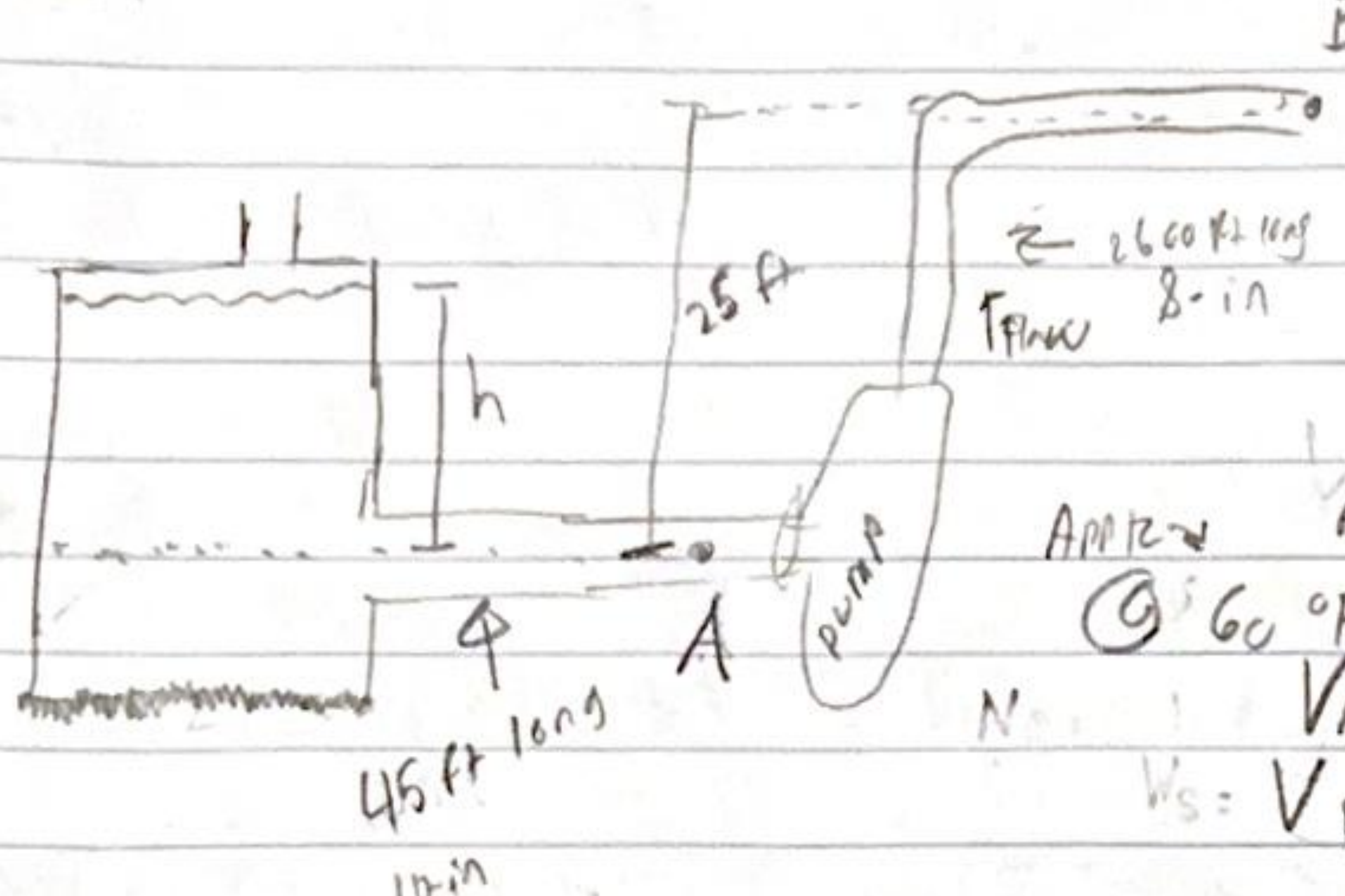
Callaway Marly 10/9/24 1/11

MET 336

HW 2.2

Ch 8: 33, 38, 44, 46, 49, 62

33|



60 °F

$Q = 1500$ gal/min

Area $A = \pi (5\,in)^2 = 78.5\,in^2$

Area $B = \pi (4\,in)^2 = 50.3\,in^2$

@ 60 °F $\gamma_w = 62.4\ lb/ft^3 = .0361\ lb/in^3$

$V_A = 73.5$ in/s

$V_B = 2.96$ m/s (on back)

a. Calculate required height h of the water level in the tank in order to maintain 5.0 psig pressure at point A

*Excluding losses!!!

