

**SECTION – A**

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

1. (a) What are the usual phases of an operations research (OR) study? Explain each phase with a suitable example. (24<sup>2</sup>/<sub>3</sub>)
- (b) What are the assumptions of linear programming (LP)? Explain with examples. (12)
- (c) Discuss the concepts of slack, surplus and artificial variables in linear programming (LP). (10)
  
2. (a) Answer **True** or **False** for each of the following statements about LP problems and justify your answer. (20)
  - (i) Although any CPF (corner point feasible) solution can be chosen to be the initial CPF solution, the simplex method always chooses the origin.
  - (ii) An LP problem cannot handle variables that could be negative.
  - (iii) If there is no leaving variable in a column selected for an entering basic variable, then the objective function is unbounded.
  - (iv) If a maximization problem in standard form and its dual have feasible solutions, then both problems have optimal solutions.
  - (v) If the final tableau of the simplex method applied to LP has a nonbasic variable with a coefficient of 0 in row 0, then the problem has multiple solutions.
- (b) Explain what you do if you have two or more basic variables tie for being the leaving basic variables in step 2 of an iteration of the simplex method. (6)
- (c) Consider the problem (20<sup>2</sup>/<sub>3</sub>)

$$\text{Max } Z = x_1 + 3x_2$$

s.t.

$$3x_1 + x_2 \leq 3$$

$$x_1 - x_2 \geq 2$$

$$x_1 \geq 0, x_2 \geq 0$$

Use the Big M method to show that there is no feasible solution to this problem.

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3. (a) Suppose that the following constraints have been provided for a linear programming model. (20<sup>2</sup>/<sub>3</sub>)

$$\begin{aligned} -x_1 + 3x_2 &\leq 30 \\ -3x_1 + x_2 &\leq 30 \\ x_1 \geq 0, x_2 &\geq 0 \end{aligned}$$

- (i) Demonstrate that the feasible region is unbounded.
- (ii) If the objective is to maximize  $Z = -x_1 + x_2$ , does the model have an optimal solution? If so, find it. If not, explain why not.
- (iii) Repeat part (ii) when the objective is to maximize  $Z = x_1 - x_2$ .
- (iv) For objective functions where this model has no optimal solution, does this mean that there are no good solutions according to the model? Explain.

(b) Consider the following simplex tableaux that result from a maximization linear program (LP) with decision variables  $x_1$  and  $x_2$ , slack variable  $x_3$ , surplus variable  $x_4$ , and artificial variable  $x_5$ . (26)

(i)

	Z	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	RHS
Z	1	0	1	-2	0	3	4
$x_1$	0	1	2	3	0	4	6
$x_4$	0	0	3	4	1	5	8

(ii)

	Z	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	RHS
Z	1	0	1	2	3	0	4
$x_1$	0	1	-2	3	4	0	6
$x_5$	0	0	-3	4	5	1	8

(iii)

	Z	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	RHS
Z	1	0	-1	-2	0	3	4
$x_1$	0	1	-2	3	0	4	6
$x_4$	0	0	-3	-4	1	5	8

(iv)

	Z	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	RHS
Z	1	0	0	2	0	3	4
$x_1$	0	1	0	3	0	4	6
$x_2$	0	0	1	4	1	5	8

Determine whether the original LP is (1) infeasible, (2) unbounded, (3) degenerate, or (4) has multiple optimal solutions. Briefly justify your answer. Also, if the LP has multiple optimal solutions, find all of them.

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4. Consider the following problem

(22 2/3)

$$\text{Max } Z = -5x_1 + 5x_2 + 13x_3$$

s.t.

$$-x_1 + x_2 + 3x_3 \leq 20$$

$$12x_1 + 4x_2 + 10x_3 \leq 90$$

$$x_1 \geq 0, x_2 \geq 0, 3x_3 \geq 0.$$

If we let  $x_4$  and  $x_5$  be the slack variables for the respective constraints, the simplex method yields the following final set of equations:

$$(0) \quad Z \quad + 2x_3 \quad + 5x_4 = 100$$

$$(1) \quad -x_1 + x_2 + 3x_3 + x_4 = 20$$

$$(2) \quad 16x_1 - 2x_3 - 4x_4 + x_5 = 10$$

Now you are to conduct sensitivity analysis by *independently* investigating each of the following six changes in the original model. For each change, use the sensitivity analysis procedure to revise this set of equations (in tableau form) and convert it to proper form from Gaussian elimination for identifying and evaluating the current basic solution. Then test this solution for feasibility and for optimality. (Do not reoptimize).

