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UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program: M.Tech. Chem Engg (with spl in PDE)	**Semester – I**
Subject (Course): Fluid Flow and Heat Transfer Equipment Design	**Max. Marks : 100**
Course Code : CHPD 7005	**Duration : 3 Hrs**
No. of page/s: 06	

Note: Assume suitable data, if necessary.

Section A

Answer all questions. Each carries 12 marks. [12X5=60 Marks]

Q.1 In the equipment shown in Figure 1, a pump draws a solution of specific gravity 2.5 from a storage tank through a 3" Schedule 40 steel pipe. The efficiency of the pump is 80%. The velocity in the suction line is 0.7 m/s. The pump discharges through a 2" Schedule 40 pipe to an overhead tank. The end of the discharge pipe is 15.2 m above the level of the solution in the feed tank. Frictional losses in the entire piping system are 30 J/Kg. What pressure must the pump develop? What is the power delivered to the fluid by the pump? Make suitable assumptions. Take kinetic energy factor α as 1. Refer to Table 1 & 2. **[12]**

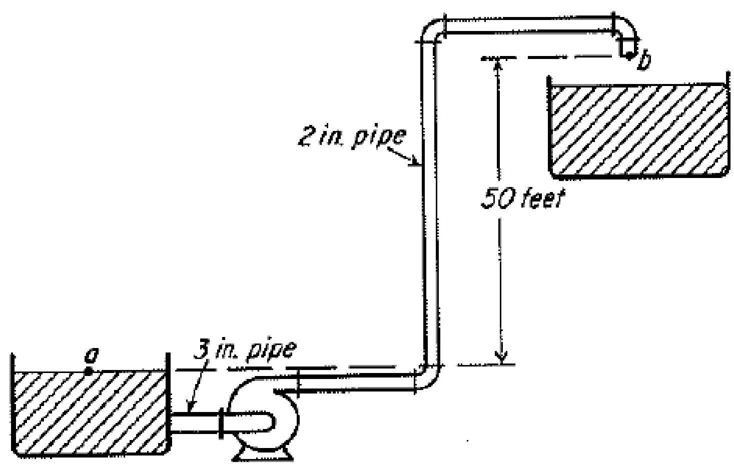

Figure 1 Flow diagram for Q. 1

Table 1 for Q.1- Conversion factors and constants of nature

To convert from	To	Multiply by†
cal_{IT}	Btu	3.9683×10^{-3}
	$ft\text{-}lb_f$	3.0873
	J	4.1868*
cal	J	4.184*
cm	in.	0.39370
	ft	0.0328084
cm^3	ft^3	3.531467×10^{-5}
	gal (U.S)	2.64172×10^{-4}
cP (centipoise)	kg/m-s	$1* \times 10^{-3}$
	lb/ft-h	2.4191
	lb/ft-s	6.7197×10^{-4}
cSt (centistoke)	m^2/s	$1* \times 10^{-6}$
faraday	C/g mol	9.648670×10^4
ft	m	0.3048*

Table 2 for Q.1 – Dimensions, capacities and weights of standard steel pipe

Nominal pipe size, in.	Outside diameter, in.	Schedule no.	Wall thickness, in.	Inside diameter, in.	Cross-sectional area of metal, $in.^2$	Inside sectional area, ft^2	Circumference, ft or surface, ft^2/ft of length		Capacity at 1 ft/s velocity		Pipe weight lb/ft
							Outside	Inside	U.S. gal/min	Water, lb/h	
2	2.375	40	0.154	2.067	1.075	0.02330	0.622	0.541	10.45	5,225	3.65
		80	0.218	1.939	1.477	0.02050	0.622	0.508	9.20	4,600	5.02
$2\frac{1}{2}$	2.875	40	0.203	2,469	1.704	0.03322	0.753	0.647	14.92	7,460	5.79
		80	0.276	2.323	2.254	0.02942	0.753	0.608	13.20	6,600	7.66
3	3.500	40	0.216	3.068	2.228	0.05130	0.916	0.803	23.00	11,500	7.58
		80	0.300	2.900	3.016	0.04587	0.916	0.759	20.55	10,275	10.25

Q.2 Benzene at 50^0C is pumped at the rate of 0.151 m^3/min. The reservoir is at atmospheric pressure. The gauge pressure at the end of the discharge line is 350 kPa. The discharge is 3.048 m and the pump suction 1.219 m above the level in the reservoir. The friction in the suction line is known to be 3.45 kPa and that in the discharge line is 37.9 kPa. The mechanical efficiency of the pump is 60%. The density of benzene is 0.851 g/ml and its vapor pressure at 50^0C is 34 kPa. Calculate NPSH. What will be new NPSH if, **[12]**

i) Benzene is pumped at 60^0C with corresponding vapor pressure of 46 kPa and density of 0.836 g/ml. Rest is unchanged.

ii) Pump suction is 1.0 m above the reservoir level. Rest is unchanged.

iii) Pump suction is 1.7 m above the reservoir level. Rest is unchanged.

