Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST 1

Sem & AY: Odd Sem. 2019-20 — **Date**: 1.10.2019

Course Code: PET 216 — **Time**: 9:30AM to 10:30AM

Course Name: ENHANCED OIL RECOVERY — **Max Marks**: 40

Program & Sem: B.Tech (PET) & VII — **Weightage**: 20%

Instructions:

i. Read the question properly and answer accordingly.
ii. Question paper consists of 3 parts.
iii. Scientific and Non-programmable calculators are permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries three marks. (4Qx3M=12M)

1. What is resistance and residual resistance factor? (C.O.NO.1) [Knowledge]
2. Discuss the main categories of EOR process. What are the two process which ensures success as compared to others? (C.O.NO.2) [Knowledge]
3. Why most of the EOR problems lead to failure? (C.O.NO.1) [Knowledge]
4. What is the importance of pilot testing in EOR. (C.O.NO.2) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries six marks. (3Qx6M=18M)

5. What are the two main applications of polymer flood? Explain them. (C.O.NO.2) [Comprehension]
6. Explain the various stability properties of polymers. (C.O.NO.2) [Comprehension]
7. What are the test done in laboratory polymer core flood tests and what data are obtained? (C.O.NO. 2) [Comprehension]

Part C [Problem Solving Questions]

Answer the Question. The Question carries ten marks. (1Qx10M=10M)

8. What are the various stages of polymer flooding? Explain stage 2 in detail. (C.O.NO.2) [Comprehension]

SCHOOL OF ENGINEERING

Semester: 7th
Course Code: PET 216
Course Name: Enhanced Oil Recovery

Date: 1/10/2019
Time: 1 hr
Max Marks: 40
Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	2	Unit 1	3									3
2	2	Unit 1	2			1						3
3	1	Unit 1				3						3
4	2	Unit 1				3						3
5	2	Unit 1	6									6
6	2	Unit 1	6									6
7	2	Unit 1	6									6
8	2	Unit 1	10									10
	Total Marks		33			7						49

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I here certify that All the questions are set as per the above lines Anmol Bhargava]

SCHOOL OF ENGINEERING

SOLUTION

Semester: 7th

Course Code: PET 216

Course Name: Enhanced Oil Recovery

Date: 1/10/2019

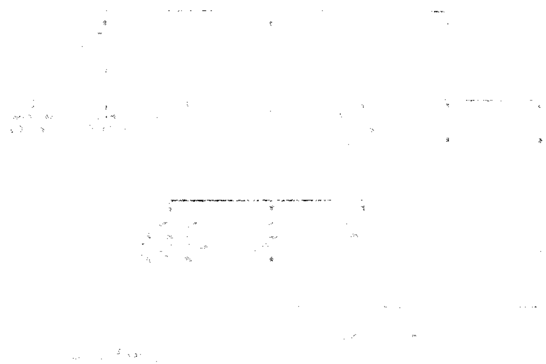
Time: 1 hr

Max Marks: 40

Weightage: 20%

Part A (4Q x 3M = 12Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	Resistance factor is the relative pressure drop caused by Polyacrylamide solutions in porous media. If a solution of PAM is passed through a reservoir core at a constant rate, pressure drop of the system is much greater than would be calculated by the viscosity change using Darcy's law. Resistance factor, R, is defined by the following equation $R = M_w / M_p = (k_{rw}/\mu_w) / (k_{rp}/\mu_p)$ where M_w = mobility to water; M_p = mobility to polymer; k_{rw} = water relative permeability, mD; k_{rp} = polymer relative permeability, mD; μ_w = water viscosity, cP; and μ_p = polymer viscosity, cP Under many conditions, the reduction in permeability to water caused by the polymer persists after the solution itself has apparently been displaced from the core matrix. When brine is injected after the polymer, this excess mobility reduction is termed residual resistance factor R_r, and is defined by the following equation: $R_r = M_w / M_{wp}$ where M_w = initial water mobility, and M_{wp} = water mobility after polymer injection.	1.5 marks for each	5 mins
2	A) The objective of EOR is to increase the recovery from reservoirs depleted by secondary recovery with water flooding or gas injection. The EOR processes can be divided into three major categories: 1. Chemical 2. Thermal, and 3. Miscible 4. Microbial EOR	2 marks for part A 1 mark for part B	5 mins