(i) Change the right-hand side of constraint 1 to  $b_1 = 30$

(ii) Change the right-hand side of constraint 2 to  $b_2 = 70$

(iii) Change the right-hand sides to

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 100 \end{bmatrix}$$

(iv) Change the coefficient of  $x_3$  in the objective function to  $c_3 = 8$

(v) Introduce a new variable  $x_6$  with coefficients

$$\begin{bmatrix} c_6 \\ a_{16} \\ a_{26} \end{bmatrix} = \begin{bmatrix} 10 \\ 3 \\ 5 \end{bmatrix}$$

(vi) Introduce a new constraint  $2x_1 + 3x_2 + 5x_3 \leq 50$ .

(b) Consider the problem

(24)

$$\text{Max } Z = 5x_1 + 7x_2$$

s.t.

$$x_1 + 2x_2 \leq 4$$

$$x_1 + x_2 \leq 3$$

$$x_1 \geq 0, x_2 \geq 0$$

(i) Find the dual to this LP.

(ii) Exhibit the BF solutions of the simplex method applied to the primal along with the corresponding complementary basic solutions to the dual. You may use the simplex method or graphical methods. (You may assume that the simplex method moves along CPF solutions  $(0,0) \rightarrow (0,2) \rightarrow (2,1)$ .)

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**SECTION – B**

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

5. (a) Compare the Transportation and Assignment problems. (5<sup>2</sup>/<sub>3</sub>)

(b) State the various methods of finding the Basic Feasible solution in Transportation problem and compare them. (15)

(c) The Versatech Corporation has decided to produce three new products. Five branch plants now have excess product capacity. The unit manufacturing cost of the first product would be \$31, \$29, \$32, \$28 and \$29 in Plants 1, 2, 3, 4 and 5 respectively. The unit manufacturing cost of the second product would be \$45, \$41, \$46, \$42 and \$43 in Plants 1, 2, 3, 4 and 5 respectively. The unit manufacturing cost of the third product would be \$38, \$35 and \$40 in Plants 1, 2 and 3 respectively, whereas Plants 4 and 5 do not have the capability for producing this product. Sales forecasts indicate that 600, 1,000 and 800 units of products 1, 2 and 3 respectively, should be produced per day. Plants 1, 2, 3, 4 and 5 have the capacity to produce 400, 600, 400, 600 and 1,000 units daily respectively, regardless of the product or combination of products involved. Assume that any plant having the capability and capacity to produce them can produce any combination of the products in any quantity. (26)

Management wishes to know how to allocate the new products to the plants to minimize total manufacturing cost.

- (i) Formulate this problem as a *transportation problem* by constructing the appropriate parameter table.
- (ii) Obtain an optimal solution.

6. (a) In a 2×2 two-person, zero-sum game (that is, where  $m = n = 2$ ) with payoff matrix (16<sup>2</sup>/<sub>3</sub>)

$$\begin{pmatrix} e_{11} & e_{12} \\ e_{21} & e_{22} \end{pmatrix}$$

derive explicit expressions for the value,  $v$  of the game and the optimal strategies in terms of the elements of the payoff matrix.

(b) Consider the following parlor game between two players. It begins when a referee flips a coin, notes whether it comes up heads or tails, and then show this result to player 1 only. Player 1 may then (1) pass and thereby pay \$5 to player 2 or (2) bet. If player 1 passes, the game is terminated. However, if he bets, the game continues, in which case player 2 may then either (1) pass and thereby pay \$5 to player 1 or (2) call. If player 2 calls, the referee then shows him the coin; if it came up heads, player 2 pay \$10 to player 1; if it came up tails, player 2 receives \$10 from player 1. (30)

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**Contd .... Q. No. 6(b)**

- (i) Give the pure strategies for each player.
- (ii) Develop the payoff table for this game, using expected values for the entries when necessary. Then identify and eliminate any dominated strategies.
- (iii) Show that none of the entries in the resulting payoff table are a saddle point. Then explain why any fixed choice of a pure strategy for each of the two players must be an unstable solution, so mixed strategies should be used instead.
- (iv) Write an expression for the expected payoff in terms of the probabilities of the two players using their respective pure strategies. Then show what this expression reduces to for the following three cases: (1) Player 2 definitely uses his first strategy, (2) Player 2 definitely uses his second strategy, (3) Player 2 assigns equal probabilities to using his two strategies.

