Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST 1

Sem AY: Odd Sem 2019-20
Course Code: PET 318
Course Name: UNCONVENTIONAL HYDROCARBONS
Program & Sem: B.Tech. (PET) & V DE

Date: 30.09.2019
Time: 11:00AM to 12:00PM
Max Marks: 40
Weightage: 20%

Instructions:

(i) Read the questions correctly and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) To the point answer will be appreciated.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries six marks. (2Qx6M=12M)

1. Fill in the blank with appropriate word.
   i. _____ Energy sources are natural energy sources which do not get used up.
   ii. India holds _____ position in Proven Coal Reserve (in million metric tons) till 2018 as per the report published in 2019.
   iii. _____ reservoirs typically consist of porous and permeable sandstones or carbonate rocks that yield oil and/or gas by draining interconnected pore spaces.
   iv. Coal _____ is the study of the origin, occurrence, and structure of coal.
   v. Coal _____ is important because it directly influences the gas storage capacity of coal.
   vi. Rank of Coal represents the various _____ constituents.

(Q.NO.i to vi)(C.O.NO.1)[Knowledge]

2. Choose the correct answer.
   i. _____ Energy is an example of Potential Energy.
      (a) Thermal (b) Nuclear
      (c) Electrical (d) Magnetic

   ii. As per the OPEC Share of World Crude Oil Reserves 2017, _____ has maximum share.
      (a) Venezuela (b) Iraq
      (c) Saudi Arabia (d) Kuwait

iii. EIA estimated that _____ has maximum reserve of Shale Gas.
(a) Russia (b) China
(c) United States (d) Argentina

iv. Percentage of Oxygen, Hydrogen, Nitrogen, and Sulfur etc. can be estimated from _____ Analysis.
(a) Ultimate (b) SEM
(c) Proximate (d) Chemical

v. Coal strength is most commonly determined by the _____.
(a) RSA (b) HGI
(c) UCS (d) TSA

vi. _____ is also known as Hard Coal.
(a) Peat (b) Lignite
(c) Bituminous (d) Anthracite

(Q.NO.i to vi)(C.O.NO.1)[knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries eight marks. (3Qx8M=24M)

3. Explain the relationship between Apparent Density and Coal Rank with suitable diagram.
(C.NO.2)[Comprehension]

4. How is the frequency of Cleat related with Coal Rank? Explain with suitable diagram.
(C.NO.2)[Comprehension]

5. Explain the relationship between Gas Content and Sorption Isotherm with diagram.
(C.NO.2)[Comprehension]

Part C [Problem Solving Questions]

Answer the Question. The Question carries four marks. (1Qx4M=4M)

6. "We are expecting Shale Gas Boom in North America in next two decades". If the previous statement is true, then explain the reason behind it. What could be the position of India in Shale Gas exploration?
(C.O.NO.2.)[Comprehension]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Semester: V
Course Code: PET 318
Course Name: Unconventional Hydrocarbons
Program & Sem: B.Tech. PET & V

Date: 30-09-2019
Time: 11:00 AM – 12:00 PM
Max Marks: 40
Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q. No.	CO 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	C	
1	1 (7.5%)	Unit I: Introduction to Unconventional Hydrocarbons	3			6
	2 (7.5%)	Unit II: Coal and Coal Bed Methane	3			
2	1 (7.5%)	Unit I: Introduction to Unconventional Hydrocarbons	3			6
	2 (7.5%)	Unit II: Coal and Coal Bed Methane	3			
3	2 (20%)	Unit II: Coal and Coal Bed Methane		8		8
4	2 (20%)	Unit II: Coal and Coal Bed Methane		8		8
5	2 (20%)	Unit II: Coal and Coal Bed Methane		8		8
6	1 (10%)	Unit I: Introduction to Unconventional Hydrocarbons			4	4
	Total Marks		12	24	4	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.

I here certify that All the questions are set as per the above lines Dr Suman Paul