	 b) Carbondioxide flooding and thermal recovery methods are proving to be successful.		
3	Most EOR processes lead to failure because of two reasons: 1. The geological and permeability heterogeneity of the reservoir was more than expected which resulted in poor sweep efficiency. 2. The less remaining oil that had been estimated	1.5 marks for each point	5 mins
4	To increase the accuracy of reservoir simulators, pilot field trials are often run. The more novel the technique, the more important it is to test the process in the field. This provides useful additional data: 1) More complete definition of the project area 2) Testing all phases of the flooding process in an economical *Pilot injectivity tests can provide information on the following:* (1) Injection rates and pressures. (2) Fluid properties in the reservoir. (3) Reservoir characteristics.	1.5 marks for each point	5 mins

Part B (3Q x 6M = 18 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	Mobility Control and Profile Control Processes: ▪ Polymer flooding can be used in place of waterflooding. ▪ In mobility control processes, the polymer is used to alter the fractional flow characteristics of the water phase which is displacing the oil. ▪ In profile control processes, polymer gels are used to block water channels and divert flow to portions of the reservoir which have not been properly swept. Mobility control: The conditions required for polymer mobility control in EOR: ▪ Correct polymer type depending on field conditions. ▪ Type of polymer process ▪ Polymer solutions must be well understood ▪ Viscosity effects and viscosity stability ▪ Consideration of injectivity & residual resistance factor Mobility Definition:	3 marks for each application	10 mins

	▪ The function of any type of water soluble polymer in EOR operations is to increase the viscosity of a brine and to reduce the relative permeability to water in the formation. ▪ If the flow of brine in a porous medium is decreased in relation to the flow of oil, then the oil's relative flow is improved. ▪ Mobility is a measure of the flow of a fluid through a permeable formation. ▪ It is the ratio of the relative permeability of the fluid to the apparent viscosity of the fluid. ▪ Relative mobility is the ratio of the displaced fluid's mobility to the mobility of the displacing fluid. $M = k_r / \mu_a$ & $M_r = M_o / M_w$ where k_r = relative permeability, mD; μ_a = apparent viscosity, cP; M_o = Mobility of oil (=k_{ro} / μ_{ao}), M_w = Mobility to water(=k_{rw} / k_{aw}) Wellbore profile control: ▪ Improvement of vertical SE around the vicinity of polymer injection wellbores is next important function. ▪ Water diverting techniques (profile correction, conformation improvement, etc.,) have been performed for many years. ▪ The top one shows the flood water fingering through a high permeability streak. The bottom one shows gelled solution treated which improves SE in the rest of the formation. ▪ Viscosity of polymer solutions can be increased by adding gelling agent (surface gels) to create a 3-D polymer gel network. ▪ Viscosity enhancement by gelling (in-situ gels) can also be achieved by crosslinking the polymer within the formation. ▪ Sequential injection of polymer and crosslinking agent to create a chemical which adsorbs on the walls of the formation pores.		
6	Stability refers to the maintenance of the integrity of the polymer molecule during oilfield operations. Polymers must have 1. Mechanical strength. 2. Thermal stability 3. Bacteriological stability 4. Chemical stability Mechanical Strength: ➢ Under most circumstances, XG solutions are shear stable, but PAM can be degraded by mechanical shear, such as in mixing equipment. Mixing shears and flow rates within the formation, therefore, can be of extreme importance to the economics of the EOR process. Thermal Stability: ➢ PAM and XG solutions are relatively thermally stable to above 200^0 F if protected against catalytic degradation by O_2 ➢ The temp stabilizers thiourea, isopropyl alcohol, N_2 purges, sulfates, propylene glycol , formaldehyde and acetone have been recommended to retard the degradation of EOR polymers. ➢ XG solutions are not as stable thermally as are PAM at above 225^0 F. ➢ Both polymers can be protected to extend their usefulness at elevated temps for many months or even years. ➢ Most lab tests have not shown long term temp stability much higher than 250^0 F for either polymer. Bacteriological Stability: ➢ XG solutions are more susceptible to microbial attack than PAM. ➢ Bacterial protection may well be needed in any water/ polymer flooding.	1.5 marks for kind	10 mins

