1. (a) Each year, sector 'A' purchases $5 million of goods from sector 'B' and $10 million from sector 'C'. Sector 'B' makes annual purchase of $2 million from sector 'A' and $8 million from sector 'C'. Annual purchase of sector 'C' are $3 million from sector 'A' and $6 million from sector 'B'. Within-sector purchases are $1 million for sector 'A', $4 million for sector 'B', and $5 million for sector 'C'. Total sales in the sectors are $20 million, $20 million and $30 million, respectively.

(i) Write the transaction matrix for the three sectors,

(ii) How much is value added for sector 'A'?

(iii) How much is final demand in sector 'A'?

(iv) Write the direct requirements matrix for the model.

Also explain each component of the third column of the direct requirements matrix.

(b) The design of a special use structure, two mutually exclusive alternative are under consideration. These alternatives are as follows:

<table>
<thead>
<tr>
<th>Design</th>
<th>Capital Investment</th>
<th>Annual expenses</th>
<th>Useful life (years)</th>
<th>Market value (at the end of useful life)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>$50,000</td>
<td>$9,000</td>
<td>20</td>
<td>$10,000</td>
</tr>
<tr>
<td>D2</td>
<td>$120,000</td>
<td>$5,000</td>
<td>50</td>
<td>$20,000</td>
</tr>
</tbody>
</table>

If perpetual service from the structure is assumed, which design alternative do you recommend? The MARR is 10% per year.

2. (a) As the supervisor of a facilities engineering department, you consider mobile cranes to be critical equipment. The purchase of a new medium-sized, truck mounted crane is being evaluated. The economic estimates for the two best alternatives are given below.

<table>
<thead>
<tr>
<th>Design</th>
<th>Capital Investment</th>
<th>Annual expenses</th>
<th>Useful life (years)</th>
<th>Market value (at the end of useful life)</th>
</tr>
</thead>
<tbody>
<tr>
<td>'A'</td>
<td>$272,000</td>
<td>$28,800</td>
<td>6</td>
<td>$25,000</td>
</tr>
<tr>
<td>'B'</td>
<td>$316,000</td>
<td>$19,300</td>
<td>9</td>
<td>$40,000</td>
</tr>
</tbody>
</table>
You have selected the longest useful life (9 years) for the study period and would lease a crane for the final three years under alternative 'A'. Based on previous experience, the estimated annual leasing cost at that time will be $36,000 per year. The MARR is 15% per year. Show that the same selection is made based on
(i) the PW method and (ii) the ERR method.
(b) Using a 3×3×3 matrix explain the Optimistic-Most likely-Pessimistic Method for dealing with uncertainty.

3. (a) Suppose that the California Agricultural Department is considering a temporary irrigation project to be used for the five years until a major irrigation project will be ready. The direct and indirect costs and benefits of the temporary public project are those given in the following table, and they are paid on received at the end of each year. Determine whether the project should be undertaken if the social discount rate is (i) 6% or (ii) 14%, by the conventional B-C ratio method. (iii) What is the effect of neglecting the indirect costs and benefits of the project, if the social discount rate is 10%?

<table>
<thead>
<tr>
<th>Year</th>
<th>Costs (in thousands of Tk.)</th>
<th>Benefits (in thousands of Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction</td>
<td>Maintenance</td>
</tr>
<tr>
<td>0</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>30</td>
</tr>
</tbody>
</table>

(b) What is the role of Taxes and Insurance in projects?

(c) To build up a sum of Tk. 10,00,000 at the end of 10 years, how much money must be deposited every year (equal installment) if the nominal interest rate is 11% compounded continuously?

4. (a) A particular project, whose initial cost is Tk. 1,000,000 has the following cash flow:

<table>
<thead>
<tr>
<th>End of year</th>
<th>Net cash flow (Tk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-100,000</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>500,000</td>
</tr>
<tr>
<td>4</td>
<td>500,000</td>
</tr>
<tr>
<td>5</td>
<td>1,400,000</td>
</tr>
</tbody>
</table>

Calculate the IRR of the project showing all works.
(b) Two electric motors are being considered to power an industrial hoist. Each is capable of providing 90 hp. Pertinent data for each motor are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Motor D-R</th>
<th>Motor West house</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Investment</td>
<td>$ 2,500</td>
<td>$ 3,200</td>
</tr>
<tr>
<td>Electrical efficiency</td>
<td>0.74</td>
<td>0.89</td>
</tr>
<tr>
<td>Yearly maintenance cost</td>
<td>$ 40</td>
<td>$ 60</td>
</tr>
<tr>
<td>Useful life (years)</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

If the expected usage of the hoist is 500 hours per year, what would be the cost of electrical energy (in cents per kilowatt-hour) before the D-R motor is favoured over the West house motor? The MARR is 12% (Note: 1 hp = 0.746 kW).

