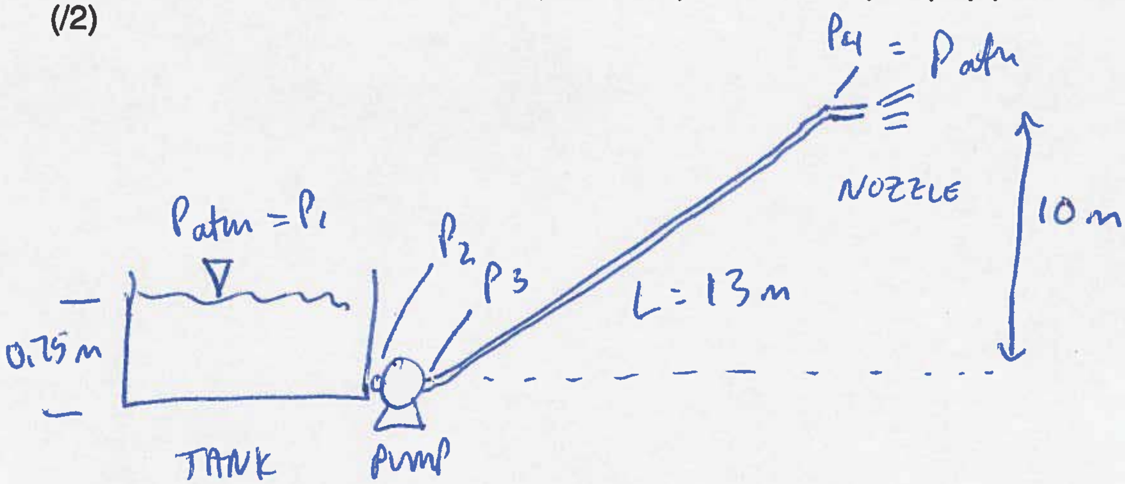
Question Number IV *(24 Marks ~ 45 minutes)*

PART A

A construction company is adding asphalt (bitumen) roof coating to one of the University of Calgary buildings. The asphalt material is supplied in blocks (sold form) and needs to be heated in a heating tank, and then sent to the asphalt spraying machine (pump and hose with nozzle) which is right beside the tank. The pump removes the bitumen from the bottom of the tank, which has 0.75 m (depth) of bitumen. The liquid asphalt is pumped from the heating tank, which is open to atmospheric pressure, through 13 m of pipe to the spray nozzle located 10 m above the pump. The pipe exit spray nozzle is exposed to atmospheric pressure (P_{atm} = 1 atm).

a) Sketch the system indicating the pressure points, tank, pump, pipe and nozzle. (/2)



b) It is required to pump 8 l/min of asphalt at an elevated temperature of 175ºC through 2" (5.08 cm) inside diameter commercial steel pipe. The density and viscosity of the liquid asphalt at 175ºC are 900 kg/m³ and 0.1 Pa.s, respectively. Categorize the liquid asphalt flow (laminar or turbulent flow). (/3)

$$Re = \frac{D\bar{v}\rho}{\mu}$$

$$D = 5.08 \times 10^{-2}\ m$$

$$Q = \frac{8\ L}{min} \times \frac{1\ m^3}{1000\ L} \times \frac{1\ min}{60\ s} = 1.33 \times 10^{-4}\ \frac{m^3}{s}$$

$$Re = \frac{(5.08 \times 10^{-2})(0.0164)(900)}{0.1}$$

$$Q = \bar{v} A$$

$$A = \pi r^2$$

$$A = \pi \left(\frac{5.08 \times 10^{-2}\ m}{2}\right)^2$$

$$\boxed{\begin{array}{l} Re = 7.52 \\ \text{LAMINAR} \end{array}}$$

$$A = 8.107 \times 10^{-3}\ m^2$$

Re=30

2,0268E-3

$$\bar{v} = \frac{Q}{A} = 0.0164\ m/s$$

0.0656 m/s

c) Calculate the pump discharge pressure and pump power consumption for the flow rate in part (b). (/6)

$$-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{32\mu \bar{v}}{D^2}$$

0.0656

$$-\left[\frac{\Delta P}{13} + (900)(9.81)\frac{10}{13}\right] = \frac{32 \times 0.1 \times 0.0164}{(5.08\times10^{-2})^2}$$

