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ENME 314-21S1 Homework 1

- This is worth 2.5% of the course marks.
- Attempt all the questions.
- Marks may be lost for illegible script, incorrect number of significant figures and failure to state assumptions.
- You may discuss general concepts and methods with others, but you should not discuss or share your solutions to these specific questions. Submitting solutions based on such a discussion will be treated as plagiarism.
- Hand in a hardcopy version of your answers.
- Your submission should be clearly marked with your name, 8 digit student ID, date and “ENME 314 Homework 1” on all pages. Keep a copy of your solution (a photo is adequate if the writing can be read).
- Place your submission into the dropbox on level 2 of the Mechanical Engineering Lab Wing, on the balcony overlooking the RJ Scott Atrium.
- The deadline is 5pm Fri 12th March.
- You may assume the acceleration due to gravity $\mathrm{g} = 9.81\ \mathrm{ms}^{-2}$

1) A pressure field is described by the equation $p = 1{,}000x + 500y + 10{,}000$ where p is the absolute static pressure in Pascals and x, y are Cartesian coordinates in metres. Determine the static pressure at $x = 0.10\ m, y = 2.0\ m$ (2 marks)

2) Calculate the static pressure 2500 m above sea level in a stationary atmosphere. Assume the atmosphere has a constant density of 1.2 $\mathrm{kgm^{-3}}$ (note, this is not very realistic). Also assume the absolute static pressure at sea level is 101,325 Pa. (1 mark)

3) Calculate the absolute stagnation pressure in a flow of water (density 1,000 kg $\mathrm{m^{-3}}$ to 2 s.f.) moving at 10. $\mathrm{ms^{-1}}$ in at a depth of 15 m with atmospheric pressure equal to 101,325 Pa at the free surface. (3 marks)

4) If atmospheric pressure is 101,000 Pa, what is an absolute pressure of 401,000 Pa, expressed as a gauge pressure?

5) Water at $15.0\ ^\circ\mathrm{C}$, flows at $1.5\ \mathrm{m/s}$ in a pipe of $0.050\ \mathrm{m}$ diameter.
    a. Calculate the Reynolds number. (1 mark)
    b. Is the flow laminar or turbulent? (1 mark)

6) An aircraft is climbing (gaining altitude) at constant speed, through air which has constant properties. Is the flow steady or unsteady, and what is its dimensionality (0, 1, 2 or 3 D)? (2 marks)

7) A hydraulic jack has one cylinder of 100. mm diameter, and another of 200. mm diameter. If a force of 2,500 N is used to push down the piston in the smaller cylinder, what is the force developed on the piston the larger cylinder? (1 mark)

8) Calculate the absolute static pressure in Pipe B in the system shown in Figure 1 (2 marks).

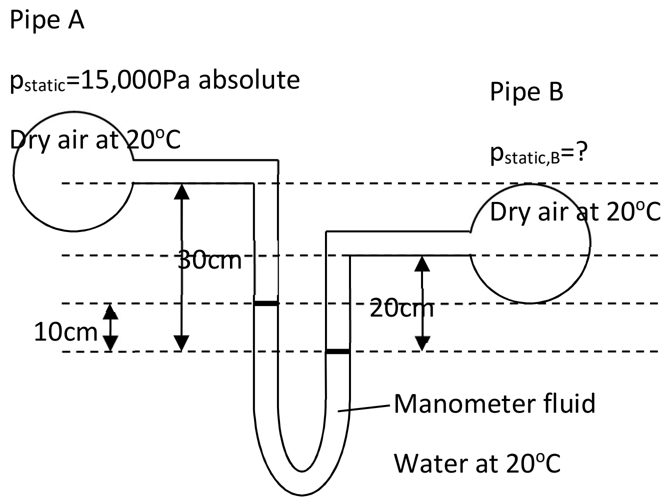


Figure 1: pipe and manometer system for question 8. All values are to 2 s.f.

