FM S2 2015

1) $\Delta P = 1000 \times 9.8\,(0.3 - 0.8 \times 0.15 + 13.6 \times 0.15 - 0.1)$

$= 20776$ Pa

or 20.81 kPa

2) (i) $\frac{\cancel{\Delta p}^{0}}{\rho} + \cancel{g\Delta z}^{0} + \cancel{\frac{1}{2}\Delta v^2}^{0} + Ws + F = 0$ $\qquad -WsG = P_F$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\eta \rho g \rho a$

$-Ws = F$

$\frac{30\,J/s}{\rho A V} = F$

$$\frac{30J/s}{\rho AV} = \frac{2 \times (60 + 5 \times 25 \times 0.03) \times 0.01}{0.03} \times V^2 + \frac{1}{2}(12 + 6 + 0.8 + 1) \times V^2$$

$$\frac{30J}{1000 \times \pi \times \frac{0.03^2}{4}} = 52.4\,V^3$$

$V = 0.932$ m/s

$Q = VA$
$= 0.932 \times \pi \times \frac{0.03^2}{4} \times 10^3 \times 60$
$= 36.8$ L/min

(ii) Cavitation is when pressure in pump drops below vapour pressure and thus bubble form within the pump. It should be avoided because it can damage pump.

To avoid cavitation, $NPSH_A > NPSH_R$

(iii) Net +ve suction head: margin of pressure over pressure @ pump suction side

$NPSHA = \frac{P_1 - P_{vap}}{\rho g} + z_1 - h_{fs}$

(iv) $= \frac{(101.3 - 2.3) \times 10^3}{10^3 \times 9.81} + 3 - \left[\frac{2 \times (30 + 25 \times 0.03 \times 3) \times 0.01}{0.03} + \frac{0.8}{2}\right] \frac{\times 0.932^2}{9.8}$

$= 11.16$ m

(v) NO! $NPSHA > NPSH_R$ thus we are operating above margin of safety

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4 (a) φ polytropic index $= \frac{C_p}{C_v}$

used during adiabatic modelling

(b). Water hammer ⇒ flow of liquid stopped instantaneously and liquid becomes compressed

↳ pressure waves propagation up and downstream causing physical damage to system and surrounding

(c) $Fr = \frac{\text{inertia}}{\text{gravitational}}$

Fr from > 1 to < 1 ⇒ hydraulic jump.

(f) Presence of yield stress // threshold stress must be applied before material is affected by shear rate.

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5 (i) $$\frac{(150\times10^3)^2-(500\times10^3)^2}{\frac{2\times8.314\times298}{44\times10^{-3}}} + \left(\frac{G}{A}\right)^2\left[\ln\left(\frac{500}{150}\right)+\frac{2\times2000\times0.0005}{0.15}\right]=0$$

$$-2020122927 + \left(\frac{G}{A}\right)(17.87\ kg/s) = 0$$

$$\left(\frac{G}{A}\right)^2 = 113041$$

$$\frac{G}{A} = 336\ kg/m^2s$$

$$G = 336\times\frac{\pi\times0.15^2}{4}$$

$$= 5.94\ kg/s$$

(ii) $$\frac{P_2^2-(500\times10^3)^2}{\frac{2\times8.314\times298}{44\times10^{-3}}} + \frac{336^2\times2\times625\times0.0005}{0.15}=0$$

$$P_2 = 444\ kPa$$

if incompressible,

$$500 - \frac{1}{4}(500-150) = 412.5\ kPa$$

different

ΔP linear with length in incompressible, but not with compressible.

(c) $$\frac{4\times0.0005\times L_{min}}{0.15} = \left(\frac{1500}{150}\right)^2 - \ln\left(\frac{1500}{150}\right)^2 - 1$$

$L_{min} = 7079\ m$

as $L_{pipe} < L_{min}$, probably not achieved

(d) $$\frac{4\times0.0005\times2500}{0.15} = \left(\frac{P_1}{150}\right)^2 - \ln\left(\frac{P_1}{150}\right)^2 - 1$$

trial and error gives 924 kPa //

$$\rho_2 = \frac{150\times10^3}{\frac{8.314\times298}{44\times10^{-3}}} = 2.66\ kg/m^3 \qquad v = \frac{G}{A\rho} = \frac{924\times10^3}{\sqrt{\frac{8.314\times298}{44\times10^{-3}}}\times2.66\ kg/m^3}$$

$$= 1464\ m/s.$$

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6) (a) x-component

$$-\frac{\partial P}{\partial x} + \mu\frac{\partial^2 V_x}{\partial y^2} + \rho g_x = 0$$

pressure, viscous, gravity

(b) steady → do not depend on x

independent of z → do not depend on z.

$V_x = V_x(y)$

(c) $$\frac{\partial P}{\partial x} = \mu\frac{\partial^2 V_x}{\partial y^2} + \rho g_x.$$

↳ $\frac{P_L - P_0}{L}$

(d) $$\underbrace{\left[\frac{P_L - P_0}{L} - \rho g_x\right]}_{A} = \mu\frac{\partial^2 V_x}{\partial y^2}$$

$$\frac{\partial V_x}{\partial y} = \frac{A}{\mu}y + C_1$$

$$V_x(y) = \frac{A}{2\mu}y^2 + C_1 y + C_2.$$

$V_x(b) = 0$

$V_x(-b) = 0$

$$\frac{A}{2\mu}b^2 - C_1 b + C_2 = \frac{A}{2\mu} + C_1 b + C_2$$

$C_1 = 0$

$$C_2 = -\frac{A}{2\mu}b^2$$

$$V_x(y) = \frac{A}{2\mu}(y^2 - b^2)$$

$$= \left[\frac{P_L - P_0}{2\mu L} - \frac{\rho g_x}{2\mu}\right](y^2 - b^2)$$

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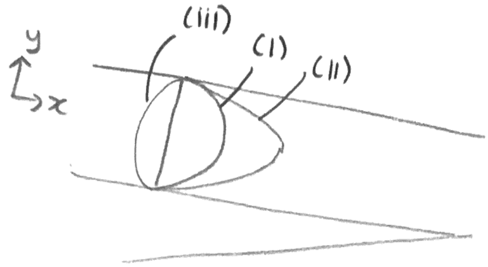
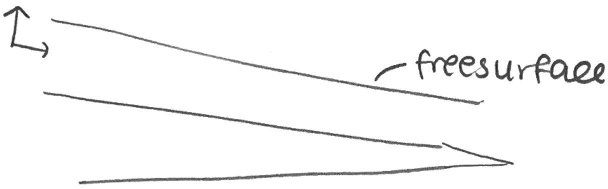
6 (e)



(f).



(i) less velocity because less driving force (pressuregrad=0)

(ii) $V_x(y=-b)=0$

and $\left.\frac{\partial V_x}{\partial y}\right|_{y=b} = 0.$