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEEING

SOLUTION

Semester: V

Course Code: PET 318

Course Name: Unconventional Hydrocarbons

Program & Sem: B.Tech. PET & V

Date: 30-09-2019

Time: 11:00 AM – 12:00 PM

Max Marks: 40

Weightage: 20%

Part A

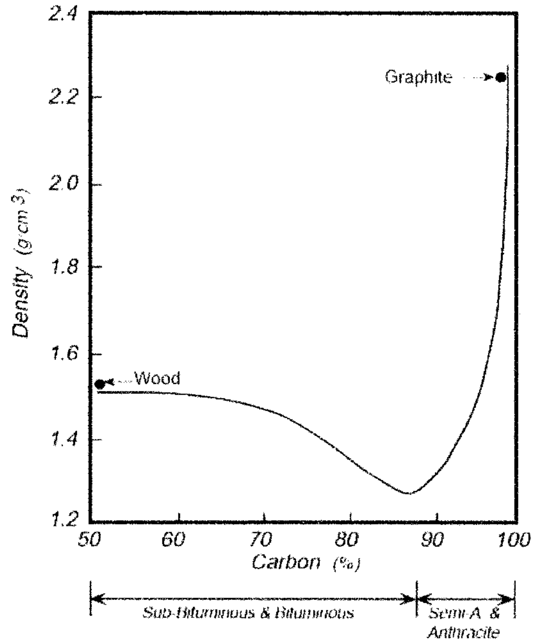
(2Q x 6M = 12 Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
1	i. Renewable ii. 5th iii. Conventional iv. Petrology v. Rank vi. organic	(1M + 1M + 1M + 1M + 1M + 1M)	4
2	i. (b) ii. (a) iii. (c) iv. (a) v. (b) vi. (d)	(1M + 1M + 1M + 1M + 1M + 1M)	4

Part B

(3Q x 8M = 24 Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
3	**Relationship between Apparent Density and Coal Rank:** Coal resources can be more accurately estimated if the coal density is known. Because of the porous nature of coal, it can be difficult to accurately determine its volume and thus its density. Usually, apparent density is measured rather than true density. The apparent density of coal reaches a minimum at about 85 percent carbon in the low-volatile bituminous range, as shown in Figure 1. Porosity for coals of medium-volatile bituminous through anthracite rank is typically less than five percent.	4M + 4M (Figure + Explanation)	12

<table>
<tr><td></td><td>
Figure 1: Relationship Between Apparent Density and Coal Rank (Carbon Content) (Adapted from Williamson, 1967)</td><td></td><td></td></tr>
<tr><td>4</td><td>Relationship between Frequency of Cleat and Coal Rank:
Cleat formation appears to be influenced by shrinkage, stress release, and extensional strain. Shrinkage during the process of coalification may contribute to cleat formation. Cleat is present in coals with a rank of lignite through anthracite and is commonly best developed in low-volatile bituminous rank coals, as shown in Figure 1.

The increased heat and pressure associated with metamorphism causes plastic flow that usually destroys cleat. The effect of rock flowage can be seen by contrasting the highly developed cleat of most seams of bituminous coal which, in general, show few signs of flowage, with the relative absence of cleat in anthracite where such signs are abundant. Some flat-lying or gently inclined anthracite coalbeds have well developed cleat systems.

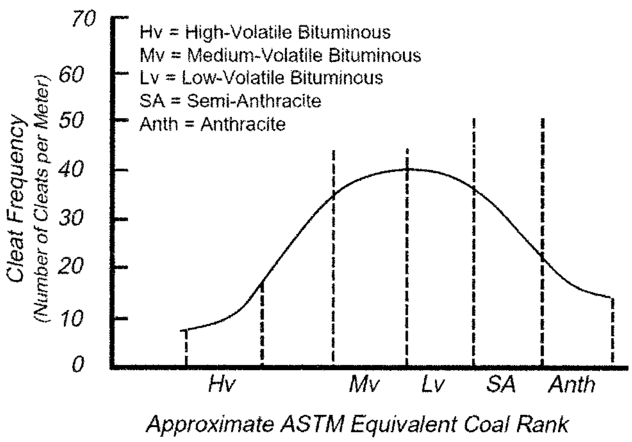
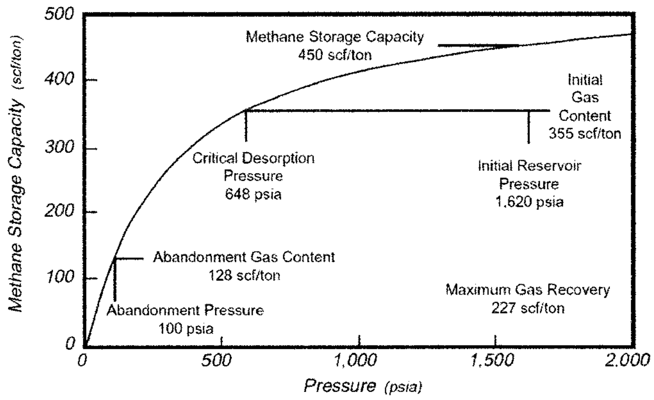
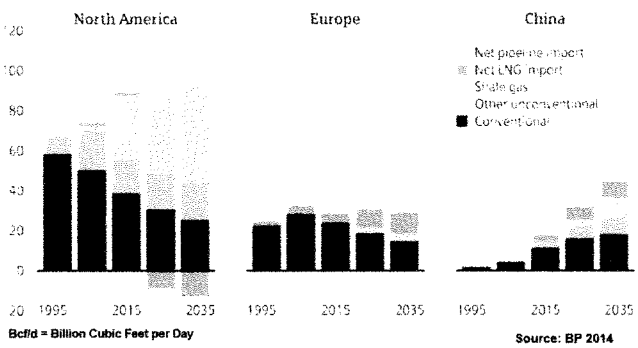