(c) Explain the Capital Budgeting process with an example of your choice.

SECTION – B
There are FOUR questions in this section. Q. No. 5 is COMPULSORY. Answer any TWO from the rest.

5. COMPULSORY: Select correct answer and give concise reason for your choice.

(i) What is the duty to act according to the authority that has been given?
   A. Responsibility
   B. Professionalism
   C. Power
   D. Delegation

(ii) Which of the following is not a good reason to set up staff departments?
   A. To improve upward communication
   B. To improve communication links for technical information
   C. To make the best use of scarce specialist skills
   D. Through rotation, to give trainee managers a range of experience
   E. To enable line managers to focus on the main activities of the organization

(iii) According to the text, which of the following activities is better decentralized in the typical organisation?
   A. Setting conditions of employment
   B. Information systems design
   C. Controlling international cash flows
   D. Purchasing capital equipment
   E. Operations management
   F. Management development
(iv) Which of the following was not given as a means to achieve co-ordination?
A. Rules and procedures
B. Line management
C. Liaison staff
D. Cross-functional teams
E. Information systems

(v) What are the three themes found in the choice of organizational divisions?
A. Hierarchy, level and chain of command
B. Growth, specialization and co-ordination
C. Products, customers and geography
D. Size, diversity and independence
E. None of the above options

(vi) Don MacKinnon, the person in charge of "Hear Music" has been given goals related to the rollout and sales of this subsidiary of Starbucks. His success at implementing the strategy will be assessed by comparing actual performance against the goals. This comparison is known as:
A. Planning
B. Organizing
C. Implementing
D. Controlling

(vii) Because GE is organized into different divisions, one for each business, it is known as a:
A. multidivisional enterprise
B. poorly managed firm
C. multi-business unit
D. multi-corporate concern

(viii) When call center managers spend much of their time monitoring customer calls and giving employees feedback about how to improve their dialogue with customers in the future, these managers are using ___________ skills.
A. technical
B. conceptual
C. situational
D. ethical

(ix) Individuals such as Albert Einstein, Bill Gates and Steve Jobs lead through which type of power?
A. Legitimate
B. Reward
C. Expert
D. Charismatic

Contd ....... P/5
(x) Select the four decisional roles that the manager's informational roles typically lead to:
   A. Entrepreneur
   B. Disturbance handler
   C. Spokesperson
   D. Resource allocator
   E. Negotiator

6. (a) What is a Technology S-curve? With the help of an example explain fully the concept. 
   (b) In terms of technology distinguish between a "Developed" and an "Underdeveloped" country. Your answer must include illustrations. 
   (c) Discuss the barriers in Communication. 

7. (a) What is a MATRIX organisation? Explain fully how it functions and give a real life example of such an organisation. 
   (b) What are aspects of the changing environment under which a modern manager must function? Briefly explain the challenges facing the modern manager in this respect. 
   (c) Distinguish between 'Decision Making by Individuals' and 'Decision Making by Groups' by discussing the advantages and disadvantages of each type of decision making.

8. The CEO of a Chemical plant is planning to introduce a new product in the market. For this purpose a project report is to be prepared. Activities involved in preparing such a report are given below

<table>
<thead>
<tr>
<th>Activity</th>
<th>Predecessor</th>
<th>Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>B, C</td>
<td>4</td>
</tr>
<tr>
<td>G</td>
<td>B, C</td>
<td>2</td>
</tr>
<tr>
<td>H</td>
<td>E, F</td>
<td>6</td>
</tr>
<tr>
<td>I</td>
<td>E, F</td>
<td>5</td>
</tr>
<tr>
<td>J</td>
<td>D, H</td>
<td>3</td>
</tr>
<tr>
<td>K</td>
<td>G, I</td>
<td>5</td>
</tr>
</tbody>
</table>

   (a) Draw a PERT and a CPM network, identify float times and the critical path for the project. 
   (b) Draw a Gantt chart from the above analysis. 
   (c) What is Dummy line? Did you have to use a Dummy activity while drawing the above activity network? Give reason for your answer.
SECTION – A
There are FOUR questions in this section. Answer any THREE.