7. (a) What are the three primary determinants of computational difficulty for an integer programming (IP) problem? (3)

(b) Use the branch and bound algorithm to solve the following MIP problem interactively. (28<sup>2</sup>/<sub>3</sub>)

$$MaxZ = 5x_1 + 4x_2 + 4x_3 + 3x_4$$

s.t.

$$x_1 + 3x_2 + 2x_3 + x_4 \leq 10$$

$$5x_1 + x_2 + 3x_3 + 2x_4 \leq 15$$

$$x_1 + x_2 + x_3 + x_4 \leq 6$$

$$x_j \geq 0, \quad \text{for } j = 1, 2, 3, 4$$

$$x_j \text{ is integer, for } j = 1, 2, 3$$

(c) 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. (15)

- (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.
- (iv) Find the expected waiting time (including service) for those cars that stay.

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8. (a) Discuss the characteristics of the dynamic programming problems. (6)
- (b) List three methods of 1-dimensional unconstrained optimization that solve  $f'(x) = 0$  and discuss one of them. (9)
- (c) What is LICQ? State the first-order necessary conditions for constrained optimization with inequality constraints. (8)
- (d) The problem of minimizing  $f(x) = 2x_1^2 + 2x_1x_2 + x_2^2 - 10x_1 - 4x_2$  subject to  $3x_1 + x_2 \leq 13$  is known to have a solution. Use the KKT conditions to find it. You should deal with the issue of whether a constraint qualification holds. (23  $\frac{2}{3}$ )
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**SECTION – A**

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

1. (a) Draw a single-point turning tool and visualize its different rake angles, clearance angles and cutting edge angle in ASA and ORS system. (7)
- (b) Derive simple equations, using proper diagrams, for conversion of the clearance angles of single-point turning tool from (16)
  - (i) ASA system to ORS system and (ii) ORS to ASA system.
- (c) Determine the values of side rake ( $\gamma_x$ ) back rake ( $\gamma_y$ ) and maximum rake ( $\gamma_m$ ) angles of the single-point turning tool whose geometry is specified in ORS as  $10^\circ, 0^\circ, 5^\circ, 8^\circ, 20^\circ, 90^\circ, 0^\circ$  (mm). (12)
2. (a) Classify the types of chips and also state under what conditions of machining those different types of chips form. (7)
- (b) With the help of a suitable diagram explain what is meant by shear strain. Based on that diagram derive an expression to visualize the dependence of shear strain on tool rake angle, chip velocity and cutting velocity in turning. (12)
- (c) What will be the value of average shear strain in case of orthogonal turning of a ductile material, if (i) feed = 0.24 mm/rev, (ii) principal cutting edged angle =  $90^\circ$ , (iii) orthogonal rake of the tool =  $12^\circ$  and (iv) chip thickness = 0.6 mm. (10)
- (d) What properties should a cutting tool material essentially possess and why? (6)
3. (a) Draw a Merchant's circle diagram (MCD) and visualize in it the various cutting force components that arise during orthogonal turning. (7)
- (b) Based on the relevant machining condition and type of work material, deduce the following expression. (14)
 
$$P_z = \tau_s S_0 t [\cot \beta + \tan(\epsilon - \beta)]$$

Where the notations indicate their usual meanings.
- (c) During the turning of a steel rod of 150 mm diameter, at a speed of 650 rpm, feed of 0.32 mm/rev. and 4.0 mm depth of cut by a tool of geometry  $0^\circ, -12^\circ, 8^\circ, 7^\circ, 30^\circ, 60^\circ, 0^\circ$  (mm), it was observed that  $P_z = 1000$  N and  $P_y = 200$  N and chip thickness = 0.80 mm. (14)
  - Determine (i) Frictional force (ii) Normal force (iii) Co-efficient of friction
  - (iv) Shear force (v) Dynamic yield shear strength