Figure 1: Cross-plot of Coal Rank and Cleat Frequency (Adapted from Ammosov and Eremin, 1960)</td><td>4M + 4M
(Figure + Explanation)</td><td>12</td></tr>
</table>

5	**Relationship Between Gas Content and Sorption Isotherm:** Another mechanism that controls production is the relationship of gas content to sorption isotherm, as shown in Figure 1. The sorption isotherm defines the relationship of pressure to the capacity of a given coal to hold gas at a constant temperature. Gas content is a measurement of the actual gas contained in a given coal reservoir. A coal reservoir is undersaturated if the actual gas content is less than the isotherm value at reservoir temperature and pressure. Accurate measurements of both gas content and the isotherm are required to estimate the production profile of the well.  Figure 1: Example of the Relationship Between the Sorption Isotherm Curve and Gas Content and the Influence on Recovery.	4M + 4M (Figure + Explanation)	12

Part C

(1Q x 4M = 4 Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
6	 The students are expected to explain their views on the given topic.	2M + 2M (Figure + Explanation)	12

Roll No.												

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 2

Semester: V
Course Code: PET 318
Course Name: Unconventional Hydrocarbons
Program & Sem: B.Tech. PET & V

Date: 18-11-2019
Time: 11:00 AM – 12:00 PM
Max Marks: 40
Weightage: 20%

Instructions:
(i) Read the questions correctly and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) To the point answer will be appreciated.

Part A [Memory Recall Questions]

Answer ALL the Questions. Each question carries 7 marks. **(3Q x 5M = 15 Marks)**

1. Fill in the blank with appropriate word. [5M] (CO No. 4) [Bloom's Level: Knowledge]
   i. Assessment of global shale data includes identification of the shale depositional environment and _____ type.
   ii. The key challenges that shale gas industry faces are environmental issues and _____ challenges.
   iii. Shale gas is considered an _____ gas resource, since conventionally gas is produced from granular, porous, and permeable formations (i.e., sandstone), within which gas can readily flow.
   iv. Gas Shale refers to the _____ material from which the gas is extracted in a shale gas play.
   v. Mineralogy plays a central role when evaluating gas shale, due to its impact on the performance of fracture treatment which is also known as _____.

2. Choose the correct answer. [5M] (CO No. 4) [Bloom's Level: Knowledge]
   i. Shale gas organic geochemistry is a function of the _____ environment and is similar to conventional source rock geochemistry.
      (a) marine (b) depositional
      (c) lacustrine (d) deltaic

   ii. Marine shale is typically associated with _____
      (a) Type I Kerogen (b) Type II Kerogen
      (c) Type III Kerogen (d) Type IV Kerogen

   iii. Organic-rich shale can be divided as _____
      (a) marine shale (b) lacustrine shale
      (c) marine-terrigenous carbonaceous shale (d) All that mentioned before

iv. The depositional setting that directly controls key factors in shales are _____
(a) organic geochemistry (b) organic richness
(c) rock composition (d) All that mentioned before

v. The key features of successful shale gas plays include _____.
(a) high TOC content (>2%) (b) thermal maturity (Ro 1.1-1.5%)
(c) low clay / high brittle mineral content (d) All that mentioned before

3. Discuss the sequence of sub-stages generally followed to characterize any shale gas play. [5M]
(CO No. 4) [Bloom's Level: Knowledge]

Part B [Thought Provoking Questions]

Answer ALL the Questions. Each question carries 6 marks. (2Q x 8M = 16 Marks)

4. Is there any relation between 'Gas Production Rate' and 'Drainage Area'? Explain your answer with suitable diagram. (CO No. 3) [Bloom's Level: Comprehensive]

5. 'Permeability' of any reservoir influences its 'Production Rate'. Explain the statement for CBM reservoirs with suitable diagram. (CO No. 3) [Bloom's Level: Comprehensive]

Part C [Problem Solving Questions]