$$-\frac{\Delta P}{13} - 6791.538 = 20.336$$

81.344

$$-\frac{\Delta P}{13} = 6811.87$$

6872.88

$$-\Delta P = 88554 \qquad P_4 - P_3$$

89347.466

$$\Delta P = -88554 = P_{atm} - P_3$$

$$\boxed{P_3 = 189\,879 \text{ Pa}}$$

190672.466

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

$$P_2 = 101325 + (900)(9.81)(0.75)$$

$$P_2 = 107946.75 \text{ Pa}$$

$$\text{Power} = Q\Delta P = Q\,(P_3 - P_2)$$

190672.466

$$= (1.33\times10^{-4}\,m^3/s)(189879 - 107946.75)$$

$$\boxed{\text{Power} = 10.23 \text{ W}}$$

11.00 W

d) After using the system, the machine was drained, charged with solvent for cleaning and the solvent was circulated at a rate of 36~~6~~0 l/min. The density and viscosity of the cleaning solvent are 800 kg/m³ and 2 mPa.s, respectively. Assume that the liquid height in the tank is ~~1.5 m~~ 0.75m as above. Calculate the pump power consumption during the cleaning cycle. (/~~6~~5)

$P_2 = 107946.75$ Pa

$Re = \frac{D v \rho}{\mu}$

$Q = \frac{360L}{min} \times \frac{1}{1000} \times \frac{1}{60} = 6 \times 10^{-3} \frac{m^3}{s}$

$Re = \frac{(5.08\times10^{-2})(0.74)(800)}{2\times10^{-3}}$

$\bar{v} = \frac{Q}{A} = \frac{6\times10^{-3}}{8.107\times10^{-3}}$

2,0268E-3

60153

$\bar{v} = 0.74$ m/s

2.96 m/s

$Re = 15039$ TURBULENT

1.5×10^4

$-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{2 f \bar{v}^2 \rho}{D}$ $\quad f: 0.008$

0.006

$-\left[\frac{\Delta P}{13} + 800\times9.81\,\frac{10}{13}\right] = \frac{2\times0.008\times(0.74)^2\,800}{5.08\times10^{-2}}$

$-\frac{\Delta P}{13} - 6036.92 = 137.98$

1655.73

$-\frac{\Delta P}{13} = 6174.9$

7692.65

100004.5

$\Delta P = -80273.7 = P_{atm} - P_3$

$P_3 = 181598$

201329.5

$Power = Q\Delta P$

$= Q(P_3 - P_2) = 6\times10^{-3}(181598 - 107946)$

$\boxed{Power = 441.9\ W}$

560.3 W

PART B

A power-law fluid is used to lubricate moving metal on a flat base sliding horizontally ~~at acceleration a = 2 m/s²~~. The sliding area between the two metals is 1.2 m² and a gap of 1 mm was fixed between the upper and lower metals. Use the following information to answer the questions.

τ (Pa)	du/dy(s^{-1})
50	10
30	5

a) Calculate the apparent viscosity of the fluid at both values of shear stress. (/2)

$$\mu_{APP_1} = \tau / du/dy = 50/10 = \underline{5\ Pa\,s}$$

$$\mu_{APP2} = 30/5 = \underline{6\ Pa\,s}$$

b) Determine the Power-law parameters (K and n) for the fluid. (/3)

$$\tau = K\left(\frac{du}{dy}\right)^n$$

$$\log \tau = \log K + n \log \frac{du}{dy}$$

$$\log 50 = \log K + n \log 10$$

$$\log 30 = \log K + n \log 5$$

$$\log\left(\frac{50}{30}\right) = n \log\left(\frac{10}{5}\right)$$

$$\boxed{n = 0.737}$$

$$50 = K\,(10)^{0.737}$$

$$\boxed{K = 9.16\ Pa\,s^{0.737}}$$

c) If the mass of the sliding metal was 30 kg, what is the sliding velocity of the metal sheet? (/3) initial acceleration 2 m/s²

$$F = m \cdot a$$

$$F = 30\,kg \times 2\,m/s^2 = 60\ N$$

$$\tau = \frac{F}{A} = \frac{60N}{1.2m^2} = 50\ Pa \longrightarrow \frac{du}{dy} = 10\ s^{-1}$$

$$\frac{du}{dy} = \frac{\Delta u}{\Delta y} = 10 = \frac{\Delta u}{1\times10^{-3}m} \rightarrow \boxed{u = 0.01\,m/s}$$