Date : .....

A CONSOLIDATED QUESTION PAPER-CUM-ANSWER BOOKLET

IMS™ (INSTITUTE OF MATHEMATICAL SCIENCES)

MAINS TEST SERIES-2020

(JULY *to* DEC.-2020)

IAS/IFoS

MATHEMATICS

Under the guidance *of* K. Venkanna

ALGEBRA, REAL ANALYSIS AND COMPLEX ANALYSIS & LPP

TEST CODE: TEST-2: IAS(M)/19-JULY.-2020

Time: 3 Hours **Maximum Marks: 250**

INSTRUCTIONS

1. This question paper-cum-answer booklet has 54 pages and has **38 PART/SUBPART** questions. Please ensure that the copy of the question paper-cum-answer booklet you have received contains all the questions.
2. Write your Name, Roll Number, Name of the Test Centre and Medium in the appropriate space provided on the right side.
3. A consolidated Question Paper-cum-Answer Booklet, having space below each part/sub part of a question shall be provided to them for writing the answers. Candidates shall be required to attempt answer to the part/sub-part of a question strictly within the pre-defined space. Any attempt outside the pre-defined space shall not be evaluated. ''
4. Answer must be written in the medium specified in the admission Certificate issued to you, which must be stated clearly on the right side. No marks will be given for the answers written in a medium other than that specified in the Admission Certificate.
5. Candidates should attempt Question Nos. 1 and 5, which are compulsory, and any **THREE** of the remaining questions selecting at least **ONE** question from each Section.
6. The number of marks carried by each question is indicated at the end of the question. Assume suitable data if considered necessary and indicate the same clearly.
7. Symbols/notations carry their usual meanings, unless otherwise indicated.
8. All questions carry equal marks.
9. All answers must be written in blue/black ink only. Sketch pen, pencil or ink of any other colour should not be used.
10. All rough work should be done in the space provided and scored out finally.
11. The candidate should respect the instructions given by the invigilator.
12. The question paper-cum-answer booklet must be returned in its entirety to the invigilator before leaving the examination hall. Do not remove any page from this booklet.

READ INSTRUCTIONS ON THE LEFT SIDE OF THIS PAGE CAREFULLY

Name

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Medium

Do not write your Roll Number or Name anywhere else in this Question Paper-cum-Answer Booklet.

I have read all the instructions and shall abide by them

Signature of the Candidate

I have verified the information filled by the candidate above

Signature of the invigilator

IMPORTANT NOTE:
Whenever a question is being attempted, all its parts/ sub-parts must be attempted contiguously. This means that before moving on to the next question to be attempted, candidates must finish attempting all parts/ sub-parts of the previous question attempted. This is to be strictly followed. Pages left blank in the answer-book are to be clearly struck out in ink. Any answers that follow pages left blank may not be given credit.

P.T.O.

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INDEX TABLE

QUESTION	No.	PAGE NO.	MAX. MARKS	MARKS OBTAINED
1	(a)			
	(b)			
	(c)			
	(d)			
	(e)			
2	(a)			
	(b)			
	(c)			
	(d)			
3	(a)			
	(b)			
	(c)			
	(d)			
4	(a)			
	(b)			
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	(e)			
6	(a)			
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7	(a)			
	(b)			
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	(d)			
8	(a)			
	(b)			
	(c)			
	(d)			
Total Marks				

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SECTION – A

1. (a) Which of the following multiplication tables defined on the set G = {a, b, c, d} form a group ? Support your answer in each case.

(i)

o	a	b	c	d
a	a	c	d	a
b	b	b	c	d
c	c	d	a	b
d	d	a	b	c

(ii)

o	a	b	c	d
a	a	b	c	d
b	b	a	d	c
c	c	d	a	b
d	d	c	b	a

(ii)

o	a	b	c	d
a	a	b	c	d
b	b	c	d	a
c	c	d	a	b
d	d	a	b	c

(iv)

o	a	b	c	d
a	a	b	c	d
b	b	a	c	d
c	c	b	a	d
d	d	d	b	c

[10]

1. (b) Show that the ring $\mathbb{Z}_p$ of integers modulo p is a field if and only if p is prime. **[10]**

1. (c) Show that the function $f(x) = 1/x$, $x > 0$ is continuous in $(0, 1)$ but not uniformly continuous. **[10]**

1. (d) Prove that the function f defined by

$$f(z)=\begin{cases}\dfrac{z^5}{|z|^4}, z\neq 0\\ 0,\ z=0\end{cases}$$ is not differentiable at z = 0 **[10]**

1. (e) A manufacturer has three machines I, II and III installed in his factory. Machines I and II are capable of being operated for at the most 12 hours, whereas machine III must be operated at least for 5 hours a day. He produces only two items M and N each requiring the use of all the three machines. The number of hours required for producing 1 unit of each of the items M and N on the three machines are given in the following table :

Item	Number of hours required on machines		
	I	II	II
M	1	2	1
N	2	1	1.25

He makes a profit of Rs. 600 and Rs. 400 on item M and N respectively. How many of each item should he produce so as to maximize his profit assuming that he can sell all the items that he produces ? What will be the maximum profit ?