Answer ALL the Questions. Each question carries 10 marks. (1Q x 9M = 9 Marks)

6. Explain 'Three Phases of Producing Life' of a typical CBM production profiles for gas and water rates with diagram. (CO No. 3) [Bloom's Level: Comprehensive]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE REACH GREATER HEIGHTS

Semester: V
Course Code: PET 318
Course Name: Unconventional Hydrocarbons
Program & Sem: B.Tech. PET & V

Date: 18-11-2019
Time: 11:00 AM – 12:00 PM
Max Marks: 40
Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q. No.	CO 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	C	
1	4 (12.50%)	Unit IV: Shale Gas Reservoirs	5			**5**
2	4 (12.50%)	Unit IV: Shale Gas Reservoirs	5			**5**
3	4 (12.50%)	Unit IV: Shale Gas Reservoirs	5			**5**
4	3 (20%)	Unit III: Coal Bed Methane Reservoir Properties		8		**8**
5	3 (20%)	Unit III: Coal Bed Methane Reservoir Properties		8		**8**
6	3 (22.50%)	Unit III: Coal Bed Methane Reservoir Properties			9	**9**
	Total Marks		**15**	**16**	**9**	**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.

I here certify that all the questions are set as per the above lines - Dr Suman Paul

SCHOOL OF ENGINEEING

SOLUTION

Semester: V
Course Code: PET 318
Course Name: Unconventional Hydrocarbons
Program & Sem: B.Tech. PET & V

Date: 18-11-2019
Time: 11:00 AM – 12:00 PM
Max Marks: 40
Weightage: 20%

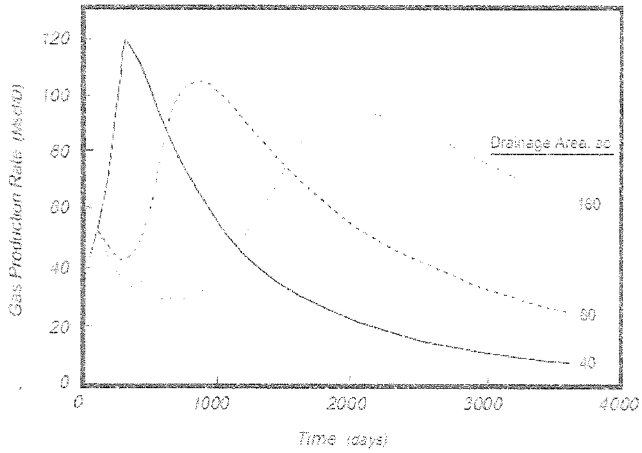
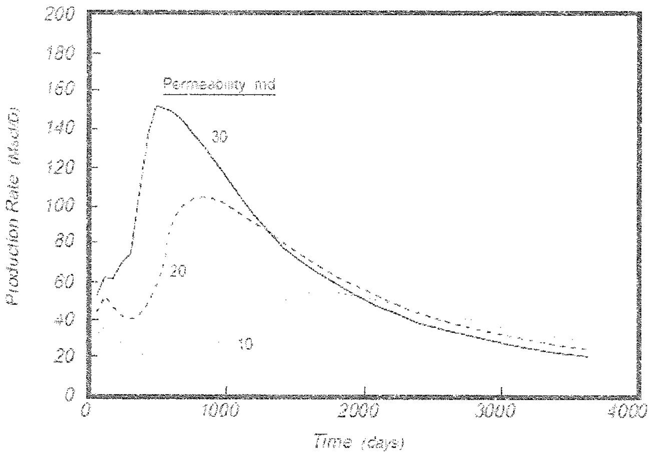
Part A

(3Q x 5M = 15 Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
1	i. basin ii. commercial iii. unconventional iv. geologic v. hydraulic fracturing	(1M + 1M + 1M + 1M + 1M)	4
2	i. (b) ii. (b) iii. (d) iv. (d) v. (d)	(1M + 1M + 1M + 1M + 1M)	4
3	The sequence of sub-stages generally followed to characterize any shale gas play are **1. Test phase** - validating the integrity of the well casings and cement, **2. Acid treatment** - pumping acid mix into the borehole to clean walls of "damage," **3. Slickwater pad** - pumping water-based fracturing fluid mixed with a friction-reducing agent in the formation, which is essentially designed to improve the effectiveness of the subsequent substage, **4. Proppant stage** - numerous sequential substages of injecting large volumes of fracture fluid mixed with fine-grained mesh sand (proppant) into the formation, with each subsequent substage gradually reducing the water-to-sand ratio, and increasing the sand particle size. The fracture fluid is typically 99.5% water and sand, with the remaining components being additives to improve performance.	5M	4

