Round 1, Answers to the problems 09.9.2021

Problem 1

1. You are pulling a plate (size 0.3m x 3m) with a constant velocity of $u = 2\frac{m}{s} \cdot 1.y$, where '$y$' is the last digit of your student number (If it is e.g. 5, then y =5, and the multiplier is 1.5. If it is e.g. zero, then y =0, the multiplier is 1.0). The plate is on an oil film. Below the oil film, there is another, non-moving, plate. The molecular viscosity of the oil is μ=0.38 kg/ms.

   a. Calculate the velocity gradient du/dy (=rate of shearing strain $\dot{\gamma}$) when the oil film thickness is 1mm. What if the film thickness is 0.5mm.
   b. Calculate the shearing stress in the a) problem
   c. Calculate the force needed in both cases.

<u>Answer: Student number y=0</u>

a) Velocity gradient $\frac{\partial u}{\partial y} = \frac{U}{b}$

$$\frac{U}{b} = \frac{2\ m/s}{0.001m} = 2000\ \frac{1}{s}$$

Or

$$\frac{2\ m/s}{0.005m} = 4000\frac{1}{s}$$

b) Shearing stress is $\tau = \mu\frac{\partial u}{\partial y}$

$$\tau = 0.38\ \frac{kg}{ms}\ x\ 2000\frac{1}{s} = 760\ \frac{kg}{ms^2}$$

$$or$$

$$\tau = 0.38\ \frac{kg}{ms}\ x\ 4000\frac{1}{s} = 1520\ \frac{kg}{ms^2}$$

c)

$$P = \tau\, A = 760\frac{kg}{ms^2} * 0.90\ m^2 = 684\ \frac{kgm}{s^2}\ or\ N$$

or

$$P = 1520\frac{kg}{ms^2} * 0.90\ m^2 = 1368\ N$$

2. An U-manometer has oil, mercury, and water as shown in the Fig. 1. What is the pressure difference between the pipes A and B with the given dimensions ? (Prob. 2.22)

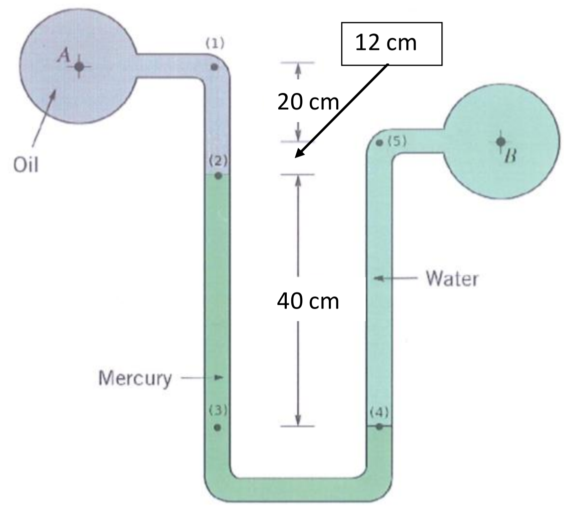

Fig. 1. Problem 2 (Young et al., 2012)

Answer:

The fluid is at rest in the manometer so that the pressure is due to hydrostatic pressure. Hydrostatic pressure can be calculated from $p = p_0 + \Delta p = p_0 + \rho g h$ where *p* is the pressure at the point of interest, p_0 is the reference pressure and *h* is the height difference between the point of interest and the reference point.

Problems involving manometers are solved by calculating the pressure difference for each fluid section starting from point A.

The pressure difference for each fluid section are:

Distance	Δh	Δp
A→1	0	0
1→2	h_1	$\rho_1 g h_1$
2→3	h_2	$\rho_2 g h_2$
3→4	0	0
4→5	$-h_3$	$-\rho_3 g h_3$
5→ B	0	0

$$h_1 = 0.2m + 0.12m \quad h_2 = 0.4m \quad h_3 = 0.4m + 0.12m$$

$$\rho_1 = \rho_{oil} = 800\ \frac{kg}{m^3} \qquad \rho_2 = \rho_{Hg} = 13000\ \frac{kg}{m^3} \qquad \rho_3 = \rho_{H_2O} = 1000\ \frac{kg}{m^3}$$