Q No	Solution	Scheme of Marking	Max. Time required for each Question
	➢ Aerobic bacteria can grow in surface systems causing polymer degradation and injectivity problems. ➢ Anaerobic bacteria can flourish within the formation causing plugging problems, polymer degradation and reportedly can change a sweet crude to sour. ➢ Both PAM & XG are compatible with modest concentrations found in oilfield brines. Polyacrylamides are less tolerant to high concentrations of divalent cations,such as Ca and Mg. ➢ Trivalent cations such as Fe, Cr, Al react with the polymers to form gels. Quaternary amine chemicals have a deleterious effect on polymer performance, i.e., loss of viscosity. ➢ The viscosity of PAM solutions is sensitive to pH. At low values of pH, the carboxylic side group is nonionic. As pH increases the side group is converted to the anionic carboxylate ion. ➢ At pH values above 10.5, hydrolysis of Polyacrylamide side chains occurs even at room temp. Xanthan gum solutions stable at the pH values found in oilfields. ➢ Both the type of polymer and the polymer flooding technique to be used can then be tailored to the water in the candidate reservoir.		
7	(table below)	1 Mark for each test	10 mins

[illegible]	[illegible] parameters	Information obtained	Limitations
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Part C

(1Q x 10M = 10Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
8	a) Stage-1: The initial studies identify the most promising reservoir candidate for polymer flooding. The major reservoir characteristics are determined in the screening studies (lab tests & field reviews). Stage-2: Initial process design worked out from the data evolved from lab and engineering studies. Performance predictions are made & simplified design is made from process economics.	4 marks for part A 6 marks for part B	15 mins

Stage-3: Consists of a field test of the EOR process. If necessary, process design is changed to accommodate reservoir characteristics.
Stage-4: It is field development. The EOR injection facility is planned during this stage. A field wide simulation study is performed.

b) This consists of study of the EOR potential for the candidate reservoir. The EOR specialist visit the site along with his team and collect samples of oil and water. The data needed for field review are shown in the below table. .

To characterize the reservoir, four key parameters should be identified:
1) Volume of oil-in –place,
2) Reservoir transmittance,
3) Reservoir permeability variation,
4) Rock wettability.

Core analysis and laboratory evaluations are performed to collect the following information, thereafter reservoir modelling and simulation is performed to check the performance on polymer flood on a computer model and evaluation the economical analysis.

Listing of data needed for a complete field review

Facilities	type and quality size monitoring facilities quality control
Process	well spacing source and type of water current water–oil ratio current pressure
Oil-in place	reserves
Reservoir transmittance	permeability net pay productivity indices
Reservoir permeability variation	logs core analysis

[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]
Special core analysis	[illegible] wettability and saturation	[illegible]
	electrical properties [illegible]	[illegible]
	[illegible]	[illegible]
Core flood tests	[illegible]	[illegible] —polymer retention —shear degradation
	[illegible]	[illegible]
	[illegible]	

[illegible]	Control parameter	Information obtained	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST –2

Sem & AY: Odd Sem 2019-20 | **Date**: 19.11.2019
Course Code: PET 216 | **Time**: 9.30 AM to 10.30 AM
Course Name: ENHANCED OIL RECOVERY | **Max Marks**: 40
Program & Sem: B.Tech (PET)& VII | **Weightage**: 20%

Instructions:

(i) *Read the question properly and answer accordingly.*
(ii) *Question paper consists of 3 parts.*
(iii) Scientific and Non-programmable calculators are not permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries eight marks. (4Qx4M=16M)

1. What is alkaline flooding. Name four alkaline agents. (C.O.2) [Knowledge]

2. List the factors responsible for surfactant loss in the reservoir? (C.O.2) [Knowledge]

3. What are the reservoir criteria for steam flooding? (C.O.2) [Knowledge]

4. What is the difference between steam flooding and huff and puff method?

(C.O.2) [Knowledge]

Part B [Problem Solving Questions]

Answer both the Questions. Each Question carries eight marks. (2Qx8M=16M)

5. How does the concentration of surfactant effect the recovery during surfactant flooding? (C.O.2) [Comprehension]

6. How does the interfacial charge of the rock effect the recovery during surfactant flooding? (C.O.2) [Comprehension]

Part C [Problem Solving Question]

Answer the Question. The Question carry ten marks. **(1Qx10M=10M)**

7. The primary recovery of the field located in Barmer, Rajasthan having payzone at a depth of 8000 ft and reservoir temperature 150°F is declined due to high crude oil viscosity (1500cP). The Cairn India limited is planning for enhancing the recovery using secondary/tertiary methods. As a Petroleum Engineer suggest a technique to enhance production with minimum losses and proper justification. Also, explain the process/mechanism in recovering the oil using the suggested technique with neat diagram. (C.O.3) [Comprehension]