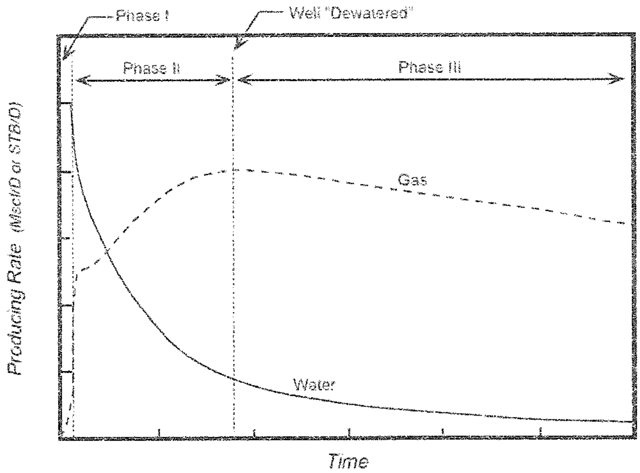
Part B

(2Q x 8M = 16 Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
4	 Figure 1: Sensitivity of Gas Production Rate to Well Drainage Area. Explanation: 1. 2. 3. 4.	4M + 4M (Figure + Explanation)	15
5	 Figure 1: Sensitivity of Gas Production Rate to Permeability. Explanation: 1. 2. 3. 4.	4M + 4M (Figure + Explanation)	15

Part C

(1Q x 9M = 9 Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
6	 **Figure 1:** Typical CBM Production Profiles for Gas and Water Rates: Three Phases of Producing Life. A typical production profile of a coalbed methane well is shown in Figure 1. This profile differs significantly from the typical decline of a conventional gas well. The inclining gas rate trend in the early life of a coalbed methane well occurs because water initially occupies the fracture (cleat) system in the reservoir, which controls flow to the well. Water must be removed from the cleat system before gas can effectively flow to the well. This process is called dewatering. Phase I is characterized by a constant water production rate and declining flowing bottomhole pressure. During this phase, the well is being "pumped-off" and the gas rate may be inclining, as shown in Figure 1. The gas rate may also decline, depending on the near-well relative permeability characteristics of the reservoir. At the end of Phase I, the well has reached its minimum flowing bottomhole pressure. Phase II is characterized by "negative decline" in the gas production rate and a significant decline in the water production rate. Phase II is characterized by several dynamic changes in reservoir flow conditions: - Water relative permeability decreases. - Gas relative permeability increases. - Outer boundary effects become significant (pseudosteady state flow). - Gas desorption rates change dynamically. - Phase III begins when reservoir flow conditions have stabilized. The well has reached its peak gas rate, and gas production is characterized by a more typical decline trend. During this phase, water production is low and/or negligible, and gas and water relative permeabilities	4M + 5M (Figure + Explanation)	15

	change very little. The well is considered to be "dewatered" at the beginning of Phase III. At this point, water production has reached a low (and sometimes negligible) level, and gas and water relative permeabilities change little hereafter. Pseudo-steady state flow exists for the rest of Phase III. The length of the dewatering process and the magnitude of the producing rates of gas and water are controlled by the physical properties of the coal as well as project development parameters. This process may take weeks, months, or years depending on the properties of the producing coalbed.		

END TERM FINAL EXAMINATION

Semester: Odd Semester: 2019 - 20

Course Code: PET 318

Course Name: Unconventional Hydrocarbons

Program & Sem: B. Tech. (PET) & V Sem (DE-II)

Date: 24 Dec 2019

Time: 09:30 AM – 12:30 PM

Max Marks: 80

Weightage: 40 %

Instructions:

(i) Read the questions carefully and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) To the point answer will be appreciated.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 6 marks. (5Q x 6M = 30M)

1. List three sources each for Renewable Energy and Non-Renewable Energy.
(C.O.No. 1) [Knowledge]

2. The composition of coal is often described by Proximate Analysis and Ultimate Analysis. Briefly discuss the Proximate Analysis process with flow diagram.
(C.O.No. 2) [Knowledge]

3. Fill in the blanks below with one word:
(a) _____ are the naturally occurring fractures rarely visible with naked eye.
(b) Unit of cleat permeability is expressed in milli _____ range.
(c) Coal bed generally show dual _____ system.
(d) In general, Porosity _____ with increasing depth.
(e) _____ content is one of the factors that affect the sorption isotherm.
(f) Coal contains a very fine 'micropore' structure and the diameters of pores typically range from five to ten _____. (Hint: Need to mention unit)
(C.O.No. 3) [Knowledge]

4. Discuss the sequence of sub-stages followed for characterizing a Shale Gas Play.
(C.O.No. 4) [Knowledge]

5. Mention the conditions required to be fulfilled for formation of hydrates.

(b) Discuss the factors that control production in coal reservoirs.