1. (a) What are the different stages of Project Implementation of a chemical process plant? List the parties involved at each stage. (8)
   (b) An 800 MT/day di-ammonium phosphate plant is to be built in Chittagong. Give complete definition of the project. (8)
   (c) 'Project engineering best suited for a chemical engineer' – justify this statement. (7 1/3)

2. (a) Why do you think feasibility study of a new process plant includes Environmental Impact Assessment (EIA)? (7)
   (b) What are the major components of technical definition? (6)
   (c) Provide a list of auxiliary and offsite facilities needed in a grass-roots project. Although Chhatak cement and Lafarge cement factories are situated next to each other, the offsite and auxiliary facilities to deliver raw materials to each factory differ considerably – explain. (10 1/3)

3. (a) 'Design basis is critical in plant design' – elaborate this statement with examples. How does design basis influence performance and guarantee tests of a plant? (10 1/3)
   (b) Which factors should be considered during evaluation of a process licensor? (7)
   (c) List the name of two process licensors for each of ammonia and urea process. (6)

4. (a) Write short notes on (i) Detailed engineering design (ii) Project engineer vs Process engineer (iii) General Contractor. (15)
   (b) List four areas of plant design where codes and standards are applicable. Also give names of the respective codes and standards issuing organization. (8 1/3)
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SECTION - B
There are FOUR questions in this section. Answer any THREE.

5. (a) A newly established Bangladeshi EPC company specializing in Process Industries has requested for pre-qualification as General Contractor for a proposed contact Sulphuric Acid plant. Recommend a procedure for evaluation of this EPC company. (12)
(b) Justify the practice of informing the engineering contractor regarding the client's scope of work along with the scope of work for the EPC firm. (11 1/4)

6. (a) How important is the plot plan in planning a "safe" process plant? Draw a rough plot plan to show the possible "unsafe" or "hazardous areas". (15)
(b) Equipment Data Sheets and Drawings transmit a number of information to the Vendors. Under what circumstances Vendor can suggest changes to such Data Sheets? How will such changes will affect the P&I diagram? (8 1/2)

7. (a) When a Performance Test fails, how does a foreign general contractor usually react in Bangladesh? What steps should be taken by the client in the event the contractor fails to conduct Performance Test? (10)
(b) Comment on the discussion issues during contract negotiation. Which issues, you feel, one more important than others in the context of Bangladesh? (13 1/3)

8. Write short notes on:
   (a) The "Bhopal Tragedy" (10)
   (b) "Liquidated Damage" (5 1/2)
   (c) "Over design" of some units in a plant (8)
SECTION – A

There are FOUR questions in this section. Answer any THREE.

1. (a) How can a cathodic protection cause corrosion to a nearby unprotected metallic structure? How can we protect metallic structures from this kind of corrosion? (12)
   (b) Briefly discuss the mechanism of hydrogen cracking. (8)
   (c) Coatings and cathodic protection are complementary to one another and neither, on its own, can provide the complete answer. — Do you agree with the statement? Give reasons for your answer. (7)
   (d) Discuss the importance of critical concentration in the use of passivators. (8)

2. (a) Nickel coating on steel is a noble coating, while zinc coating on steel is a sacrificial one. How do nickel and zinc protect the base metal (e.g. steel) from corrosion? (10)
   (b) Discuss the anodizing and Parkerizing processes to produce chemical conversion coatings on metals. (10)
   (c) Why do we need to treat boiler feed water? What treatment steps are usually taken for boiler water for corrosion control? — Discuss. (15)

3. (a) What are the steps one need to follow for the screening of materials of construction for a particular job? (10)
   (b) How to silicon-iron and silicon-nickel alloys provide corrosion resistance to acids of all concentrations and temperatures up to boiling temperature? (5)
   (c) Intergranular corrosion of austenitic stainless steels is linked with carbon content of the alloy — Explain. (10)
   (d) What are the remedial measures for preventing atmospheric corrosion of metallic structures? (10)

4. (a) Briefly discuss three basic laws of oxidation. Can these models be used for industrial oxidations? Explain. (9+5)
   (b) A pulp and paper mill has pulp digesters, liquor recovery system, boilers etc. Do you think having a continuous corrosion monitoring system for such a process plant is justifiable? Give reasons for your answer. (5)
   (c) By comparing the volume occupied by metal oxide and the volume of metal destroyed, Pilling and Bedworth were able to determine the protective nature of oxides. Explain the concept proposed by Pilling and Bedworth. Sodium, Calcium and Vanadium have Pilling - Bedworth ratio of 0.57, 1.16 and 3.18, respectively. How would you interpret these numbers? (10+6)
There are FOUR questions in this section.
Answer Q. No. 5, which is COMPULSORY, and any TWO from the rest.