SCHOOL OF ENGINEERING

Semester: 7th

Course Code: PET 216

Course Name: Enhanced Oil Recovery

Date: 1/10/2019

Time: 1 hr

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	2	Unit 3	4									4
2	2	Unit 2	4									4
3	2	Unit 2	4									4
4	2	Unit 2	4									4
5	2	Unit 2				8						8
6	2	Unit 2				8						8
7	3	Unit 3							8			8
	Total Marks		16			16			8			40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Semester: 7th

Course Code: PET 216

Course Name: Enhanced Oil Recovery

Date: 19/11/2019

Time: 1 hr

Max Marks: 40

Weightage: 20%

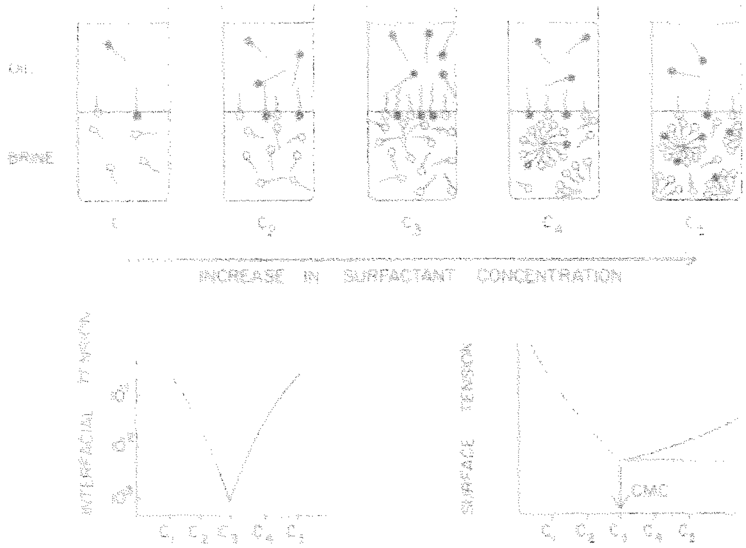
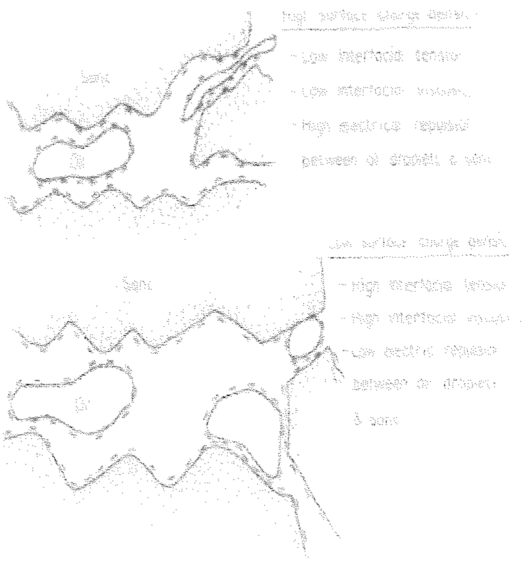
Part A (4Q x 4M = 16Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	a) Alkaline water flooding is an EOR process where the pH of the injection water is increased by the addition of alkaline agents. Alkaline flooding has started because of its low cost, simple process and availability of suitable alkaline chemicals. In this process, the alkali reacts with the acidic constituents in the crude leading to lower water-oil interfacial tension (IFT), emulsification of oil & water, solubilization of interfacial films. The alkali may react with the reservoir rock, leading to wettability alternation. All of these mechanisms will potentially increase oil recovery . b) such as sodium carbonate, sodium silicate, sodium hydroxide and potassium hydroxide in an effort towards IOR.	3 marks for part a 1 mark for part b	5 mins
2	Surfactant adsorption Surfactant precipitation Surfactant degradation Surfactant-polymer mixing Surfactant partitioning in residual oil phase	1 marks for each (any 4)	5 mins

