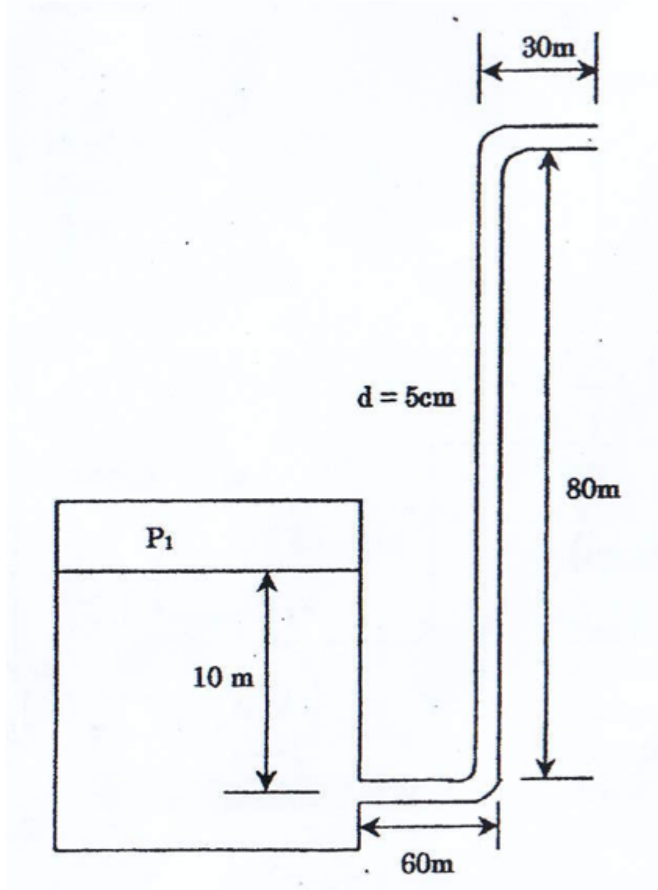
FLUID MECHANICS I

SEMM 2313

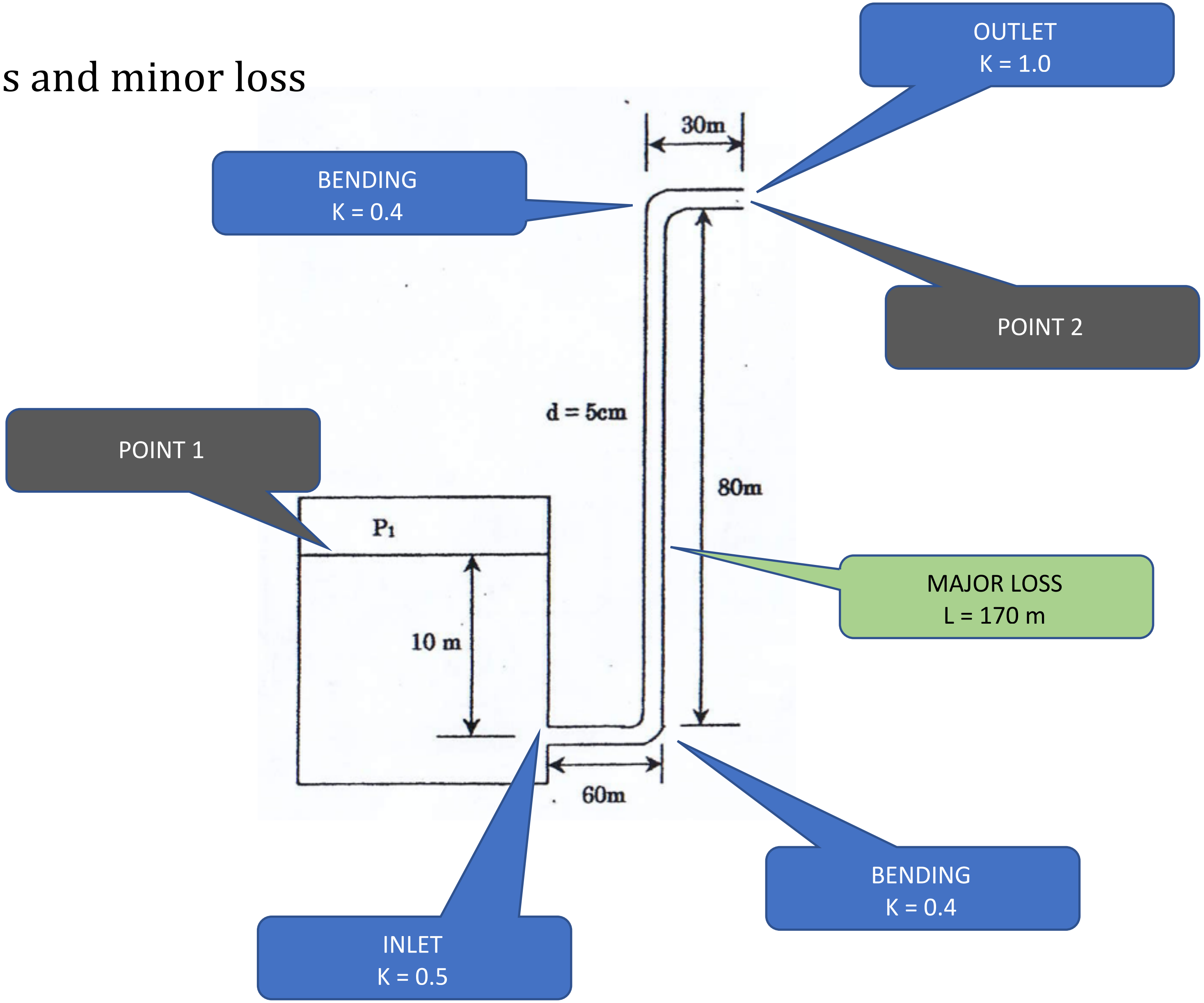
Question 1

The diagram shows a flow in a smooth pipe controlled by air pressure, P1 in a tank. Calculate the pressure P1 required for the water to flow at a rate of 60 m^3-per-hour. Take the bending coefficient as 0.4, the density of water as 998 kg/m^3 and the viscosity of water as 1.003×10^{-3} kg/m.s.



Answer 1

Identify the major loss and minor loss



Bernoulli equation:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + \text{Major losses} + \text{Minor losses}$$

Minor losses:

$$Minor\ loss = K\frac{V^2}{2g} = (0.5 + 0.4 + 0.4 + 1.0)\frac{V^2}{2g}$$

$$V = 8.49 \quad m/s$$

$$Minor\ loss = 8.45 \quad m$$

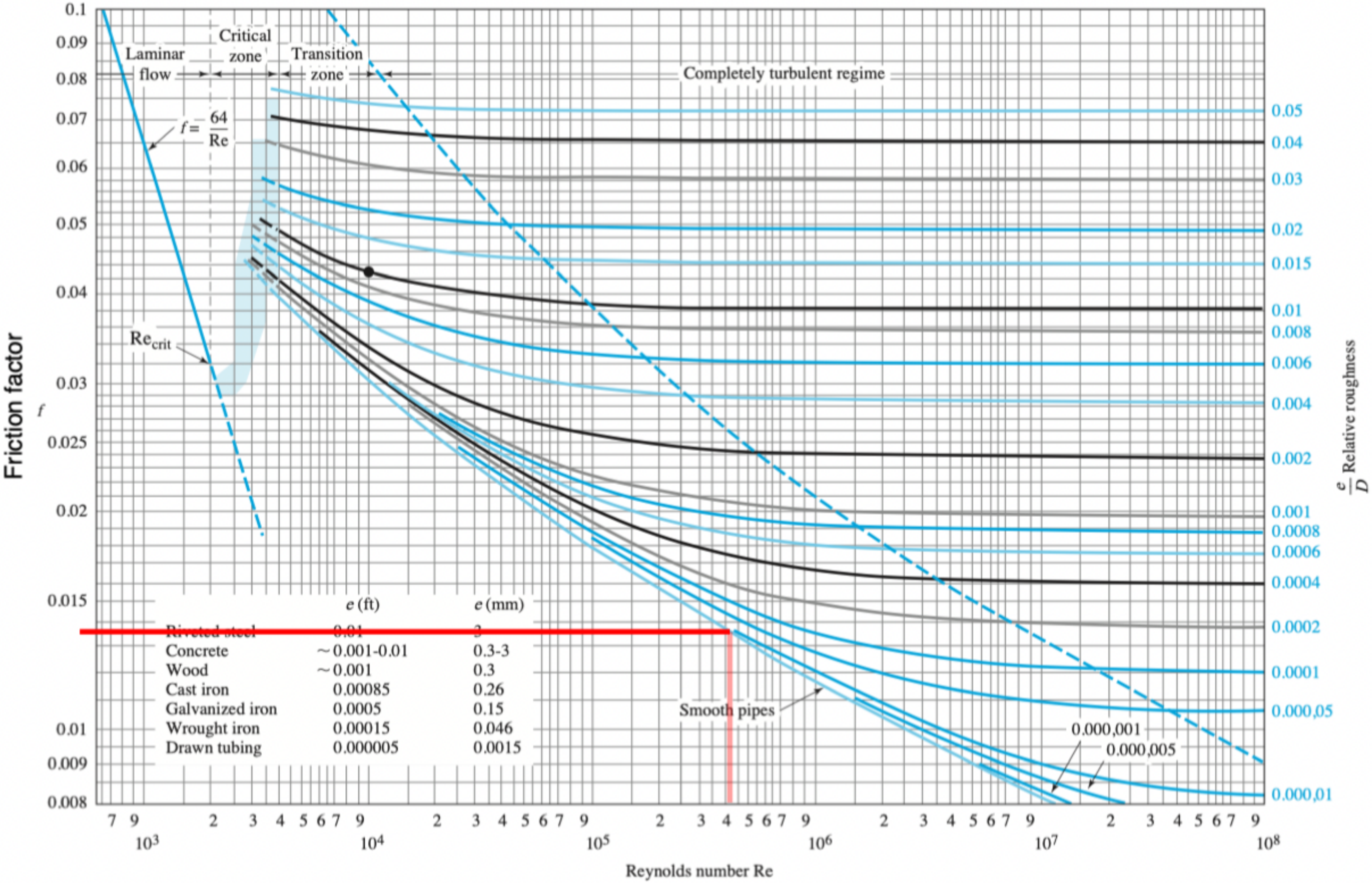
Major loss:

$$Re = \frac{\rho V D}{\mu} = \frac{(998)(8.49)(0.05)}{1.003 \times 10^{-3}} = 4.2 \times 10^{5}$$

From Moody chart

$$f = 0.0135$$

$$Major\ loss = f\,\frac{L}{D}\frac{V^2}{2g} = (0.0135)\,\frac{170}{0.05} \times \frac{(8.49)^2}{2g} = 168.628 \quad m$$


Laminar flow
Critical zone
Transition zone
Completely turbulent regime
$f = \frac{64}{Re}$
Re_{crit}
Friction factor
f
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
0.05
0.04
0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.000,05
0.000,01
0.000,001
0.000,005
Smooth pipes
$\frac{e}{D}$ Relative roughness
7 9 2 3 4 5 6 7 9 2 3 4 5 6 7 9 2 3 4 5 6 7 9 2 3 4 5 6 7 9 2 3 4 5 6 7 9
10^3
10^4
10^5
10^6
10^7
10^8
Reynolds number Re

	e (ft)	e (mm)
Riveted steel	0.01	3
Concrete	~0.001-0.01	0.3-3
Wood	~0.001	0.3
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Wrought iron	0.00015	0.046
Drawn tubing	0.000005	0.0015

Bernoulli equation,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + \text{Major losses} + \text{Minor losses}$$

