## THEOREY ANSWERS

### Problem I: Oil Extraction

<table>
<thead>
<tr>
<th>I – 1 (1.0 points)</th>
<th>The initial pressure of the gas in the deposit: ( p_i = 45 \times 10^6 \text{ Pa} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>The pressure at the top of the deposit is found from the relationship ( P_s = \rho_s \times g \times h ) (0.7 points) ( P_i = 3000 \times 10 \times 1500 = 45 \times 10^6 \text{ Pa} ) (0.3 points)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I – 2a (0.5 points)</th>
<th>Mass of the gas in the deposit: ( M_g = 84 \times 10^8 \text{ kg} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – 2b (0.5 points)</td>
<td>Mass of the oil in the deposit: ( M_o = 64 \times 10^9 \text{ kg} )</td>
</tr>
<tr>
<td>The equation of state for the gas ( PV = m/\mu \frac{RT}{\mu} = \frac{PV\mu}{RT} ) (0.1 points)</td>
<td></td>
</tr>
<tr>
<td>Here we need the volume of the gas to calculate its mass. From the equation for a sphere segment ( V = \frac{1}{3} \pi h^2 (3R - h) = \frac{1}{3} \times 3 \times 200^2 \times (3 \times 300 - 200) = 28 \times 10^6 \text{ m}^3 ) (0.2 points)</td>
<td></td>
</tr>
<tr>
<td>Substituting the data ( M_g = 45 \times 10^6 \times 28 \times 10^6 \times 0.016/(8 \times 300) = 84 \times 10^8 \text{ kg} ) (0.2 points)</td>
<td></td>
</tr>
<tr>
<td>I – 3a (0.5 points)</td>
<td>Indicate the position of the well:</td>
</tr>
<tr>
<td>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} \pi R^3 - V_g = 80 \times 10^6 \text{ m}^3 ) (0.3 points)</td>
<td></td>
</tr>
<tr>
<td>The mass of the oil will be ( M_o = \rho_o \times V_o = 800 \times 80 \times 10^6 = 64 \times 10^9 \text{ kg} ) (0.2 points)</td>
<td></td>
</tr>
</tbody>
</table>
The well has to be drilled as shown in the figure such that the amount of gushed oil is maximum.

\[ P_1 V_1 = P_2 V_2 \]
\[ P_1 = 45 \times 10^6 \text{ Pa} \]
\[ V_1 = 28 \times 10^6 \text{ m}^3 \]
\[ V_2 = \frac{2}{3} \pi R^3 = \frac{2}{3} \times 3 \times 300^3 = 54 \times 10^6 \text{ m}^3 \]
\[ P_2 = \frac{P_1 V_1}{V_2} = \frac{45 \times 10^6 \times 28 \times 10^6}{54 \times 10^6} = 233.3 \times 10^5 \text{ Pa} \]

The hydrostatic pressure of the oil in the well can be found from the equation
\[ P_o = \rho_o g h = 800 \times 10 \times 1800 = 144 \times 10^5 \text{ Pa} \]

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: \( M_{max} = 208 \times 10^8 \text{ kg} \)
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

\[ V_{\text{max}} = \frac{2}{3} \pi R^3 - \frac{1}{3} \pi h^2 (3R - h) = 26 \times 10^6 \text{ m}^3 \quad (0.3 \text{ points}) \]

\[ M_{\text{max}} = V_{\text{max}} \times \rho_o = 26 \times 10^6 \times 800 = 208 \times 10^8 \text{ kg} \quad (0.2 \text{ points}) \]

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 $h=1800\text{m}$, we can find the amount of work done from the following diagram.

From the similarity of the triangles $\frac{\Delta E}{500} = \frac{800}{1000}$, we have $\Delta E=400\text{kJ/m}$ \hspace{1cm} (0.4 points)

$E_{1800}=1100 + \Delta E=1500\text{kJ/m}$ \hspace{1cm} (0.2 points)

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

$$W_{1t}=\frac{1000+1100}{2}\times1000 + \frac{1100+1500}{2}\times800 = 209\times10^4 \text{kJ}=209\times10^7 \text{J}$$ \hspace{1cm} (0.5 points)

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

$$E_o=EE_o\times m_o=45\times10^6\times208\times10^8=936\times10^{15}\text{J}$$ \hspace{1cm} (0.4 points)

$$\text{OPC} = \frac{E_o}{E_{1t}} = \frac{936\times10^{15}}{209\times10^7} = 4.48\times10^8$$ \hspace{1cm} (0.5 points)

1 – 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 the 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:

\[ E_W = 54 \times 10^8 \text{ J} \]

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.

\[ V = \frac{2}{3} \pi R^3 = 54 \times 10^6 \text{ m}^3 \]  

(1.0 points)

To pump this amount of water, work of

\[ E_W = V \times E_{\text{water}} = 54 \times 10^6 \times 100 = 54 \times 10^8 \text{ J} \]  

has to be done.  

(0.5 points)

I – 8 (2.0 points). The total \( O\!P\!C \):

\[ O\!P\!C_T = 3.59 \times 10^8 \]
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. Let's calculate the amount of work done to drill the second well with the help of the following diagram.