5. (COMPULSORY) Answer all the questions. Choose the correct answer and give reasons for your answer. Give (√) tick mark to the correct answer. (5×9=45)
   (a) Elastically strained metal is anodic to annealed metal, TRUE/FALSE
   (b) Oxygen Electrode can be used as a reference electrode. TRUE/FALSE
   (c) A potentiostatic polarization curve of an active-passive metal gives same information regarding passive behavior as a galvanostatic curve. TRUE/FALSE
   (d) Activation polarization is absent when concentration polarization is present. TRUE/FALSE
   (e) Breakdown of metal passivity by chloride ions is local. TRUE/FALSE
   (f) During hot working there is extensive strain hardening. TRUE/FALSE
   (g) Within pH range 1-4, O₂ diffusion is the only controlling factor for corrosion of steel. TRUE/FALSE
   (h) Iron and steel cannot be protected from corrosion by higher O₂ pressure. TRUE/FALSE
   (i) There will be no Cavitation-Erosion if there is no pressure fluctuation. TRUE/FALSE

6. (a) Design an experiment to determine the stability of passivity for an active-passive metal. (10)
   (b) Why one has to be very careful when using passivators for reduction of corrosion? (10)
   (c) Discuss the effect of increasing Temperature, Velocity and Concentration on corrosion due to combined polarization. (10)

7. (a) You have received a metal whose metallurgical history IS known. Hence its corrosion behavior is known. (15)
    (i) How can its corrosion behavior be improved?
    (ii) Under what conditions its corrosion behavior can deteriorate?
   (b) Compare the effect of temperature rise on corrosion in open and closed systems. What will happen if the system is thoroughly deaerated? (15)

8. Write short notes on (7½×4=30)
   (a) Pourbaix Diagrams
   (b) Ultra pure metals
   (c) Crystal imperfections and corrosion
   (d) Corrosion in multiphase alloys.
1. (a) Discuss the challenges involved in controlling the air pollution? (5)
(b) What are the environmental discharges from different process of petroleum industry? Describe the gas treatment technology for petroleum industry? (12)
(c) Discuss the sources of air pollution in steel mills. (8)
(d) Classify the air pollutants according to their origin and describe briefly with example, their sources and possible impact. (10)

2. (a) Discuss the measurement techniques of particulate emission from point source and area source. (10)
(b) The composition of barapukuria coal is found by weight as (15)

<table>
<thead>
<tr>
<th>No.</th>
<th>Element</th>
<th>Wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hydrogen</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Carbon</td>
<td>75.8</td>
</tr>
<tr>
<td>3</td>
<td>Nitrogen</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>Sulfur</td>
<td>2.6</td>
</tr>
<tr>
<td>5</td>
<td>Oxygen</td>
<td>7.4</td>
</tr>
<tr>
<td>6</td>
<td>Ash</td>
<td>8.7</td>
</tr>
</tbody>
</table>

If it is burned with 25% excess air with humidity of 0.012 mol/mol dry air and combustion is complete, determine amount and composition of gas produced.
(c) Write short note on
(i) Adiabatic lapse rate
(ii) Fumigation (10)

3. (a) A power plant is emitting gaseous pollutant 200 g/s at stack height 200 m and diameter 0.8 m. Wind speed is \( u \). The stack gas temperature is 100°C, flow rate is 500 \( m^3/min \), pressure is 1050 millibars. Develop a relationship between the ground level concentration and downwind distance based on modified Gaussian Plume Model. The plume rise is given by

\[
\Delta h = \frac{V_s D}{u} \left( 1.5 + 0.00268 \frac{PD}{T_s} \right)
\]

Where, \( V_s \) = stack exit velocity, \( D \) = diameter, \( P \) = pressure in millibars, \( u \) = wind velocity. (15)

Contd .......... P/2
(b) If the plant emits 100 g/s of SO\textsubscript{x} from the stack and wind speed is 1.5 m/s, considering the worst case scenario,

(i) What will be the maximum concentration of SO\textsubscript{x} at ground level due to this source?

