SECTION – A
There are FOUR questions in this section. Answer any THREE.

1. (a) What is "fit"? With necessary sketches describe three types of fit. (15)
   (b) Calculate dimensions of plug and ring gauges to control the production of 50mm shaft and hole pair of H7/d8 as per I.S. specification. The following assumption may be made: 50 mm lies in diameter step 40 and 50 mm. Use diagrams to show your calculations. (20)

2. (a) Using two-wire method, formulate the equations to measure the effective diameter of screw thread. (15)
   (b) What is the difference between precision and accuracy? Explain. How is it important in measurement and industry? (5)
   (c) Write short notes on:
      (i) Strain Gauge
      (ii) Proximity sensors
      (iii) Incremental Encoders
      (iv) Tachogenerator (10)

3. (a) What are logic gates in PLC? How do latching, timers and internal relays work in PLC? (12)
   (b) Give a brief description of the components of PLC system. (8)
   (c) Draw ladder diagram for starting 3 motors sequentially with delay i.e. starting the oil pump motor immediately when START is pressed. The main motor will be started after a 10 sec delay and then the auxiliary motor after a 5 sec delay. In addition, all motors stop immediately when STOP is pressed. (15)

4. (a) How does an open and close-loop control system work? Illustrate with an example in each case. (15)
   (b) What is derivative control? When is it necessary? (5)
   (c) Sketch graphs showing how the controller output will vary with time for the error signal shown in Figure 1 when the controller is set initially at 30% and operates as (a) just proportional with \( K_p = 3 \), (b) proportional plus derivative with \( K_p = 3 \) and \( K_d = 1.0 \text{ s}^{-1} \), (c) proportional plus integral with \( K_p = 3 \) and \( K_i = 0.5 \text{ s}^{-1} \). (continued on P/2)
IPE 301
Contd... Q. No. 4 (b)

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

5. (a) Suppose, Mr. X, a reputed businessman, has a Samsung Galaxy S7 edge phone. Once, in one of his important official meetings, his phone began to ring and he saw the caller and turned over his phone to make the call silent. What type of sensor, do you think, is used in that phone to do so? What type of system model/s can justify this complete operation? Perform mathematical derivation for this particular system model or any similar type of system model.

(b) Differentiate between primary and secondary texture with neat sketches. In the measurement of surface roughness, heights of 25 successive peaks and trough were measured from a datum and were 20,35,18,37,21,32,22,42,18,36,18,22,36,35, 25,42,18,35,22,40,25,35,37,27,36. If these measurements were obtained over a length of 20 mm, determine the C.L.A. and R.M.S. value of the rough surface.

(c) “Only surface crack defects can be measured by liquid penetrate testing” – Rationalize this statement with necessary sketch(es).

(d) Why cracks so far from the surface cannot be detected by magnetic inspection? Explain with necessary sketch(es).

6. (a) Calculate the involute function of a spur gear for 14.5 and 20-degree pressure angle. If you draw a spur gear having 40 teeth and module 5 and then measure tooth thickness along the pitch circle diameter for these two different pressure angles, will the two thickness will be the same? Justify your answer.

(b) Compare among spiral bevel gear, hypoid bevel gear, miter gear and double helical bevel gear. Also write one of the applications of these of bevel gears.

(c) Consider a pair of bevel gear, one of which is pinion. Derive the relation of pitch angle for each in terms of the angle between their shaft axes and each of their pitch diameter with neat sketches.
IPE 301
Contd... Q. No. 6

(b) Draw different views of worm in mating state with the worm gear and exhibit different diameter of worm gear, normal lead, center distance between the shafts and worm diameter in their proper views and with the help of these diagrams, derive relation between lead angle and number of start of worm, pitch circle diameter and module of the worm gear.

7. (a) With the advancement of science and technology, men are inventing more and more new sophisticated products. But, yet the most sophistication lies in human body. Each of the organs functioning mechanisms is still a miracle to humans. Actually, many of sciences of human inventions already lie in human body. One such organ is human ear. You may see different transducer around you. But the most surprising transducer is our ear. Do you agree? Justify.

(b) Suppose, once in a developed country, in supplying gas from its one of the reservoirs, a leaking took place accidently. But, it was immediately indentified remotely and proper actions had been taken. What is your opinion regarding the modern measuring technology used in identifying so? Justify your answer. Do you think the same physics can be used in identifying a cut-down of optical fiber line in Pacific Ocean? Briefly describe.

(c) “LEICA” is a renounced name in industrial measurement solution. They have different products under ‘Leica Absolute Tracker’ brand. Some of them are TV515, AT402, AT901, AT960 etc. used in different industries. One of the uses of Leica absolute tracker in automation industry is point to point inspections. How is it done? Briefly describe. Do you think it is a dynamic measurement? Reason your side. If this is not a dynamic measurement, then provide an example of dynamic measurement.