3	(1) The crude in situ has a gravity of 10–36° API, with a viscosity around 1000 cP. (2) The oil-in-place in the reservoir is at least 1200 bbl/acre-ft, with an average oil saturation in excess of 40%, and reservoir porosity greater than 20%. (3) The reservoir depth is less than 5000 ft. (4) Reservoir injectivity is high enough to permit steam injection. (5) The formation pressure and reservoir productivity are sufficient to ensure at least moderate production rates. (6) Reservoir pressure and temperature are such that an optimum steam temperature of 300–400°F can be maintained.	0.75 marks for each point	8 mins
4	Steam flooding (SF) has acquired a major role in the tertiary recovery of heavy, viscous crude oils and provides a higher ultimate recovery.The injection of steam generated at the surface or down hole (to reduce heat loss) continuously, or in cycles. Cyclic steam injection, is also known as 'steam soak' or 'huff & puff', is a single well operation. Steam is injected into a well (producer) for some time, is allowed to soak for a period of time, and the well is subsequently returned to production. Recoveries from SF are typically in the range of 50-60% of OIP. The ultimate recovery from cyclic steam injection is considerably lower, typically in the range of (10-25%) of the oil-in-place.	2 marks for steam and cyclic flooding each point	5 mins

Part B (2Q x 8M = 16 Marks)

Q N o	Solution	Scheme of Marking	Max. Time required for each Question
5	***Effect of surfactant concentration on IFT:*** • The IFT decreases with increasing surfactant conc., and at a critical conc. IFT approaches its minimum value. Beyond this, the IFT increases with an increase in surfactant conc. • The aqueous phase is predominantly responsible for the ultra-low IFT. • From surfactant partition measurements, it was shown the no. of surfactant monomers in oil and brine phase increases with increasing conc. of surfactant. • The molecular mechanism for the effect of surfactant conc. on IFT minimum was proposed for the TRS 10-80-n-octane brine system (fig.10.15). • The molecular mechanisms for the effects of salt conc. (fig.10.12), oil chain length (fig.10.14), and surfactant conc. (fig.10.15) explain all results of U-L IFT. This unified understanding of the molecular mechanisms for producing ultra – low IFT could be utilized in designing surfactant formulations for EOR under particular reservoir conditions	5 marks for write up 3 marks for diagram	10 in s

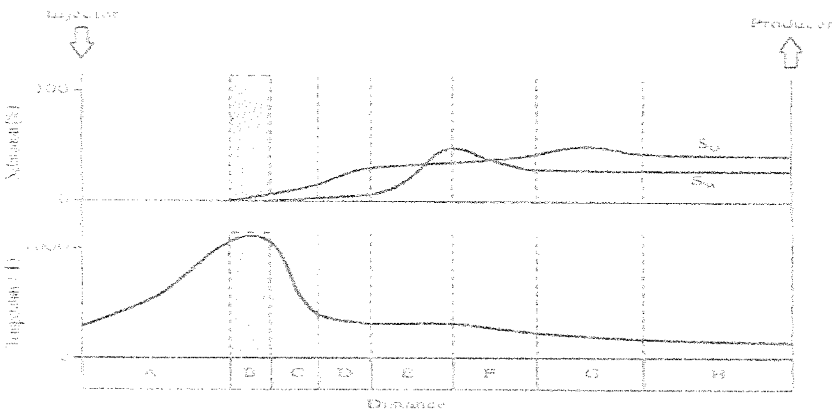
	 Fig. 10-15. The proposed molecular mechanism for the effect of surfactant concentration interfacial and surface tensions.		
6	Fig.10.6 summarizes the relevance of surface charge in the oil displacement process from the reservoir channels. A better understanding of the magnitude and nature of interfacial charge in the oil -displacement process can contribute significantly to the design of surfactant formulations for optimum performance under given reservoir conditionsA low surface charge density causes high IFT & high IFV as well as low electrical repulsion between the oil globules and sand particles Fig.10.6. The addition of a suitable surfactant would increase IF charge density. This high charge density in the presence of surfactant would result in a decrease in IFT & IFV, and would also result in an increase in electrical repulsion between oil globules & sand particles. This facilitates the movement of oil ganglia through the pore channels if the oil does not adhere to the sand particles fig.10.6.  Fig. 10-6. Schematic diagram of the role of surface charge in the oil displ	4 marks for theory 4 marks for diagram	10 mins

Part C (1Q x 8M = 8Marks)

<table>
<tr><th>Q No</th><th>Solution</th><th>Scheme of Marking</th><th>Max. Time required for each Question</th></tr>
<tr><td>7</td><td>

a) Since the oil is viscous and at a great depth to avoid heat losses insitu combustion is suggested. In other thermal processes like steam flooding and cyclic injection due to heat losses when the steam reaches downstream it reaches with zero thermal energy.

