MATH/I/EC/01 **Student's Copy**

2 0 2 3

(CBCS)

(1st Semester)

MATHEMATICS

FIRST PAPER

(Calculus)

Full Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

(SECTION : A—OBJECTIVE)

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : $1\times10=10$

1. The derivative of $\sin x$ with respect to $\cos x$ is

(a) $-\tan x$ ( )

(b) $-\cot x$ ( )

(c) $\tan x$ ( )

(d) $\cot x$ ( )

2. The nth derivative of $5x^n$ is

(a) $5n(n-1)^{x^{n-1}}$ ( )

(b) $(5n)!$ ( )

(c) $5n!$ ( )

(d) $5x(n-1)!$ ( )

3. The function $f(x) = \log x$ can be expanded in power of $(x-1)$ by using

(a) Maclaurin's theorem ( )

(b) Taylor's theorem ( )

(c) Leibnitz's theorem ( )

(d) None of the above ( )

4. The value of c of the mean value theorem for the function $f(x) = x^2$ in the interval $[1, 2]$ is

(a) 0 ( )

(b) 1 ( )

(c) 0·5 ( )

(d) 1·5 ( )

5. If for an even function $f(x)$, $\int_0^1 f(x)\,dx = 4$, then the value of $\int_{-1}^1 f(x)\,dx$ is

(a) 4 ( )

(b) –4 ( )

(c) 8 ( )

(d) –8 ( )

6. The value of the integral $\int_0^{\pi/4} \tan^5 \theta \, d\theta$ is

(a) $\frac{1}{4}\log 2$ ( )

(b) $\frac{1}{4}(2\log 2 - 1)$ ( )

(c) $\frac{1}{4}(\log 2 - 1)$ ( )

(d) $\frac{1}{4}(\log 3 - 1)$ ( )

7. Let $f(x, y) = \frac{x+y}{x^2+y}$, when $x^2 + y \neq 0$. Then $\lim f(x, y)$ as $(x, y) \to (1, -1)$ along the line $x = 1$ is

(a) 0 ( )

(b) 1 ( )

(c) Does not exist ( )

(d) None of the above ( )

8. If $f(x, y) = ax^2 + 2hxy + by^2$, then $x\frac{\partial f}{\partial x} + y\frac{\partial f}{\partial y}$ is

(a) $2(ax^2 + 2hxy + by^2)$ ( )

(b) $ax^2 + 2hxy + by^2$ ( )

(c) $\frac{1}{2}(ax^2 + 2hxy + by^2)$ ( )

(d) None of the above ( )

9. If in a sequence $< x_n >$, $\lim_{n\to 0} x_n$ is finite, the sequence is

(a) convergent ( )

(b) divergent ( )

(c) oscillatory ( )

(d) Cauchy ( )

10. Every Cauchy sequence must be

(a) monotonic ( )

(b) bounded above only ( )

(c) bounded below only ( )

(d) bounded ( )

(SECTION : B—SHORT ANSWERS)

(*Marks* : 15)

Answer the following questions : 3×5=15

UNIT—I

1. Use L' Hospital rule to evaluate

$$\lim_{x \to 0} \frac{e^x + \sin x - 1}{\log(1+x)}$$

OR

2. Find y_n, if $y = x^2 e^{ax}$.

UNIT—II

3. Expand e^x in an infinite series in powers of x.

OR

4. Verify Rolle's theorem for $f(x) = x\sqrt{a^2 - x^2}$ on $[0, a]$.

UNIT—III

5. Find the reduction formula for $\int e^{ax} x^n dx$.

OR

6. Find $\int \sec^6 x \, dx$.

UNIT—IV

7. Prove that $\int_0^1 \int_0^{1-x} xy\, dx\, dy = \frac{1}{24}$.

OR

8. Give an example of a function of two variables x and y such that

$$\frac{\partial^2 f}{\partial x \partial y} \neq \frac{\partial^2 f}{\partial y \partial x}$$

UNIT—V

9. Give an example of two sequences $\{a_n\}$ and $\{b_n\}$ such that the sequence $\{a_n\}$ and $\{b_n\}$ are divergent and diverges to $+\infty$ and $-\infty$ respectively but $\{a_n + b_n\}$ is convergent.