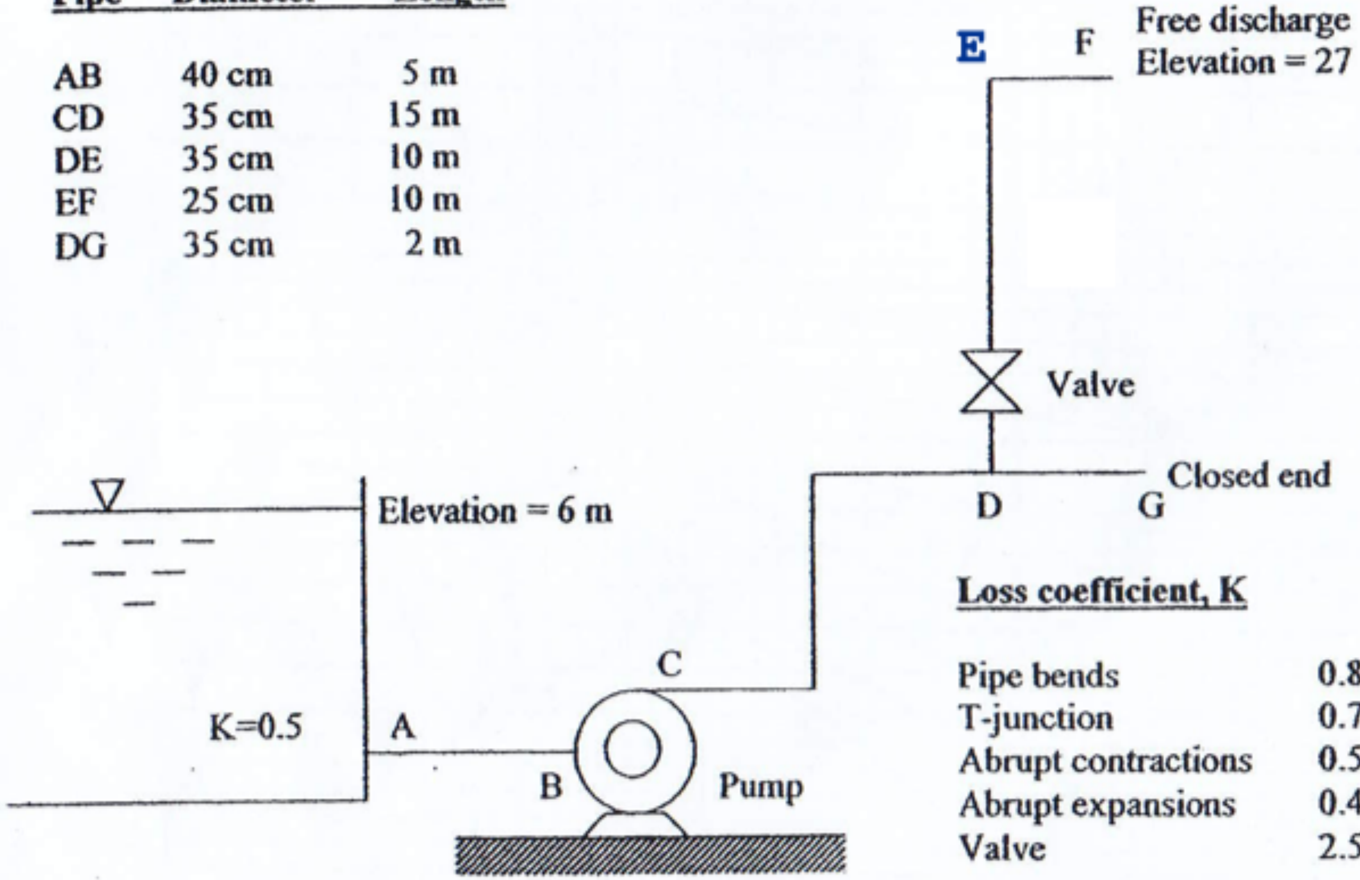
$$\frac{P_1}{\rho g} + \frac{0^2}{2g} + 10 = \frac{0}{\rho g} + \frac{(8.49)^2}{2g} + 80 + 168.628 + 8.45$$

$$P_1 = 2.4598 \quad MPa$$

Question 2

Water is pumped at the rate of 60 liters per second from a reservoir to free discharge. All pipes are made of commercial steel. Determine the power required by the pump if the efficiency of the pump is 85%. Included all the losses in the pipe system. Viscosity of water is 0.001 Pa.s.