b)



A. Burned Zone
B. Combustion Zone
C. Cracking Region
D. Evaporation and Visbreaking Region
E. Steam Plateau
F. Water Bank
G. Oil Bank
H. Initial Zone

A—The burned zone is the volume already burned. This zone is filled with air and may contain small amounts of residual unburned organic solids. Because it has been subjected to high temperatures, mineral alterations are possible. Because of the continuous airflow from the injector, the burned-zone temperature increases from injected-air temperature at the injector to combustion-front temperature at the combustion front.

B—The combustion front is the highest temperature zone. It is very thin, often no more than several inches thick. It is in this region that oxygen combines with the fuel and high-temperature oxidation occurs. The products of the burning reactions are water and carbon oxides. The fuel is often misnamed coke. In fact, it is not pure carbon but a hydrocarbon with H/C atomic ratios ranging from approximately 0.6 to 2.0. This fuel is formed in the thermal-cracking zone just ahead of the front and is the product of cracking and pyrolisis, which is deposited on the rock matrix. The amount of fuel burned is an important parameter because it determines how much air must be injected to burn a certain volume of reservoir.

C/D—The cracking/vaporization zone is downstream of the front. The crude is modified in this zone by the high temperature of the combustion process. The light ends vaporize and are transported downstream, where they condense and mix with the original crude. The heavy ends pyrolize, resulting in:
CO_2
CO
Hydrocarbon gases
Solid organic fuel deposited on the rock

E—The steam plateau. This is the zone in which some of the hydrocarbon vapors condense. Most of those condense further downstream as the steam condenses. The steam plateau temperature depends on the partial pressure of the water in the gas phase. Depending on the temperature, the original oil

</td><td>2 marks for part A
6 marks for part B (1 marks for figure)</td><td>15 marks</td></tr>
</table>

	may undergo a mild thermal cracking, often named visbreaking, that usually reduces oil viscosity. F—A water bank exists at the leading edge of the steam plateau, where the temperature is less than steam saturation temperature. This water bank decreases in temperature and saturation downstream, with a resulting increase in oil saturation. G—The oil bank. This zone contains most of the displaced oil, including most of the light ends that result from thermal cracking. H—Beyond these affected areas is the undisturbed original reservoir. Gas saturation will increase slightly in this area because of the high mobility of combustion gases.		

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

END TERM FINAL EXAMINATION

Extract of question distribution [outcome wise & level wise]

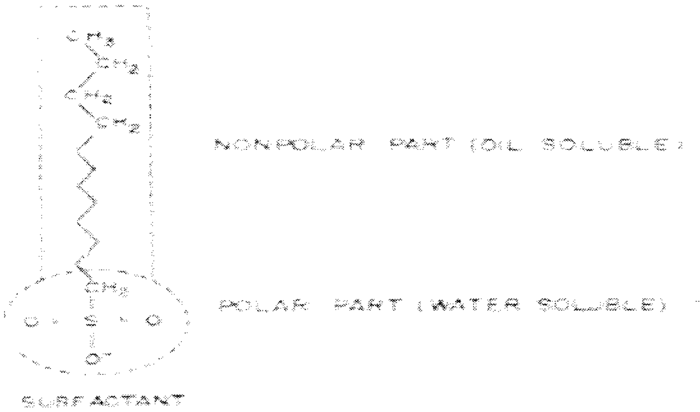
Q.NO.	C.O.NO (% age of CO)	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	A	
1	4	5	4			4
2	2	3	4			4
3	1	1	4			4
4	3	3	4			4
5	4	4	4			4
6	3	3		8		8
7	3	4		8		8
8	2	4		8		8
9	2	3		8		8
10	2	3		8		8
11	4	5			20	20
	Total Marks		20	40	20	80

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

<table>
<tr><td></td><td>atoms, the compounds are called water-insoluble surfactants. The lipophilic group is ionic or highly polar. Surfactants can be classified as anionic, cationic, amphoteric or non-ionic. Anionic surfactants widely used in EOR due to their lower adsorption on the reservoir rocks.