(d) Casting is one of the common manufacturing processes. Among many defects of casting, pores and voids is one of them. What non-destructing testing method, do you think most suitable to three dimensionally inspect this cast product for voids and pores? Provide some arguments to support your preferred answer.

(e) Tesla model is one of the different models of ever faster electric cars. Different control mechanisms are used to make it move starting form fuel consumption. Do you think the number of system conversion for transferring the fuel energy to wheel rotation in the tesla model is more than that of the traditional car? Justify your answer.

8. (a) Suppose, you eat cucumber every morning as your breakfast. You, yourself chop this with a knife. At your regular use, you, one of the future talented engineers, noticed that actually from beginning the knife’s sharpness is not enough for you. Eventually, you wish to design a new knife concentrating its sharpness and its ergonomic design modification in your product design courses in upcoming semester. Upon your search on methods of increasing sharpness, you discovered that the proper measurement of knife angle plays a vital role in its sharpness and angle measurement by leisure is the most updated method. Briefly describe the physics of this angle measurement by leisure.
(b) Consider, a rectangular block manufacturing is completed by machining. Due to irregular machining by an amateur worker, different dark lines are created on to the surface. These dark lines are in different orientation onto the surface. How can be all these dark lines in different orientation made visible under ultraviolet light? Illustrate with neat sketches.

(c) In ultrasonic inspection of cylindrical block of height 100 mm, two echoes are obtained approximately at 44 mm and 87 mm distance while inspecting one of the flat surfaces with a piezoelectric probe. How can you describe these scenarios? Why is an especial type of gel used in ultrasonic inspection?

(d) Suppose, once on a holiday, you were going to a long drive. Suddenly, you saw a pedestrian on your way and immediately pressed the brake pedal and fortunately saved that person from an accident. Deduce the equation/s of the gain of this system model after deriving the generalized equation/s of this system model. If we consider the system model as dynamic, then what else you have to do? Briefly describe.
The relative magnitudes of eighteen grades for sizes above 500 mm and up to 3150 mm are given below in Table 4.

Table 2

<table>
<thead>
<tr>
<th>Grades</th>
<th>IT5</th>
<th>IT6</th>
<th>IT7</th>
<th>IT8</th>
<th>IT9</th>
<th>IT10</th>
<th>IT11</th>
<th>IT12</th>
<th>IT13</th>
<th>IT14</th>
<th>IT15</th>
<th>IT16</th>
<th>IT17</th>
<th>IT18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values</td>
<td>7i</td>
<td>10i</td>
<td>16i</td>
<td>25i</td>
<td>40i</td>
<td>64i</td>
<td>100i</td>
<td>160i</td>
<td>250i</td>
<td>400i</td>
<td>640i</td>
<td>1000i</td>
<td>1600i</td>
<td>2500i</td>
</tr>
</tbody>
</table>

Table 3

<table>
<thead>
<tr>
<th>IT1</th>
<th>IT2</th>
<th>IT3</th>
<th>IT4</th>
<th>IT5</th>
<th>IT6</th>
<th>IT7</th>
<th>IT8</th>
<th>IT9</th>
<th>IT10</th>
<th>IT11</th>
<th>IT12</th>
<th>IT13</th>
<th>IT14</th>
<th>IT15</th>
<th>IT16</th>
<th>IT17</th>
<th>IT18</th>
</tr>
</thead>
<tbody>
<tr>
<td>2i</td>
<td>2.7i</td>
<td>3.7i</td>
<td>6i</td>
<td>7i</td>
<td>10i</td>
<td>16i</td>
<td>25i</td>
<td>40i</td>
<td>64i</td>
<td>100i</td>
<td>160i</td>
<td>250i</td>
<td>400i</td>
<td>640i</td>
<td>1000i</td>
<td>1600i</td>
<td>2500i</td>
</tr>
</tbody>
</table>
Table 4.2: Formulae for Fundamental Deviations
for Shafts for sizes upto 500 mm

