1. (a) Solve the problem
\[ \min x_1 + x_2 \ \text{subject to} \ x_1^2 + x_2^2 = 1 \]
by eliminating the variable \(x_2\). Show that the choice of sign for a square root operation during the elimination process is critical; the "wrong" choice leads to an incorrect answer.

(b) A monopolist can purchase up to 17.25 oz of a chemical for $10/oz. At a cost of $3/oz, the chemical can be processed into an ounce of product 1; or, at a cost of $5/oz, the chemical can be processed into an ounce of product 2. If \(x_1\) oz of product 1 are produced, it sells for a price of $30 - \(x_1\) per ounce. If \(x_2\) oz of product 2 are produced, it sells for a price of $50 - 2\(x_2\) per ounce. Determine how the monopolist can maximize profits.

(c) Show that the KKT conditions fail to hold at the optimal solution to the following NLP:
\[ \max z = x_1 \]
\[ \text{s.t.} \quad x_2 - (1 - x_1)^3 \leq 0 \]
\[ x_1 \geq 0, \ x_2 \geq 0 \]

2. (a) HiDec produces two models of electronic gadgets that use resistors, capacitors, and chips. The following table summarizes the data of the situation:

<table>
<thead>
<tr>
<th>Resource</th>
<th>Unit resource requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1 (units)</td>
</tr>
<tr>
<td>Resistor</td>
<td>2</td>
</tr>
<tr>
<td>Capacitor</td>
<td>2</td>
</tr>
<tr>
<td>Chips</td>
<td>0</td>
</tr>
<tr>
<td>Unit price ($)</td>
<td>3</td>
</tr>
</tbody>
</table>

Let \(x_1\) and \(x_2\) be the amounts produced of Models 1 and 2, respectively. Following are the LP model and its associated optimal simplex tableau.

Contd .......... P/2
Maximize $z = 3x_1 + 4x_2$
subject to
\[2x_1 + 3x_2 \leq 1200 \quad \text{(Resistors)}\]
\[2x_1 + x_2 \leq 1000 \quad \text{(Capacitors)}\]
\[4x_2 \leq 800 \quad \text{(Chips)}\]
\[x_1, x_2 \geq 0\]

<table>
<thead>
<tr>
<th>Basic</th>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$s_1$</th>
<th>$s_2$</th>
<th>$s_3$</th>
<th>solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>$z$</td>
<td>0</td>
<td>0</td>
<td>5/4</td>
<td>1/4</td>
<td>0</td>
<td>1750</td>
</tr>
<tr>
<td>$x_1$</td>
<td>1</td>
<td>0</td>
<td>-1/4</td>
<td>3/4</td>
<td>0</td>
<td>450</td>
</tr>
<tr>
<td>$s_3$</td>
<td>0</td>
<td>0</td>
<td>-2</td>
<td>2</td>
<td>1</td>
<td>400</td>
</tr>
<tr>
<td>$x_2$</td>
<td>0</td>
<td>1</td>
<td>1/2</td>
<td>-1/2</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

(i) Determine the status of each resource.

(ii) In terms of the optimal revenue, determine the dual prices for the resistors, capacitors, and the chips.

(iii) Determine the feasibility ranges for the dual prices obtained in (ii).

(iv) If the available number of resistors is increased to 1300 units, find the new optimum solution.

(v) If the available number of chips is reduced to 350 units, will you be able to determine the new optimum solution directly from the given information? Explain.

(vi) If the availability of capacitors is limited by the feasibility range computed in (iii), determine the corresponding range of the optimal revenue and the corresponding ranges for the number of units to be produced of Models 1 and 2.

(vii) A new contractor is offering to sell HiDec additional resistors at 40 cents each, but only if HiDec would purchase at least 500 units. Should HiDec accept the offer?

(b) Consider the following linear programming problem:
\[
\begin{align*}
\max & \quad z = 4x_1 + x_2 \\
\text{s.t.} & \quad 3x_1 + 2x_2 \leq 6 \\
& \quad 6x_1 + 3x_2 \leq 10 \\
& \quad x_1, x_2 \geq 0
\end{align*}
\]

Suppose that in solving this problem, row 0 of the optimal tableau is found to be
\[z + 2x_2 + s_2 = 20/3\]. Use the Dual Theorem to prove that the computations must be incorrect.
3. (a) Consider the birth-and-death process with all $\lambda_n = 2$ ($n = 0, 1, \ldots$), $\mu_1 = 2$, and $\mu_n = 4$ for $n = 2, 3, \ldots$ (16\%)

(i) Display the rate diagram.

