National Exams December 2015

98-Pet-B4, Petroleum Geology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK exam.

3. Candidates may use one of two calculators, the Casio or Sharp approved models.

4. FIVE (5) sections constitute a complete exam paper. Each section contains between 2 and 5 questions.

5. The first five sections as they appear in the answer book will be marked.

6. All sections are of equal value. All parts in a multipart question have equal weight unless otherwise stated.

7. Clarity and organization of your answers are important, clearly explain your logic.

8. Pay close attention to units, some questions involve oilfield units, and these should be answered in the field units. Questions that are set in other units should be answered in the corresponding units.

9. Useful formulas are provided at the end of questions.

Section 1 – Source Rock Geology and Hydrocarbon Generation (20 Marks)

Q1-1 (5 marks) What are the five conditions necessary for a commercial accumulation of petroleum?

Q1-2 (8 marks) Define the following terms:

a) Lignin
b) Vitrinite
c) Sapropelic kerogen
d) Catagenesis

Q1-3 (7 marks) Draw a cross section through a deep lake (700 m deep) that is thermally stratified and transitions from oxygenated surface waters (upper 100 m) to anoxic water at depth (below 500 m) (2 of 7 marks). Indicate the relative organic carbon concentrations (as a percentage range) you would expect to be preserved in the lake sediments along the lake-bed profile (3 of 7 marks), and the expected dissolved oxygen concentrations in the seawater at different depths (2 of 7 marks).

Section 2 – Hydrocarbon Chemistry and Physical Properties (20 Marks)

Q2-1 (8 marks) Provide the chemical formula and draw the structural formula for the following hydrocarbon compounds:

a) Heptane
b) Toluene
c) Isoprene
d) Phenol

Q2-2 (8 marks) Define the following terms:

a) Petroleum
b) Bitumen
c) Condensate
d) Thermogenic gas

Q2-3 (4 marks) The density of oil is often given in API. What is the formula for calculating API? What is the typical API range for light oil? Heavy oil?

Section 3 – Hydrocarbon Migration and Unconventional Reservoirs (20 Marks)

Q3-1 (3 marks) What is secondary clay dewatering and why is it important?

Q3-2 (4 marks) Calculate the maximum hydrocarbon column height that can be trapped in sandstone and below shale before the shale is breached. Assume that the rock is water wet. Equations are provided at the end of the exam booklet. Assumptions:

Pore throat diameter in sandstone: 37 μm
Pore throat diameter in shale: 3.5 μm
Interfacial tension: 28 dynes cm^{-1}

Hydrocarbon density: 880 kg m^{-3}
Saltwater density: 1070 kg m^{-3}

Q3-3 (4 marks) Illustrate and describe what is meant by "basin-center gas" and how does it form?

Q3-4 (5 marks) What is the difference in the production technique between conventional natural gas production and coal-bed methane production?

Q3-5 (4 marks) Why are oil sands considered to be unconventional hydrocarbon targets? Be specific and consider production methodologies.

Section 4 – Carbonate Traps (20 Marks)

Q4-1 (8 marks) Define and illustrate the following:

a) Rimmed platform
b) Ramp
c) Sabkha
d) Lagoon

Q4-2 (10 marks) Draw a cross-section and plan-view map of a detached carbonate bank (2 of 10 marks). Indicate the geomorphic features (distinct depositional environments) of the carbonate bank, and the dominant and subordinate wind directions (3 of 10 marks). Briefly describe the potential of carbonate bank sub-environments as hydrocarbon reservoirs assuming they undergo no diagenesis, and that the bank is preserved in the subsurface and has been charged with hydrocarbons (5 of 10 marks). Don't forget a scale and be sure to label everything clearly.

Q4-3 (2 marks) What are the typical latitudes between which carbonate banks form?

Section 5 – Structural Traps (20 Marks)

Q5-1 (15 marks) Draw a cross-section and plan-view map of a thrust fault play with a repeated permeable sandstone sequence (4 of 15 marks). Label the key reservoir components (e.g., seal, spill point, etc.)(3 of 15 marks). List and describe the main risks associated with encountering hydrocarbons and the economic viability of exploiting them (8 of 15 marks).

Q5-2 (5 marks) Draw a cross section through a growth fault and label it (2 of 5 marks). In what two depositional systems are growth faults commonly found (2 of 5 marks)? Provide an example of a region with significant volumes of hydrocarbons trapped in growth faults (1 of 5 marks).

Section 6 – Geography of Petroleum Basins in Canada (20 Marks)

Q6-1 (10 marks) Draw a generalized NE-SW cross-section through the Western Canada Sedimentary Basin. Indicate the major rock types and the main play types that might be expected along the section. Include scales.

Q6-2 (10 marks) On the attached map of Canada, indicate as many basins and arches as you are aware of. Marks are given for the correct placement of lines for arches and specific basin names.

Useful Equations:

$$P_d = \frac{2\gamma \cos\theta}{R}$$

Where:

P_d = Pressure of diplacement (dynes cm^{-2})
γ = interfacial tension (dynes cm^{-1})
θ = wettability angle (expressed as the contact angle between rock and hydrocarbon)
R = radius of the largest connected pore throats (cm)

$$z = \frac{4\gamma}{D} \cdot \frac{1}{(\rho_w - \rho_{HC})g}$$

Where:

z = height of HC column needed to breakthrough a pore throat
D = diameter of largest connected pore throat (effective pores)
ρ_w = density of water
ρ_{HC} = density of hydrocarbon
g = gravity

Map for Q6-2