<table>
<thead>
<tr>
<th>Shaft Designation</th>
<th>Upper Deviation (es) In microns (for D in mm)</th>
<th>Lower Deviation (ei) In microns (for D in mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a )</td>
<td>(- (265 + 1.3D)) for ( D \leq 120 )</td>
<td>( j ) No formula</td>
</tr>
<tr>
<td></td>
<td>(- 3.5D) for ( D &gt; 120 )</td>
<td>( js ) ( IT7/2 )</td>
</tr>
<tr>
<td>( b )</td>
<td>(- (140 + 0.85D)) for ( D \leq 160 )</td>
<td>( k4 ) to ( k7 ) (+ 0.6 \sqrt{D} )</td>
</tr>
<tr>
<td></td>
<td>(- 1.8D) for ( D &gt; 160 )</td>
<td>( k ) for grade ( \leq 3 ) and ( \geq 7 )</td>
</tr>
<tr>
<td>( c )</td>
<td>(- 52D^{0.2} ) for ( D \leq 40 )</td>
<td>( m ) (+ (IT7 - IT6) )</td>
</tr>
<tr>
<td></td>
<td>(- (95 + 0.8D)) for ( D &gt; 40 )</td>
<td>( n ) (+ 5D^{0.24} )</td>
</tr>
<tr>
<td>( cd )</td>
<td>G.M. of values for ( c ) and ( d )</td>
<td>( p ) (+ IT7 + 0 ) to ( 5 )</td>
</tr>
<tr>
<td>( d )</td>
<td>(- 16D^{0.44} )</td>
<td>( r ) (+ ) geometric mean of values for ( p ) and ( s )</td>
</tr>
<tr>
<td>( e )</td>
<td>(- 11D^{0.41} )</td>
<td>( s ) (+ IT8 + 1 ) to ( 4 ) for ( D \leq 50 )</td>
</tr>
<tr>
<td>( ef )</td>
<td>G.M. of values for ( e ) and ( f )</td>
<td>( t ) (+ IT7 + 0.63D )</td>
</tr>
<tr>
<td>( f )</td>
<td>(- 5.5D^{0.41} )</td>
<td>( u ) (+ IT7 + D )</td>
</tr>
<tr>
<td>( fg )</td>
<td>G.M. of values for ( f ) and ( g )</td>
<td>( v ) (+ IT7 + 1.25D )</td>
</tr>
<tr>
<td>( g )</td>
<td>(- 2.5D^{0.24} )</td>
<td>( x ) (+ IT7 + 1.6D )</td>
</tr>
<tr>
<td>( h )</td>
<td>(&lt; 0 )</td>
<td>( y ) (+ IT7 - 2D )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( z ) (+ IT7 + 2.5D )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( za ) (+ IT8 + 3 + 3.15D )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( zb ) (+ IT9 + 4D )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( zc ) (+ IT10 + 5D )</td>
</tr>
</tbody>
</table>

Same formulae also applicable for corresponding fundamental deviations for holes also.

For Table 4.2 A).

The ranges of shafts \( cd \), \( ef \) and \( fg \) are only in the range of 0—10 mm.

Table 4
Table: Laplace functions and their corresponding time functions

<table>
<thead>
<tr>
<th>Time Functions $f(t)$</th>
<th>Laplace Functions $F(s)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^{-at}$, exponential decay</td>
<td>$\frac{1}{s+a}$</td>
</tr>
<tr>
<td>$1 - e^{-at}$, exponential growth</td>
<td>$\frac{a}{s(s+a)}$</td>
</tr>
<tr>
<td>$te^{-at}$</td>
<td>$\frac{1}{(s+a)^2}$</td>
</tr>
<tr>
<td>$t - \frac{1-e^{-at}}{a}$</td>
<td>$\frac{a}{s^2(s+a)}$</td>
</tr>
<tr>
<td>$e^{-at} - e^{-bt}$</td>
<td>$\frac{b-a}{(s+a)(s+b)}$</td>
</tr>
<tr>
<td>$(1-at)e^{-at}$</td>
<td>$\frac{ab}{s(s+a)(s+b)}$</td>
</tr>
<tr>
<td>$1 - \frac{b}{b-a}e^{-at} + \frac{a}{b-a}e^{-bt}$</td>
<td>$\frac{s}{(s+a)^2(s+b)}$</td>
</tr>
<tr>
<td>$\frac{e^{-at}}{(b-a)(c-a)} + \frac{e^{-bt}}{(c-a)(a-b)} + \frac{e^{-a}}{(a-c)(b-c)}$</td>
<td>$\frac{1}{(s+a)(s+b)(s+c)}$</td>
</tr>
<tr>
<td>$\sin \omega t$, a sine wave</td>
<td>$\frac{\omega}{s^2 + \omega^2}$</td>
</tr>
<tr>
<td>$\cos \omega t$, a cosine wave</td>
<td>$\frac{s}{s^2 + \omega^2}$</td>
</tr>
<tr>
<td>$e^{-at} \sin \omega t$, a damped sine wave</td>
<td>$\frac{\omega}{(s+a)^2 + \omega^2}$</td>
</tr>
<tr>
<td>$e^{-at} \cos \omega t$, a damped cosine wave</td>
<td>$\frac{s+a}{(s+a)^2 + \omega^2}$</td>
</tr>
<tr>
<td>$\frac{\omega}{\sqrt{1-\zeta^2}}e^{-\zeta \omega t} \sin \omega \sqrt{1-\zeta^2} t$</td>
<td>$\frac{\omega^2}{s^2 + 2\zeta \omega + \omega^2}$</td>
</tr>
<tr>
<td>$1 - \frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta \omega t} \sin (\omega \sqrt{1-\zeta^2} t + \phi)$, $\cos \phi = \zeta$</td>
<td>$\frac{\omega^2}{s(s^2 + 2\zeta \omega + \omega^2)}$</td>
</tr>
</tbody>
</table>
L-3/T-1/IPE

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA


Sub: IPE 307 (Operations Research)

Full Marks: 280 Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) Distinguish between a conventional design method and an optimum design method.