(ii) Calculate $P_0$ and $P_1$. Then give a general expression for $P_n$ in terms of $P_0$ for $n = 2, 3, \ldots$

(iii) Consider a queuing system with two servers that fits this process. What is the mean arrival rate for this queuing system? What is the mean service rate for each server when it is busy serving customers?

(b) Machinists who work at a tool-die plant must check out tools from a tool center. An average of ten machinists per hour arrive seeking tools. At present, the tool center is staffed by a clerk who is paid $6 per hour and who takes an average of 5 minutes to handle each request for tools. Since each machinist produces $10 worth of goods per hour, each hour that a machinist spends at the tool center costs the company $10. The company is deciding whether or not it is worthwhile to hire (at $4 per hour) a helper for the clerk. If the helper is hired, the clerk will take an average of only 4 minutes to process requests for tools. Assume that service and interarrival times are exponential. Should the helper be hired? (18)

(c) For $M/M/1$ model, derive the probability distribution of the waiting time in the queue for a random arrival when the queue discipline is first-come-first-served. (12)

4. (a) Briefly discuss two applications of dynamic programming with suitable examples. (10)

(b) Explain memoryless property of exponential distribution with an appropriate example. (6)

(c) Consider the general $m \times n$, two-person, zero-sum game. Let $p_{ij}$ denote the payoff to player 1 if he plays his strategy $i$ ($i = 1, \ldots, m$) and player 2 plays her strategy $j$ ($j = 1, \ldots, n$). Strategy 1 (say) for player 1 is said to be weakly dominated by strategy 2 (say) if $p_{ij} \leq p_{ij}$ for $j = 1, \ldots, n$ and $p_{ij} = p_{ij}$ for one or more values of $j$. (30\%)

(i) Assume that the payoff table possesses one or more saddle points, so that the players have corresponding optimal pure strategies under the minimax criterion. Prove that eliminating weakly dominated strategies from the payoff table cannot eliminate all these saddle points and cannot produce any new ones.

(ii) Assume that payoff table does not possess any saddle points, so that the optimal strategies under the minimax criterion are mixed strategies. Prove that eliminating weakly dominated pure strategies from the payoff table cannot eliminate all optimal mixed strategies and cannot produce any new ones.

Contd ........... P/4
5. (a) Briefly discuss the relationship between optimal solutions and corner point feasible (CPF) solutions in a linear programming (LP) problem. In LP, what happens when the following assumptions do not hold as reasonable approximations? (4\%).

(i) Proportionality assumption
(ii) Additivity assumption

(b) Label each of the following statements as true or false, and then justify your answer. (12)

(i) The simplex method’s rule for choosing the entering basic variable is used because it always leads to the best adjacent basic feasible (BF) solution.
(ii) The simplex method’s minimum ratio rule for choosing the leaving basic variable is used because making another choice with a larger ratio would yield a basic solution that is not feasible.
(iii) When the simplex method solves for the next BF solution, elementary algebraic operations are used to eliminate each non-basic variable from all but one equation (its equation) and to give it a coefficient of +1 in that one equation.

(c) A company makes products $P_1$, $P_2$, $P_3$ using limestone (LI), electricity (EP), water (W), fuel (F), and labor (L) as inputs. Labor is measured in man hours, and other inputs in suitable units.

Each input is available from one or more source. The company has its own quarry for LI, which can supply up to 250 units/day at a cost of $20/unit. Beyond that, LI can be purchased in any amounts from an outside supplier at $50/unit. EP is only available from the local utility. Their charges for EP are: $30/unit for the first 1000 units/day, $45/unit for up to an additional 500 units/day beyond the initial 1000 units/day, $75/unit for amounts beyond 1500 units/day. Up to 800 units/day of water is available from the local utility at $6/unit; beyond that they charge $7/unit of water/day. There is a single supplier for F who can supply at most 3000 units/day at $40/unit; beyond that there is currently no supplier for F. from their regular workforce they have up to 640 man hours of labor/day at $10/man hour; beyond that they can get up to 160 man hours/day at $17/man hour from a pool of workers.