Pipe	Diameter	Length
AB	40 cm	5 m
CD	35 cm	15 m
DE	35 cm	10 m
EF	25 cm	10 m
DG	35 cm	2 m

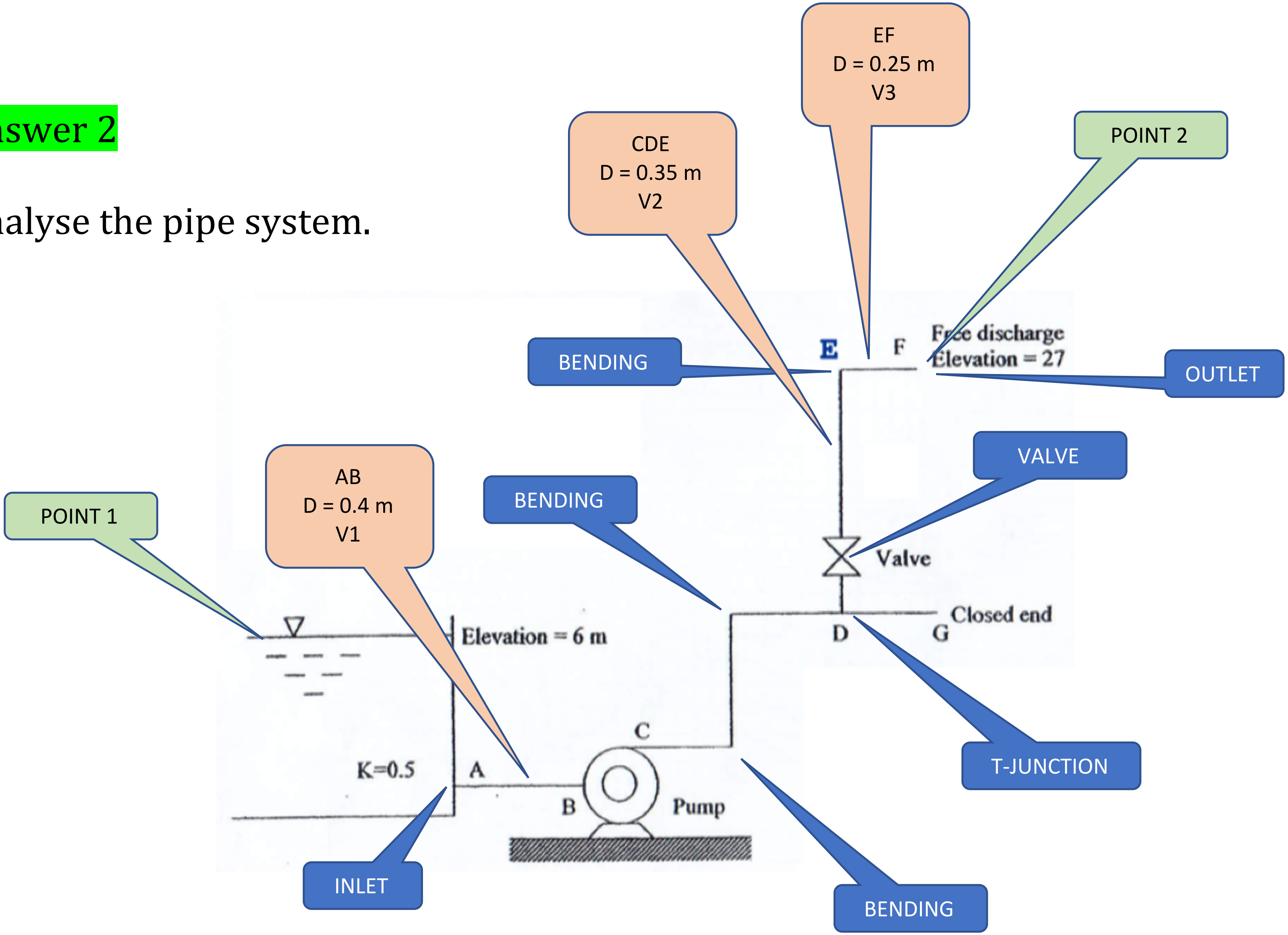


Loss coefficient, K

Pipe bends	0.85
T-junction	0.70
Abrupt contractions	0.50
Abrupt expansions	0.45
Valve	2.55

Answer 2

Analyse the pipe system.