[5M + 5M] (C.O.No. 3) [Comprehension]

7. (a) Explain the issues that influence the significance and future of Shale Gas.
   (b) Discuss the environmental challenges expected to influence the Shale Gas industry in future.

[5M + 5M] (C.O.No. 3) [Comprehension]

8. Why is Gas Hydrates also known as 'clathrates' or 'inclusion compounds'? Explain the conditions required for formation of a hydrate. Explain the phenomena that enhance hydrate formation.

[2M + 4M + 4M] (C.O.No. 5) [Comprehension]

Part C [Problem Solving Questions]

Answer both the Questions. Each Question carries 10 marks. (2Q x 10M = 20M)

9. (a) Identify the key geological characteristics of a successful shale gas play.
   (b) Explain the challenges of Gas Shale systems.

[5M + 5M] (C.O.No. 4) [Comprehension]

10. There is a myth in the Natural Gas Industry that free-water (i.e., an aqueous phase) must be present in order to form a hydrate. Is this belief true? Explain your answer. Is it necessary to have free-water in order to form ice? Explain the difference between 'deuterium' and 'normal hydrogen'. Does heavy water form a hydrate? Explain your answer.

[3M + 2M + 3M + 2M] (C.O.No. 5) [Comprehension]

Extract of question distribution [Outcome wise & Level wise]

Q. No.	C.O. No. (% age of C.O.)	Unit / Module Number / Unit / Module Title	Memory Recall Type [30 Marks] Knowledge Level	Thought Provoking Type [30 Marks] Comprehension Level	Problem Solving Type [20 Marks] Comprehension Level	Total Marks
			K	C	C	
1	CO 1	Unit I: Introduction to Unconventional Hydrocarbons	6			6
2	CO 2	Unit II: Coal and Coal Bed Methane	6			6
3	CO 3	Unit III: Coal Bed Methane Reservoir Properties	6			6
4	CO 4	Unit IV: Shale Gas Reservoirs	6			6
5	CO 5	Unit V: Natural Gas Hydrates	6			6
6	CO 3	Unit III: Coal Bed Methane Reservoir Properties		10		10
7	CO 4	Unit IV: Shale Gas Reservoirs		10		10
8	CO 5	Unit V: Natural Gas Hydrates		10		10
9	CO 4	Unit IV: Shale Gas Reservoirs			10	10
10	CO 5	Unit V: Natural Gas Hydrates			10	10
	Total Marks		30	30	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.

Faculty Signature:

Reviewer Commend:

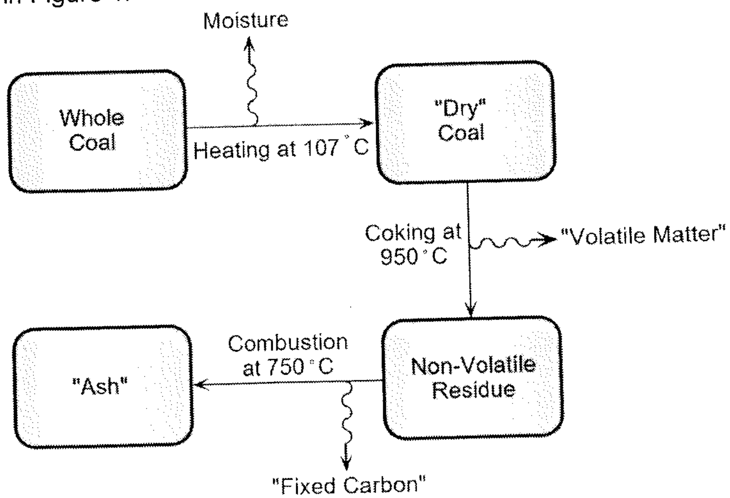
GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Semester: Odd Semester: 2019 - 20
Course Code: PET 318
Course Name: Unconventional Hydrocarbons
Program & Sem: B. Tech. (PET) & V Sem (DE-II)