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4. (a) Show schematically the general pattern (geometry) of wear that develops at the rake surface and the clearance (or flank) surfaces of cutting tool. State the difference among abrasion wear, adhesion wear and diffusion wear in respect of cutting tool wear. (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: (15)
- (i) Lamination process
- (ii) Thermoforming process
- (c) With the help of diagram, discuss some of the defects that occur in plastic injection molding and methods to eliminate them. (10)

**SECTION - B**

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

5. (a) Explain the working principle of Abrasive Jet Machining (AJM) process with neat sketches. Do you think SOD affects machining accuracy? Justify your answer with appropriate explanations. (20)
- (b) Describe your thoughts regarding the laser-beam machining of nonmetallic materials. Give several applications, including their advantageous as compared to other processes. (10)
- (c) It was stated that graphite is the preferred material for EDM tooling. Would graphite be suitable for wire EDM? (5)
6. (a) Briefly discuss the economics of non-conventional machining process over conventional machining. (7)
- (b) Briefly explain the working principles of electrochemical grinding with appropriate figures. How does electrochemical grinding differs from electrochemical machining? (20)
- (c) What are the design considerations for an electron beam machining process? Explain in brief. (8)
7. (a) What do you mean by 'grindability' and 'grinding ratio'? Describe the working principle of surface grinding operation. (17)
- (b) Mention some design considerations for drilling, reaming and tapping operations. (10)
- (c) Discuss the slab milling and face milling operation with appropriate sketches. (8)
8. (a) Describe the following operations with appropriate figures. (16)
- (i) Counterboring (ii) Form turning (iii) Grooving (iv) Knurling
- (b) Briefly describe the up-milling and down milling process with appropriate sketches. (10)
- (c) Sketch different view of a drill tool and mention different elements and angles. (9)
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L-3/T-1/IPE

Date : 01/03/2012

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2010-2011

Sub : **IPE 301** (Measurement, Instrumentation and Control)

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**.

1. (a) Explain fundamental triangle of screw thread. (05)  
(b) Describe briefly the working principle of Autocollimator. (10)  
(c) Discuss the functions of different types of calipers. (10)  
(d) What are the elements of gears which are checked for accuracy? (10)
  
2. (a) Explain involute function of a gear. Show the relationship between involute function and pressure angle. (15)  
(b) Prove that, for Effective Diameter measurement in Two Wire Method, P Value =  $0.866p - d$  for metric thread, where  $p$  = pitch of the thread and  $d$  = diameter of each wire. What will be the best wire diameter for 16 threads per inch and  $60^\circ$  thread angle? (20)
  
3. (a) How many slots are needed to measure a minimum angular displacement of  $11^\circ$  in incremental encoders? (03)  
(b) Describe an instrumentation amplifier and calculate the output voltage. (12)  
(c) Explain the working principle of 4-bit Analog-to-digital convertor with necessary sketches. (20)
  
4. (a) What are the differences between standard gauge and limit gauge? (06)  
(b) A hole and mating shaft have a nominal assembly size of 60 mm. The assembly is to have a maximum total interference of 0.04 cm and a minimum total interference of 0.01 cm. Determine the specifications of the parts (a) for 100% interchangeability and (b) for statistical average interchangeability with necessary sketch. Design the GO and NOT GO gauges for the shaft and hole using unilateral system. (29)

**SECTION – B**

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

5. (a) For a rotational translational system derive the differential equation relating system input and output. (15)  
(b) What do you understand by “linearity” in a system? Explain the concept of linearity with a suitable example. (10)

