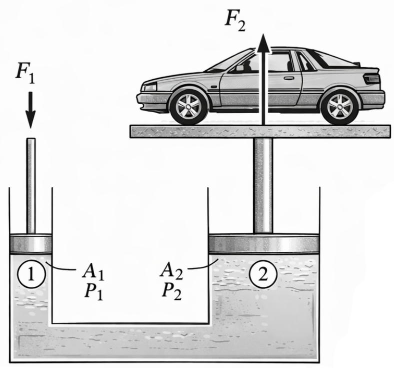
Problem Solving Part

Q3. Consider a hydraulic jack being used in a car repair shop, as shown in the figure below. The pistons have an area of A1 = 0.8 cm² and A2 = 0.04 m². The hydraulic oil used has a specific gravity of 0.870. A car that weighs 13000 N is to be jacked up. Calculate the force F1 in Newton (N) required to hold the car in the following two conditions:

a) When both pistons are at the same elevation.
b) When the car has been lifted for 2 meters above the level of piston 1.



a)

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

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

$$F_1 = 13000 \times \frac{0.8 \times 10^{-4}}{0.04}$$

$$F_1 = 26 \text{ N}$$

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b)

$$P_1 = P_2 + \rho g h$$

$$P_2 = \frac{13000}{0.04} = 325000 \text{ Pa}$$

$$P_1 = 325000 + (870)(9.81)(2)$$

$$P_1 = 325000 + 17069.4$$

$$P_1 = 342069.4 \text{ Pa}$$

$$F_1 = P_1 A_1 = 342069.4 \times 0.8 \times 10^{-4}$$

$$F_1 \approx 27.4 \text{ N}$$

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Q4. Water flows steadily through a splitter as shown in the figure below with volumetric flow rate $Q_1 = 0.08\ m^3/s$, $Q_2 = 0.05\ m^3/s$, $D_1 = D_2 = 12$ cm, $D_3 = 10$ cm. If the pressure readings at the inlet and outlets are $P_1 = 100$ kPa, $P_2 = 90$ kPa, and $P_3 = 80$ kPa, determine external force needed to hold the device fixed. Take the weight of the splitter with water inside it to be 200 N.

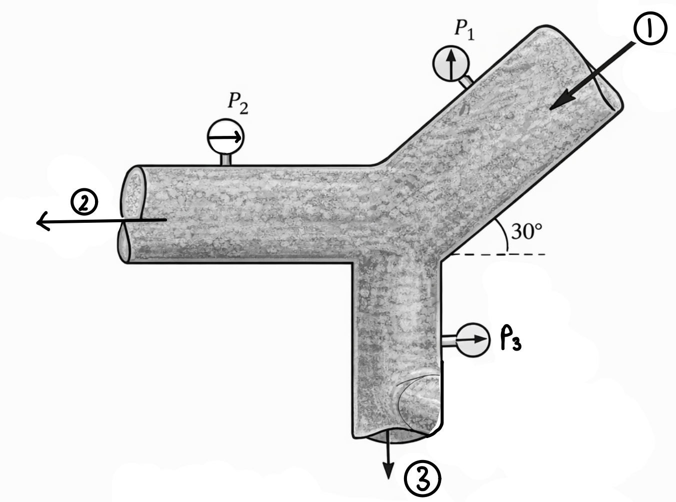
given:

$Q_1 \rho = Q_2 \rho + Q_3 \rho$

ρ constant

so: $Q_1 = Q_2 + Q_3$

$Q_1 = 0.08\ m^3/s$
$Q_2 = 0.05\ m^3/s$
$Q_3 = Q_1 - Q_2 = 0.03\ m^3/s$



$D_1 = D_2 = 0.12$ m
$D_3 = 0.10$ m

$\rho = 1000\ kg/m^3$
$P_1 = 100$ kPa
$P_2 = 90$ kPa
$P_3 = 80$ kPa
$W = 200$ N

areas:

$$A_1 = A_2 = \frac{\pi(0.12)^2}{4} = 0.0113\,m^2$$

$$A_3 = \frac{\pi(0.10)^2}{4} = 0.00785\,m^2$$

velocities: $V = \frac{Q}{A}$

$$V_1 = \frac{0.08}{0.0113} = 7.07\,m/s$$

$$V_2 = \frac{0.05}{0.0113} = 4.42\,m/s$$

$$V_3 = \frac{0.03}{0.00785} = 3.82\,m/s$$

$$\dot{m}_1 = 80\,kg/s,\ \dot{m}_2 = 50\,kg/s,\ \dot{m}_3 = 30\,kg/s$$

$\dot{m}_{in} = \dot{m}_{out}$, $\dot{m}_1 = \dot{m}_2 + \dot{m}_3$

$$R_x - P_1 A_1 \cos 30^\circ + P_2 A_2 = \dot{m}_2(-V_2) - \dot{m}_1(-V_1)\cos 30^\circ$$

$R_x = 230.4$ N ()

$$R_y - W - P_1 A_1 \sin 30 + P_3 A_3 = Q_3 \rho(-V_3) - Q_1 \rho(-V_1)\sin 30^\circ$$

$R_y = 305.3$ N ()

$$R = \sqrt{R_x^2 + R_y^2}$$

$$R = \sqrt{(230.4)^2 + (305.3)^2}$$

Q5. A fluid flowing in turbulent flow in the axial direction inside a horizontal pipe of 10 cm diameter has a velocity profile given by the following equation:

$$v_x = \frac{n}{n+1}\left(\frac{P_0 - P_L}{2KL}\right)^{1/n} (R_0)^{(n+1)/n}\left[1 - \left(\frac{r}{R_0}\right)^{(n+1)/n}\right]$$

Where *n* and *K* are constants, *(P₀ – P_L)* is the pressure drop in the pipe, *L* is the length of the pipe, and *R₀* is the radius (diameter).

For a 35 m long pipe with pressure drop of 35000 Pa, n = 2, and K = 5, find the following:

a) The maximum velocity in the pipe
b) The average velocity in the pipe

D = 10 cm → R_0 = 0.05 m
L = 35 m
ΔP = 35000 Pa
n = 2
K = 5

(a) Maximum Velocity (عند r = 0)

$$V_{max} = \frac{2}{3}\left(\frac{35000}{2 \times 5 \times 35}\right)^{1/2} (0.05)^{3/2}$$

$$V_{max} = 0.21 \text{ m/s}$$

(b) Average Velocity

$$V_{avg} = \frac{1}{\pi R_0^2}\int_0^{R_0} v(r)\, 2\pi r \, dr$$

$$V_{avg} = 0.197 \text{ m/s}$$

$$V_{avg} = \frac{1}{A}\iint v \, r \, dr \, d\theta$$

$$= \frac{1}{\pi R_0^2}\int_0^{2\pi}\int_0^{R_0} v \, r \, dr \, d\theta$$

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