Date: 24 Dec 2019
Time: 09:30 AM – 12:30 PM
Max Marks: 80
Weightage: 40 %

Part A

(5Q x 6M = 30Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
1	**Sources for Renewable Energy are:** - Solar - Hydropower - Biomass - Geothermal - Wind **Sources for Non- Renewable Energy are:** - Fossil Fuel - Coal - Nuclear - Natural Gas	3 + 3	12
2	The composition of coal often is described by Proximate Analysis and Ultimate Analysis. A Proximate Analysis provides the percentage of Fixed Carbon (FC), Volatile Matter (VM), Moisture (H_2O) Content, and Ash Content of the coal as shown in Figure 1.  **Figure 1:** Flow diagram for Proximate Analysis Process. The relative amount of these components can be reported in several ways; the most common include: ... FC, VM, H_2O, and ash based on moisture	3 + 3	12

	which may have widely differing ash contents. However, when calculating resources, need to be careful for using density and tonnage numbers calculated on the same basis as the gas content or make proper adjustments.		
3	(a) Cleats (b) darcy (c) porosity (d) decreases (e) ash / moisture (f) Angstorms	1 x 6	12
4	The sequence of sub-stages followed for characterizing a Shale Gas Play are: 1. **Test Phase:** validating the integrity of the well casings and cement, 2. **Acid Treatment:** Pumping acid mix into the borehole to clean walls of "damage," 3. **Slickwater Pad:** Pumping water-based fracturing fluid mixed with a friction-reducing agent in the formation, which is essentially designed to improve the effectiveness of the subsequent substage, 4. **Proppant Stage:** numerous sequential substages of injecting large volumes of fracture fluid mixed with fine-grained mesh sand (proppant) into the formation, with each subsequent substage gradually reducing the water-to-sand ratio, and increasing the sand particle size. The fracture fluid is typically 99.5% water and sand, with the remaining components being additives to improve performance.	6	12
5	The formation of a hydrate requires the following three conditions: 1. *The right combination of temperature and pressure.* Hydrate formation is favored by low temperature and high pressure, 2. *A hydrate former.* Hydrate formers include methane, ethane, and carbon dioxide, 3. *A sufficient amount of water - not* too much, not too little.	6	12

Part B

(3Q x 10M = 30Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
6	**(a) Relationship between Apparent Density and Coal Rank:** Coal resources can be more accurately estimated if the coal density is known. Because of the porous nature of coal, it can be difficult to accurately determine its volume and thus its density. Usually, apparent density is measured rather than true density. The apparent density of coal reaches a minimum at about 85 percent carbon in the low-volatile bituminous range, as shown in Figure 1. Porosity for coals	5 + 5	20

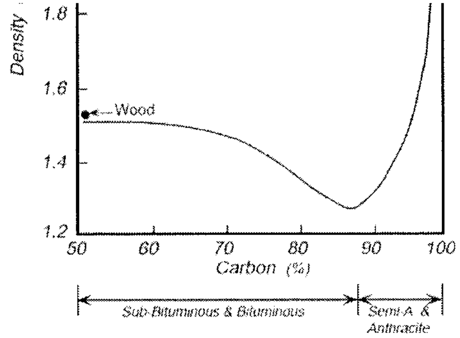
<table>
<tr><td></td><td>

Figure 1: Relationship Between Apparent Density and Coal Rank (Carbon Content) (Adapted from Williamson, 1967)

(b) The factors that control production in coal reservoirs are:
1. Early work showed that gas is stored in an adsorbed state on coal, and thus for a given reservoir pressure much more gas can be stored in a coal seam than in a comparable sandstone reservoir.
2. Production of gas is controlled by a three step process - desorption of gas from the coal matrix, diffusion to the cleat system, and flow through fractures.
3. Many coal reservoirs are water saturated, and water provides the reservoir pressure that holds gas in the desorbed state.</td><td></td><td></td></tr>
<tr><td>7</td><td>The significance and future of shale gas may be influenced by the interplay of a wide variety of issues, including the followings:
- Potentially falling gas prices, due to increased production
- Reduced production costs due to technological developments, and the associated competitiveness of gas produced from shale in comparison to other sources
- Increased demand for gas due to increased adoption of natural gas to produce energy and in new markets (i.e., natural gas-fuelled vehicles)
- The regulatory environment for shale gas development in each country

The following environmental challenges expected to influence the Shale Gas industry in future:
- Protecting Existing Water Resources – (a) Drilling, casing, and cementing programs, (b) Fracture treatment design, (c) Fracturing process
- Sustainable Use of Groundwater Resources for Formation Fracturing
- Responsible Treatment and Disposal of Exploration and Production-Related Water
- Other Environmental Considerations</td><td>5 + 5</td><td>20</td></tr>
<tr><td>8</td><td>Hydrates are crystalline solid compounds formed from water and smaller molecules. They are a subset of compounds known as clathrates or inclusion compounds. A clathrate compound is one in which a molecule of</td><td>2M + 4M + 4M</td><td>20</td></tr>
</table>

2. *A hydrate former.* Hydrate formers include methane, ethane, and carbon dioxide.
3. *A sufficient amount of water--not* too much, not too little.

