}36$$

by substituting in éq.(1):

$$P_1 - P_2 = \frac{1}{2}\rho_{CO_2} V_2^2 (1 - 0{,}36^2) = \frac{1}{2} \times 3{,}07 \times 0{,}87 \times V_2^2$$ (1)

$$= 1{,}335\, V_2^2$$

$$V_2 = \sqrt{\frac{P_1 - P_2}{1{,}335}} \simeq \boxed{22\,m/s = V_2}$$ (0,5)

$$q_V = A_2 V_2 = \frac{\pi (0{,}06)^2}{4} \times 22 \Rightarrow \boxed{q_V = 0{,}062\,m^3/s}$$ (0,5)