The manometer equation is then

$$p_A + \rho_1 g h_1 + \rho_2 g h_2 - \rho_3 g h_3 = p_B$$

From which we can solve the pressure difference

$$p_A - p_B = \rho_3 g h_3 - \rho_1 g h_1 - \rho_2 g h_2$$

$$p_A - p_B = 1000 * 9.81 * 0.52 - 800 * 9.81 * 0.32 - 13000 * 9.81 * 0.4$$

$$p_A - p_B = -48422.16\ Pa\ \sim -48\ kPa$$

3. A large, open tank has water. The tank is connected to a 1.1 m high, rectangular shaped, pipe (Fig. 2). The rectangular shaped plug is used to seal the pipe. Determine the magnitude, direction, and location of the force of the water on the plug.

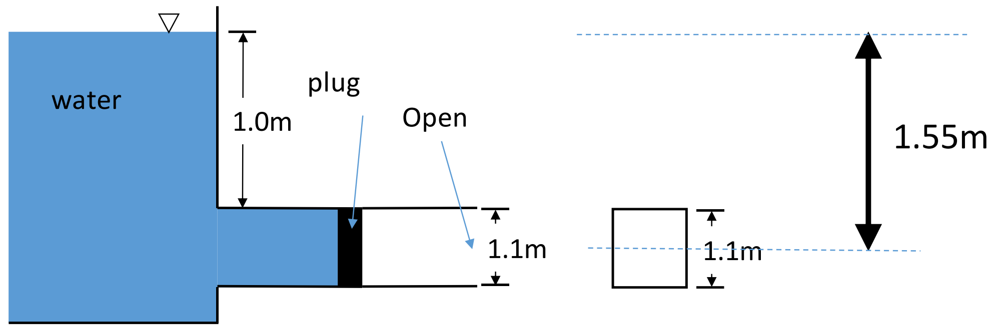

Fig. 2. Problem 3.

Answer:

$$F_R = \gamma h_c A = 999.6\frac{kg}{m^3} * 9.81\frac{m}{s^2} * 1.55m * 1.1^2$$

$$F_R = 18391.29\ N \quad \sim 18.4\ kN$$

$y_R = \frac{I_{XC}}{y_C A} + y_C$ where $I_{XC} = \frac{1}{12}ba^3 = \frac{1}{12} * 1.1 * 1.1^3 = 0.122\ m^4$

We get

$$y_R = \frac{0.122\ m^4}{1.55m * 1.1^2} + 1.55m = 1.615\ m$$

So the force is 1.615m below the water surface level and perpendicular to the plug.

4. Lets start with Matlab. It is recommended to start the learning process by looking at e.g. Youtube videos suggested during the lecture. **It is recommended to start the problem by creating a new script (top menu left, New → script)**. **When all the below points are ready, you can print it to pdf (print menu, print-to-pdf).**

a. Define in Matlab 1x6 size vectors a and b which both have the same integer numbers (e.g. 1,2,3,4,5,6). The 1st number of the vectors a and b is the last number of your student id (e.g. 9,10,11,12,13,14, where the number 9 would be the last number of your student id).

b. Multiply the vectors (syntax [a*b]). Explain briefly why you get an error.

c. Multiply the vectors with the syntax [a.*b]. Explain briefly why the result is different from the point b).

d. Make the vector b vertical. Multiply now the vectors a and b [a*b]. Show the result.

e. Show two additional ways (in addition to a)) to define the vectors.

f. Explain briefly what does the %-sign mean in Matlab. What does a semicolon mean at the end of a line ?

Answer:

a) a=[8,9,10,11,12,13]
b=[8,9,10,11,12,13]

b) a*b
Error using *
Inner matrix dimensions must agree.
% When multiplying matrixes, the number of columns in the matrix (or vector) a must be the same as the number of rows in the vector b. Now this is not the case but a has 6 columns and b 1 row.

c) a.*b
% Here we are not performing matrix multiplication but each element of the vector is multiplied with corresponding element from the other vector.
ans =
64 81 100 121 144 169

d) b=b'
a*b
ans=
679

e) a=[8:1:13]
a=linspace(8,13,6)

f) the %-sign means that the line is not executed. One can add e.g. explanations to the coding after the %-sign.
Semicolon ; at the end of the line means that the command output is not printed out.