THEORY ANSWERS

Problem I: Oil Extraction

I – 1 (1.0 points). The initial pressure of the gas in the deposit: $P_i = 45 \times 10^6$ Pa

The pressure at the top of the deposit is found from the relationship

$$P_s = \rho_s \times g \times h \quad \textbf{(0.7 points)}$$

$$P_i = 3000 \times 10 \times 1500 = 45 \times 10^6 \text{ Pa} \quad \textbf{(0.3 points)}$$

I – 2a (0.5 points). Mass of the gas in the deposit: $M_G = 84 \times 10^8$ kg

The equation of state for the gas

$$PV = m/\mu\ RT \Rightarrow m = \frac{PV\mu}{RT} \quad \textbf{(0.1 points)}$$

Here we need the volume of the gas to calculate its mass. From the equation for a sphere segment

$$V = \frac{1}{3} \times \pi \times h^2 \times (3R - h) =$$

$$\frac{1}{3} \times 3 \times 200^2 \times (3 \times 300 - 200) = 28 \times 10^6\, m^3$$

(0.2 points)

Substituting the data

$M_g = 45 \times 10^6 \times 28 \times 10^6 \times 0.016/(8 \times 300) = 84 \times 10^8$ kg
(0.2 points)
is the amount of the gas in the deposit.

I – 2b (0.5 points). Mass of the oil in the deposit: $M_O = 64 \times 10^9$ kg

To obtain the volume of oil, we need to subtract the volume of gas from the total volume of the sphere. Here we obtain the volume of the oil to be

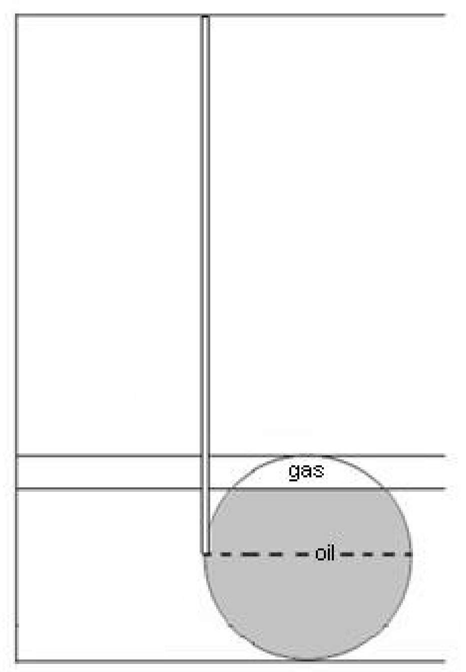
$$V_o = \frac{4}{3} \times \pi \times R^3 - V_q = 80 \times 10^6\, m^3$$

(0.3 points)
The mass of the oil will be

$M_o = \rho_o \times V_o = 800 \times 80 \times 10^6 = 64 \times 10^9$ kg
(0.2 points)

I – 3a (0.5 points). Indicate the position of the well:

The well has to be drilled as shown in the figure such that the amount of gushed oil is maximum.



I – 3b (0.5 points). The justification of the finding.

To confirm if the point does give the maximum gushed oil rate, we have to check that when the gas has expanded, its pressure is still sufficient to pump the oil out.
First lets find the final pressure of the gas upon expansion. Taking the temperature to be constant

$$P_1V_1=P_2V_2$$
$$P_1=45\times10^6 \text{ Pa}$$
$$V_1=28\times10^6 m^3$$

$$V_2=\frac{2}{3}\pi R^3=\frac{2}{3}\times3\times300^3=54\times10^6 m^3 \Rightarrow P_2=P_1V_1/V_2=\frac{45\times10^6\times28\times10^6}{54\times10^6}=233.3\times10^5 \text{ Pa}$$

The hydrostatic pressure of the oil in the well can be found from the equation

$$P_o=\rho_o\times g\times h=800\times10\times1800=144\times10^5 \text{ Pa}$$

It is seen that $P_o < P_2$, which means that chosen point will result in a successful oil gush.