They can sell up to 50 units of $P_1$ at $3000/unit/day in an upscale market; beyond that they can sell up to 50 more units/day of $P_1$ to a wholesaler at $250/unit. They can sell up to 100 units/day of $P_2$ at $3500/unit. They can sell any quantity of $P_3$ produced at a constant rate of $4500/unit.

Data on the inputs needed to make the various products are given in Table 5(a).
Formulate the product mix problem to maximize the net profit/day at this company.

6. (a) Briefly discuss the big advantage of reoptimization technique over re-solving from scratch during postoptimality analysis. Also, explain how shadow price is helpful when an increase in resources can be achieved only by going outside the organization to purchase more of the resources in the marketplace.

(b) Label each of the following statements as true or false, and then justify your answer.

(i) An unbounded function in a practical problem represents misformulation of the model.

(ii) The big $M$ method can be thought of as having two phases.

(iii) An LP problem cannot handle variables that could be negative.

(c) Consider the following simplex tableaux that result from a maximization LP with decision variables $x_1$ and $x_2$, slack variable $x_3$, surplus variable $x_4$, and artificial variable $x_5$.

<table>
<thead>
<tr>
<th>Basic variables</th>
<th>Coefficient of:</th>
<th>RHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z$</td>
<td>$x_1$ $x_2$ $x_3$ $x_4$ $x_5$</td>
<td></td>
</tr>
<tr>
<td>$Z$</td>
<td>1 0 1 -2 0 3 4</td>
<td></td>
</tr>
<tr>
<td>$x_1$</td>
<td>0 1 2 3 0 4 6</td>
<td></td>
</tr>
<tr>
<td>$x_4$</td>
<td>0 0 3 4 1 5 8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basic variables</th>
<th>Coefficient of:</th>
<th>RHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z$</td>
<td>$x_1$ $x_2$ $x_3$ $x_4$ $x_5$</td>
<td></td>
</tr>
<tr>
<td>$Z$</td>
<td>1 0 1 2 3 0 4</td>
<td></td>
</tr>
<tr>
<td>$x_1$</td>
<td>0 1 -2 3 4 0 6</td>
<td></td>
</tr>
<tr>
<td>$x_5$</td>
<td>0 0 -3 4 5 1 8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basic variables</th>
<th>Coefficient of:</th>
<th>RHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z$</td>
<td>$x_1$ $x_2$ $x_3$ $x_4$ $x_5$</td>
<td></td>
</tr>
<tr>
<td>$Z$</td>
<td>1 0 -1 -2 0 3 4</td>
<td></td>
</tr>
<tr>
<td>$x_1$</td>
<td>0 1 -2 3 0 4 6</td>
<td></td>
</tr>
<tr>
<td>$x_4$</td>
<td>0 0 -3 -4 1 5 8</td>
<td></td>
</tr>
</tbody>
</table>
For each of the above cases, determine whether the original LP is infeasible, or unbounded, or degenerate, or has multiple optimal solutions. Briefly justify your answer. Also, if the LP has multiple optimal solutions, find all of them.

7. (a) Consider the following linear program.  

Maximize \( Z = -x_1 - 2x_2 \)
Subject to \( 2x_1 + 3x_2 = 4 \)
\( 3x_1 + 4x_2 \geq 5 \)
and \( x_1 \geq 0, x_2 \geq 0 \)

(i) Construct the initial tableau for the Big M method and determine whether the initial basic feasible solution of the resulting artificial problem is optimal. If not, identify the initial entering basic variable and the leaving basic variable.

(ii) Construct the initial tableau for phase I of the two-phase method and determine whether the initial basic feasible solution of the resulting artificial problem is optimal. If not, identify the initial entering basic variable and the leaving basic variable.

(b) Plans need to be made for the energy systems for a new building. The three possible sources of energy are electricity, natural gas, and a solar heating unit. Energy needs in the building are for electricity, water heating, and space heating, where the daily requirements (all measured in the same units) are:

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>20 units</td>
</tr>
<tr>
<td>Water heating</td>
<td>10 units</td>
</tr>
<tr>
<td>Space heating</td>
<td>30 units</td>
</tr>
</tbody>
</table>

The size of the roof limits the solar heater to 30 units, but there is no limit to the electricity and natural gas available. Electricity needs can be met only by purchasing electricity (at a cost of $50 per unit). Both other energy needs can be met by any source or combination of sources. The unit costs are as follows:

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Electricity</th>
<th>Natural Gas</th>
<th>Solar Heater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water heating</td>
<td>$90</td>
<td>$60</td>
<td>$30</td>
</tr>
<tr>
<td>Space heating</td>
<td>$80</td>
<td>$50</td>
<td>$40</td>
</tr>
</tbody>
</table>
= 7 =

IPE 307

Contd ... Q. No. 7(b)

The objective is to minimize the total cost of meeting the energy needs.