Bernoulli equation:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 + H_P = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + \text{Major losses} + \text{Minor losses}$$

$$\frac{0}{\rho g} + \frac{0}{2g} + 6 + H_P = \frac{0}{\rho g} + \frac{V_2^2}{2g} + 27 + f\,\frac{L}{D}\frac{V^2}{2g} + K\,\frac{V^2}{2g}$$

Minor losses:

$$Minor\ loss = K\frac{V^2}{2g}$$

	AB	CDE	EF
Velocity (m/s)	0.48	0.62	1.22

$$Minor\ loss = (0.5)\frac{(0.48)^2}{2g} + (0.85 + 0.85 + 0.7 + 2.55)\frac{(0.62)^2}{2g} + (0.5)\frac{(1.22)^2}{2g} + (1.0)\frac{(1.22)^2}{2g}$$

$$Minor\ loss = 0.225\ \ m$$

Major losses:

$$Major\ loss = f\frac{L}{D}\frac{V^2}{2g}$$

	AB	CDE	EF
Velocity (m/s)	0.48	0.62	1.22
Re	1.92×10^5	2.18×10^5	3.05×10^5
$\frac{e}{D}$	0.0001	0.0001	0.0002
f	0.0167	0.0164	0.0155

$$Major\ loss = (0.0167)\frac{(5)}{(0.4)}\frac{(0.48)^2}{2g} + (0.0164)\frac{(25)}{(0.35)}\frac{(0.62)^2}{2g} + (0.0155)\frac{(10)}{(0.25)}\frac{(1.22)^2}{2g}$$

$$Major\ loss = 0.07\quad m$$

Bernoulli equation:

$$\frac{0}{\rho g}+\frac{0}{2g}+6+H_P=\frac{0}{\rho g}+\frac{V_2^2}{2g}+27+f\frac{L}{D}\frac{V^2}{2g}+K\frac{V^2}{2g}$$

$$\frac{0}{\rho g}+\frac{0}{2g}+6+H_P=\frac{0}{\rho g}+\frac{(1.22)^2}{2g}+27+0.07+0.225$$

$$H_P=21.375\quad m$$

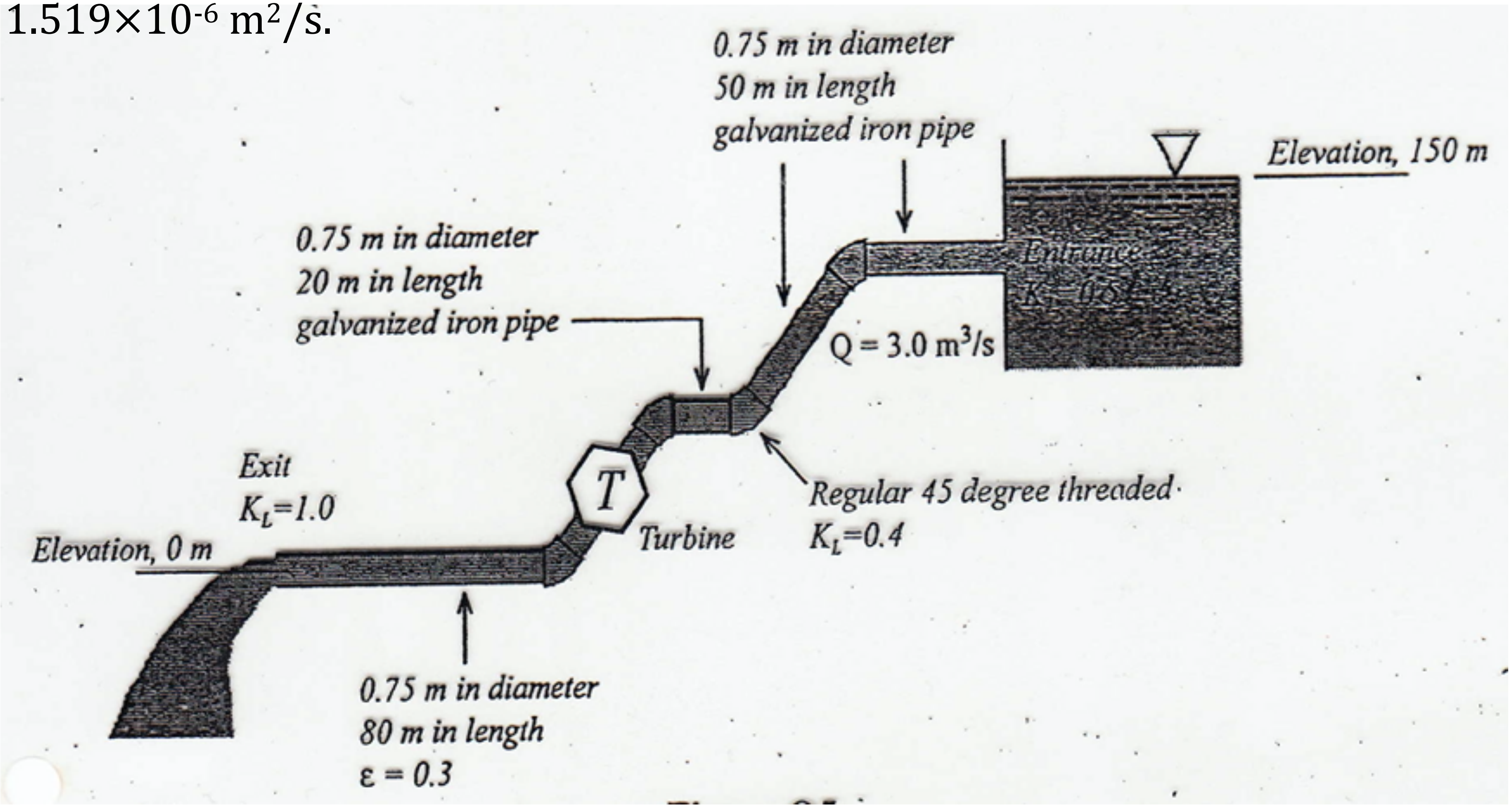
$$\text{Efficiency}=\frac{\text{Power out}}{\text{Power in}}=\frac{\text{Generated power}}{\text{Power required}}$$