P_A must equal 5 psig

$$\frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 = \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1$$

↓ tank, Point A ↓, must be 5 psi

tank side has 0 speed, no pressure, its to atmosphere! Only height!

bernoullis

$$\frac{(0)^2}{2g} + \frac{(0\ gauge)}{\gamma} + h = \frac{(73.5\ in/s)^2}{2g} + \frac{(5\ psi)}{\gamma}$$

$Q = (V_1)(\text{Area } A)$

$$V_1 = Q/(\text{Area}A) = \frac{\left[(1500\ gal/min)\cdot\left(\frac{1\ ft^3/s}{449\ gal/min}\right)\cdot\left(\frac{1728\ in^3}{1\ ft^3}\right)\right]}{78.5\ in^2}$$

$V_1 = 73.5$ in/s

inch second power

$$h = \frac{(73.5\ in/s)^2}{2\cdot(9.81\ m/s^2)\left(\frac{39.37\ in}{1\ m}\right)} + \frac{5\ lb/in^2}{.0361\ lb/in^3} = 145.5 \text{ inches}$$

a. Conclusion: h must be at least 145.5 inches to maintain a 5psig measurement at point A.

.3472 ft^2

ft^3/min m^3/s

continued, using all info and numbers from last page

33 5. if $P_A = 5$ psig, calculate power delivered by pump in order to maintain 85 psig at point B. Include losses to friction only

$\boxed{125.8\ HP}$

No pump loss

P_1 is A

P_2 is B

Pump $h_a + h_L$ friction

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

we know it.

At 15°C, near 60

$N_R = \frac{vD\rho}{\eta}$

Laminar turbulent?

$$N_{RA} = \frac{(1.37\ m/s)/(1.15 \times 10^{-3}\ Pa \cdot s)}{(1.15 \times 10^{-6}\ m^2/s)} = 1370 < 2000 \text{ Laminar}$$

Checked?

$Q = V \cdot A$

$V = Q/A$

$$N_{RB} = (2.46\ m/s)(1.15 \times 10^{-3}\ Pa \cdot s) / (1.35 \times 10^{-6}\ m^2/s) = 2462 > 2000,\ < 4000$$

Velocity at B is $V = Q/A = \frac{(1500\ gal/min)(1\ min/60\ sec)(1\ m^3/264\ gal)}{(50.3\ in^2)(1\ m^2/1550\ in^2)} = 2.46\ m/s$

2.461

So Power required for the pump is $P_A = h_a W$

Friction first:

$$h_L = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} = (.024) \cdot 2600\ ft/(8/12)\ ft \cdot \left[2.46\ m/s \left(\frac{3.281\ ft}{m}\right)\right]^2 / 2g$$

$(64/N_R)$

[F1] → Relative roughness: 5×10^{-6} ft ε → Checked w/ Re ~ 3000 Not plotted in between 2000 & 4000

$h_L = 122$ ft

On front (convert) 85 is on front (convert)

Now h_{pump} 5 psi

$$h_a - h_L + P_1/\gamma + \cancel{z_1} + v_1^2/2g = P_2/\gamma + z_2 + v^2/2g$$

$$h_a = \left(\frac{P_2 - P_1}{\gamma}\right) + z_2 + \left(\frac{v_2^2 - v_1^2}{2g}\right) + h_L$$

$$= \frac{(85\ psi - 5\ psi)\left(\frac{144\ in^2}{1\ ft^2}\right)}{62.4\ lb/ft^3} + 25\ ft + \frac{\left((2.46\ m/s)\left(\frac{3.28\ ft}{1\ m}\right)\right)^2 - 735\ in/s^2}{2(32.2\ ft/s)} + 122\ ft$$