(ii) How far downwind of the source does the maximum occur?

4. (a) Describe the working principle of Wet Scrubber and Electrostatic Separator.

(b) Let's consider a rainstorm is depositing R in/h and it's D\textsubscript{a} mm spherical drops. The polluted air by the fugitive emission of steel mills contains particles of size D\textsubscript{p} micrometer. Before raining, the concentration of particulate matters is C\textsubscript{o}. What will be the concentration after t hour of raining?

(c) A cyclone separator that is operating with D\textsubscript{cut} = 6 µ. You are required to increase the flow rate to the cyclone by 30%. All other parameters will be unchanged. Considering the block flow model is valid, estimate the new cut diameter.

SECTION-B

There are FOUR questions in this section. Answer Q. No. 8 and any TWO from the rest.

5. (a) Briefly discuss Water Footprint? The water footprint of a Bangladeshi made denim jeans is 9900 litre. If the readymade garment product is sold in European market, enlist the possible sources of water consumption and categorize them according to different types of Water Foot-Print.

(b) Briefly discuss the objectives, effects and benefits of Environmental Impact Assessment (EIA)?

(c) Considering the increasing power demand of the country, a group of non-resident Bangladeshi entrepreneurs has initiated to establish hydro power project at the hill tract areas. As a part of the feasibility study the government has recruited a local consulting company to assess the environmental impact of the proposed projects. As the project leader of the consulting company, how would you proceed to assess the relevant environmental impacts? What are the key factors one would consider for the environmental impact assessment during the operation phase and construction phase of the projects?
6. (a) Briefly discuss the membrane technologies used in waste water treatment. Explain the mechanism of Reverse Osmosis (RO) process.

(b) The average flowrate at a medium paper mill is 720 m$^3$/day. The highest observed peak daily flowrate is 1200 m$^3$/day. Design cylindrical primary clarifiers with a water depth of 3 m. Use a minimum of two clarifiers. Calculate the scour velocity if settled material will become resuspended. Estimate the BOD and TSS removal at average and peak flow. What would be the maximum flow rate that the primary clarifier can function satisfactorily without resuspending settled material? Use an overflow rate of 30 m$^3$/m$^2$-day at average flow.

**Equation for BOD and TSS Removal:**

\[ R = \frac{1}{a + bt} \]

Where,

- $R$ = expected removal efficiency, %
- $t$ = nominal detention time (retention time), hr
- $a, b$ = empirical constants
  - for BOD, $a = 0.018$ and $b = 0.020$
  - for TSS, $a = 0.0075$ and $b = 0.014$

**Equation and Parameters of Scour Velocity:**

\[ V_H = \left( \frac{8k(s-1)gd}{f} \right)^{1/2} \]

Where,

- $V_H$ = horizontal velocity that will just produce scour, m/s
- $k$ = constant that depends on type of material being scoured = 0.05
- $s$ = specific gravity of particles = 1.25
- $g$ = acceleration due to gravity = 9.81 m/s$^2$
- $d$ = diameter of particles = 100 $\mu$m
- $f$ = Darcy-Weisbach friction factor = 0.025.

7. (a) Briefly discuss different aeration techniques used in wastewater treatment process and the key selection criteria.

(b) Compare the points of Activated Sludge (AS) process and Moving Bed Bio-reactor (MBBR) process: mechanisms, applications, advantages and disadvantages.

(c) A pharmaceutical industry produces 15,000 litre wastewater per day. The key pollution indicating parameters are:

- pH 6-8,
- total dissolved solids (TDS) <500 ppm,
- total suspended solids (TSS) <200 ppm,
- biological oxygen demand (BOD$_5$) <350 ppm,
- chemical oxygen demand (COD) <550 ppm.