9) Water flows into a pond with a flow rate of 0.015 m^3/hour and out of the same pond with a flow rate of 0.010 m^3/hour. If the pond is empty at the start, and has a maximum capacity of 2.0 m^3, how long does it take to fill? You may assume that evaporation is negligible. (2 marks)

1) A pressure field is described by the equation $p = 1{,}000x + 500y + 10{,}000$ where p is the absolute static pressure in Pascals and x, y are Cartesian coordinates in metres. Determine the static pressure at $x = 0.10\ m, y = 2.0\ m$ (2 marks)

$p = 1000x + 500y + 10000$

$x = 0.1\,m$

$y = 2.0\,m$

$p = 1000(0.1) + 500(2) + 10000$

$= 100 + 1000 + 10000$

$= 11.1$ kPa

$= 11$ kPa abs (2 s.f)

2) Calculate the static pressure 2500 m above sea level in a stationary atmosphere. Assume the atmosphere has a constant density of 1.2 kgm^{-3} (note, this is not very realistic). Also assume the absolute static pressure at sea level is 101,325 Pa. (1 mark)

Using piezometric pressure $p_* = p(z) + \rho g z$

@ sea level $(z=0)$ $p_* = 101325 + 0 = 101325\,Pa$

rearrange for $p(z) \rightarrow p(z) = p_* - \rho g z$

@ $z = 2500$ with $\rho_{air} = 1.2\,kgm^{-3}$, $g = 9.81\,ms^{-2}$

$p(2500) = 101325 - 1.2 \times 9.81 \times 2500$

$= 71895\,Pa$

$= 72$ kPa abs. (2s.f)

3) Calculate the absolute stagnation pressure in a flow of water (density 1,000 kg m^{-3} to 2 s.f.) moving at 10. ms^{-1} in at a depth of 15 m with atmospheric pressure equal to 101,325 Pa at the free surface. (3 marks)

$P_{stagnation} = P_{static} + \frac{1}{2}\rho U^2$

$P_{static} = P_{atm} + \rho g h$

$\rho = 1000\,kgm^{-3}$

$U = 10\,ms^{-1}$

$h = 15\,m$

$P_{atm.} = 101325\,Pa$

$P_{stagnation} = P_{atm} + \rho g h + \frac{1}{2}\rho U^2$

$= 101325 + (1000 \times 9.81 \times 15) + \frac{1}{2}(1000 \times 10^2)$

$= 298475\,Pa$

$= 300$ kPa abs (2s.f)

4) If atmospheric pressure is 101,000 Pa, what is an absolute pressure of 401,000 Pa, expressed as a gauge pressure?

$P_{abs} - P_{atm} = P_{gauge}$

$401000 - 101000 = 300000$

$= 300$ kPa gauge (2s.f)

5) Water at 15.0 °C, flows at 1.5 m/s in a pipe of 0.050 m diameter.

a. Calculate the Reynolds number. (1 mark)

b. Is the flow laminar or turbulent? (1 mark)

a) $U = 1.5\,ms^{-1}$ $\quad$ ν for water at 15.0°C $= 1.141 \times 10^{-6}$

$d = 0.050\,m$

$Re = \frac{UL}{\nu}$

$= \frac{1.5 \times 0.05}{1.41 \times 10^{-6}}$

$= 65789$ (5s.f)

$= 66000$ (5s.f)

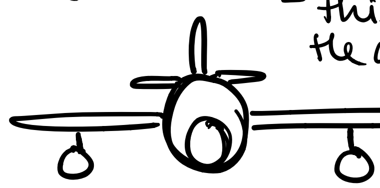
b) flow is almost certainly turbulent as Reynolds number is $\gg 4000$

6) An aircraft is climbing (gaining altitude) at constant speed, through air which has constant properties. Is the flow steady or unsteady, and what is its dimensionality (0, 1, 2 or 3 D)? (2 marks)

Depends on what is meant by the air's 'properties'.

→ Assuming that 'constant properties' means that the pressure, temperature, density, kinematic viscosity, etc. do not change in any way, particularly time or altitude, then the flow will be steady.

→ The flow will be 3-dimensional as the plane has only mirror symmetry → this assumes the aircraft looks roughly similar to this.



