Name: **Enrolment No:**	UPES UNIVERSITY WITH A PURPOSE

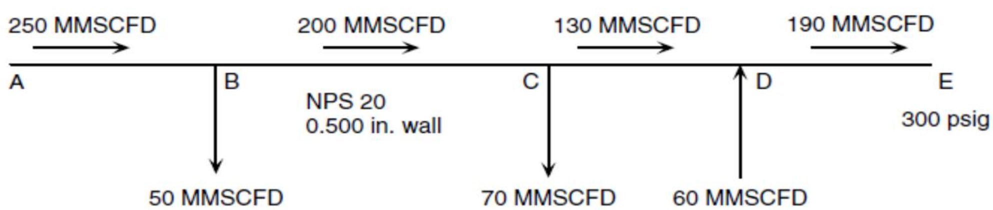
UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, December- 2021

Course: Pipeline Transportation of Oil and Gas — **Semester: VII**
Program: B. Tech. Applied Petroleum Engineering (Spl-Gas) — **Time : 03 Hrs.**
Course Code: CHGS3007P — **Max. Marks: 100**

Instructions:

- **Missing data can be suitably assumed**
- **The equations are provided in the APPENDIX at the last of the paper**

S. No.	SECTION A Attempt All Questions	Marks	CO
Q.1	Illustrate the performance curves of a Centrifugal pump.	4	CO1
Q.2	Define the term "Adiabatic efficiency" and hydraulic balance in compressors.	4	CO4
Q.3	Explain the equation used for calculating the number of pumps required to compensate pressure drop in a cross-country oil pipeline.	4	CO1
Q.4	State the hydrostatic test pressure in pipelines.	4	CO3
Q.5	Discuss the difference between $NPSH_A$ and $NPSH_R$.	4	CO2
	SECTION B **Attempt All Questions**		
Q.6	Demonstrate the 'Maximum allowable operating pressure in gas pipelines.	10	CO4
Q.7	Describe the various activities in laying of pipelines.	10	CO5
Q.8	Summarize in ten points that makes pipeline a better transportation mode as compared to other transportation modes.	10	CO4
Q.9	A gas pipeline is used for transporting gas between the two stations. Applying the fundamental knowledge for horse power calculations, calculate the compressor horsepower required for an adiabatic compression of 106 MMSCFD gas with inlet temperature of 68°F and 725 psia pressures. The discharge pressure is 1305 psia. Assume the compressibility factors at suction and discharge conditions to be Z1 = 1.0 and Z2 = 0.85, respectively, and the adiabatic exponent = 1.4, with the adiabatic efficiency = 0.8. If the mechanical efficiency of the compressor driver is 0.95, what BHP is required? Also, calculate the outlet temperature of the gas.	10	CO4

SECTION-C Attempt All Questions			
Q.10	A 150 mi long natural gas pipeline consists of several injections and deliveries as shown in Figure. The pipeline is NPS 20, has 0.500 in. wall thickness, and has an inlet volume of 250 MMSCFD. At points B (milepost 20) and C (milepost 80), 50 MMSCFD and 70 MMSCFD, respectively, are delivered. At D (milepost 100), gas enters the pipeline at 60 MMSCFD. All streams of gas are assumed to have a specific gravity of 0.65 and a viscosity of 8.0×10^{-6} lb/ft-s. The pipe is internally coated (to reduce friction), resulting in an absolute roughness of 150 μ in. Assume a constant gas flow temperature of 60°F and base pressure and base temperature of 14.7 psia and 60°F, respectively. Use a constant compressibility factor of 0.85 throughout. Neglect elevation differences along the pipeline.  **a)** Using the AGA equation, calculate the pressures along the pipeline at points A, B, C, and D for a minimum delivery pressure of 300 psig at the terminal E. Assume a drag factor = 0.96 **b)** Evaluate the pipe diameter required for section DE if the required delivery pressure at E is increased to 500 psig? The inlet pressure at A remains the same as calculated above.	**10+10**	**CO3**
Q11	A pipeline from origin station A to delivery point B is 48 miles long and is 18 inch in nominal diameter, with a 0.281 inch. wall thickness. It, is constructed of 5LX-65 grade steel. At origin station A, crude oil of specific gravity 0.85 and 10 cSt viscosity enters the pipeline at a flow rate of 6000 bbl./hr. At first intermediate station C (milepost 22) a new stream of crude oil with a specific gravity of 0.82 and 3.5 cSt viscosity enters the pipeline at a flow rate of 1000 bbl./hour. The mixed stream then continues to another intermediate station D (milepost 32) where 3000 bbl./hour is stripped off the	**7+7+6**	**CO5**