As an Environmental Engineer what are the key treatment units (physical, chemical, and/or biological) you would recommend to treat above wastewater?
8. An export oriented Knit Dyeing plant of daily capacity 15 ton, uses 1.75 kg dye for every 100 kg fabric. The major pre-dyeing, dyeing and post-dyeing stages are shown in the table below. The liquor ratio for any stage (except rinsing) of pre-dyeing, dyeing and post-dyeing stages is 1:7 (i.e. 7 liters of liquid for 1 kg fabric). For rinsing, the dyeing machine uses three times more water that a regular dyeing step. Key pollution indicating parameters of different dyeing steps for a 550 kg fabric batch are given in the following table. The pollution load of the wastewater varies from stage to stage (see the table below). For simplification, it is assumed that the COD:BOD ratio of wastewater produced from any stage above 3:1 is considered highly polluted, and COD:BOD ratio of wastewater below 3:1 is considered less polluted.

The industry runs an ETP to treat the wastewater produced from Knit Dyeing plant. The ETP contains Physico-Chemical and Biological units. To reduce the operating cost, the industry plans to segregate the less polluted wastewater from the highly polluted wastewater, and treat them separately; only biological treatment for less polluted streams, and physico-chemical followed by biological treatment for highly polluted streams.

On an annual basis,
(a) What would be the yearly TDS, TSS and BODs load (in tonnes) discharged in the environment by the effluent produced from the industry?
(b) What would be the composite characteristics (in mg/L) of the highly polluted and less polluted wastewater produced by the above mentioned industry?
(c) What volume of wastewater (m³) would have to be treated by the physico-chemical and biological units annually?

<table>
<thead>
<tr>
<th>Fabric: 550 kg; 1.175 kg dye for every 100 kg fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stages</strong></td>
</tr>
<tr>
<td>Scouring</td>
</tr>
<tr>
<td>Hot Wash</td>
</tr>
<tr>
<td>Neutralization</td>
</tr>
<tr>
<td>Dyeing</td>
</tr>
<tr>
<td>Rinsing</td>
</tr>
<tr>
<td>Neutralization</td>
</tr>
<tr>
<td>Rinsing</td>
</tr>
<tr>
<td>Hot Wash with Soap Agent</td>
</tr>
<tr>
<td>Rinsing</td>
</tr>
<tr>
<td>softening</td>
</tr>
</tbody>
</table>
Fig. for Q3. Dispersion coefficient vs downwind distance
1. (a) State the boundary conditions for "Steady State Flow". For one-dimensional, radial flow the simplified diffusivity equation is as follows:

\[
\frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial P}{\partial r} \right) = \frac{\Phi \mu c}{k} \frac{\partial P}{\partial t}
\]

Solve the above equation for the following conditions considering steady state flow:

\[ P(r = r_e) = P_e \text{ and } P(r = r_w) = P_w \]

(b) Reservoir and well data are as follows-

- Outer boundary pressure = 3350 psi
- Radius of outer boundary = 2000 ft
- Well bore radius = 0.5 ft
- Total compressibility = \(10^{-6} \text{ psia}^{-1}\)
- Oil viscosity = 0.65 cP
- Well bore pressure = 3050 psi
- Oil formation volume factor = 1.150rb/stb

The well is producing oil through the well bore at the rate of 900 stb/day.

(i) Calculate the porosity-thickness if the well bore flowing pressure is declining at a constant rate of 2.2 psi/day?

(ii) Calculate permeability-thickness assuming there is water drive and bottom hole pressure remains constant.

See attached table 1(b) for the radial inflow equations for stabilized flow conditions.

(c) What is skin factor? Draw a schematic figure of pressure profile of a formation where stimulation has been done near the well bore zone.

(d) A well has been analyzed and found following data.

- Production rate = 100 stb/day
- Average reservoir pressure = 2000 psia
- Well bore flowing pressure = 1500 psia
- Net sand thickness = 10 ft
- Borehole radius = 0.25 ft
- The well drains an area with drainage radius of 1000 ft
Formation permeability from well test analysis = 16 mD and formation permeability from core data analysis = 50 mD

Does this imply that the well is either damaged or stimulated? What is the apparent skin factor? The equation relating the skin effect is as:

\[ S = \left( \frac{k}{k_s} - 1 \right) \ln \left( \frac{r_w}{r_i} \right) - \frac{3}{4} \]

Here \( k \) = permeability in the unaltered zone
\( k_s \) = permeability in the altered zone.