$$0.85=\frac{\rho g Q\cdot H_P}{\text{Power required}}$$

$$\text{Power required}=14.75\quad \text{kW}$$

Question 3

A series pipe system is shown below. The flowrate of water in the system is 3 m^3/s. The system contains a sharp-edge entrance and exit, four regular 45-degree threaded. Determine the head of turbine in the system. Density of water is 1000 kg/m^3, dynamic viscosity of water is 1.519×10^{-3} Ns/m^2 and kinematic viscosity of water is 1.519×10^{-6} m^2/s.



Answer 3

Friction factor for galvanized iron pipe = 0.014

Friction factor for cast iron pipe = 0.016

Total major loss = 9.30 m

Total minor loss = 7.31 m

Head of turbine = 131.03 m

Question 4

A pump is used to transfer water from tank A to tank B as shown in Figure Q3. The required flow rate is 0.15 m^3/s. The kinematic viscosity of the water is 1.2×10^{-6} m^2/s. Determine

(a) Major head losses,

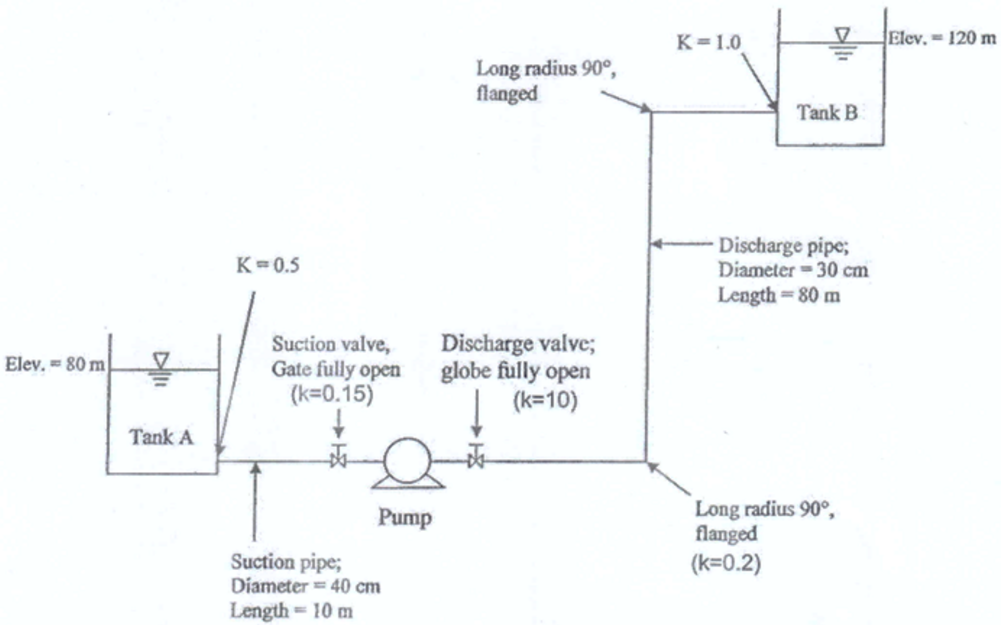
(b) Minor head losses,

(c) Head of the pump, and

(d) Input power to drive the pump.