[10]

2. (a) (i) In S_3 give an example of two elements x, y such that $(x.y)^2 \neq x^2.y^2$.

(ii) Construct a multiplication table for $Z_2[i]$, the ring of Gaussian integers modulo 2. Is this ring a field? Is it an integral domain? **[18]**

2. (b) Find three elements σ in S_9 with the property that $\sigma^3 = (157)(283)(469)$. **[06]**

2. (c) Test the convergence and absolute convergence of the series $\sum_{n=1}^{\infty}(-1)^{n+1}\frac{n}{n^2+1}$. **[10]**

2. (d) Evaluate $\int_0^{2\pi} \frac{d\theta}{\left(a+b\cos^2\theta\right)^2}$, where a > b > 0. **[16]**

3. (a) Let $z = \cos\theta + i\sin\theta$ be in T where $\theta \in Q$. Prove that the order of z is infinite. **[10]**

3. (b) Examine the convergence of

$$\int \frac{\log x}{\sqrt{2\quad x}}\,dx$$

[08]

3. (c) f (x) is defined as follows:

$$f(x)=\begin{cases}\frac{1}{2}(b^2-a^2) & for \quad 0<x<a\\ \frac{1}{2}b^2-\frac{x^2}{6}-\frac{a^3}{3x} & for \quad a<x<b\\ \frac{1}{3}\frac{b^3-a^3}{x} & for \quad x>b\end{cases}$$

Prove that f (x) and $f'(x)$ are continuous but $f''(x)$ is discontinuous. **[14]**

3. (d) Determine an optimal transportation programme so that the transportation cost of 340 tons of a certain type of material from three factories F_1, F_2, F_3 to five warehouses W_1, W_2, W_3, W_4, W_5 is minimized. The five warehouses must receive 40 tons, 50 tons, 70 tons, 90 tons and 90 tons respectively. The availability of the material at F_1, F_2, F_3 is 100 tons, 120 tons, 120 tons respectively. The transportation costs per ton from factories to warehouses are given in the table below:

	W_1	W_2	W_3	W_4	W_5
F_1	4	1	2	6	9
F_2	6	4	3	5	7
F_3	5	2	6	4	8

Use Vogel's approximation method to obtain the initial basic feasible solution. **[18]**

4. (a) Let $R = \left\{ \begin{bmatrix} \alpha & \beta \\ -\overline{\beta} & \overline{\alpha} \end{bmatrix} \in M_2(\mathbb{C}) \mid \overline{\alpha}, \overline{\beta} \text{ denote the conjugates of } \alpha, \beta \right\}$.

Define addition + and multiplication • in R by usual matrix addition and matrix multiplication. Show that R is a division ring but not a field. **[14]**

4. (b) (i) Define $\{x_n\}$ by $x_1 = 5$ and $x_{n+1} = \sqrt{4 + x_n}$ for $n > 1$. Show that the sequence converges to $\frac{1+\sqrt{17}}{2}$

(ii) Test the Riemann integrability of the function f defined by

$$f(x) = \begin{cases} 0 & \text{when x is rational} \\ 1 & \text{when x is irrational} \end{cases}$$

on the interval [0, 1]. **[16]**

4. (c) Expand the function $f(z)=\dfrac{2z^2+11z}{(z+1)(z+4)}$ in a Laurent's series valid for $2 < z < 3$.

[10]

4. (d) How many basic solutions are there in the following linearly independent set of equations? Find all of them.