3.28 ft / m

$h_a = 332$ ft

$$P_A = h_a W = h_a \gamma Q = (332\ ft) \cdot 62.4\ lb/ft^3 \cdot (1500\ gal/min)\left(\frac{1\ ft^3/s}{449\ gal/min}\right)$$

$= 69204$ lb-ft/s and 1hp/550 lb ft/s

You'd need to deliver this much power $= 125.8$ HP

8.38 A pipeline transporting crude oil (sg=0.93) @ 1200 L/min
w/ DN 150 schedule 80 steel pipe
Stations are 3.2 km apart if oil at 10°C, normally

a) If the oil is heated to 100 °C to decrease viscosity, ν

the influence that friction has in the energy equation w/ losses, is determined with the Darcy-Weisbach eqn. stating:

$$h_L = f \frac{L}{D} \frac{v^2}{2g}$$

where the friction factor, f, is found as a relation between relative roughness and Reynolds number, or Re.

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

viscosity

Since a lower Re trends laminar flow, and viscosity is inverse,

1. then a lower viscosity is a higher Re
2. a higher Re results in a lower friction factor f (if it's not already at the limit)
3. a lower friction factor, f, means lower h_L
4. a lower h_L literally means less 'loss' due to friction, meaning the pump would have to do LESS work, requiring less power

b. per book, pressure loss at 10 °C oil temp was
Δp between stations = 853 kPa, P_a = 17.1 kW
Pump power

what distance per pumps to have same Δp = 853 kPa across pumping stations.

b cont general energy equation

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + h_A - h_R - h_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

P, Z, V dont change
only h_L and h_A

$\Delta P = 853$ kPa between stations 1 & 2, pump covered
Nothing is changing accept the temperature of the crude oil using (D 1).
With $sg = .93$, at $100°C$, Dynamic Viscosity η (
$\eta = 8 \times 10^{-3}$ N·s/m² or Pa/s

$H_L = H_A$?
Yes

Reynolds number is dependent on this,

$$Re = \frac{vD\rho}{\eta}$$

$\dot{V} = 1200$ L/min $\left(\frac{1 m^3/s}{60000 L/min}\right)$
$= .02$ m³/s

D = DN 150 schedule 80 means 146.3 mm ID

$\rho = sg \cdot \rho_w = (.93)(958$ kg/m³$) = 890.94$ kg/m³
at 100°C

$$Re = \frac{(.02 m^3/s)(.1463 m)(890.94 kg/m^3)}{(8 \times 10^{-3} \frac{N \cdot s}{m^2})}$$

$Re = 325$ laminar flow

$f = 64/Re$
$= .196$ new

So the friction factor is .196 @ 100 °C

Now we need it from before;

Old at 10 °C
$V = .02$ m³/s
$D = 146.3$ mm ID
$\rho = sg \cdot \rho_w = (.93)(1000$ kg/m³$) = 930$ kg/m³
at 10°C
$\eta = 1.5 \times 10^{-1}$ N·s/m² (D-1)

$$Re = \frac{(.02 m^3/s)(.1463 m)(930 kg/m^3)}{(1.5 \times 10^{-1} N \cdot s/m^2)}$$

$= 181$ laminar!

$f = 64/Re = .35$ old

now we can equate and solve for length

8.38 b continued

$$H_L @ 10°C = H_L @ 60°C$$

$$f_{old} \cdot \frac{L_{old}}{D} \cdot \frac{V^2}{2g} = f_{new} \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$$

V doesn't change
g doesn't change
or D

$$(3.5)(3.2\,km) = (.196)(L)$$

new length $L = 57.14$ km

all that added energy takes a look at the pump frequency? makes sense I guess

8-44 at 60°F, water is pumped from stream to reservoir.