I – 4 (0.5 points). The maximum amount (mass) of oil that gushes: $M_{max} = 208\times10^8$ kg

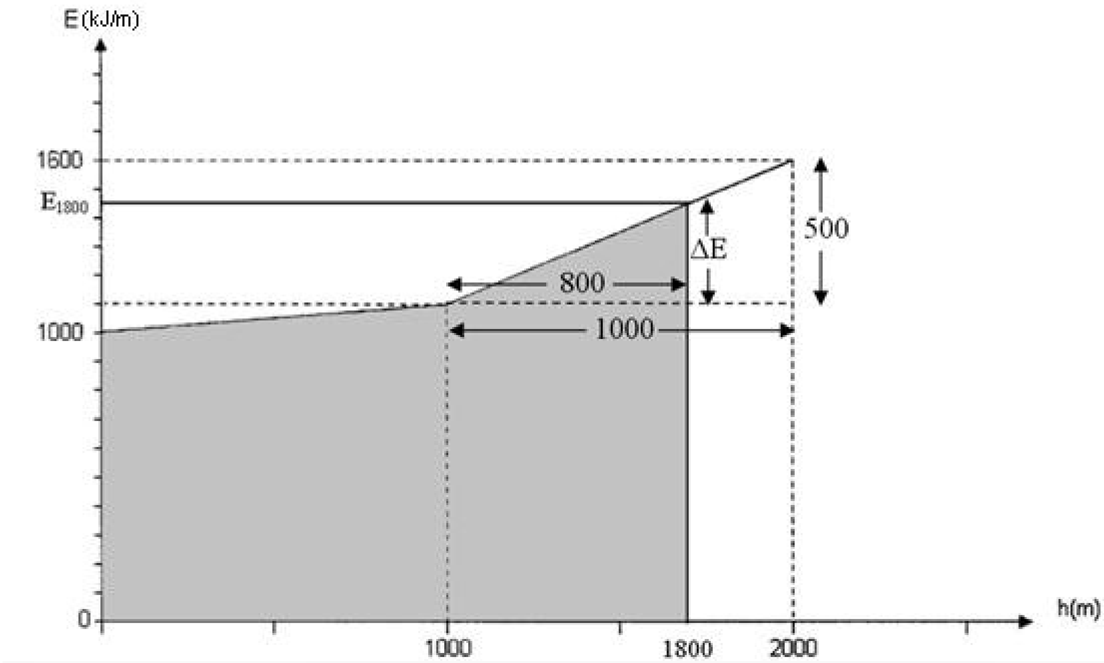
The gas can expand until occupying the half of the volume of the deposit. The maximum amount of oil that will be pumped up during this process is

$$V_{max}= \frac{2}{3}\pi R^3 - \frac{1}{3}\pi h^2(3R-h) = 26\times 10^6\, m^3 \qquad \textbf{(0.3 points)}$$

$$M_{max}= V_{max}\times\rho_o=26\times10^6\times800=208\times10^8 \text{ kg} \qquad \textbf{(0.2 points)}$$

I – 5 (2.0 points).The OPC of the oil gush method: $OPC_o = 4.48\times 10^8$

To calculate the OPC we need to evaluate the amount of work necessary to drill the well first. Since the depth of the well is h=1800m, we can find the amount of work done from the following diagram.



From the similarity of the triangles $\frac{\Delta E}{500}=\frac{800}{1000}$ => ΔE=400 kJ/m **(0.4 points)**

E_{1800}=1100 + ΔE=1500 kJ/m **(0.2 points)**

The amount of energy necessary to drill this well will then be

$$W_{1t}=\frac{1000+1100}{2}\times 1000+\frac{1100+1500}{2}\times 800=209\times 10^4 \text{ kJ}=209\times 10^7 \text{ J}$$ **(0.5 points)**

And the amount of energy that will be obtained from the gush oil is equal to

$$E_o=EE_o\times m_o=45\times 10^6\times 208\times 10^8=936\times 10^{15} \text{ J}$$ **(0.4 points)**

$$OPC=\frac{E_p}{E_{1t}}=\frac{936\times 10^{15}}{209\times 10^7}=4.48\times 10^8$$ **(0.5 points)**

I – 6 (1.0 points). Indicate the position of the second well:

To extract all the oil and gas a second well has to be drilled down to the topmost point of the deposit. Water will be pumped in from he first well and oil will be obtained from the second one. The depth of this second well has to be**1500m**.

I – 7 (1.5 points). The work done to pump the water: $E_W = 54\times 10^8\ J$

No energy will be spent on water pumping until the oil reaches the bottom of the well. Once the oil starts to be pumped through the well, energy has to be spent to expel all the oil from the deposit. The volume of the water that will expel the oil from the deposit is then equal to the volume of the oil left.