Q.3 Calculate the critical radius of insulation for asbestos (k=0.17 W/(m K) surrounding a pipe and exposed to room air at 20 ^{0}C with h=3 W/(m^2 K). Calculate the heat loss from a 200^0C, 5 cm outside diameter pipe when covered with i) critical radius of insulation, ii) twice critical radius of insulation and iii) without insulation. Justify your answers. **[12]**

Q.4 Discuss the practices for calculation of pressure drop in condensers. **[12]**

Q.5 Describe with diagrams, ‘Air Cooled Exchangers’. **[12]**

Section B

Q.6 is compulsory. Out of Q.7 and 8 answer any one question. [30+10= 40 Marks]

Q.6 Calculate minimum-utility requirements and pinch point for a HEN problem by using the problem table algorithm of Linnhoff and Flower. The stream data for the same problem is as follows. Select the value of ΔT_{min} = 10, 20 & 30^0C respectively. In addition to four process streams, there is a single hot utility available at a temperature above 150^0C and a single cold utility available at a temperature below 20^0C. Comment on your answers. **[30]**

Stream Data

Stream	Type	*TS* (°C)	*TT* (°C)	*CP* (kW/°C)	Duty (kW)
1	Hot	150	60	2.0	180
2	Hot	90	60	8.0	240
3	Cold	20	125	2.5	262.5
4	Cold	25	100	3.0	225

where $CP \equiv \dot{m}C_P$ = heat capacity flow rate

TS = supply temperature

TT = target temperature

Q.7 Explain in brief, the design methods for furnaces. **[10]**

Q.8 Light crude oil coming from storage at 40^0C exchanges heat with kerosene leaving the base of a kerosene side-stripping column at 200^0C in a shell and tube heat exchanger (1-6). A pressure drop of 0.8 bar is permissible on both streams. Tube side fluid is light crude oil while shell side fluid is kerosene. Calculate pressure drop on shell side as well as tube side. Neglect viscosity correction on either side. Use Eqns 1 and 2 for calculation of pressure drop on tube and shell side respectively. Refer to Figs. 2 and 3. Justify your answers. **[10]**

Data for Q.8:

Flow rate of light crude oil = 70000 kg/h
Flow rate of kerosene = 20000 kg/h

Number of tubes = 240
Number of tube side passes = 06
Tube inside diameter = 14.83 mm
Length of one tube = 5 m
Tube arrangement = Square pitch

Shell inside diameter (D_s) = 0.8 m
Shell equivalent diameter (d_e)= 13.52 mm
Baffle type = segmental (Baffle Cut % = 35)
Baffle spacing (l_B) = 0.2 D_s

Tube side velocity = 2.3 m/s
Shell side velocity = 0.75 m/s

Data for Q.8:

Density of light crude oil = 820 kg/m^3
Density of kerosene = 730 kg/m^3

Viscosity of light crude oil = 3.2 X 10^{-3} Ns/m^2
Viscosity of kerosene = 0.43 X 10^{-3} Ns/m^2

$$\Delta P_t = N_p \left[8 j_f \left(\frac{L}{d_i} \right) \left(\frac{\mu}{\mu_w} \right)^{-m} + 2.5 \right] \frac{\rho u_t^2}{2}$$

where ΔP_t = tube-side pressure drop, N/m^2 (Pa),
N_p = number of tube-side passes,
u_t = tube-side velocity, m/s,
L = length of one tube.

-----Eqn1

$$\Delta P_s = 8 j_f \left(\frac{D_s}{d_e} \right) \left(\frac{L}{l_B} \right) \frac{\rho u_s^2}{2} \left(\frac{\mu}{\mu_w} \right)^{-0.14}$$

where L = tube length,
l_B = baffle spacing.