Pipe: 8 in Schedule 40 steel

$L = 2500$ ft

$Q = 4.00\ ft^3/s$

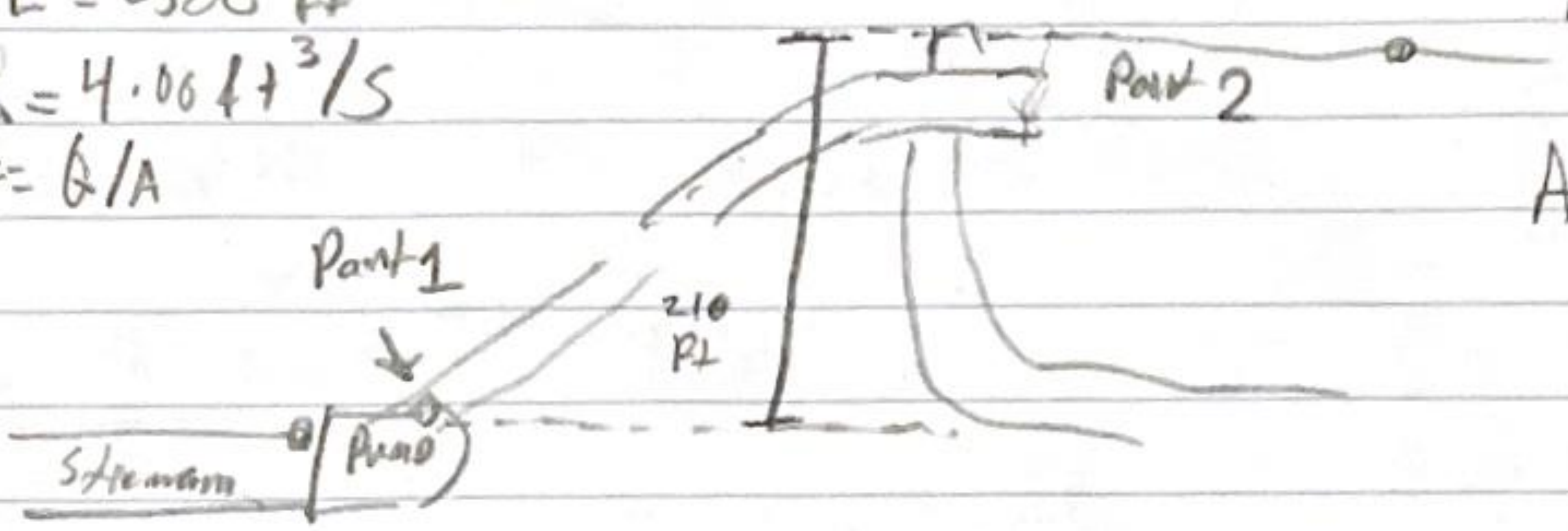
$V = Q/A$

App D:

$D = .6651$ ft

$A = \pi (D/2)^2$

$= .347\ ft^2$



Only consider friction loss, neglect other losses

what is pressure at pump outlet?

atmosphere

no motion on reservoir surface

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + h_A - h_R - H_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

bottom 0

don't include pump/turbine losses

210 feet up

specific weight doesn't change

Solving for P_1, pressure at

$$P_1 = H_L + Z_2 + V_1^2/2g$$

$V = Q/A$

$= 4.00\ ft^3/s \,/\, .347\ ft^2$

$= 11.5$ ft/s

$g = 32.2$ ft/s

$z = 210$ ft

$\varepsilon = 1.5 \times 10^{-4}$ (ft)

$D/\varepsilon = 4434$

f using eq (8-7)

$f = .01546$

App (A-2)

$H_L = f \times L/D \times V^2/2g$

$Re = vD/\nu = (11.5\ ft/s)(.6651\ ft) / (1.21 \times 10^{-5}\ ft^2/s) = 630k$

vel   visc kine   turbulent

$$H_L = .01546 \cdot \frac{(2500\ ft)}{(.6651\ ft)} \cdot \frac{(11.5\ ft/s)^2}{2 \cdot (32.2\ ft/s)} = 119.7\ ft$$

$$P_1 = \underbrace{(119.7\ ft)}_{H_L} + \underbrace{(210\ ft)}_{z_2} + (11.5\ ft/s)^2 / 2 \cdot (32.2\ ft/s)$$

