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1) (a) (i) Bingham plastic fluid => exhibits a yield stress

(ii) Power Law fluid => apparent viscosity can change with shear rate according to the power law index

(iii) Newtonian fluid -> viscosity constant for a given T/P or independent of shear rate

(b) boundary conditions
↳ no-slip at the walls and Vmax at the furthest distance away from wall

(c) Low visc => High Reynolds number and inertial forces is greater so small impellers can mix

High visc fluid => Low Re number, small impeller ≠ turbulence to mix.

(d) ?

2 (a) sometimes true. There can be no ΔP as long as the mechanical energy balance is satisfied

(b) yes. Density of liquids do not change greatly enough w/ pressure to deem them compressible

(d) $h_p = h_{sys}$ ✓ always true

(e) not true => changes as a function of temperature

(d) centrifugal pump provide mechanical energy by raising velocity / acceleration
-> always true

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3(a) at junction, pressure/head is the same

$$\rho g h_1 = \rho g x + \rho g h_2 \qquad \text{(static pressure)}$$

$$x = h_1 - h_2$$

$$= 10 - 1.5$$

$$= 8.5\,m$$

pipe length

$$L \sin 30^\circ = 8.5$$

$$L = \frac{8.5}{\sin 30}$$

$$= 17\,m$$

(b) $\Delta P = \rho g h_3$

$$= 1000 \times 9.8 \times (10+7)$$

$$= 166.6\ kPa.$$

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4 (a) $\frac{\Delta P}{\rho} + g\Delta z + \frac{1}{2}(V_2^2 - V_1^2) + W_s + F = 0$

$V = \frac{Q}{A} = \frac{7 \times 10^{-3}}{\frac{\pi \times 0.1^2}{4}} = 0.891$ m/s

$Re = \frac{\rho v d}{\mu} = \frac{1000 \times 0.891 \times 0.1}{1.307 \times 10^{-3}} = 68191$

assume e for steel pipe = 4.5mm.

$\frac{e}{D} = 0.045$

$f_F \Rightarrow 0.017$

$\frac{7 \times 10^3}{10^3} + 9.8 \times 200 + 0 + W_s + 2 \times \frac{\overset{1000 + 2 \times 90 \times 0.1 + 7 \times 0.1}{1010.7} \; 0.017}{0.1} \times (0.891)^2 = 0$

$-W_s = 2732$ J/kg

$P_F = -W_s G$

$= h_p g \rho Q$

$= 2732 \text{ J/kg} \times 1000 \text{ kg/m}^3 \times 7 \times 10^{-3} \text{ m}^3/\text{s}$

$= 19124$ J/s

$P_B = \frac{P_F}{0.7}$

$= 27.32$ kW

(b) $h_p = \frac{2732}{9.8} = 278.8$ m apalagi ini...

$\frac{7L}{s} \times \frac{60s}{min} \times \frac{0.26 gal}{1L} = \underline{109.2 \text{ gal}}$ // ga masuk range

(c) No suitable pumps

→ use pumps in parallel I guess ... ?

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6) (a) $\frac{4fL_{min}}{D} = \left(\frac{P_1}{P_2}\right)^2 - \ln\left(\frac{P_1}{P_2}\right)^2 - 1$

$L_{min} = \frac{0.1}{4 \times 0.005}\left[\left(\frac{7}{3}\right)^2 - \ln\left(\frac{7}{3}\right)^2 - 1\right]$

$= 17.99\,m$

as $L_{pipe} > L_{min}$, flow is not choked

(b) $\frac{(300\times10^3)^2 - (700\times10^3)^2}{2 \times 8.314 \times \frac{323}{28\times10^{-3}}} + \left(\frac{G}{A}\right)^2\left[\ln\left(\frac{7}{3}\right) + \frac{2\times0.005\times20}{0.1}\right] = 0$

$\uparrow$

$-2085333.329 + \left(\frac{G}{A}\right)^2 (2.847) = 0$

$(G/A)^2 = \frac{2085333}{2.847}$

$\left(\frac{G}{A}\right)^2 = 732390.2983$

$\frac{G}{A} = 855.8$

$G = 855.8 \times \frac{0.1^2}{4} \times \pi$

$= 6.72\,kg/s$

(c) $L_{min} = \frac{0.1}{4 \times 0.005}\left[\left(\frac{14}{3}\right)^2 - \ln\left(\frac{14}{3}\right)^2 - 1\right]$

$= 88.48\,m$

as $L_{pipe} < L_{min}$, flow will be choked

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7 (a) $Q = \bar{V}A$

$$= \frac{1}{0.030}\left(\frac{1.6\times5}{5+2\times1.6}\right)^{2/3}\left(\frac{1}{500}\right)^{1/2} 1.6\times5$$

$$= 11.73\ m^3/s$$

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

② $h_{crit} = \left(\frac{11.73^2}{9.8\times5^2}\right)^{1/3}$

$$= 0.825\ m$$

$$E_1 = \frac{11.73^2}{2\times9.8\times5^2\times1.6^2} + 1.6$$

$$= 1.71\ m$$

$$\Delta h = 1.71 - \frac{3}{2}\times0.825$$

$$= 0.47\ m$$

(c) $E_1 = E_3$. (assuming frictionless bump)

$$E_3 = \frac{11.73^2}{2\times9.8\times5^2\times0.48^2} + 0.48$$

$$= 1.71\ m$$

or proof by

$$1.71 = \frac{11.73^2}{2\times9.8\times5^2\times h_3^2} + h_3$$

$$h_3^2 - 1.71h_3 + 0.281 = 0$$

$h_3 = 1.6,\ 0.48,\ -0.37$

↳ non-physical

$$\text{Velocity} = \frac{11.73}{5\times0.48}$$

$$= 4.91\ m/s$$

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8 (a) using Bond number for object

$$\frac{mg}{\varphi L} > 1$$

$$\frac{m}{L} > \frac{\varphi}{g}$$

$$> \frac{0.07}{9.8} = 0.00714 \text{ kg/m}$$

(b) $Fr_R = Fr_M$

$$\frac{u_R}{\sqrt{g h_R}} = \frac{u_M}{\sqrt{g h_M}} \qquad h_M = \frac{1}{10} h_R$$

$$u_M = \sqrt{\frac{1}{10}}\, u_R$$

$$Q = u_M A_M$$

$$= \sqrt{\frac{1}{10}}\, u_r \frac{h_r}{10} \frac{1}{10} b_r$$

$$= \left(\frac{1}{10}\right)^{5/2} Q_r$$

$$= 0.037 \text{ m}^3/\text{s}$$