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1) (a) τ_{ij} => i is the plane which the shear stress act on /tangential to direction of the flow which is j.

(b) Pressure wave will travel at sonic velocity

$$V = \sqrt{\frac{RT}{M}}$$

(c) Low Re number or inertial force is smaller than viscous → laminar

(d) gravitational / elevation, pressure, friction, pump, kinetic energy heads

(e) Fluid travels at such a turbulent state that laminar boundary layer → 0 and the pipe's roughness is fully exposed to flow hence it becomes independent of Re,,

(f) Gas is compressible and density changes with changes in pressure

(g) Static pressure is a function of vertical height only

(h) 3 planes / 3D flow considered

(i) $Re = \dfrac{1000 \times 0.25 \times 5 \times 10^{-3}}{8.9 \times 10^{-4}}$

$= 1404 \qquad < 2000$ so can use NSE due to laminar flow

(j) Bingham fluid exhibits a yield stress → threshold stress must be applied before fluid begins to flow

(k) what type of impeller is best for each system

(l) $c = \sqrt{\frac{RT}{M}}$ / Sonic velocity

(m) ?

(n) Net positive suction head available in the system

— " ——— required by the pump

NPSHA > NPSHR to avoid cavitation within pump.

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2 (a) $$\frac{(20\times10^5)^2-(25\times10^5)^2}{2\times 8.314\times \frac{298}{2\times10^{-3}}} + \frac{(0.2)^2}{\left(\frac{\pi\times D^2}{4}\right)^2} \quad \frac{2\times0.005\times400}{D} = 0$$

$\uparrow$

$$-908147.1699 + \frac{0.259}{D^5} = 0$$

$$D^5 = \frac{0.259}{908147.1699}$$

$$D = \left(\frac{0.259}{908147}\right)^{1/5}$$

$$= 0.05\,m$$

(b) $$\rho_1 = \frac{P_1}{RT/M}$$

$$= \frac{25\times10^5}{8.314\times\frac{298}{2\times10^{-3}}}$$

$$= 2.02\,kg/m^3$$

$$\rho_2 = \frac{P_2}{RT/M}$$

$$= \frac{20\times10^5}{8.314\times\frac{298}{2}\times10^3}$$

$$= 1.614\,kg/m^3$$

$$V_1 = \frac{G}{A\rho_1}$$

$$= \frac{0.2\,kg/s}{\frac{\pi\times0.05^2}{4}\times2.02}$$

$$= 50.4\,m/s.$$

$$V_2 = \frac{G}{A\rho_2}$$

$$= \frac{0.2\,kg/s}{\frac{\pi\times0.05^2}{4}\times1.614}$$

$$= 63.09\,m/s$$

(c) $$\frac{4fL}{D} = \left(\frac{P_1}{P_w}\right)^2 - \ln\left(\frac{P_1}{P_w}\right)^2 - 1$$

increasing length will decrease P_w so both LHS and RHS $\uparrow$

(d) yes.

$$L_{min} = \left(\frac{D}{4f}\right)\left[\left(\frac{P_1}{P_2}\right)^2 - \ln\left(\frac{P_1}{P_2}\right)^2 - 1\right]$$

when $L_{pipe} < L_{min} \rightarrow$ choked flow

(e) $$c = \sqrt{\frac{RT}{M}} = \sqrt{\frac{8.314\times298}{2\times10^{-3}}}$$

$$= 1113\,m/s$$

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3) (a) continuity equation

$$Q_1 = Q_2$$

$$V_1 A_1 = V_2 A_2$$

$$V_2 = \frac{2.12\,m/s \times \frac{0.3^2}{4} \times \pi}{\pi \times \frac{0.15^2}{4}}$$

$$= 8.48\,m/s$$

$$\cancel{\frac{\Delta p}{\rho}}^{\,0} + \Delta z \times g + \frac{1}{2}(V_2^2 - V_1^2) + Ws + F = 0$$

manometer height the same = same pressure.

$$(-2) \times 9.8 + \frac{1}{2}(8.48^2 - 2.12^2) + Ws + F = 0$$

$$Ws + F = -14.108 \ J/kg$$

(b) energy gain because Ws+F is negative that means "Ws" is greater than "F" or energy added greater than energy loss //

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5) (a) $h_2 = h_{cnt}$

$$= \left(\frac{q^2}{g}\right)^{1/3}$$

$$= \left(\frac{1.6^2}{9.8}\right)^{1/3}$$

$$= 0.639 \text{ m}$$

$E_1 = E_3$ assuming frictionless bump

$$\frac{1.6^2}{2\times 9.8\times 1^2} + 1 = \frac{1.6^2}{2\times 9.8\times h_3^2} + h_3$$

$$1.13 = \frac{0.1306}{h_3^2} + h_3 \qquad \times h_3^2$$

$$h_3^2 - 1.13h_3^2 + 0.1306 = 0$$

solving for $h_3 = 1, 0.43284, -0.30201$

sub: 1
super: 0.43284
non-physical: -0.30201

$h_3 = 0.43284$ m

$$Fr_3 = \frac{\frac{1.6}{0.43284}}{\sqrt{9.8\times 0.43284}} = 1.79$$

$$\frac{h_4}{h_3} = \frac{-1+\sqrt{8\times 1.79^2+1}}{2}$$

$$= 2.087$$

$$h_4 = 2.087\times 0.43284$$

$$= 0.903 \text{ m}$$

(b) $E_1 - E_2 = \Delta h$

$$1.13 - \frac{3}{2}\times 0.639 = \Delta h$$

$$\Delta h = 0.1715 \text{ m}$$

(c) $$h_L = \frac{(h_4-h_3)^2}{4h_4h_3} = \frac{(0.903-0.43284)^3}{4\times 0.903\times 0.43284} = 0.066 \text{ m}$$

$$\frac{0.66}{1.13}\times 100\% = 5.88\%$$

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6) (a) Froude number

$$\frac{q_1/h_1}{\sqrt{gh_1}} = \frac{q_2/h_2}{\sqrt{gh_2}}$$

$$h_2 = \frac{1}{10} h_1$$

$$\frac{q_1}{h_1\sqrt{h_1}} \times \sqrt{1/10 h_1} \times h_1 = q_2$$

$$q_2 = q_1 \sqrt{\frac{1}{10}}$$

$$= 1.6 \sqrt{\frac{1}{10}}$$

$$= 0.506 \, m^2/s.$$

(b) surface tension and gravity → Bond number

$$Bo = \frac{\rho L^3 g}{\varphi L} = \frac{\rho L^2 g}{\varphi}$$

largest pendant ⇒ $Bo \leq 1$

$$\frac{\rho L^2 g}{\varphi} \leq 1$$

$$L^2 \leq \frac{\varphi}{\rho g}$$

$$L \leq \frac{0.07}{1000 \times 9.8}$$

$$L \leq 7.14 \times 10^{-6} \, m$$