$P_1 = 332$ ft

8-44/ Cont

$P_1 = 332$ ft pressure head

$\cancel{A}$ Answer

$P_1 \cdot \gamma_{water} = \text{Pressure}$

$(332\ ft)\cdot(62.4\ lb/ft^3) = 20701\ lb/ft^2$

$(20701\ lb/ft^2)(1\ ft^2/144\ in^2) = 144\ psig$ at Pump outlet

144 psig

8-46 gas @ 50°F

Point 1 → Point 2

L = 3200 ft or 10 in Schedule 40 Steel

(F-1) $D = .8350\ ft \rightarrow A = \pi (D/2)^2 = .548\ ft^2$

$Q = 4.25\ ft^3/s$

$V = Q/A = (4.25\ ft^3/s)/(.548\ ft^2) = 7.76\ ft/s$

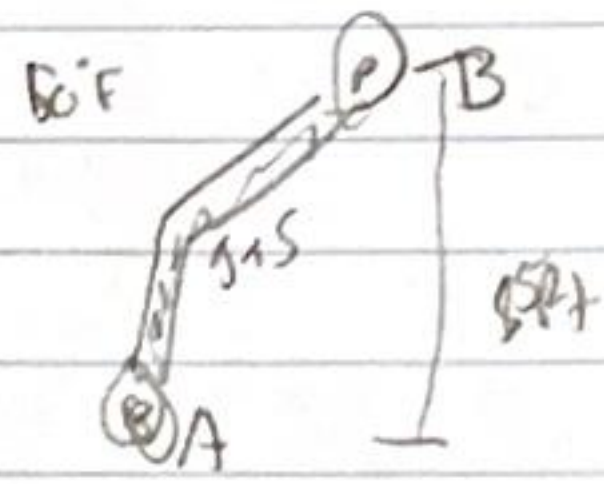
Elevation = 85 ft

$P_2 = 40.0\ psig$

Consider friction loss, neglect other loss

find pressure at point A

(B-2) Sg gas = .68



over 40 > psig

General energy eq (head form)

$$\frac{P_1}{\gamma} + \cancel{z_1} + \cancel{\frac{V_1^2}{2g}} + \cancel{h_A} - \cancel{h_R} - H_L = \frac{P_2}{\gamma} + z_2 + \cancel{\frac{V_2^2}{2g}}$$

base point

pipe size doesn't change, speed won't change either. mass in → mass out

Velocity in → Velocity out

no turbine, not considering pump only friction loss

$$\frac{P_1}{\gamma} = \left(\frac{40\ psig}{\gamma_{gas}}\right) + 85\ feet + H_L$$

This is an approx, but it clearly shows that it's turbulent

find H_L

$$H_L = f \cdot L/D \times V^2/2g$$

where $L = 3200\ ft$

$D = .8350\ ft$

$V = 7.76\ ft/s$

$g = 32.1\ ft/s^2$

find f

first $Re = VD/\nu$

kinematic viscosity @ 77°F

$= (7.76\ ft/s)(.8350\ ft)/(4.55 \times 10^{-6}\ ft^2/s)$

$= 1424087$, 140 million turbulent

$1.5 \times 10^{-4}\ ft$

$D/\epsilon = 556\ldots$

$f = .01413$

f found using eqn (8-7) you know the one

Cont

$f = .0143$

$$H_L = .0143 \cdot \frac{3200\ ft}{.8350\ ft} \cdot \frac{(7.76\ ft/s)^2}{2(32.1\ ft/s^2)}$$

$= 51.3\ ft$

$$\text{So } \frac{P_1}{\gamma} = \frac{40\ psig}{\gamma} + 85\ ft + 51.3\ ft$$

"Sg of gas at 50°F is" .73 (I was stuck here for a while, I raw googled this value, sorry!)

with this search phrase

$.73 = \gamma / 62.4\ lb/ft^3 \Rightarrow \gamma = 45.6\ lb/ft^3$

plug $45.6\ lb/ft^3$ in for γ & (2 of them)

and $(40\ psi)(144\ in^2/1\ ft^2) = 5760\ lb/ft^2$

$$P_1 = 45.6\ lb/ft^3 \left(\frac{5760\ lb/ft^2}{45.6\ lb/ft^3} + 85\ ft + 51.3\ ft \right)$$