OR

10. Show that the sequence $\left\{\frac{n^2+5}{3n^2+7}\right\}$ converges to $\frac{1}{3}$.

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer the following : 10×5=50

UNIT—I

1. *(a)* If the area of a circle increases at a uniform rate, show that the rate of increase of the perimeter varies inversely as the radius. 5

(b) Using ε-δ definition of continuity, prove that $f(x) = 2x + 5$ is continuous at $x = 2$. 5

OR

2. *(a)* Prove that a function which is derivable at a point is necessarily continuous at the point, but the converse is not true. 6

(b) Differentiate $\cos^{-1}(2x^2 - 1)$ with respect to $\sin^{-1}\sqrt{1-x^2}$. 4

UNIT—II

3. (a) Verify Lagrange's mean value theorem for $f(x) = x^2 + 2x + 3$ on $[4, 6]$. 3

   (b) Expand $\sin x$ by Maclaurin's theorem. 7

OR

4. (a) State Lagrange's mean value theorem and discuss geometrical interpretation of Lagrange's mean value theorem. 2+4=6

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5. Evaluate $\int_2^4 e^{-x} dx$ as a limit of sum. 10

OR

6. Obtain the reduction formula for $\int x^m e^x dx$ and use the formula to evaluate $\int_0^1 x^m e^x dx$. 10

UNIT—IV

7. (a) Prove that the function defined by

$$f(x) = \begin{cases} x & , \quad x \le 1 \\ 2 - x & , \quad 1 < x \le 2 \\ -2 + 3x - x^2 & , \quad x > 2 \end{cases}$$

   is continuous at $x = 1$ and $x = 2$. 5

   (b) State and prove Euler's theorem on a homogeneous function for two variables. 5

OR

8. (a) Let $f : R^2 \to R$ be a function of two variables given as $f(x, y) = \dfrac{x^2}{x^2 + y}$. Examine the limit of $f(x, y)$ as $(x, y) \to (0, 0)$. 5

(b) If $u = \log\sqrt{x^2 + y^2 + z^2}$, then prove that

$$(x^2 + y^2 + z^2)\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) = 1$$ 5

UNIT—V

9. (a) Prove that every convergent sequence is bounded. 5

(b) Prove that a sequence cannot converge more than one limit. 5

OR

10. (a) Prove that every convergent sequence is a Cauchy sequence. 5

(b) Test the convergence or divergence of the series whose nth term is $\{(n^3 + 1)^{1/3} - n\}$. 5

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OR

8. *(a)* Let $f : R^2 \to R$ be a function of two variables given as $f(x, y) = \dfrac{x^2}{x^2 + y}$.

Examine the limit of $f(x, y)$ as $(x, y) \to (0, 0)$. 5

(b) If $u = \log\sqrt{x^2 + y^2 + z^2}$, then prove that

$$(x^2 + y^2 + z^2)\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) = 1$$ 5

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9. (a) Prove that every convergent sequence is bounded. 5

(b) Prove that a sequence cannot converge more than one limit. 5

OR

10. (a) Prove that every convergent sequence is a Cauchy sequence. 5

(b) Test the convergence or divergence of the series whose nth term is $\{(n^3 + 1)^{1/3} - n\}$. 5

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(CBCS)

(3rd Semester)

MATHEMATICS

THIRD PAPER

(Differential Equations)

Full Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

(SECTION : A—OBJECTIVE)

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. The differential equation of all circles in the *xy*-plane which have their centre at the origin is

   (a) $\frac{dy}{dx} - \frac{x}{y} = 0$ ( )

   (b) $\frac{dy}{dx} + xy = 0$ ( )