-----Eqn2

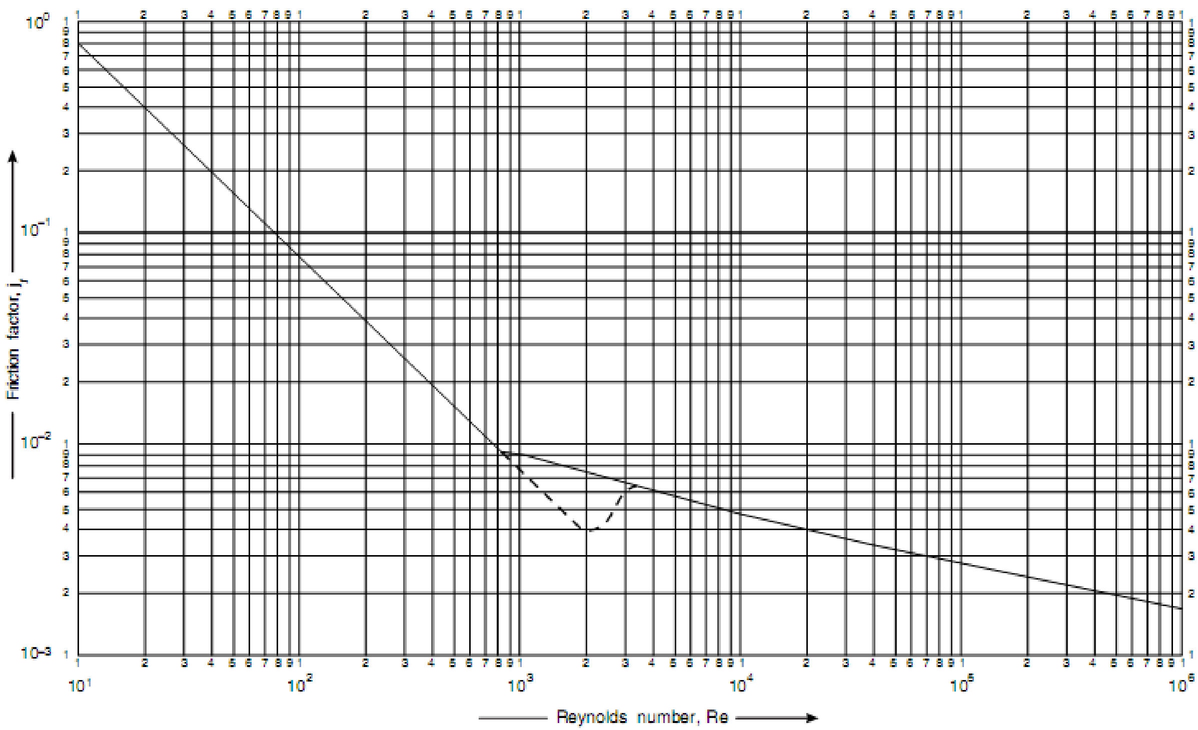

Figure 2 Tube-side friction factors

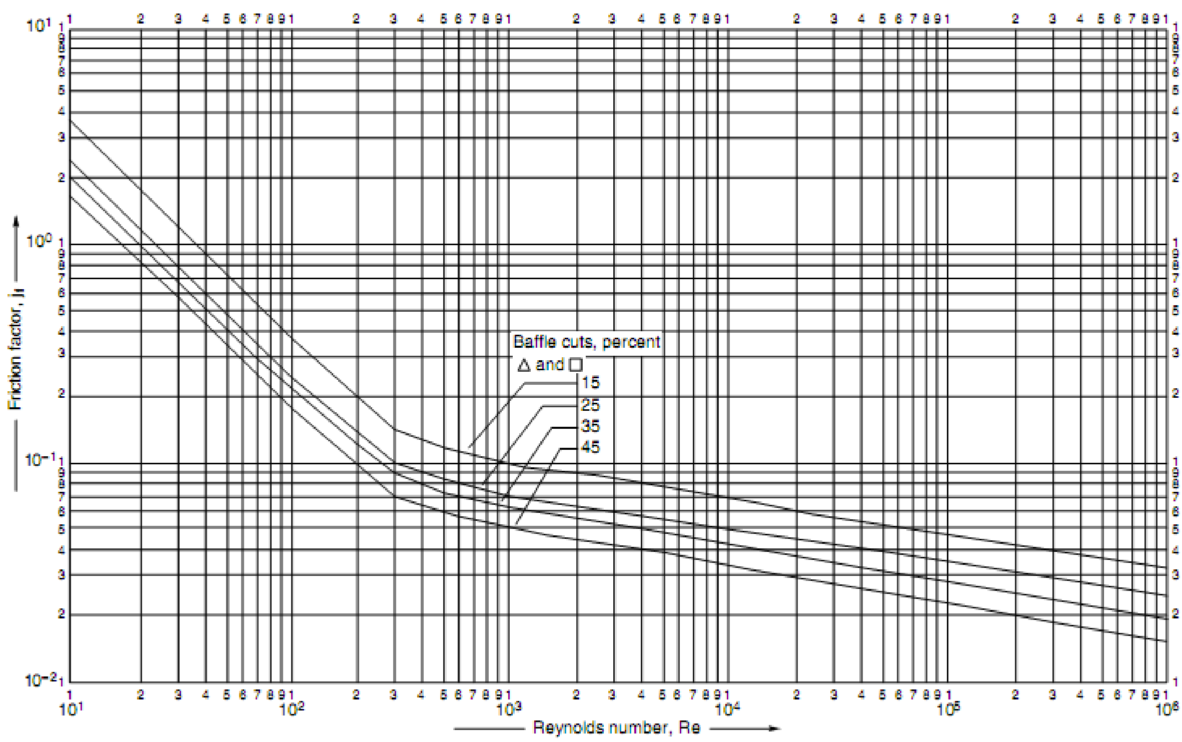

Figure 3 Shell-side friction factors, segmental baffles