(i) Formulate this problem as a transportation problem by constructing the appropriate cost and requirements table.

(ii) Use Russell's approximation method to obtain an initial BF solution for this problem.

(iii) Starting with the initial BF solution obtained in (ii), interactively apply the transportation simplex method to obtain an optical solution.

8. (a) Suppose that a mathematical model fits linear programming except for the restriction that \( |x_1 - x_2| = 0, \text{ or } 3, \text{ or } 6 \). Show how to reformulate this restriction to fit an MIP model. \( \text{(6\%)} \)

(b) Suppose a company has five factories and five warehouses. Each factory's requirements must be met by a single warehouse, and each warehouse can be assigned to only one factory. The costs of assigning a warehouse to meet a factory's demand (in thousands) are shown in Table 8(b) \( \text{(16)} \)

<table>
<thead>
<tr>
<th>Warehouse</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>12</td>
<td>5</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>17</td>
<td>18</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>10</td>
<td>5</td>
<td>11</td>
<td>7</td>
</tr>
</tbody>
</table>

Solve this assignment problem for minimum cost using the Hungarian method.

(c) Although the Hungarian method is an efficient method for solving an assignment problem, the branch-and-bound method can also be used to solve an assignment problem. Solve the assignment problem of 8(b) again using the branch-and-bound method. Use the following idea.

Let \( x_{ij} = 1 \) if warehouse \( i \) is assigned to factory \( j \) and 0 otherwise. Begin by branching on the warehouse assigned to factory 1. This creates the following five branches: \( x_{11} = 1, x_{21} = 1, x_{31} = 1, x_{41} = 1, \text{ and } x_{51} = 1 \). To obtain a lower bound on the total cost associated with a branch, examine \( x_{21} = 1 \). If \( x_{21} = 1 \), no further assignments can come from row 2 or column 1 of the cost matrix. In determining the factory to which each of the unassigned warehouses (1, 3, 4, and 5) is assigned, we cannot do better than assign each to the smallest cost in the warehouse's row (excluding the factory 1 column). Thus, the minimum-cost assignment having \( x_{21} = 1 \) must have a total cost of at least \( 10 + 10 + 9 + 5 + 5 = 39 \).

Contd ......... P/8
Similarly, in determining the warehouse to which each of the unassigned factories (2, 3, 4, and 5) is assigned, we cannot do better than assign each to the smallest cost in the factory's column (excluding the warehouse 2 row). Thus, the minimum-cost assignment having $x_{21} = 1$ must have a total cost of at least $10 + 9 + 5 + 5 + 7 = 36$. Thus, the total cost of any assignment having $x_{21} = 1$ must be at least $\max(36,39) = 39$. So, if branching ever leads to a candidate solution having a total cost of 39 or less, the $x_{21} = 1$ branch may be eliminated from consideration.
SECTION – A
There are FOUR questions in this section. Answer any THREE.

1. (a) Define demand function. (5)
   (b) What are the factors that influence the shifting of the demand curve? (10)
   (c) From the following demand function, make a hypothetical demand schedule and plot the curve.
   \[ Q = 120 - 20P + P^2 \] (10)
   (d) What are the exceptions to the law of demand? Explain them. (10)

2. (a) Define cross elasticity of demand and income elasticity of demand. (10)
   (b) How would you measure price elasticity of demand at any point on a straight line demand curve? Explain graphically. (15)
   (c) From the following table calculate elasticity of demand if you move from point A to C and explain what you understand from the result. (10)

<table>
<thead>
<tr>
<th>POINT</th>
<th>Py</th>
<th>Qx</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1500</td>
<td>350</td>
</tr>
<tr>
<td>B</td>
<td>1600</td>
<td>550</td>
</tr>
<tr>
<td>C</td>
<td>1700</td>
<td>850</td>
</tr>
</tbody>
</table>