In order to prevent hydrate formation, one merely has to eliminate one of the three conditions stated previously. Typically we cannot remove the hydrate formers from the mixture. In the case of natural gas, hydrate formers are the desired product. So we attack hydrates by addressing the other two considerations. Other phenomena that enhance hydrate formation include the following:

- ***Turbulence***
  - ***High velocity.*** Hydrate formation is favored in regions where the fluid velocity is high. This makes choke valves particularly susceptible to hydrate formation. First, there is usually a significant temperature drop when natural gas is choked through a valve because of the Joule-Thomson effect. Second, the velocity is high through the narrowing in the valve.
  - ***Agitation.*** Mixing in a pipeline, process vessel, heat exchanger, and so on enhances hydrate formation.
- ***Nucleation sites.*** In lay terms, a nucleation site is a point at which a phase transition is favored, and in this case the formation of a solid from a fluid phase. Nucleation sites for hydrate formation include an imperfection in the pipeline, a weld spot, a pipeline fitting (e.g., elbow, tee, valve), and so on. Silt, scale, dirt, and sand all make good nucleation sites as well.
- ***Free-water.*** This is not a contradiction to other statements in this book. Free-water is not necessary for hydrate formation, but the presence of flee-water certainly enhances hydrate formation. In addition, the water-gas interface is a good nucleation site for hydrate formation.

Part C

(2Q x 10M = 20Marks)

Q. No.	Solution	Scheme of Marking	Max. Time required for each Question
9	(a) The key geological characteristics of a successful shale gas play include the following: - Organic rich, minimum TOC of 2% - Low clay content (<50%) / high brittle mineral content (>40%). Generally associated with marine shales - Thermally mature, Ro >1.1%, ideally 1.1–1.4% (Types II and III kerogen), >0.7% (Type I kerogen). Kerogen type is a function of depositional environment. - Thickness of shale bed (minimum of 100 ft). - Porosity >5%	5 + 5	25

	Fracture stimulation is required for the systems to economically produce gas. Fractures are created easily in silica-rich and carbonate-rich shales when compared to clay-rich shales, and total porosities are larger in clay-rich shales than in silica-rich shales. One of the most important and difficult variables to determine is the *in situ* permeability, which is controlled by the pore structure. Rock typing in terms of the hydraulic process from porosity-permeability cross-plots is not practical in gas shale reservoirs because the dynamic range for porosity in shales is very narrow compared to the conventional reservoirs. Undeniably, a fluid's efficiency in flowing through the pore system (hydraulic conductivity and permeability) will also depend on the fluid–solid interactions, the tortuosity of the pore network, intrinsic structures such as veins, faults, or bedding (i.e. heterogeneities), and the anisotropic aspects of these characteristics. Currently, the only way to extract gas from gas shale is through extensive hydraulic fracturing (Gale et al., 2007), and the gas recovery efficiency will depend on the flow and trap properties of the gas shale. It is therefore crucial to understand the pore structures of gas shale. As yet, there is no clear understanding of how these pore systems are connected.		
10	"There is a myth in the Natural Gas Industry that free-water (i.e., an aqueous phase) must be present in order to form a hydrate." – According to me the said belief is not correct because Free-water certainly increases the possibility that a hydrate will form, but it is not a necessity. A strong argument demonstrating that free-water is not necessary for hydrate formation. It is not necessary to have free-water in order to form ice because frost forms without liquid water forming. The water goes directly from the air to the solid phase without a liquid being encountered. The air-water mixture is a gas, and the water is not present in the air in a liquid form. The difference between 'deuterium' and 'normal hydrogen': Deuterium is an isotope of hydrogen. In the simple hydrogen molecule there is one proton, one electron, and no neutrons~protons, electrons, and neutrons being the elementary particles that make up the atom. Deuterium, on the other hand, is composed of one proton, one electron, and one neutron. Because of the additional particle, deuterium is heavier than normal hydrogen. Water is composed of two hydrogen atoms and an oxygen atom. Heavy water, also called deuterium oxide, is composed of two deuterium atoms and an oxygen atom. Heavy water do form a hydrate because it still exhibits hydrogen bonding the key to hydrate formation; however, it requires slightly more pressure to form hydrates in heavy water than in regular water		25