Birla Institute of Technology & Science, Pilani
Hyderabad Campus

FIRST SEMESTER 2022 - 2023
COMPREHENSIVE EXAMINATION (Regular)
(Open Book)

Course No: CE F411 **Date:** 26-12-2022
Course Name: Operations Research for Engineers **Weightage:** 40 %
Max. Marks: 40 **Time:** 02.00 pm - 05.00 pm

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1) Define "hypervolume" and "generational distance" performance metric in multiobjective optimization. Determine the hypervolume of the following pareto optimal solution using the reference point as f_1=11 and f_2=10. **(6 M)**

Solution ID	f_1	f_2
1	1.2	7.8
2	2.8	5.1
3	4.0	2.8
4	7.0	2.2
5	8.4	1.2

2) Assume that you are the president of ASCE student chapter of BITS Pilani, Hyderabad campus. Your team has planned on conducting a concrete bowling event and for that event, you need to decide upon the best mix design for making the bowling balls as well as the mix. So, you need to have 12 bowling balls of 20 cm diameter and 7 bowling pins. Assume, bowling pins are of rectangle in shape and of 38 X 38 X 13 cm. You need to come up with the optimal mix proportion based on the cost of the material and compressive strength. The cost of each material used is mentioned in table below. To ease your work, you have decided to go with Self Compacting Concrete. You have approached a chemical industry sponsor for your event, who has agreed to provide you super plasticizer free of cost. To choose the optimal mix, you have decided to perform multi-objective optimization between cost and

compressive strength. After performing 10 iterations using a popular meta-heuristic optimization algorithm, you have got the below mentioned mix proportions and their corresponding compressive strength as shown below. Divide all the obtained mixes (A to H) into subsequent pareto optimal solution sets of cost and compressive strength into various pareto fronts. **(6 M)**

Material	Cost (Rs per kg)
Cement	8
Fly ash	0.75
GGBS	3.5
Coarse Aggregate	0.85
Fine Aggregate	3.5

Mix	Cement (Kg/m^3)	GGBS (Kg/m^3)	Fly Ash (Kg/m^3)	Water (Kg/m^3)	Super plasticizer (ml/m^3)	Coarse Aggregate (Kg/m^3)	Fine Aggregate (Kg/m^3)	Concrete compressive strength (MPa)
A	425	106.3	0	153.5	16.5	852.1	887.1	60.29
B	315	137	0	145	5.9	1130	745	81.75
C	397	17.2	158	167	20.8	967	633	55.65
D	165	0	143.6	163.8	0	1005.6	900.9	26.2
E	173.8	93.4	159.9	172.3	9.7	1007.2	746.6	37.81
F	149.5	236	0	175.8	12.6	846.8	892.7	32.96
G	139.7	163.9	127.7	236.7	5.8	868.6	655.6	35.23
H	159.1	186.7	0	175.6	11.3	989.6	788.9	32.77

3) In the SBI bank at our campus, one staff deals with withdrawals and another staff deals with deposits. The service time of both these is exponentially distributed with average 3 minutes per customer. The arrivals of both the withdrawers and the depositors are in Poisson pattern with average arrival rate of 14 per hour and 16 per hour respectively.
    a) Find the average waiting time in the system for withdrawers and depositors.
    b) Let both the staff handle both withdrawals and deposits. If arrivals are pooled, what will be the effect in waiting time in the system for a customer in comparison to the earlier case. **(6 M)**

4) Solve the following problem by geometric programming and determine the optimal values of a, b & c. **(6 M)**

$$Minimize \quad z = \frac{5a}{bc^2} + \frac{1}{a^2c} + 10b^3 + \frac{2b}{ac^3}$$

$$a, b, c > 0$$

5) Solve the following problem using Lagrangian Multiplier method. **(6 M)**

$$Minimize \quad \frac{k}{x_1 x_2^{\,2}}$$

subject to

$$x_1^{\,2} + x_2^{\,2} = a^2$$

$$x_1, x_2 \geq 0$$

6) Minimize $x_1^2 + x_2^2 + x_3^2 - 4x_1 - 6x_2$

Subject to

$$x_1 + x_2 \leq 2$$

$$2x_1 + 3x_2 \leq 12$$

using Kuhn-Tucker conditions. **(5 M)**

7) Consider the primal linear problem

Maximize $6x_1 + x_2$

Subject to

$$x_1 \leq 1$$

$$2x_1 + x_2 \leq 4$$

$$x_1, x_2 \geq 0$$

State the dual of this problem. Solve both primal and dual to verify the duality principle. **(5 M)**

ALL THE BEST