	pipeline. The remaining volume continues to the end of the pipeline at delivery station B. **(a)** Evaluate the pressure required at origin station A & the composition of the crude oil arriving at terminus B at a minimum delivery pressure of 50 psi. Assume elevations at A, C, D, and B to be 100, 150, 250, and 300 feet, respectively. Use the Modified Colebrook-White equation for pressure drop calculations and assume a pipe roughness of 0.002 in. **(b)** Calculate the pump HP will be required to maintain this flow rate at A, assuming 50 psi pump suction pressure at A and 80% pump efficiency? **(c)** If a positive displacement (PD) pump is used to inject the stream at C, solve for pressure and HP are required at C?		

APPENDIX

All Notations have their usual meaning and units

1. Reynolds Equation for Gas Pipelines in USCS units

$$\mathrm{Re} = 0.0004778\left(\frac{P_b}{T_b}\right)\left(\frac{GQ}{\mu D}\right)$$

2. Reynolds No. for Crude Oil Pipelines

(a) $$R = \frac{92.24Q}{\nu D}$$

Where: Q = Flow rate, bbl./day; D = Internal diameter, in.; ν = Kinematic viscosity, cSt

b) $$R = \frac{353678Q}{\nu D}$$

Where: Q = Flow rate, m^3/h; D = Internal diameter, mm; ν = Kinematic viscosity, cSt

3. Modified Colebrook White Equation $$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{e}{3.7D} + \frac{2.825}{\mathrm{Re}\sqrt{f}}\right)$$

4. Coversion Equations for SSU to Centistokes

$$Centistokes = 0.226(SSU) - \frac{195}{SSU} \qquad 32 \le SSU \le 100$$

$$Centistokes == 0.220(SSU) - \frac{135}{SSU} \qquad SSU \succ 100$$

5. Horsepower required to compress gas in compressor

$$HP = 0.0857\left(\frac{\gamma}{\gamma-1}\right)QT_1\left(\frac{Z_1+Z_2}{2}\right)\left(\frac{1}{\eta_a}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

6. Adiabatic Efficiency of Compressor

$$\eta_a = \left(\frac{T_1}{T_2 - T_1}\right)\left[\left(\frac{z_1}{z_2}\right)\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

7. BHP required to pump the liquid $$BHP = \frac{QP}{2449E}$$

Q = flow rate (barrel per hr.) **P** = Differentia pressure (psi)

8. AGA Equations

For the fully turbulent zone- $F = 4\log_{10}\left(\frac{3.7D}{e}\right)$

For the partially turbulent zone- $F = 4D_f \log_{10}\left(\frac{\mathrm{Re}}{1.4125F_t}\right)$ $F_t = 4\log_{10}\left(\frac{\mathrm{Re}}{F_t}\right) - 0.6$

9. Relation between head and specific gravity

$$H = \frac{2.31 \times psig}{G}$$

10. Pressure drop due to friction in oil pipelines

$$P_m = 0.0605 \times f \times Q^2 \times \left(\frac{S_g}{D^5} \right)$$

11. Specific gravity of blended liquids

$$S_b = \frac{(Q_1 \times S_1) + (Q_2 \times S_2) + (Q_3 \times S_3)}{Q_1 + Q_2 + Q_3}$$

12. Viscosity of blended liquids

$$\sqrt{\nu_b} = \frac{Q_1 + Q_2 + Q_3 + \ldots}{\left(\frac{Q_1}{\sqrt{\nu_1}} \right) + \left(\frac{Q_2}{\sqrt{\nu_2}} \right) + \left(\frac{Q_3}{\sqrt{\nu_3}} \right) + \ldots}$$