   (c) $\frac{dy}{dx} + \frac{x}{y} = 0$ ( )

   (d) $\frac{dy}{dx} - \frac{y}{x} = 0$ ( )

2. Which among the following differential equations is not homogeneous?

(a) $(x^2 + xy)\frac{dy}{dx} = 1$ ( )

(b) $\frac{dy}{dx} = \frac{x^2 + y^2}{2xy}$ ( )

(c) $\frac{dy}{dx} = \frac{x^2 y}{x^3 + y^3}$ ( )

(d) $\frac{dy}{dx} = \frac{\sqrt{x^2 - y^2} + y}{x}$ ( )

3. The general solution of the differential equation

$$\frac{d^2y}{dx^2} + 4\frac{dy}{dx} + 4y = 0$$

is

(a) $y = (A + B)e^{-2x}$ ( )

(b) $y = Ax + Be^{-2x}$ ( )

(c) $y = (A + Bx)e^{-2x}$ ( )

(d) None of the above ( )

4. The particular integral (PI) of the differential equation $(D^4 - D^2)y = e^{2x}$, where $D = \frac{d}{dx}$ is

(a) $\frac{e^{2x}}{2}$ ( )

(b) $-\frac{e^{2x}}{4}$ ( )

(c) $\frac{e^{2x}}{12}$ ( )

(d) $-\frac{e^{2x}}{12}$ ( )

5. Clairaut's equation of the form $y = px + f(p)$ has solution, if

(a) $p = x$ ( )

(b) $p =$ constant ( )

(c) $p = \frac{dy}{dx}$ ( )

(d) $p = y$ ( )

6. The orthogonal trajectories of the family of curves given by $xdy - 2ydx = 0$ are

(a) $x^2 + 2y^2 = c$ ( ) (b) $2x^2 + y^2 = c$ ( )

(c) $2x^2 + 2y^2 = c$ ( ) (d) $x^2 + y^2 = c$ ( )

7. The condition for exactness for the equation

$$(1+x^2)\frac{d^2y}{dx^2} + 3x\frac{dy}{dx} + y = 0$$

is

(a) $P_2 - P_1' + P_0'' = 0$ ( ) (b) $P_2 + P_1' + P_0'' = 0$ ( )

(c) $P_2 + P_1' - P_0'' = 0$ ( ) (d) $P_2 - P_1' - P_0'' = 0$ ( )

8. Sometimes a differential equation is transformed to an integrable form by changing the

(a) dependent variable ( ) (b) independent variable ( )

(c) constant ( ) (d) coefficient ( )

9. The required PDE by eliminating a and b from the equation $z = (x+a)(y+b)$ is

(a) $z = p$ ( ) (b) $z = q$ ( )

(c) $z = pq$ ( ) (d) $z = \frac{p}{q}$ ( )

10. The Lagrange's auxiliary equations of the equation $y^2p - xyq = x(z-2y)$ are given by

(a) $\frac{dx}{-xy} = \frac{dy}{y^2} = \frac{dz}{x(z-2y)}$ ( ) (b) $\frac{dx}{y^2} = \frac{dy}{-xy} = \frac{dz}{x(z-2y)}$ ( )

(c) $\frac{dz}{y^2} = \frac{dy}{-xy} = \frac{dx}{x(z-2y)}$ ( ) (d) $\frac{dx}{y^2} = \frac{dz}{-xy} = \frac{dy}{x(z-2y)}$ ( )

(SECTION : B—SHORT ANSWERS)

(*Marks* : 15)

Answer the following : 3×5=15

UNIT—I

1. Solve $\frac{dy}{dx} = \sin(x + y)$.

OR

2. Check the exactness of the differential equation

$$\left\{y\left(1+\frac{1}{x}\right)+\cos y\right\}dx + (x + \log x - x\sin x)\,dy = 0$$

and solve it.