</td><td></td><td></td></tr>
<tr><td>5</td><td><table>
<tr><th>Criteria</th><th>Optimum condition</th></tr>
<tr><td>Depth, ft</td><td>2500 [73]–3000 [74]</td></tr>
<tr><td>Reservoir temperature, °F</td><td><120</td></tr>
<tr><td>Reservoir pressure, psi</td><td>>3000</td></tr>
<tr><td>Total dissolved solids (TDS)</td><td><10,000 mg/L</td></tr>
<tr><td>Oil gravity</td><td>Medium to light oils (27–39° API)</td></tr>
<tr><td>Oil viscosity, cp</td><td><3</td></tr>
<tr><td>Reservoir type</td><td>Carbonate reservoirs preferred than sandstone one</td></tr>
<tr><td>Minimum miscibility pressure (MMP), psi</td><td>1300–2500</td></tr>
<tr><td>Oil saturation</td><td>>20% [73]</td></tr>
<tr><td>Net pay thickness, ft</td><td>75–137</td></tr>
<tr><td>Porosity</td><td>>7%</td></tr>
<tr><td>Permeability</td><td>>10 mD</td></tr>
</table></td><td>6 criteria needed 0.75 marks for each point</td><td>8 min</td></tr>
</table>

Part B (5Q x 8M = 40 Marks)

<table>
<tr><th>Q No</th><th>Solution</th><th>Scheme of Marking</th><th>Max. Time required for each Question</th></tr>
<tr><td>6</td><td>a) Ex-situ production of the MEOR metabolites such as biosurfactants, biopolymers, and emulsifiers using exogenous or indigenous bacteria. In this case, microorganisms are grown using industrial fermenters or mobile plants and then injected into the oil formation as aqueous solutions.

In-situ production of the MEOR metabolites. In this case, the formation of metabolites is the result of the microbiological activity that takes place directly in the reservoir. The MEOR metabolites are produced by indigenous bacteria or by exogenous bacteria that are injected into the reservoir.

b) In-situ MEOR can be divided into two categories depending upon the method of injection of microorganisms and nutritional media (e.g., molasses, whey, and other waste food or chemical products) into the reservoir. The first category consists in the in-situ</td><td>4 marks for part A
4 marks for part B</td><td>15 min</td></tr>
</table>

	Figure shows a pseudo-ternary composition diagram (not to use for quantitative predictions) to understand the miscibility process for complex hydrocarbon mixtures. The three-component system shown consists of methane (C_1), the intermediates (C_2 through C_6) & heavier hydrocarbon (C_{7+}). **Region A** represents an all gas phase **Region D** is all liquid (oil) In all critical regions B or C both gas and liquid are present. **Region B** shows the range of compositions for a given temp & pr that would be miscible with mixtures in the dry gas region. **Region C** contains mixtures that are miscible with the liquid region. The tie lines terminate at points on the saturated vapor curve and saturated liquid curve. These two points represent a saturated gas and saturated oil which are in equilibrium. If the equilibrium ratios total less than one, the slope is negative. If the total is more than one, the slope is positive. The limiting tie line passes through the critical point. All fluids having an intermediate composition equal to or greater than that of the critical composition are either immediately miscible or are capable of becoming miscible with the crude in region D.		
8	• The oil in the immediate vicinity of the injection end is vaporized & pushed a head. • The advancing steam eventually condenses, due to heat losses into the overburden and underburden, into water at the steam temperature thereby generating a hot condensate bank. This hot water bank drives oil ahead as it moves, cooling down to reservoir temperature. • From this point onwards, displacement process continues as it would be in a conventional water flood. It is clear that there are three distinct flow regimes: 1. Steam zone 2. Hot condensate zone 3. Cold water zone **Steam zone:** ➢ The predominant effect is steam distillation. High temperature and the presence of a gas phase lead to the vaporization of the light ends, which are carried forward by the advancing steam until they condense in the cooler portion of the reservoir. ➢ The relatively heavier components of the oil, characterized by a high vapor pressure, are left behind. The actual oil recovery by steam distillation is determined by the composition of the oil involved. **Hot-water zone:** ➢ The oil recovery for the hot-water zone is largely governed by the thermal characteristics of the oil involved. If the viscosity of the oil exhibits a sharp decrease with an increase in temperature, considerable amount of oil will be recovered by the hot water flood. ➢ Based upon residual saturation and relative permeability models, this can lead to the recovery as much as 10-20% of the oil in the underlying zones of the reservoir not swept by steam. **Cold-water zones :** ➢ The oil recovery from the cold-water zone is approximately equal to that for an equivalent water flood, a residual oil saturation of about 20-35% is achieved.	2 marks for write up 2 marks for each zone	15 mins