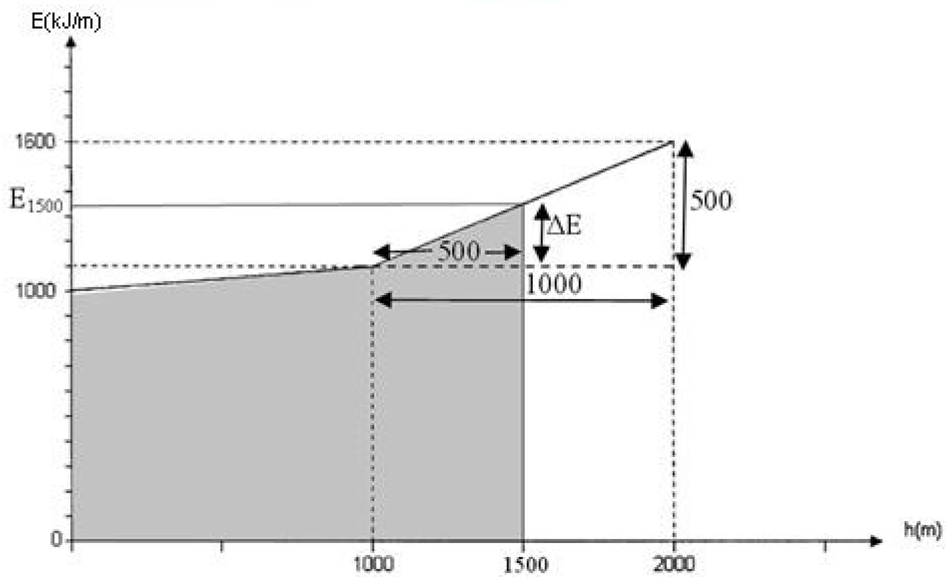
$$V=\frac{2}{3}\pi R^3 = 54\times 10^6\ m^3$$ **(1.0 points)**

To pump this amount of water, work of

$E_W = V\times E_{water} = 54\times10^6\times100 = 54\times10^8$ J has to be done. **(0.5 points)**

I – 8 (2.0 points). The total OPC: $OPC_T = 3.59\times 10^8$

To compute the total OPC we need to calculate the energy obtained from all the oil and petrol and the work done to drill the two wells. Lets calculate the amout of work done to drill the second well with the help of the following diagram.



Again from the similarity of the triangles

$$\frac{\Delta E}{500} = \frac{500}{1000} \Rightarrow \Delta E = 250 \text{ kJ/m}$$

$E_{1500} = 1100 + \Delta E = 1350$ kJ/m **(0.4 points)**

The amount of work needed to drill the second well is

$$W_{2t} = \frac{1000+1100}{2} \times 1000 + \frac{1100+1350}{2} \times 500 = 166.25\times10^4 \text{ kJ} = 166.25\times10^7 \text{ J}$$

(0.4 points)

The total energy obtain from the oil is

$E_{ot} = EE_o \times m_{ot} = 45\times10^6 \times 64\times10^9 = 288\times10^{16}$ J **(0.2 points)**

And the total energy obtained from the gas is

$E_g = EE_g \times m_g = 48\times10^6 \times 84\times10^8 = 40.32\times10^{16}$ J **(0.2 points)**

The total energy obtained from the resources

$E_t = E_{ot} + E_g = 288\times10^{16} + 40.32\times10^{16} = 328.32\times10^{16}$ J **(0.2 points)**

The total work done

$E_r = W_{1t} + W_{2t} + W = 166.25\times10^7 + 209\times10^7 + 54\times10^8 = 915.25\times10^7$ J **(0.2 points)**

And the total OPC is

$$OPC=\frac{E_t}{E_r}=\frac{328.32\times10^{16}}{915.25\times10^{7}}=3.59\times10^{8}$$ **(0.4 points)**

Problem II: Metal Corrosion

II – 1 (0.4 points). The oxidation – reduction of iron induced by SRB cells

$$Fe + H_2SO_4 + 3H_2 \rightarrow FeS + 4H_2O$$

II – 2a (0.55 points). The amount (mg/L) of FeS in the first mixture = **51mg/L**

1st mixture: 45 x 0.04 + 55 x 0.06 = 1.8 + 3.3 = 5.1 mg **(0.50 points)**;
5.1mg /100ml = 51mg/L **(0.05 points)**

II – 2b (0.55 points). The amount (mg/L) of FeS in the second mixture = **49 mg/L**

2nd mixture: 45 x 0.06 + 55 x 0.04 = 2.7 + 2.2 = 4.9 mg **(0.50 points)**;
4.9mg/100ml = 49 mg/L **(0.05 points)**