3. (a) Explain consumer’s equilibrium with the help of budget line and indifference curve. (10)
   (b) Make a hypothetical indifference schedule and plot the curve. Explain the properties of an indifference curve. (15)
   (c) From the following budget line and the utility function, calculate the amount of two commodities that maximizes satisfaction. What is the maximum amount of satisfaction?
   \[ 3000 = 25X + 35Y \]
   \[ U = 1500X^{0.6}Y^{0.7} \] (10)

4. (a) How is price determined in an economy under competition? What will happen to the price and quantity due to change in demand and supply? (15)
   (b) From the following demand and supply functions, calculate equilibrium price and quantity and show the result in a graph.
   \[ P = 0.50Q + 250 \]
   \[ P = -0.40Q + 340 \] (20)

Contd ......P/2
HUM277/IPE
Contd... Q. No. 4

(i) What will happen to the equilibrium price and quantity if government imposes a unit tax of TK 15 per unit?
(ii) What will happen if government gives a subsidy of TK 15 per unit?
(iii) Describe the change in equilibrium. Show the equilibrium coordinates on the same graph.

SECTION – B

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

5. (a) Explain the assumptions of a perfectly competitive market and illustrate the long run equilibrium of a firm under perfect competition. (25)
(b) From the following revenue and cost functions, calculate the profit maximizing level of output and maximum profit.

\[ R = 100Q - Q^2 \]
\[ C = \frac{1}{3}Q^3 - 7Q^2 + 111Q + 90 \]

Where, \( R \), \( C \) and \( Q \) refer to revenue, cost and output respectively. (10)

6. (a) Define ‘Lorenz curve’ and ‘Gini coefficient’. How would you measure inequality of income distribution of a society with the help of these concepts? (You may use hypothetical data) (25)
(b) Why is inequality among those above the poverty line a matter of big concern? Discuss. (10)

7. (a) Distinguish between ‘project evaluation’ and ‘cost-benefit analysis’ with examples. Briefly describe the procedure of a cost-benefit analysis (CBA). (10)
(b) Discuss the different types of costs and benefits involved in a Cost-Benefit Analysis. (15)
(c) What is the present value of an equipment that lasts ten years, earns Tk. 100,000 in year 1, Tk. 110,000 in year 2 and Tk. 120,000 in each of the remaining years, and then has a scrap value of Tk. 135,000? Assume that the rate of discount is 9 per cent. If the equipment costs Tk. 450,000, is the investment worthwhile? Would it be worthwhile if the rate of discount is 13 per cent? (10)

8. (a) Write short notes on any THREE of the following
(i) Evaluation of the miraculous economic development of China
(ii) The Neocolonial Dependence Model
(iii) Harrod-Domar Growth Model
(iv) Criticisms of the Structural-Change Model of W. Arthur Lewis. (35)
SECTION - A

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

1. (a) Find the expression for cutting ratio and shear strain in orthogonal chip formation mechanism. (12)
   (b) Derive expression for optimum cutting speeds to minimize cost and machining time. (13)
   (c) What do you understand by "built up edge"? How does it form in metal cutting? How does it affect the machining process? (10)

2. (a) Discuss the mechanisms of chip formation and with the help of Merchant Circle Diagram develop an expression for cutting force in order to calculate minimum power consumption. (12)
   (b) Discuss different types of tool wear with necessary sketches. Also mention the type of wear which is mainly responsible for tool life. Explain briefly. (10)
   (c) Derive simple equations, using proper diagrams, for conversion of the clearance angles of single-point turning tool from (8)
       (i) ASA system to ORS system and (ii) ORS to ASA system.
   (d) Classify the types of chips and also state under what conditions of machining those different types of chips form. (5)

3. (a) Discuss the working principle of "Ultrasonic Machining" with neat sketches. (10)
   (b) Write short notes on the following: (i) re-solidification of molten metal in EDM, (10)
       (ii) minimization of bowing of wire in wire EDM.
   (c) What is the principal cause of tool wear in ECM? (10)
   (d) The frontal working area of the electrode is 2000 mm² in a certain ECM operation in which the applied current = 1800 amps and the voltage = 12 volts. The material being cut is nickel (valence = 2), whose specific removal rate \( C = 3.42 \times 10^{-2} \text{ mm}^3/\text{A-s} \).
       (i) If the process is 90% efficient, determine the rate of metal removal in mm³/min. (5)
       (ii) If the resistivity of the electrolyte = 140 ohm-mm, determine the working gap.
4. (a) Explain the production of laser beam and working principle of Laser Beam Machining. (10)
   (b) With the help of neat sketches, describe briefly the principles of operation and give two suitable industrial application of the following plastic manufacturing processes: (10)
   (i) Lamination process (ii) Thermoforming process.
   (c) Discuss abrasive water jet cutting with its advantages and limitations. (10)
   (d) A metal removal rate of 0.01 in³/min is achieved in a certain EDM operation on a pure iron workpart. What metal removal rate would be achieved on nickel in this EDM operation, if the same discharge current were used? (T_m = 2802°F for iron, 2651°F for nickel). (5)