'Aircraft' could mean anything. A flying sphere would only have 2D flow

7) A hydraulic jack has one cylinder of 100. mm diameter, and another of 200. mm diameter. If a force of 2,500 N is used to push down the piston in the smaller cylinder, what is the force developed on the piston the larger cylinder? (1 mark)

$p_1 = p_2$ $\quad F_1 = p_1 A_1$, $F_2 = p_2 A_2$

$F_1 d_1 = F_2 d_2$ e.g $W_1 = W_2$

$p_1 A_1 d_1 = p_2 A_2 d_2$ $\quad$ let D = diameter

$p_1 \frac{\pi D_1^2}{4} d_1 = p_2 \frac{\pi D_2^2}{4} d_2 \rightarrow$ canceling $p_1 = p_2$, $\frac{\pi}{4}$

$D_1^2 d_1 = D_2^2 d_2$

$0.1^2 d_1 = 0.2^2 d_2$

$d_1 = \frac{0.2^2}{0.1^2} d_2 \Rightarrow F_1 d_1 = F_2 d_2$ subs

$d_1 = 4 d_2$

$4F_1 d_2 = F_2 d_2$ cancel

$4F_1 = F_2$

$F_2 = 10 kN$ (2s.f)

MUCH FASTER WAY

let smaller piston = 1 , larger = 2

$p_1 = p_2 \rightarrow F_1 = p_1 A_1$, $F_2 = p_2 A_2$

$p_1 = \frac{F_1}{A_1}$ $\quad p_2 = \frac{F_2}{A_2}$

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$F_2 = \frac{A_2}{A_1} F_1 \leftarrow F_1 = 2500 N$

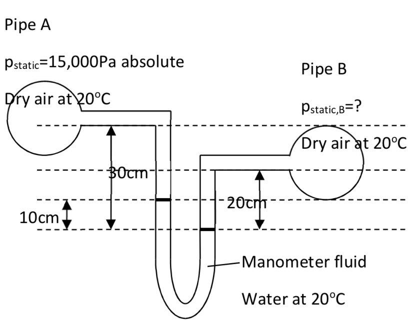
$A_2 = \frac{\pi \times 0.2^2}{4}$

$A_1 = \frac{\pi \times 0.1^2}{4} \Rightarrow \frac{A_2}{A_1} = \frac{0.2^2}{0.1^2} = 4$

$F_2 = 4F_1 = 4(2500) = 10,000 N$

$= 10 kN$ (2 s.f)

8) Calculate the absolute static pressure in Pipe B in the system shown in Figure 1 (2 marks).



$P_A + \rho_{air} \times 0.2m \times 9.81 + \rho_{water} \times 0.1 \times 9.81 = P_B + \rho_{air} \times 0.2m$

$15000 + \cancel{1.204 \times 0.2 \times 9.81} + 998.2 \times 0.1 \times 9.81 = P_B + \cancel{1.204 \times 0.2 \times 9.81}$

$15000 + 979.23 = P_B$

$= 15979.23 Pa$

$= 16 kPa$ abs (2s.f)

9) Water flows into a pond with a flow rate of 0.015 m³/hour and out of the same pond with a flow rate of 0.010 m³/hour. If the pond is empty at the start, and has a maximum capacity of 2.0 m³, how long does it take to fill? You may assume that evaporation is negligible. (2 marks)

Taking the pond as control volume $\quad$ * Assume evaporation is negligible and no other losses and volume is conserved throughout system, no changes in pressure, density, etc.

values in volume flow rate, e.g $\dot{V}$

$\Sigma \dot{V} = \frac{dV}{dt} \Rightarrow$ let flow into control volume be +ve, flow out be −ve $\quad$ flow in = 0.015 m³/hour, flow out = −0.010 m³/hour

$\Sigma \dot{V} = 0.015 - 0.010$

$\therefore \frac{dV}{dt} = 0.005 m^3/hour$

maximum capacity = 2.0 m³

$\frac{2.0 m^3}{0.005 m^3/hour} = 400$ hours (2 s.f)

≈ 17 days (2 s.f)