UNIT—II

3. Solve $(D^2 + 5 - 2D)y = 10\sin x$.

OR

4. Find the particular integral of $(D^3 + D^2 - 6D)y = 1 + x^2$, where $D = \frac{dy}{dx}$.

UNIT—III

5. Find the general and singular solutions of $p^3 + y^2 = 1$.

OR

6. Solve $p + \frac{1}{p} = \frac{10}{3}$.

UNIT—IV

7. Solve $x^2 \frac{d^2y}{dx^2} - x\frac{dy}{dx} + y = 2\log x.$

OR

8. Solve $(yz + xyz)dx + (zx + xyz)dy + (xy + xyz)dz = 0.$

UNIT—V

9. Find the general solution of $xzp + yzq = xy.$

OR

10. Find the integral of $p^3 + q^3 = 27z.$

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer the following : 10×5=50

UNIT—I

1. *(a)* Find the differential equation of the family of curves $y = Ae^{3x} + Be^{5x}$ for different values of A and B. 5

   (b) Solve the differential equation

$$(x + y)^2 \frac{dy}{dx} = a^2$$ 5

OR

2. *(a)* Solve :

$$(1 - x^2)\frac{dy}{dx} - xy = 1$$ 5

   (b) Reduce the equation $(3x^2 + 4xy)\,dx + (2x^2 + 2y)\,dy = 0$ to exact form and solve it. 5

UNIT—II

3. Solve the following : 5+5=10

(a) $(D^2 - 2D + 1)y = x \sin x$

(b) $(D^3 + 3D^2 + 2D)y = x^2$

OR

4. (a) Solve $(D^2 - 2D + 4)y = e^x \cos x$. 5

(b) Solve the differential equation

$$(D^2 + 4)y = x \sin x$$ 5

UNIT—III

5. (a) Solve the differential equation

$$p^3 - p(y + 3) + x = 0$$

where $p = \frac{dy}{dx}$. 5

(b) Find the orthogonal trajectories of the family of curves

$$\frac{x^2}{a^2} + \frac{y^2}{b^2 + \lambda} = 1$$

λ being parameter. 5

OR

6. (a) Reduce the differential equation $(px - y)(x - yp) = 2p$ to Clairaut's form by substituting $x^2 = u$, $y^2 = v$ and find its general and singular solutions. 5

(b) Solve $y = x + p^3$, where $p = \frac{dy}{dx}$. 5

UNIT—IV

7. (a) Solve the equation

$$x^3 \frac{d^3y}{dx^3} + 2x^2 \frac{d^2y}{dx^2} + 2y = 10\left(x + \frac{1}{x}\right)$$ 5

(b) Show that the equation

$$x\frac{d^3y}{dx^3} + (x^2 - 3)\frac{d^2y}{dx^2} + 4x\frac{dy}{dx} + 2y = 0$$

is exact and solve it. 5

OR

8. (a) Check the condition of integrability and solve the equation

$$yz^2(x^2 - yz)dx + zx^2(y^2 - xz)dy + xy^2(z^2 - xy)dz = 0$$ 5

(b) Transform the equation

$$x\frac{d^2y}{dx^2} - \frac{dy}{dx} + 4x^3y = x^5$$

and find the solution. 5

UNIT—V

9. (a) Use Lagrange's auxiliary equations to solve the equation

$$(x^3 + 3xy^2)p + (y^3 + 3x^2y)q = 2(x^2 + y^2)z$$ 5

(b) Apply Charpit's method to find the complete integral of the equation $px + qy = pq$. 5

OR

10. (a) Find the general solution of the equation

$$(y^2 + z^2 - x^2)p - 2xyq + 2zx = 0$$ 5

(b) Solve $\cos(x + y)p + \sin(x + y)q = z$. 5

★★★

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(b) $\frac{dy}{dx} = \frac{x^2 + y^2}{2xy}$ ( )

(c) $\frac{dy}{dx} = \frac{x^2 y}{x^3 + y^3}$ ( )

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3. The general solution of the differential equation

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