   **SECTION - B**

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

5. (a) "Turning is micro-threading process" — Explain and justify. (6)
   (b) Explain the following machining processes with necessary sketches and also mention necessary direction of motion in the sketches (12)
      (i) Taper boring
      (ii) Face milling
      (iii) Knurling
   (c) What are the purposes of mandrels in lathe operation? Explain different types of mandrels with necessary sketches. (10)
   (d) What are the applications of fly cutting process? Explain the process with necessary sketches. (7)

6. (a) What do you mean by strain-back effect? How does it affect the tool tip during shaping process? Discuss the mechanism of clapper box in the tool head of a shaper machine. (10)
   (b) Discuss the necessity of body diameter clearance and lip relieving angle of a drill tool. (10)
   (c) Sketch the details of a hole broach and label all necessary features. (10)
   (d) How do you determine the grit size of abrasive particle? Suppose you have abrasive of 40 grit and 20 grit size. Which one is finer? Justify. (5)
7. (a) What are the important factors that govern the properties of grinding wheel? Discuss the centerless grinding with necessary sketches. (10)
(b) What are the different forms of screw threads? Explain them with necessary sketches. (10)
(c) Explain the features of index plate. How does it help in indexing the gear blank? (10)
(d) What do you understand by a 24 inch shaper? Explain. (5)

8. (a) Briefly explain the working principles of electrochemical grinding with appropriate figures. How does electrochemical grinding differ from electrochemical machining? (10)
(b) With the help of suitable sketch, describe the different sections of an injection molding machine. What are the functions of gates in injection molds? (10)
(c) In an orthogonal cutting operation, the tool has a rake angle \( \alpha = 0 \) deg. The cut thickness is \( t_c = 0.30 \) mm and the chip thickness is \( t_e = 0.65 \) mm, the width of cut is \( w = 1 \) mm. Calculate the total (resultant) force for the operation, \( R \), if the specific cutting force for this material is \( K_c = 5000 \) N/mm\(^2\). (10)
(d) Explain the transfer molding process for plastic manufacturing. (5)
SECTION – A

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

Chart-1 supplied with the question must be attached to the answer script if the problem related to this chart is answered.

1. (a) From the fundamental concept, derive the pressure equation of fluids undergoing an accelerating motion. From this equation, derive the hydrostatic pressure relation.
   (b) The pressure difference between an oil pipe and water pipe is measured by a manometer (as shown in Fig. for Que. No. 1(b)). Calculate the pressure difference $\Delta P = P_B - P_A$.

2. (a) Derive Bernoulli's equation of fluid flow.
   (b) Oil at 20°C ($\rho = 888$ kg/m$^3$ and $\mu = 0.800$ kg/m.s) is flowing steadily through a 5 cm-diameter 40 m-long pipe. The pressure at the pipe inlet and outlet are measured as 745 and 97 kPa, respectively. Determine the flow rate of oil through the pipe assuming the pipe is (i) horizontal, (ii) inclined 15° upward, (iii) inclined 15° downward. Also verify that the flow through the pipe is laminar.

3. (a) Water at 60°F ($\rho = 62.36$ lbm/ft$^3$ and $\mu = 7.536 \times 10^{-4}$ lbm/ft.s) is flowing steadily in a 2-inch diameter horizontal pipe made of stainless steel at a rate of 0.2 ft$^3$/s. Determine the pressure drop, the head loss, and the required pumping power input for flow through 200-ft-long pipe if the pump is 100% efficient.
   (b) Differentiate between orifice meter and venturimeter.
   (c) A circular venturimeter of 150 mm × 75 mm size is used to measure the flow rate of oil having specific gravity of 0.9. The reading shown by the U tube manometer connected to the venturimeter is 150 mm of mercury column. Calculate the coefficient of discharge for the venturimeter if the flow rate is 1.7 m$^3$/min.