All pipes are made of commercial steel.

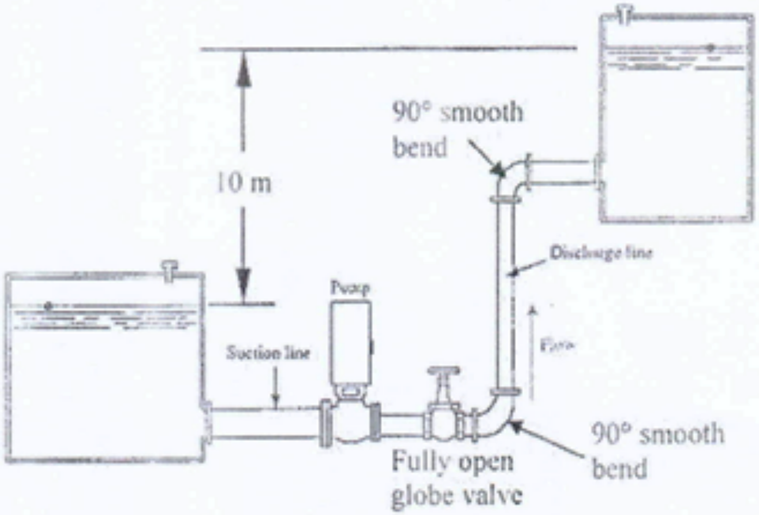
Refer Appendix 1, Appendix 2, and Appendix 3.



Question 5

(a) Define major losses of a pipe system.

(b) Methyl alcohol (specific gravity = 0.8 and dynamic viscosity 5.6×10^{-4} Pa.s) is flowing at the rate of 0.015 m^3/s. The suction line is standard 10 cm diameter steel pipe, 12 m long. The total length of 5 cm diameter pipe in the discharge line is 200 m. With all the data given, determine the power supplied to the pump shown in Figure Q3 if its efficiency is 76 percent. *Note:* Moody chart is provided.



Question 6

(a) Define major and minor losses of a pipe system.

(b) Figure Q3 shows the water with density, $\rho = 995$ kg/m^3, and viscosity, $\mu = 7 \times 10^{-4}$ Pa.s is pumped at the rate of 0.001 m^3/s from tank A to tank B. The suction and delivery pipe conditions are:

	Delivery	Suction
Diameter (m)	0.025	0.02
Length (m)	5	30
Material	Commercial Steel	PVC
Total minor losses coefficient, K	5	8

Determine the power must be supplied to the pump if the efficiency of the pump is 85 percent. Assume that the PVC pipe is a smooth pipe.

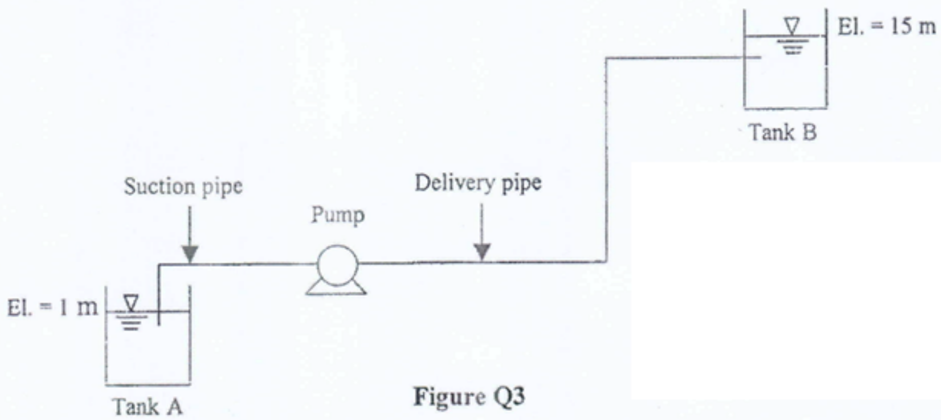


Figure Q3