$2x_1 - x_2 + 3x_3 + x_4 = 6$

$4x_1 - 2x_2 - x_3 + 2x_4 = 10$ **[10]**

SECTION – B

5. (a) Prove that all cyclic groups of infinite order are isomorphic to Z. **[10]**

5. (b) Investigate what derangement of the series

$$1-\frac{1}{2}+\frac{1}{3}-\frac{1}{4}+\frac{1}{5}.....$$

will reduce its sum to zero. **[10]**

5. (c) Determine whether

$$f(x) = 2x\sin\frac{1}{x} - \cos\frac{1}{x}$$

is Riemann-integrable on [0, 1] and justify your answer **[10]**

5. (d) If f(z) = u + iv is analytic function and $u - v = e^x (\cos y - \sin y)$, find f(z) in terms of z. **[10]**

5. (e) $x_1 = 4, x_2 = 1, x_3 = 3$ is a feasible solution of the system of equations

$2x_1 - 3x_2 + x_3 = 8$

$x_1 + 2x_2 + 3x_3 = 15$

Reduce the feasible solution to two different basic feasible solutions. **[10]**

6. (a) (i) Let $\beta \in S_7$ and suppose $\beta^4 = (2143567)$. Find β. What are the possibilities for β if $\beta \in S_9$?

(ii) Let $\beta = (123)(145)$. Write β^{99} in disjoint cycle form.

[7+5=12]

6. (b) Show that the group G of four transformations f_1, f_2, f_3, f_4 defined by $f_1(z) = z$. $f_2(z) = -z$, $f_3(z) = \frac{1}{z}, f_4(z) = -\frac{1}{z}$ with composite composition is isomorphic to the permutation group G′of degree 4 consisting of the permutation I, (a b), (c d), (a b) (c d). **[15]**

6. (c) Is the ideal $M = \{\overline{0}, \overline{3}, \overline{6}, \overline{9}\}$ a maximal ideal of $Z/(12)$, the ring of integers modulo 12? Justify your answer. **[08]**

6. (d) Every Euclidean domain is a principal ideal domain Is a converse true? Justify your Answer. **[15]**

7. (a) Prove that $\frac{x}{1+x} < \log(1+x) < x$ for all $x > 0$. Deduce that

$$\log\frac{2n+1}{n+1} < \frac{1}{n+1} + \frac{1}{n+2} + ... + \frac{1}{2n} < \log 2,$$ n being a positive integer. **[15]**

7. (b) Show that if $f_n(x) = \dfrac{n^2 x}{1 + n^4 x^2}$, then $<f_n>$ converges non-uniformly on [0, 1]. **[10]**

7. (c) Obtain $\frac{\partial^2 f(0,0)}{\partial x \partial y}$ and $\frac{\partial^2 f(0,0)}{\partial y \partial x}$ for the function

$$f(x,y)=\begin{cases}\frac{xy(3x^2-2y^2)}{x^2+y^2} & ,(x,y)\neq(0,0)\\ 0 & ,(x,y)=(0,0)\end{cases}$$

Also, discuss the continuity of $\frac{\partial^2 f}{\partial x \partial y}$ and $\frac{\partial^2 f}{\partial y \partial x}$ at (0, 0). **[15]**

7. (d) Show that $\iint_D \frac{(x-y)}{(x+y)^3}\,dx\,dy$ does not exist, where

$$D=\{(x,y)\in R^2 / 0\le x\le 1,\ 0<y<1\}$$ **[10]**

8. (a) Using Cauchy's theorem and / or Cauchy's integral formula, calculate the following integrals :

(i) $\int_C \frac{\cosh(\pi z)\,dz}{z(z^2+1)}$, where C is circle $|z| = 2$

(ii) $\int_C \frac{e^{az}\,dz}{(z-\pi i)}$, where C is the ellipse $|z-2| + |z+2| = 6$.

(iii) $\int_C \frac{(\sin z)^2\,dz}{\left(z-\frac{\pi}{6}\right)^3}$, where C is circle $|z| = 1$. **[12]**

8. (b) (i) Show that the function e^{-1/z^2} has no singularities.

(ii) Find residue of $f(z) = e^z \operatorname{cosec}^2 z$ at all poles in the finite plane. **[12]**

8. (c) A company has a team of four salesmen and there are four districts where the company wants to start its business. After taking into account the capabilities of salesmen and the nature of districts, the company estimates that the profit per day in rupees for each salesman in each district is as follows :

		Districts			
		D_1	D_2	D_3	D_4
Salesmen	A	16	10	14	11
	B	14	11	15	15
	C	15	15	13	12
	D	13	12	14	15

Find the assignment of salesmen to various districts which yields maximum profit. **[10]**

8. (d) Solve the following problem by Big-M-method : Max. $z = x_1 + 2x_2 + 3x_3 - x_4$, subject to :

$x_1 + 2x_2 + 3x_3 = 15$, $2x_1 + x_2 + 5x_3 = 20$, $x_1 + 2x_2 + x_3 + x_4 = 10$ and $x_1, x_2, x_3, x_4 \geq 0$. **[16]**

ROUGH SPACE

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