4. (a) Explain the following in details:
   (i) Viscosity (ii) Compressibility (iii) Vapor Pressure (iv) Mach number
   (b) Determine the torque and power required to turn a 10-cm long, 5-cm diameter shaft at 500 revolutions per minute in a 5.1-cm concentric bearing flooded with a lubricating oil of viscosity 100 centipoise.
   (c) Differentiate Hydraulic Grade Line (HGL) and Energy Grade Line (EGL).

Contd ............ P/2
SECTION – B
There are FOUR questions in this section. Answer any THREE.

5. (a) Derive an expression of hydraulic efficiency for pelton wheel and show the condition of maximum efficiency.
(b) A wheel having curved blades has an inner and outer radii of 30 cm and 60 cm, respectively. The jet enters the blades at the outer tip with a velocity of 40 m/s at an angle of 30° with the direction of motion and leaves with a velocity of 9.3 m/s with an angle of 60°. If the speed of the wheel is 230 rpm, find the vane angle at inlet and outlet, work done per kg of water entering and its hydraulic efficiency.

6. (a) Show the schematic of a Francis turbine and label the major components.
(b) Describe the functions of (i) Draft tube and (ii) Surge tank used in hydraulic turbine.
(c) In an inward flow reaction turbine the inlet and outlet diameters are 1.0 m and 0.5 m, respectively. The constant velocity of flow is 2 m/s and the flow is radial at outlet. The width of the runner at inlet is 250 mm and 10% of the area is blocked by vane thickness. The speed of the runner is 210 rpm and the guide blades make an angle 10° to the wheel tangent. Find (i) the flow rate of water, (ii) vane angles at inlet and outlet, and (iii) absolute and relative velocities at inlet.

7. (a) What is rotodynamic pump? Describe different types of casing used in centrifugal pump with proper schematic.
(b) Describe different heads developed in centrifugal pump.
(c) A centrifugal pump delivers 0.15 m³/s of water against a head of 26 m. The outside diameter of impeller is 250 mm and it has 50 mm width at the outlet. If the manometric efficiency is 76%, find the vane angle at the outlet. What will be the overall efficiency if mechanical loss is 10% of head developed in the pump? Consider the pump rpm as 1500.

8. (a) Explain the advantages of reciprocating pump over centrifugal pump.
(b) Derive an expression of acceleration head developed in reciprocating pump and show its effects on indicator diagram.
(c) A single acting reciprocating pump has a stroke of 30 cm and the piston diameter of 15 cm. If the axis of the pump cylinder is 5 m above the level of water in the sump and 35 m below the reservoir level and the pump is working at 35 rpm, find the pressure head at the beginning, middle and end of each stroke and the horse power developed in the pump. The suction and delivery pipes are vertical having diameter of 7.5 cm. Take \( f = 0.035 \).
Table 1

<table>
<thead>
<tr>
<th>Material</th>
<th>Roughness, $e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass, plastic</td>
<td>0 (smooth)</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.003-0.03</td>
</tr>
<tr>
<td>Wood stove</td>
<td>0.0016</td>
</tr>
<tr>
<td>Rubber, smoothed</td>
<td>0.000033</td>
</tr>
<tr>
<td>Copper or brass</td>
<td>0.000005</td>
</tr>
<tr>
<td>Cast iron</td>
<td>0.00085</td>
</tr>
<tr>
<td>Galvanized iron</td>
<td>0.0005</td>
</tr>
<tr>
<td>Wrought iron</td>
<td>0.00015</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>0.000007</td>
</tr>
<tr>
<td>Commercial steel</td>
<td>0.00015</td>
</tr>
</tbody>
</table>

The uncertainty in these values can be as much as ±60 percent.

Chart 1

Reynolds number, $Re = \frac{\nu \cdot L}{\nu}$
SECTION – A

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

1. (a) Describe the following terms. Use suitable examples and schematic diagrams where necessary.
   (i) LVD
   (ii) Capacitive elements as displacement sensor
   (iii) Discrete-Time Control Systems

   (b) A bourden-tube acts as a first-order system with an input of pressure and an output of the mercury position against a linear scale. The setup is initially at atmospheric pressure and is then promptly placed under 0.01 MPa. After 80 s the thermometer reads 0.09435 MPa. For such a system the output is related to the input by the equation:

   \[ \text{output} = 10^3(-e^{-t} + 1). \]

   Determine the following:
   (i) the time constant,
   (ii) the delay time,
   (iii) the rise time.