2. (a) The following data are taken from an oil field that had no original gas cap and no water drive:

- Oil pore volume of reservoir = 75 MMcu.ft
- Solubility of gas in crude = 0.42 scf/stb/psi
- Initial bottom hole pressure = 3500 psia
- Bottom hole temperature = 140°F
- Bubble point pressure of the reservoir = 2400 psia
- Formation volume factor at 3500 psia = 1.333 bbl/stb
- Compressibility factor of the gas at 1500 psia and 140°F = 0.95
- Oil produced when pressure is 1500 psia = 1.0 MMstb
- Net cumulative produced GOR = 2800 scf/stb

(i) Calculate the initial stb of oil in the reservoir
(ii) Calculate the initial scf of gas in the reservoir
(iii) Calculate the scf of free gas and average gas saturation in the reservoir at 1500 psia
(iv) Calculate the liquid volume factor of the oil at 1500 psia

(b) Define reservoir drive mechanism. The general form of the material balance equation is as follows:

\[ N(B_i - B_o) + \frac{NmB_{wi}}{B_{gi}} (B_g - B_{wi}) + (1 + m)NB_{wi} \left[ \frac{c_w S_{wi} + c_f}{1 - S_{wi}} \right] \Delta P + W_c = N_p [B_i + (R_p - R_{swi})B_g] + B_w W_p \]

Show that DDI + SDI + WDI = 1

(c) Draw the reservoir gas oil ratio vs. pressure for oil reservoirs under the following drive-

(i) Dissolved gas drive
(ii) Gas cap drive
(iii) Water drive
3. (a) Show that the pressure and gas deviation factor vs. cumulative production relationship of a dry gas reservoir can be expressed as a straight line when only volumetric depletion takes place.

(b) Drainage area of Bell gas field is 160 acre unit. Following are the additional information about that field. Calculate the recovery factor considering-

(i) volumetric depletion

(ii) partial water drive

(iii) complete water drive

Given, average porosity = 22%
Connate water 23%
Residual gas saturation after water displacement = 34%
Initial pressure = 3250 psia
Initial gas formation volume factor = 0.00533
Gas formation volume factor at 2500 psia = 0.00667
Gas formation volume factor at 500 psia = 0.06323
Net productive thickness = 40 ft
1 acre = 43560 ft²

(b) What are the typical production strategies undertaken in case of gas reservoirs under hydraulic control?

4. (a) List the assumptions for decline curve analysis. What are the objectives of decline curve analysis?

(b) Using the following production data from a gas field:

(i) Plot the data to investigate the type of decline.

(ii) Calculate nominal decline rate.

(iii) Calculate effective monthly and annual decline rates.

(iv) Calculate extra time necessary to obtain future production down to 50 MMscfd.

<table>
<thead>
<tr>
<th>Q, MMscfd</th>
<th>Gp, MMscf</th>
<th>Q, MMscfd</th>
<th>Gp, MMscf</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>10</td>
<td>130</td>
<td>190</td>
</tr>
<tr>
<td>210</td>
<td>20</td>
<td>123</td>
<td>220</td>
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<td>190</td>
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</tr>
<tr>
<td>155</td>
<td>150</td>
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<td></td>
</tr>
</tbody>
</table>

(c) Show that exponential decline can be defined as constant percentage decline.
5. (a) What are the key elements that are required for the creation of petroleum deposits? (5)
(b) Write a short note of petroleum migration. (10)
(c) What are the basic rock types? Discuss briefly their roles in the creation and deposition of petroleum. (10)
(d) What is a trap? What are the basic types of traps? Describe an anticlinal trap. (2+3+5=10)

6. (a) What is porosity and what is its significance? What are the main factors that control porosity? What are the different methods available for estimating porosity? (5+5+5=15)
(b) What are the different methods for estimating fluid saturations? (5)
(c) Water and oil flow simultaneously in a core. We are interested in total flow rate, which is the summation of oil and water flow rates. Following data are available: (10+5=15)
   Core length = 10 cm, Core dia = 4 cm, Core permeability = 100 mD
   Inlet pressure = 4 atm, Outlet pressure = 1 atm
   Water viscosity = 1.0 cP, Oil viscosity = 4.0 cP
The relative permeability curves are approximated by the following functions:
\[ K_{rw} = 0.4 \left( \frac{S_w - 0.2}{0.6} \right)^2 \]
\[ K_{ro} = 0.8 \left( \frac{0.8 - S_w}{0.6} \right)^2 \]
(i) Determine the total flow rate when water saturation is 50%
(ii) At what saturation (\(S_w\) and \(S_o\)) water flow rate will be zero?