Again from the similarity of the triangles

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

\[E_{1500} = 1100 + \Delta E = 1350 \text{ kJ/m} \] (0.4 points)

The amount of work needed to drill the second well is

\[W_{2t} = \frac{1000 + 1100}{2} \times 1000 + \frac{1100 + 1350}{2} \times 500 = 166.25 \times 10^4 \text{ kJ} = 166.25 \times 10^7 \text{ J} \]

(0.4 points)

The total energy obtained from the oil is

\[E_{ot} = EE_o \times m_{ot} = 45 \times 10^6 \times 64 \times 10^8 = 288 \times 10^{16} \text{ J} \] (0.2 points)

And the total energy obtained from the gas is

\[E_g = EE_g \times m_g = 48 \times 10^6 \times 84 \times 10^8 = 40.32 \times 10^{16} \text{ J} \] (0.2 points)

The total energy obtained from the resources

\[E_t = E_{ot} + E_g = 288 \times 10^{16} + 40.32 \times 10^{16} = 328.32 \times 10^{16} \text{ J} \] (0.2 points)

The total work done

\[E_r = W_{1t} + W_{2t} + W = 166.25 \times 10^7 + 209 \times 10^7 + 54 \times 10^8 = 915.25 \times 10^7 \text{ J} \] (0.2 points)

And the total OPC is
\[ \text{OPC} = \frac{E_r}{E_i} = \frac{328.32 \times 10^{16}}{915.25 \times 10^7} = 3.59 \times 10^8 \]
## Problem II: Metal Corrosion

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

\[
\text{Fe} + \text{H}_2\text{SO}_4 + 3\text{H}_2 \rightarrow \text{FeS} + 4\text{H}_2\text{O}
\]

### II – 2a (0.55 points). The amount \(\frac{mg}{L}\) of FeS in the first mixture = 51mg/L

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

### II – 2b (0.55 points). The amount \(\frac{mg}{L}\) of FeS in the second mixture = 49 mg/L

2nd mixture: \(45 \times 0.06 + 55 \times 0.04 = 2.7 + 2.2 = 4.9\) 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 \(\frac{mol}{L}\) of \(\text{H}_2\text{SO}_4\) in the first mixture

0.021 mol/L

### II – 4b (0.6 points). The concentration \(\frac{mol}{L}\) of \(\text{H}_2\text{SO}_4\) 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; \(0.1584 – 0.0049 = 0.1535\) g = 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 \(\frac{mol}{L}\) of \(\text{H}_2\text{SO}_4\) 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 is 0.029 mol/L.

\[
A \times 0.04 + B \times 0.06 = 0.0021 \quad (0.8 \text{ points})
\]
\[
A \times 0.06 + B \times 0.04 = 0.0017 \quad (0.8 \text{ points})
\]

\[A = 0.009 \text{ mol/L } \quad H_2SO_4 \text{ in 1st sample (Azeri)} \quad (0.2 \text{ points})\]
\[B = 0.029 \text{ mol/L } \quad H_2SO_4 \text{ in 2nd sample (Chirag)} \quad (0.2 \text{ points})\]

II – 6a (0.5 points). The mass percentage of iron nail lost in the first mixture is 5.99%.

II – 6b (0.5 points). The mass percentage of iron nail lost in the second mixture is 4.76%.

I mixture: 0.1885 g FeS contains 0.1176 g (Fe$^{2+}$); $\frac{0.1176}{2} \times 100 = 5.99\%$ (0.5 points)

II mixture: 0.1535 g FeS contains 0.0952 g (Fe$^{2+}$); $\frac{0.0952}{2} \times 100 = 4.76\%$ (0.5 points)

II – 7a (0.4 points). The average corrosion rate (mg/year) in the first mixture is 1434 mg/year.

II – 7b (0.4 points). The average corrosion rate (mg/year) in the second mixture is 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:

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>$10^6$ bacteria cells/ml</td>
</tr>
<tr>
<td>2nd</td>
<td>$10^5$ bacteria cells/ml</td>
</tr>
</tbody>
</table>

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

II – 9c (1.0 points). The precipitate amount ($\text{mg/l}$) in the second mixture is 850 mg/L. 0.12 g/100 ml = 1200 mg/L, from first figure it was reached in 1st 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.

<table>
<thead>
<tr>
<th>Number in text</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roman numeral in the figure</td>
<td>III</td>
<td>II</td>
<td>IV</td>
<td>V</td>
<td>VI</td>
<td>XI</td>
<td>X</td>
<td>I</td>
<td>VII</td>
<td>IX</td>
<td>VIII</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>X</th>
<th>d</th>
</tr>
</thead>
</table>

**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

<table>
<thead>
<tr>
<th>Event</th>
<th>Cellular process</th>
<th>Subcellular structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>B</td>
<td>3</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>A</th>
<th>X</th>
</tr>
</thead>
</table>

**III – 7 (1.0 points).** Put X in appropriate box
III – 8 (0.6 points). Put X in appropriate box

<table>
<thead>
<tr>
<th>a</th>
<th>X</th>
<th>c</th>
<th>d</th>
<th>e</th>
</tr>
</thead>
</table>

III – 9 (1.5 points). Put X in appropriate boxes

<table>
<thead>
<tr>
<th></th>
<th>increases</th>
<th>decreases</th>
<th>stays the same</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

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

| X | b | c | d |