(b) A monopolist producing a single product has two types of customers. If q1 units are produced for customer 1, then customer 1 is willing to pay a price of 70 - 4q1 dollars. If q2 units are produced for customer 2, then customer 2 is willing to pay a price of 150 - 15q2 dollars. For q > 0, the cost of manufacturing q units is 100 + 15q dollars. To maximize profit, how much should the monopolist sell to each customer?

(c) Show that the KKT conditions fail to hold at the optimal solution to the following NLP:

\[
\text{max } Z = x_1 \\
\text{s.t. } x_2 - (1 - x_1)^3 \leq 0 \\
x_1 \geq 0, \ x_2 \geq 0
\]

2. (a) The following is the optimal tableau for a maximization LP model with three (\leq) constraints and all nonnegative variables. The variables \( x_3, x_4, \) and \( x_5 \) are the slacks associated with the three constraints. Determine the associated optimal objective function value in two different ways using the primal and dual objective functions.

<table>
<thead>
<tr>
<th>Basic</th>
<th>( x_1 )</th>
<th>( x_2 )</th>
<th>( x_3 )</th>
<th>( x_4 )</th>
<th>( x_5 )</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>( z )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>( x_3 )</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>-1</td>
<td>2</td>
</tr>
<tr>
<td>( x_2 )</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>( x_1 )</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

(b) Define shadow price. Also, discuss its relationship with the complementary optimal solutions property.

(c) Consider the following problem.

Maximize \( Z = 2x_1 + 7x_2 + 4x_3, \) subject to

\[
x_1 + 2x_2 + x_3 \leq 10 \\
3x_1 + 3x_2 + 2x_3 \leq 10 \\
\text{and } x_1 \geq 0, \ x_2 \geq 0, \ x_3 \geq 0.
\]
IPE 307
Contd ... Q. No. 2(c)

(i) Construct the dual problem for this primal problem.
(ii) Use the dual problem to demonstrate that the optimal value of Z for the primal problem cannot exceed 25.
(iii) It has been conjectured that \( x_2 \) and \( x_3 \) should be the basic variables for the optimal solution of the primal problem. Directly derive this basic solution (and Z) by using Gaussian elimination. Simultaneously derive and identify the complementary basic solution for the dual problem by using Eq. (0) for the primal problem. Then draw your conclusions about whether these two basic solutions are optimal for their respective problems.
(iv) Solve the dual problem graphically. Use this solution to identify the basic variables and the nonbasic variables for the optimal solution of the primal problem. Directly derive this solution, using Gaussian elimination.

3. (a) A service station has one gasoline pump. Cars wanting gasoline arrive according to a Poisson process at a mean rate of 15 per hour. However, if the pump already is being used, these potential customers may balk (drive on to another service station). In particular, if there are \( n \) cars already at the service station, the probability that an arriving potential customer will balk is \( n/3 \) for \( n = 1, 2, 3 \). The time required to service a car has an exponential distribution with a mean of 4 minutes.

(i) Construct the rate diagram for this queueing system.
(ii) Develop the balance equations.
(iii) Solve these equations to find the steady-state probability distribution of the number of cars at the station. Verify that this solution is the same as that given by the general solution for the birth-and-death process.
(iv) Find the expected waiting time (including service) for those cars that stay.
(b) 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.
(c) Assume that the probability of rain tomorrow is 0.5 if it is raining today, and assume that the probability of its being clear (no rain) tomorrow is 0.9 if it is clear today. Also assume that these probabilities do not change if information is also provided about the weather before today.

(i) Explain why the stated assumptions imply that the Markovian property holds for the evolution of the weather.
(ii) Formulate the evolution of the weather as a Markov chain by defining its states and giving its (one-step) transition matrix.
4. (a) Robin, who travels frequently between two cities, has two route options: Route A is a fast four-lane highway, and Route B is a long winding road. The highway patrol has a limited police force. If the full force is allocated to either route, Robin, with her passionate desire for driving 'superfast', is certain to receive a $100 speeding ticket. If the force is split 50-50 between the two routes, there is a 50% chance she will get a $100 ticket on Route A and only a 30% chance that she will get the same fine on Route B. Develop a strategy for both Robin and the police.

(b) Consider the game having the following payoff table

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

(i) Formulate the problem of finding optimal mixed strategies according to the minimax criterion as a linear programming problem.

(ii) Use the simplex method to find these optimal mixed strategies.

SECTION - B

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

5. (a) Write down the differences between simplex method and graphical method to solve an optimization problem.