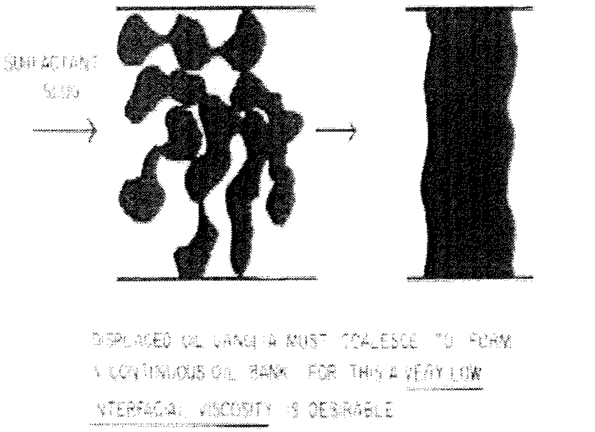


Fig. 10-7. Schematic diagram of the role of interfacial viscosity

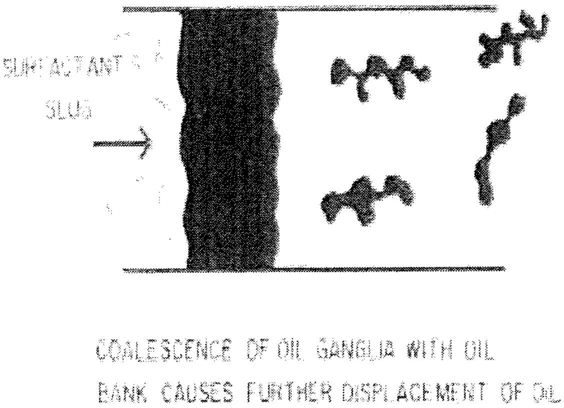


Fig. 10-8. Schematic diagram of the role of coalescence of oil

Part C (1Q x 20M = 20Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
11	a) The EOR Process is MEOR b) The MEOR process consists of two essential components: hydrocarbon-consuming microorganisms and a nutritional medium as the source of nitrogen and phosphorus. Hydrocarbon consuming microorganisms can be exogenous or indigenous. Indigenous are isolated for characterization from the hydrocarbon deposit where they will be employed. The use of industrial byproducts as nutritional media such as molasses, corn steep liquor, and cheese whey has been documented. The injection of nitrate aqueous solution at a concentration of 1.5 g/l of injected water has been recommended to suppress the activity of sulfate-reducing bacteria. Reduction of the cost of nutrients during the application of MEOR processes can be achieved by injecting only nitrogen and phosphorous sources. Nitrogen is an essential nutrient for bacterial growth. Likewise, phosphorous is another key nutrient. If	1+4+6+3+3+3	30 min

Roll No												

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Odd Semester: 2019 - 20
Course Code: PET 216
Course Name: ENHANCED OIL RECOVERY
Program & Sem: B.Tech. (PET) & VII

Date: 27 December 2019
Time: 9:30 AM to 12:30 PM
Max Marks: 80
Weightage: 40%

Instructions:
(i) Read the all questions carefully and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) Scientific and Non-programmable calculators are not permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 4 marks. **(5Qx4M=20M)**

1. What is the difference between microorganisms and metabolites? (C.O.No.4) [Knowledge]
2. Define partition coefficient. (C.O.No.2) [Knowledge]
3. Why most of the EOR problems lead to failure? (C.O.No.1) [Knowledge]
4. Write a note on surfactant with its structure. (C.O.No.3) [Knowledge]
5. List the screening criteria for CO_2 flooding. (C.O.No.4) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 8 marks. **(5Qx8M=40M)**

6. What is ex-situ and in-situ production of metabolites. Explain In-situ MEOR in detail. (C.O.No.3) [Comprehension]
7. Explain miscibility with the help of neat pseudo ternary phase diagram. (C.O.No.3) [Comprehension]
8. Explain the mechanism involved in steam flooding. (C.O.No.2) [Comprehension]
9. How does the concentration of salt effect the recovery during surfactant flooding? (C.O.No.2) [Comprehension]
10. How does the interfacial viscosity of crude oil effect the recovery during surfactant flooding? (C.O.No.2) [Comprehension]