

ENGINEERING TRIPOS PART IIB  
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Thursday 22 April 2004 9 to 10.30

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Module 4D1

PETROLEUM ENGINEERING

*Answer not more than two questions.*

*All questions carry the same number of marks.*

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*There are no attachments.*

**You may not start to read the questions  
printed on the subsequent pages of this  
question paper until instructed that you  
may do so by the Invigilator**

(TURN OVER

1 The flow of water in a two-phase oil-water system in a reservoir is governed by the following equations, in the standard notation:

$$v_w = -\frac{k}{\eta_w} k_{rel,w}(S_w) \nabla P_w$$

$$1 = S_w + S_o$$

$$P_{cap}(S) = P_w - P_o$$

where the subscripts *o* and *w* refer to water and to oil, and *S* denotes saturation.

- (a) explain the significance of each of the symbols; [25%]
- (b) explain the physical significance of each of the three equations; [25%]
- (c) explain why the response of the system to water injection is history-dependent and shows hysteresis, in the context of an initial increase in water injection rate followed by a decrease. [25%]
- (d) outline how the equations can be solved numerically, mentioning any expected special features of the solution that the numerical scheme has to be able to deal with. [25%]

2 A major oil company is planning to drill an exploration well in the western Pacific, 50 km to the north-east of northern Sakhalin (the Russian island north of Japan). The water is 700 m deep. The site is exposed to strong north-easterly gales, and drifting sea ice 1 m thick may be present from November until May.

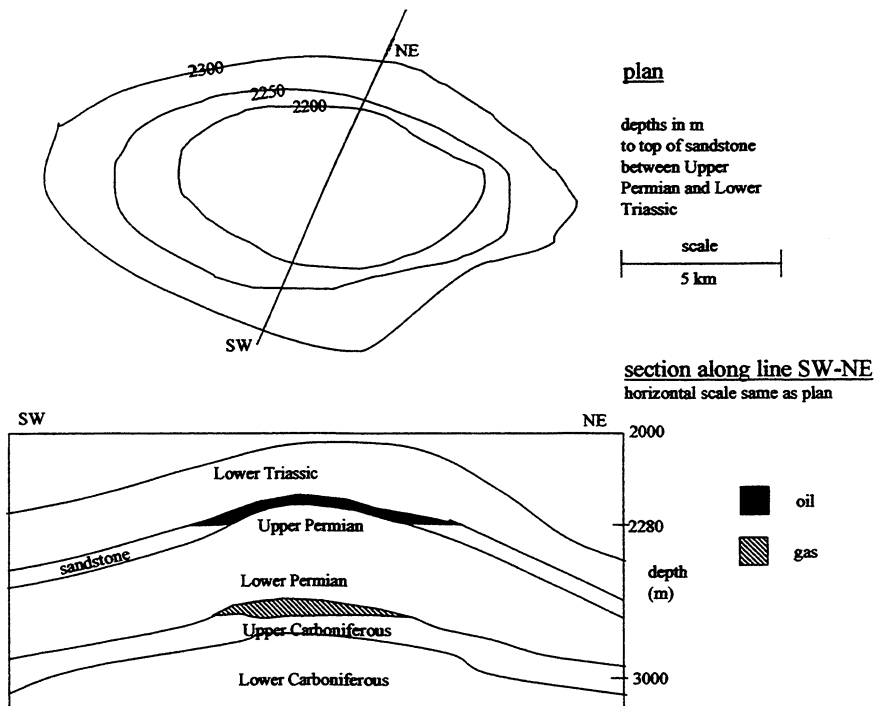
The area is highly prospective, and it is thought that there may be 1000 million barrels of recoverable oil and 500 billion m<sup>3</sup> of recoverable gas in a reservoir 50 km long and 5 km broad.

- (a) In order to assess the potential value of the field, the oil company needs to identify a market and to have a feasible production scheme for both the oil and the gas. Describe a suitable scheme. [60%]
- (b) If the exploration well is successful, what further investigations would you recommend before the production scheme is finalised? [40%]

3 The diagram below is a simplified plan and cross-section of the Severno-Gulyaevskoye field, beneath the Barents Sea north of Russia. It contains oil in the upper sandstone reservoir (between the Upper Permian and the Lower Triassic) and gas in the lower reservoir (below the Lower Permian). The plan includes the depths from sealevel to the top of the sandstone. The oil-water contact is at a depth of 2280 m. The reservoir in the Triassic sandstone has a porosity between 17 and 23%, and a permeability of 2 D (Darcys).

- (a) Estimate the volume of oil recoverable; [30%]
- (b) Estimate the pressure in the gas reservoir. [10%]
- (c) Estimate the recoverable volume of gas under standard conditions (temperature 15°C, pressure 101.3 kPa). [30%]
- (d) Explain briefly how it might have come about that the oil is higher than the gas, in contrast to the usual relative position. [15%]
- (e) Comment briefly on the porosity and the permeability. [15%]

High accuracy is not required in (a) (b) and (c). You may make whatever additional assumptions you think appropriate, but you should state what the assumptions are.



(TURN OVER)

4(a) A recent Cambridge conference explored geo-engineering responses to climate change. One suggestion is to control atmospheric CO<sub>2</sub> (by measures such as geological storage), but separately to control the Earth's radiation balance (by measures such as interposing mirrors and light-scattering devices between the Earth and the Sun). Write a short briefing note for the chief executive of an oil company, setting out the implications of this strategy for the company.

[50%

(b) The Arctic National Wildlife Refuge (ANWR) in Alaska is in part a coastal plain some 40 km wide, between mountains and the Arctic Ocean. It may contain extensive oil and gas reserves. At the present time it is closed to exploration for environmental reasons. An Alaskan author has written:

“The Wilderness Society indicates that if the US fuel efficiency mileage standard were raised on new car models from 26 miles per gallon [11 km/litre] to 27.5 miles per gallon, more oil would be saved than the anticipated production within the Arctic Refuge over the projected 30-year life of the oilfield. The [US] Department of the Interior estimates that there is only a 19 per cent chance of finding economically recoverable oil within the refuge, and that the average estimate of potential oil reserves is 3.2 billion barrels, far less than one per cent of worldwide ultimately recoverable oil resources” (Miller, D.S. *Midnight Wilderness*)

Discuss the arguments *both against and for* a proposal to impose a 50-year moratorium that would forbid any exploration or development in the ANWR.

[50%

**END OF PAPER**