(b) Consider the following problem:

Maximize \[ Z = 2x_1 + 2x_2 + 3x_3 \]

Subject to

\[ 2x_1 + x_2 + 2x_3 \leq 4 \]
\[ x_1 + x_2 + x_3 \leq 3 \]

and

\[ x_1 \geq 0, \ x_2 \geq 0, \ x_3 \geq 0. \]

Let \( x_4 \) and \( x_5 \) be the slack variables for the respective functional constraints. Starting with these two variables as the basic variables for the initial BF solution, you now are given the information that the simplex method proceeds as follows to obtain the optimal solution in two iterations: (1) In iteration 1, the entering basic variable is \( x_3 \) and the leaving basic variable is \( x_4 \); (2) in iteration 2, the entering basic variable is \( x_2 \) and the leaving basic variable is \( x_5 \).

(a) Draw a two-dimensional drawing of the feasible region for this problem,
(b) Give a geometric interpretation of why the simplex method followed this path.
(c) For each of the two edges of the feasible region traversed by the simplex method, give the equation of each of the two constraint boundaries on which it lies, and then give the equation of the additional constraint boundary at each endpoint.
(d) Identify the set of defining equations for each of the three CPF solutions (including the initial one) obtained by the simplex method. Use the defining equations to solve for these solutions.
(e) For each CPF solution obtained in part (d), give the corresponding BF solution and its set of non-basic variables. Explain how these non-basic variables identify the defining equations obtained in part (d).

6. (a) Consider following problem:

Maximize \( Z = 4x_1 + 2x_2 + 3x_3 + 5x_4. \)
subject to
\[
\begin{align*}
2x_1 + 3x_2 + 4x_3 + 2x_4 &= 300 \\
8x_1 + x_2 + x_3 + 5x_4 &= 300 \\
\end{align*}
\]
and
\[ x_j \geq 0, \text{ for } j = 1, 2, 3, 4. \]

Using the Big M method, construct the complete first simplex tableau for the simplex method and identify the corresponding initial (artificial) BF solution. Also identify the initial entering basic variable and the leaving basic variable.

(b) What is sensitivity analysis? When is it necessary to apply sensitivity analysis in optimization problem? Illustrate with example.

7. (a) Consider the transportation problem having the following parameter table:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>M</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>4</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

(i) Use Vogel's approximation method manually to select the first basic variable for an initial Basic Feasible (BF) solution.
(ii) Use the northwest corner rule manually to construct a complete initial BF solution.
(iii) Compare the two results and comment on the cause of variation of results.
7. (b) What are the assumptions of transportation problem? Explain each with an example. (16)

8. (a) What are branching, bounding and fathoming in Integer Programming problem? Explain with a numerical example. (20)

(b) A real estate development firm, Peterson and Johnson, is considering five possible development projects. The following table shows the estimated long-run profit (net present value) that each project would generate, as well as the amount of investment required to undertake the project, in units of millions of dollars. (26 2/3)

<table>
<thead>
<tr>
<th>Development Project</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated profit</td>
<td>1</td>
<td>1.8</td>
<td>1.6</td>
<td>0.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Capital required</td>
<td>6</td>
<td>12</td>
<td>10</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

The owners of the firm, Dave Peterson and Ron Johnson have raised $20 million of investment capital for these projects. Dave Ron now want to select the combination of projects that will maximize their total estimated long-run profit (net present value) without investing more that $20 million.

Formulate a Basic Integer Programming model for this problem.
1. (a) Explain the working principle of Abrasive Jet Machining (AJM) process with neat sketches. Do you think stand-off-distance (SOD) affects machining accuracy? Justify your answer with appropriate explanations.
   
   (b) Mention some design considerations for drilling, reaming and tapping operations.
   
   (c) Briefly discuss the economics of non-conventional machining process over conventional machining.

2. (a) Briefly explain the working principles of electrochemical grinding with appropriate figures. How does electrochemical grinding differ from electrochemical machining?
   
   (b) Sketch different view of a drill tool and mention different elements and angles.
   
   (c) Discuss the slab milling and face milling operation with appropriate sketches.
   
   (d) What are the differences between shaping and planning?

3. (a) Describe the working principle of Ultrasonic Machining (USM). List the advantages and limitations of USM.
   
   (b) How ‘quick return mechanism’ works in shaping machine? How strain back effect is eliminated?
   
   (c) Write down the applications of Water Jet Machining.
   
   (d) The frontal working area of the electrode is 2000 mm^2 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 is $3.42 \times 10^{-2}$ mm^3/A-s.
   
   (i) If the process is 90% efficient, determine the rate of metal removal in mm^3/min.
   
   (ii) If the resistivity of the electrolyte = 140 ohm-mm, determine the working gap.

4. (a) Describe the working principle of Laser Beam Machining with necessary sketches.
   
   (b) Explain laminated objects manufacturing and selective laser sintering method.
   