Contd ..... P/2

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Contd ... Q. No. 5

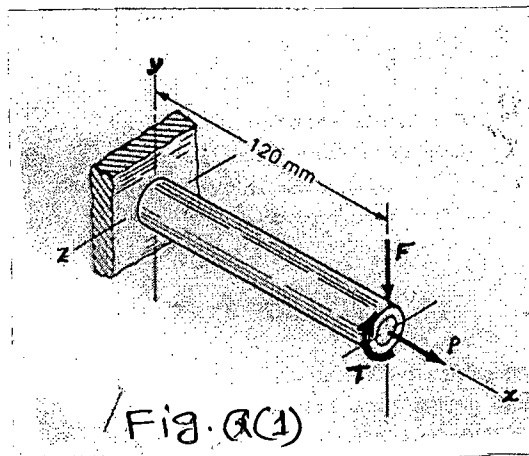
- (c) A proportional controller is used to control the height of the water in a tank where the water level can vary from zero to 4.0 m. The required height of water is 3.5 m and the controller is to fully close a valve when the water rises to 3.9 m and fully open it when water falls to 3.1 m. What proportional band and transfer function will be required? **(10)**
6. (a) What are the basic building blocks of an Electrical system? Derive separate expressions for each building block relating the potential difference across the building block and the input voltage V. **(15)**
- (b) Explain the working principle of a PD (Proportional plus Derivative) controller and how it differs from Derivative controller. **(15)**
- Assume that, the controller has a set point of 50%,  $K_p = 4$  and  $K_D = 0.4s$ . What will be the controller output for PD controller (i) Initially and (ii) 2 sec after the error begins to change from zero at the rate of 1.2% /sec? Where the symbols have usual meaning.
- (c) What is the difference between natural response and forced response? **(5)**
7. (a) Derive the system equation for first order dynamic systems for a step input taking into account both the transient and steady state responses. From the system equations derive the expression for "Time Constant" and "Steady State Gain". **(15)**
- (b) Consider a system with input V and output  $V_c$  with, **(15)**
- $$V = LC \frac{dv_c^2}{dt^2} + RC \frac{dv_c}{dt} - 20v_c$$
- a. Derive the transfer function of the above system with negative feedback transfer function of  $H(s) = 5$ .
- b. Find the output as a function of time for unit step input. Where  $L = \frac{1}{2}$ ,  $C = 2$ ,  $R = 2$ .
- (c) Explain the term "Lag" and "Steady State Error". **(5)**
8. (a) What are the advantages of closed loop system over open loop system? **(5)**
- (b) Describe the basic laws that govern thermocouple behavior. **(15)**
- (c) Explain the working principle of piezoelectric sensors. Show that voltage is proportional to the applied pressure. **(15)**
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**SECTION – A**

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

The reference book “Fundamentals of Mechanical Component Design” by K.S. Edwords and R.B. McKee is to be supplied

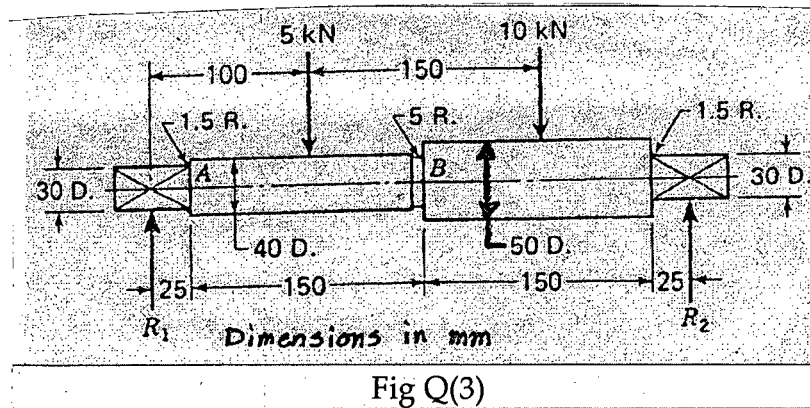
1. Fig Q (1) shows a cantilevered tube to be made of 2011 Tempered T8 aluminium. Find cross-sectional dimension for the tube based upon a bending load  $F = 0.8$  kN, an axial tension  $P = 7.2$  kN, and a torsional load  $T = 38$  N.m. The load factors of safety are to be  $FS_F = 2.20$ ,  $FS_P = 1.30$  and  $FS_T = 1.90$ . Use a strength safety factor  $FS_S = 1.50$ . (35)