7. (a) Define and explain the following terms: (2x5=10)
   (i) Formation Volume Factor of Oil
   (ii) Solution Gas-Oil Ratio
(b) PVT data from an oil field is shown in Table Q3-b. The initial pressure was 3600 psia. (5x4=20)
   (i) Does the reservoir have an initial gas cap? Explain.
   (ii) If the reservoir contained initially 250 MM reservoir bbls of oil, what is the initial oil in place in STB?
   (iii) What is the initial volume of gas (SCF) in the reservoir? What state is the gas in?
   (iv) When the reservoir pressure has dropped to 1800 psia, how much gas (SCF) is liberated?

Contd ........... P/5
Table Q3-b

<table>
<thead>
<tr>
<th>Pressure (psia)</th>
<th>Rs (SCF/STB)</th>
<th>Bo (res. bbl/STB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3600</td>
<td>567</td>
<td>1.310</td>
</tr>
<tr>
<td>3200</td>
<td>567</td>
<td>1.317</td>
</tr>
<tr>
<td>2800</td>
<td>567</td>
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<tr>
<td>2500</td>
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<td>2400</td>
<td>554</td>
<td>1.310</td>
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<tr>
<td>1800</td>
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<td>1200</td>
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<td>1.210</td>
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<tr>
<td>600</td>
<td>223</td>
<td>1.140</td>
</tr>
<tr>
<td>200</td>
<td>143</td>
<td>1.070</td>
</tr>
</tbody>
</table>

(c) Briefly outline how the bubble point pressure of a reservoir fluid is determined. (5)

8. (a) An exploration well was drilled which went through both gas and oil zones, but missed the water zone. However, following information were available:

- Gas-oil contact is at 5200 ft
- Oil-water contact is at 5500 ft
- Oil pressure gradient = 0.35 psi/ft
- Water pressure gradient = 0.45 psi/ft
- Gas pressure gradient = 0.08 psi/ft

From pressure test at 5250 ft, oil pressure is 2402 psia.

(i) Develop the pressure equations for oil and gas phases.
(ii) Determine the pressures at Oil-Water contact, and at Gas-Oil contact.
(iii) Suppose the top of the structure is at 5000 ft. What is the pressure difference between water and gas columns at that depth? Do you expect a kick while penetrating the structure? Why?

(b) What are the causes of abnormal pressure in the reservoir?

(c) Air-brine capillary pressure in a lab was determined to be 1.25 bar. The air-brine interfacial tension is 0.070 N/m, and the brine-oil interfacial tension for the reservoir fluid is 0.022 N/m. It is also known that \( \rho_{\text{brine}} = 1074 \text{ kg/m}^3 \) and \( \rho_{\text{oil}} = 752 \text{ kg/m}^3 \). Find the height of the water-oil transition zone. (5)
Table 1b: Radial inflow equations for stabilized flow conditions

<table>
<thead>
<tr>
<th></th>
<th>STEADY STATE</th>
<th>SEMI-STEADY STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>General relationship</td>
<td>( p - p_w = \frac{q \mu}{2 \pi \rho h} \ln \frac{r}{r_w} )</td>
<td>( p - p_w = \frac{q \mu}{2 \pi \rho h} \left( \ln \frac{r}{r_w} - \frac{r^2}{2 r_w^2} \right) )</td>
</tr>
<tr>
<td>Inflow equations</td>
<td>( p_e - p_w = \frac{q \mu}{2 \pi \rho h} \ln \frac{r}{r_w} )</td>
<td>( p_e - p_w = \frac{q \mu}{2 \pi \rho h} \left( \ln \frac{r}{r_w} - \frac{1}{2} \right) )</td>
</tr>
<tr>
<td>expressed in terms of</td>
<td>( \bar{p} - p_w = \frac{q \mu}{2 \pi \rho h} \left( \ln \frac{r}{r_w} - \frac{1}{2} \right) )</td>
<td>( \bar{p} - p_w = \frac{q \mu}{2 \pi \rho h} \left( \ln \frac{r}{r_w} - \frac{3}{4} \right) )</td>
</tr>
<tr>
<td>the average pressure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In field unit \((q \mu / 2 \pi \rho h)\) should be replaced by \((141.2 q \mu B / k h)\), in each of the equations in table.