   (c) A 8-in diameter grinding wheel, 1.0 in wide, is used in a certain surface grinding job performed on a flat piece of heat-treated 4340 steel. The wheel is rotating to achieve a surface speed of 5000 ft/min, with a depth of cut (infeed) = 0.002 in per pass and a cross-feed = 0.15 in. The reciprocating speed of the work is 20 ft/min, and the operation is performed dry.

Contd ........... P/2
IPE 305
Contd... Q. No. 4

(i) What is the length of contact between the wheel and the work? (ii) What is the volume rate of metal removed? (iii) If \( C = 300 \) active grits/in\(^2\), estimate the number of chips formed per unit time. (iv) What is the average volume per chip? (v) If the tangential cutting force on the workpiece = 10 lbs, what is the specific energy calculated for this job?

SECTION-B

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

5. (a) From the machining performance viewpoint which type of chip is preferred and why? What is the purpose of chip breaker? Describe different types of chip breaker with sketch

(b) Develop the relationship between the shear strain and shear angle in an orthogonal cutting.

(c) During turning of a steel rod of diameter 100 mm by a carbide tool of geometry; \(0^\circ, -10^\circ, 8^\circ, 7^\circ, 15^\circ, 75^\circ, 0.5\) (mm) at speed 625 rpm, feed 0.36 mm/rev and depth of cut 5 mm the followings were observed: Cutting force = 1000N, Feed force = 200N, chip thickness = 1 mm. Determine the expected values of the following parameter for the above mentioned machining operation.

(i) Co-efficient of friction at the chip-tool interface (\(\mu\)) and the friction angle (\(\eta\)).
(ii) Shear angle (\(\beta\)).
(iii) Shear force (\(P_s\)).
(iv) Compressive force at the Shear plane (\(P_n\)).
(v) Dynamic yield Shear strength (\(\tau_s\)).

6. (a) Identify the mechanisms by which cutting tools wear out during machining. Show the variation of average principal flank wear of cutting tool with machining time and explain its importance from the tool life point of view.

(b) With the help of MCD, show that \(P_Z = \tau_s S_0 \left[\cot(\beta + \tan(\beta))\right]\), where the notations indicate their usual meaning.

7. (a) Prove the following by master line methods for a single point cutting tool.

(i) \(\tan \lambda = -\tan \gamma_s \cos \phi + \tan \gamma_s \sin \phi\)

(ii) \(\tan \gamma_s = \tan \gamma_s \sin \phi - \tan \lambda \cos \phi\)

(iii) \(\phi_s = \phi - \tan^{-1}\left(\frac{\tan \lambda}{\tan \gamma_s}\right)\)
IPE 305
Contd. Q. No. 7

(b) Describe thermal aspects of chip formation for a turning operation. (10)

(c) Define chip reduction coefficient. Derive the following equation for chip reduction coefficient ($\xi$)

$$\xi = e^{(e/2-r)}$$

when the notation indicate their usual meaning. (10)

8. (a) Explain the principle of operation of Ram type Electrical Discharge Machining (EDM) with necessary sketch. What are the functions served by the dielectric fluid in EDM? (12)

(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? (11)

(c) With the help of suitable sketch, explain the following:

(i) Electron Beam Machining

(ii) Thermoforming. (12)
L-3/T-1/IPE  

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA  


Sub: ME 223 (Fluid Mechanics and Machinery)  

Full Marks: 210  

Time : 3 Hours  

The figures in the margin indicate full marks.  

USE SEPARATE SCRIPTS FOR EACH SECTION  

SECTION – A  

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

Make reasonable assumptions in case of any missing data.  

Symbols have their usual meaning.  

1. (a) Derive an expression for pressure variation with altitude under adiabatic condition.  

(b) A multifluid container is connected to a U-tube as shown in Fig. for Q. No. 1(b). For the given specific gravities and fluid column heights, determine the gage and absolute pressure at A. Also determine the height of a mercury column that would create the same pressure at A.  

2. (a) Fill in the blanks:  

(i) Solids applied shear while liquids 

(ii) The concept of bulk modulus is used in the analysis of 

(iii) Droplet formation and free circular jet formation is due to 

(iv) Capillary rise is when forces predominate.  

(v) The vapour pressure over a liquid when other gases are present in addition to the vapour.  

(b) In Fig. for Q. No. 2(b), there are 125 ft of 2-in pipe, 75 ft of 6-in pipe, and 150 ft of 3-in pipe, all cast iron. There are two 90° elbows and an open glove valve (k = 6.3), all threaded. If the exit elevation is zero, what horsepower is extracted by the turbine when the flow rate is 0.16 ft³/s of water at 20°C (ρ = 1.94 slug/ft³ and μ = 2.09 × 10⁻⁵ slug/ft.s)?  

3. (a) Derive the expression of velocity profile for fully developed laminar flow in an inclined circular pipe and then prove that, the average velocity of flow is one-half the maximum velocity.  