   (c) Explain the Hysteresis error and Sensitivity in instrumentation systems.

2. (a) Contrast the resistance change produced by a 150 \( \mu \text{m} / \text{m} \) strain in a metal gauge with \( GF = 2.13 \) with a semiconductor with \( GF = -151 \). Nominal resistances are 120 \( \Omega \).

   (b) How can you determine the flow velocity of a fluid? Explain two such methods.

   (c) Drawing the response curves, explain in detail the function, advantages and disadvantages of proportional-only, derivative-only and integral-only controllers with respect to system response. Explain how PID-type controllers overcome the limitations of other controllers.

3. (a) The following figure shows PD controller used for controlling the system. Determine the value of \( T_D \) so that the system is critically damped.

   ![Diagram](image)

   Contd .......... P/2
IPE 301
Contd... Q. No. 3

(b) Describe optical encoders. Differentiate between incremental and absolute optical encoders with neat sketches. Write down their relative advantages. How can you measure their resolution?

4. (a) Compute the overall transfer function for the system shown in the following figure.

(b) A PID controller has $K_p = 2, T_i = \frac{5}{22}$ second and $T_D = 4$ second. Draw the plot of controller output for the following figure. Show all the associated calculations.

(c) Suppose you have a single timer that can delay upto 1 hour. Now, for a certain application you have to delay 6 hours. How can you make do with this single timer using a counter? Explain by drawing a ladder logic diagram.

Contd ........... P/3
5. (a) Differentiate between different degrees of "Precision" and "Accuracy" with necessary diagrams. 
(b) Write down the factors affecting surface roughness. 
(c) Consider the Boolean expression: \( F = \overline{AB} + AB \) 
   (i) Prepare a "Truth table" according to the Boolean expression. 
   (ii) Construct a "Logic circuit" which gives identical output as the given Boolean expression, using NAND gate only. 
(d) Consider the fluid storage tank illustrated in Figure Q5.(d). When the start button X1 is depressed, this energizes the control relay C1. In turn this energizes solenoid S1, which opens a valve allowing fluid to flow into the tank. When the tank becomes full, the float switch FS closes, which opens relay C1, causing the solenoid S1 to be de-energized, thus turning off the inflow. Construct "Ladder logic diagram" for the system.

![Diagram](image)

Figure Q5.(d): Fluid filling operation system

6. (a) Define "Right hand thread" and "Left hand thread" along with necessary diagrams. Discuss the difference in their manufacturing techniques. 
(b) Using two-wire method, derive the expression to measure the effective diameter of a screw thread with necessary diagrams.

Contd .......... P/4
(c) For "Bilateral limit" of a shaft, illustrate the following items in a single diagram:

(i) Zero line  
(ii) High limit  
(iii) Low limit  
(iv) Tolerance  
(v) Upper deviation  
(vi) Lower deviation  
(vii) Fundamental deviation

7. (a) With necessary diagrams discuss briefly about "V-block".  
(b) The rectangular hole is to be checked whose limits of size for the width (120 mm) and breadth (80 mm) are as shown in Figure Q7(b). Determine the design requirements and tolerance limits for suitable gauges based on Taylor's principle, for bilateral system.

(c) Describe the working principle of "Parkinson's gear tester" with necessary diagrams.

(d) Differentiate between "Roughness" and "Waviness" of surface irregularities with necessary diagrams.
8. (a) In measurement of gear tooth thickness, what is the relative advantage of "Constant chord method" over use of Vernier calipers? With necessary diagrams derive expression for "Constant chord" in terms of module and pressure angle.

(b) A hole and mating shaft have a nominal assembly size of 40 mm. The assembly is to have a maximum total clearance of 0.10 mm and a minimum total clearance of 0.05 mm. Determine the specifications of the parts for "Statistical average interchangeability".

(c) Identify the symbolic representation of surface roughness as shown in Figure Q8.(c), with appropriate labeling.

(d) A control box contains two buttons, one for START and the other for STOP. When the START button is depressed momentarily by a human operator, power is supplied and maintained to a motor until the STOP button is pressed. POWER-TO-MOTOR is the output of the push-button switch. Construct "Ladder logic diagram" and "Logic circuit" representing the system.