2. A plate of width 1.4 m and length 2.8 m is required to support a tensile force of 4.0 MN in the 2.8 m direction. Inspection procedures detect through- thickness edge cracks larger than 2.7 mm. The two Ti – 6AL -4V alloys in Table 7.1 of the reference book are being considered for this application, for which the safety factor must be 1.3 and minimum weight is important. Which alloy should be used? (35)
3. Fig Q(3) shows a rotating shaft loaded by two bending forces having the bearing reactions  $R_1$  and  $R_2$ . Point A is a shaft shoulder which is required for positioning the left-hand bearing. The grinding-relief groove at B is 2.5 mm deep. The surface AB is ground, but the groove is machined. The material of the shaft is a steel and tempered to  $S_{ut} = 1300$  MPa. Determine the factor of safety corresponding to a life of  $0.35 \times 10^6$  revolutions of the shaft. (35)

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**Contd ... Q. No. 3.**



4. Design a tension bar for maximum factor of safety with following specifications: (35)

- |  |   |                             |
|--|---|-----------------------------|
| $D_{\max} = 30 \text{ mm}$                         | $130 \leq L \leq 230 \text{ mm}$            |                             |
| $\delta_{\max} = 0.1 \text{ mm (Under } F_{\max})$ |   | $M_{\max} = 1.0 \text{ kg}$ |
| $F_{\max} = 85 \text{ kN}$                         | $F_{\min} = 0$                              |                             |
| $S_{\max} = 13.00$                                 | $S_{\text{fix}} = 1.5$                      |                             |
| $k = 3.5 \text{ E} + 08 \text{ N/m}$               | $\rho = 7.75 \text{ E} + 03 \text{ kg/m}^3$ |                             |
| $S_y = 490 \text{ MPa}$                            | $S_{\text{ut}} = 586 \text{ MPa}$           | $E = 207 \text{ GPa}$       |

Use 1040 CR steel which is available in 5-mm increments. The final solution should include all design parameters and the total manufacturing cost.

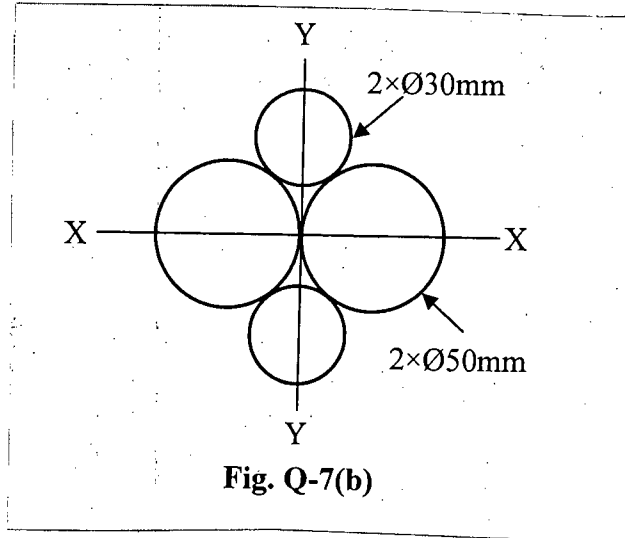
**SECTION – B**

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

5. (a) Explain the term functional decomposition. (03)
- (b) Discuss the pros and cons for applying QFD. (10)
- (c) Compare different type customer need gathering methods. (10)
- (d) Describe the functions of product manager, industrial designer and detailer in design team. (12)
  
6. (a) Compare functional matrix and project matrix structure of design teams? (06)
- (b) Prepare a black box model for stapler machine. (06)
- (c) What are the reasons for adopting concurrent engineering? (09)
- (d) Discuss the steps to establish a project plan. (14)

**IPE 303**

7. (a) Explain the terms all function, assumed function and one time function. (09)
- (b) A column made by welding two 50 mm and two 30 mm steel rods together with both end fixed as shown in Fig. Q 7(b). Find the load supported by a length of 2.2 m.  $E = 210 \text{ E} + 09 \text{ Pa}$ ,  $S_y = 620 \text{ E} + 06 \text{ Pa}$ . (26)



8. Fig. Q(8) shows a stationary torsion bar spring, loaded statistically by the forces  $F = 35 \text{ N}$ , and by a torque  $T$  which varies from 0 to 8 N.m. The material is AISI 4130 steel. The ends of the spring are ground up to the shoulders. The 2.5 m body of the spring has a hot rolled surface finish. The geometric stress concentration factors at the shoulders 1.68 for bending and 1.42 for torsion. Determine a suitable diameter  $d$ , using factor of safety of at lest 1.80. [Dimensions in meters] (35)