II – 3 (0.3 points). The formula of precipitate

FeS

II – 4a (0.6 points). The concentration (mol/L) of H_2SO_4 in the first mixture

0.021 mol/L

II – 4b (0.6 points). The concentration (mol/L) of H_2SO_4 in the second mixture

0.017 mol/L

I mixture: 5.1 mg (FeS) = 0.0051 g; 0.1936 – 0.0051 = 0.1885 g = 0.0021 mol FeS **(0.4 points)**
II mixture: 4.9 mg (FeS) = 0.0049 g; 0.1584 – 0.0049 = 0.1535g = 0.0017 mol FeS **(0.4 points)**

I mixture: 0.021 mol/L **(0.2 points)**

II mixture: 0.017 mol/L **(0.2 points)**

II – 5a (1.0 points). The concentration (mol/L) of H_2SO_4 in an original sample taken from Azeri oilfield

0.009 mol/L

II – 5b (1.0 points). The concentration (mol/L) of H_2SO_4 in an original sample taken from Chirag oilfield
0.029 mol/L
A x 0.04 + B x 0.06 = 0.0021 **(0.8 points)** A x 0.06 + B x 0.04 = 0.0017 **(0.8 points)** A = 0.009 mol/L H_2SO_4 in 1st sample (Azeri) **(0.2 points)** B = 0.029 mol/L H_2SO_4 in 2nd sample (Chirag) **(0.2 points)**
II – 6a (0.5 points). The mass percentage of iron nail lost in the first mixture
5.99%
II – 6b (0.5 points). The mass percentage of iron nail lost in the second mixture
4.76%
I mixture: 0.1885 g FeS contains 0.1176 g (Fe^{2+}); 0.1176/2 x 100 = **5.99%** (0.5 points) II mixture: 0.1535 g FeS contains 0.0952 g (Fe^{2+}); 0.0952/2 x 100 = **4.76%** (0.5 points)

II – 7a (0.4 points). The average corrosion rate ($mg/year$) in the first mixture
1434 mg/year
II – 7b (0.4 points). The average corrosion rate ($mg/year$) in the second mixture
1160 mg/year
0.1176 g / 30 days = 1434 mg/y (0.4 points) 0.0952 g / 30 days = 1160 mg/y (0.4 points).

II – 8 (0.5 points). Write down the correct reason **C**
The answer is **c)** H_2SO_4 was consumed

II – 9a (0.6 points). The concentration ($bacterial\ cells/ml$) of bacterial cells in the first mixture

From second figure on 18th day concentration of bacteria:

1st mixture **10^6 bacteria cells/ml**

II – 9b (0.6 points). The concentration ($bacterial\ cells/_{ml}$) of bacterial cells in the second mixture

2nd mixture **10^5 bacteria cells/ml**

II – 9c (1.0 points). The precipitate amount ($^{mg}/_{L}$) in the second mixture **850 mg/L**

0.12g/100ml= 1200 mg/L, from first figure it was reached in 1 st flask on 18th day. (0.5 points)

From first figure on 18th day precipitation concentration in 2nd glass was 850 mg/L. (0.5 points)

II – 10 (0.5 points). Write down the correct answer **C**

The answer is **c)** no change

Problem III: Embryonic Development of Human

III – 1 (11x0.2 points). Match the structures given in the text with the correct labels shown in the figures. Write only the corresponding roman numerals											
Number in text	1	2	3	4	5	6	7	8	9	10	11
Roman numeral in the figure	**III**	**II**	**IV**	**V**	**VI**	**XI**	**X**	**I**	**VII**	**IX**	**VIII**

III – 2a (0.4 points). Write down the correct label
VII
III – 2b (0.4 points). Write down the correct label
VIII

III – 3 (1.0 points). Put X in appropriate box			
a	b	**X**	d

III – 4 (0.5 points). The number of the cells in the embryo
8 CELLS
The formula to calculate the number of cells is 2^n and n=3 here. So, $2^3 = 8$

III – 5 (3x0.3 points). Match the following. Write only the corresponding numbers or letters		
Event	Cellular process	Subcellular structure
III	B	3

III – 6 (0.3 points). Put X in appropriate box	
A	**X**

III – 7 (1.0 points). Put X in appropriate box

a	**X**	c	d	e

III – 8 (0.6 points). Put X in appropriate box

A	B	**X**

III – 9 (1.5 points). Put X in appropriate boxes			
	increases	decreases	stays the same
1	**x**		
2			**x**
3		**x**	

III – 10 (1.2 points). Choose the right answer. Put X in appropriate box

X	b	c	d