(b) Lubricating oil of specific gravity 0.82 and viscosity 12.066 × 10⁻² N.s/m² is pumped at a rate of 0.02 m³/s through a 0.15 m diameter 300 m long pipe. Calculate pressure drop, average shear stress at the wall of the pipe and the power required to maintain flow (a) if the pipe is horizontal; (b) if the pipe is inclined at 15 degrees with the horizontal and the flow is (i) in the upward direction, (ii) in the downward direction.  

Contd ............ P/2
ME 223 (IPE)

4. (a) Derive the Darcy-Weisbach equation for the flow in circular pipes.
   (15)
   (b) A vertical Venturi meter equipped with a differential pressure gage shown in Fig. for Q.
   No. 4(b) is used to measure the flow rate of liquid propane at 10°C (ρ = 514.7 kg/m^3) through
   an 8-cm-diameter vertical pipe. For a discharge coefficient of 0.98, determine the volume
   flow rate of propane through the pipe.
   (15)
   (c) Differentiate between Orifice meter and Venturimeter?
   (5)

SECTION – B

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

5. (a) Show that the law of conservation of mass applied to an incompressible fluid flow
   may be expressed as,
   \[ \nabla \cdot \mathbf{V} = 0 \]
   (12)
   (b) Deduce Euler's equation. Clearly mention the assumptions used in the deduction of
   the equation.
   (15)
   (c) Applying Bernoullis equation, establish a relation between static pressure, stagnation
   pressure and the average velocity of flow.
   (8)

6. (a) In Fig. Q. 6(a), the flowing fluid is water. Neglect losses. If \( p_1 = 170 \text{ kPa} \) and the
   manometer fluid is Mercury, estimate (i) \( p_2 \) and (ii) the flow rate in m^3/h.
   (10)
   ![Figure for Q6.a](image)
   (b) What is undershot water wheel? Show that the maximum efficiency of an undershot
   water wheel is 50%.
   (12)
   (c) Deduce Euler momentum equation for turbines.
   (13)

7. (a) What is hydraulic turbine? Classify hydraulic turbines based on
   (i) Hydraulic action and (ii) Direction of flow of water.
   (5)
   (b) With nest sketches, briefly describe the operation of a Pelton wheel.
   (15)
   (c) Show that the hydraulic efficiency of a Pelton wheel becomes 100 per cent if its
   buckets deflect the water jet exactly through 180°.
   (15)

Contd .......... P/3
8. (a) Why are Pelton wheels not suitable for low head operation?  
(b) What is draft tube? What are its functions?  
(c) A Kaplan turbine produces 45 MW under a head of 28m with an overall efficiency of 90%. If the speed ratio and the flow ratio are 1.6 and 0.5, respectively, find the diameters and the speed of the turbine. Take the hub diameter as 0.35 times the outer diameter.  
(d) Write short notes on (i) cavitation (ii) surge tank.
Equivalent roughness values for new commercial pipes:

<table>
<thead>
<tr>
<th>Material</th>
<th>Roughness, ε</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass, plastic (smooth)</td>
<td>0.000033</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.003-0.03</td>
</tr>
<tr>
<td>Wood stave</td>
<td>0.0016</td>
</tr>
<tr>
<td>Rubber, smoothed</td>
<td>0.000033</td>
</tr>
<tr>
<td>Copper or brass tubing</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>

注：这些值的不确定性为±60%。

Table 2:

<table>
<thead>
<tr>
<th>Loss coefficients K_l of various pipe components for turbulent flow (for use in the relation ΔP = K_l V^2/2g) where V is the average velocity in the pipe that contains the component)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe inlet:</td>
</tr>
<tr>
<td>Reentrant: K_l = 0.80</td>
</tr>
<tr>
<td>(t &lt; D and l = 0.12)</td>
</tr>
<tr>
<td>Sharp-edged: K_l = 0.50</td>
</tr>
<tr>
<td>Well-rounded (dD &gt; 0.2); K_l = 0.03</td>
</tr>
<tr>
<td>Slightly rounded (dD = 0.1); K_l = 0.12</td>
</tr>
<tr>
<td>(see Fig. 8-36)</td>
</tr>
<tr>
<td>Pipe Exit:</td>
</tr>
<tr>
<td>Reentrant: K_l = α</td>
</tr>
<tr>
<td>Sharp-edged: K_l = α</td>
</tr>
<tr>
<td>Rounded: K_l = α</td>
</tr>
</tbody>
</table>

Note: The kinetic energy correction factor is α = 2 for fully developed turbulent flow, and α = 1 for fully developed turbulent flow.
Table 2-4 (Concluded)

Bends and Branches

<table>
<thead>
<tr>
<th>90° smooth bend</th>
<th>90° miter bend (with turn): K_L = 1.1</th>
<th>90° miter bend (with turn): K_L = 0.2</th>
<th>45° threaded elbow: K_L = 0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanged: K_L = 0.3</td>
<td>Threaded: K_L = 0.0</td>
<td>Flanged: K_L = 0.2</td>
<td>Threaded: K_L = 0.4</td>
</tr>
</tbody>
</table>