$= 11975\ lb/ft^2\ (1\ ft^2/144\ in^2) = 83\ psig$

the outlet pump pressure at point A needs to be at least 83 psig

Pure, Quench

8-49 / glycerin at 25 °C

Point 1 ⟶ Point 2

80 mm OD copper tube × 2.8 mm wall

Stng hydraulic tube

App B gives, @ 25°C
glycerin $\gamma = 12.34\ kN/m^3$
KV $\nu = 7.63 \times 10^{-4}\ m^2/s$

$Q = 180\ L/min\ (1\ m^3/s / 60000\ L/min) = .003\ m^3/s$

Apple

ΔP for $L = 25.8\ m$ (pipe length)
$h = .68\ m$ (elevation)

App G $\rightarrow D = 74.4\ mm = .00744\ m$

$A = \pi (7.44\ E{-3}\ m/2)^2 = 4.347\ E{-5}\ m^2$

I'm including friction! no other losses

$V = Q/A$
$= (.003\ m^3/s) / (4.347E{-5}\ m^2) = 69.0\ m/s$

Straight pipe $V_1 = V_2$
base elevation = 0
no pumps/turbines

$$P_1/\gamma + \cancel{z_1} + \cancel{\frac{v_1^2}{2g}} + \cancel{h_A} - \cancel{h_R} - H_L = P_2/\gamma + z_2 + \cancel{\frac{v_2^2}{2g}}$$

Ske to Rating Friction

$Re = vD/\nu = (69.0\ m/s)(.00744\ m) / (7.36 \times 10^{-4}\ m^2/s)$
$= 697.5$, thats laminar!

So $f = 64/Re$
$= .0918$

and then $H_L = f \cdot L/D \cdot V^2/2g$
$= (.0918) \cdot (25.8\ m)/(.00744\ m) \cdot \frac{(69.0\ m/s)^2}{2(9.8\ m/s^2)}$
$= 7729.0\ m$

ΔP

Parts the alert of friction?

this feels wrong? too for a pert?

$P_1 - P_2 = \gamma (H_L + z_2)$
$\Delta p = (12.34\ kN/m^3)(7729.0\ m + .68\ m)$
$\Delta p = 953767\ kN/m^2 = 954\ MPa$

$1\ kN/mm^2 = 1\ GPa = 1000\ MPa$
$1000000\ mm^2 = 1\ m^2$

954 MPa difference feels high but It's glycerin... doesn't flow well! too high!

8-62

Compute energy loss as water flows in a standard hydraulic copper tube, 120 mm OD x 3.5 mm wall, at a flow rate of 1000 L/min over a length of 45 m (8-3)

L = 45 m

design Ch = 130

$Q = 1000\ L/min\ (1\ m^3/s / 60000\ L/min) = .016\ m^3/s$

$A = \pi (D/2)^2 = .010\ m^2$

$D = 113\ mm = .113\ m$ $\qquad R = D/4 = .02825\ m$ $\qquad V = .85\ C_h R^{.63} S^{.54}$

$Q = VA$ $\qquad$ Ch $\quad$ D/4 $\quad$ find

needed $\rightarrow V = Q/A = (.016\ m^3/s) / (.010\ m^2) = 1.6\ m/s$

needed $\rightarrow H_L = f \times L/D \times v^2/2g$

for f we need Re

$Re = vD/\nu = \overbrace{(1.6\ m/s)(.113\ m)}^{.1808\ ^2/s} / \nu$

I'm [illegible] here, so I'm going to make typical assumptions

If [illegible] is at a typical temp of

[illegible] for water at

$1.6\ m/s = \underbrace{(.85)(130)(.02825\ m)^{.63}}_{=} \cdot (S)^{.54}$ $\qquad S = (H_L/L)$

$S^{.54} = .1426$

$S = .1426^{(1/.54)} = .0272$ $\qquad \frac{H_L}{L} = .0272$

where L = 45 m

$H_L = (.0272)(45\ m) = 1.2\ m$

You lose 1.2 meters of head, H_L, using this method