180° return bend

<table>
<thead>
<tr>
<th>180° return bend</th>
<th>Tee (branch flow): Flanged: K_L = 1.0</th>
<th>Tee (line flow): Flanged: K_L = 0.2</th>
<th>Threaded union: K_L = 0.98</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanged: K_L = 0.2</td>
<td>Threaded: K_L = 1.5</td>
<td>Threaded: K_L = 0.6</td>
<td>Threaded: K_L = 0.08</td>
</tr>
</tbody>
</table>

Valves

<table>
<thead>
<tr>
<th>Valve type</th>
<th>Fully open: K_L = 10</th>
<th>Gate valve, fully open: K_L = 0.2</th>
<th>Angle valve, fully open: K_L = 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanged</td>
<td>Closed: K_L = 0.3</td>
<td>Smooth check valve: K_L = 2</td>
<td>Smooth check valve: K_L = 17</td>
</tr>
<tr>
<td>Threaded</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Values are representative values for loss coefficients. Actual values strongly depend on the design and manufacture of the components and may differ from the given values. Numbers (especially those) must be used in the final design.*

![Chart 1](chart1.png)

Chart 1
SECTION - A

1. (a) What are the assumptions of a perfectly competitive market? Explain them. (10)
   (b) Explain the long run equilibrium of a firm under perfect competition. (15)
   (c) From the following revenue and cost functions, calculate the profit maximizing level of output and maximum profit.
   \[ R = 100Q - Q^2 \]
   \[ C = \frac{1}{3}Q^3 - 7Q^2 + 111Q + 90 \]

2. (a) When does a firm emerge as a monopolist? (10)
   (b) Explain the short run equilibrium of a firm under monopoly. (10)
   (c) What is the relation among marginal revenue (MR), price (P) and price elasticity of demand (e). (10)
   (d) What are the conditions of equilibrium of a firm under monopoly? (5)

3. (a) A manufacturer has a fixed cost of $40,000 and a variable cost $1.60 per unit made and sold. Selling price is $2 per unit. (10)
   (i) Find the revenue, cost and profit functions using q for the number of units.
   (ii) Compute profit if 150,000 units are made and sold.
   (iii) Find the break-even quantity.
   (iv) Construct the break-even chart. Label the cost and revenue lines, the fixed cost line and the break-even point.
   (b) Complete the following table and sketch the graph explaining the relations among the various short run cost curve. (15)

<table>
<thead>
<tr>
<th>Quantity of output</th>
<th>Total fixed cost</th>
<th>Total variable cost</th>
<th>Total cost</th>
<th>Average fixed cost</th>
<th>Average variable cost</th>
<th>Average total cost</th>
<th>Marginal cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>70</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>70</td>
<td>75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>70</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   (c) Define fixed cost and variable cost. (10)
HUM 277

4.  (a) What do you understand by MRTS? Explain any three characteristics of an isoquant. (10)
   (b) Complete the following table and plot the total product (TP), average product (AP) and marginal product (MP) of labour. (15)

<table>
<thead>
<tr>
<th>Number of workers</th>
<th>Total product (TP)</th>
<th>Average product (AP)</th>
<th>Marginal product (MP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) Explain producer's equilibrium with the help of iso-cost and iso-quant lines. (10)

SECTION-B
There are FOUR questions in this section. Answer any THREE questions.

5.  (a) What is meant by production possibility frontier (PPF)? How does PPF of a country indicate efficient resource allocation? Explain. (20)
   (b) Illustrate the following applications of PPF:
       (i) Choice between public goods and private goods.
       (ii) Choice between necessities and luxuries.
       (iii) Choice between current consumption goods and investment. (15)

6.  (a) What are the assumptions of cardinal utility theory? Discuss. (5)
   (b) Mathematically derive the cardinal theory of utility maximization. (15)
   (c) Distinguish between the concepts of 'change in quantity demanded' and 'change in demand'. Explain graphically the above changes with reference to the change in prices of substitute and complementary commodities. (10)
   (d) Discuss how the prices of other commodities affect the demand for a commodity. (5)

7.  (a) Explain the concept of supply function. (5)
   (b) Discuss the factors that affect the supply of a commodity in general. (10)
(c) Calculate the equilibrium price and quantity from the following demand and supply functions

\[ QD_x = 1200 - 5P_x \]
\[ QS_x = -500 + 12P_x \]

What will happen to the equilibrium price and quantity if government provides a subsidy of TK. 10 per unit? Graphically show the results.

(d) Explain the concept of cross elasticity of demand with suitable examples.

8. (a) What do you understand by localization of industries? What are the causes of localization of industries?

(b) Explain the advantages and disadvantages of localization of industries.

(c) What do you understand by division of labour? Explain different types of division of labour.