

MA202: STATISTICS AND NUMERICAL METHODS
UNIT IV
INTERPOLATION, NUMERICAL DIFFERENTIATION AND INTEGRATION

PART-A

1. Lagrange's formula applicable for (c)
a) Equal intervals b) unequal intervals c) both (a) and (b) d) None of the above
2. If $f(3)=5$ and $f(5)=3$, what is the form of $f(x)$ by Lagrange's formula?
a) $8-x$ b) $8-y$ c) $8-x$ d) None of the above (a)
3. The process of finding the value of a function inside the given range is called
a) Derivatives b) Extrapolation c) Interpolation d) None of the above (c)
4. The n^{th} divided differences of a polynomial of the n^{th} degree
a) Constant b) Variable c) $n-1$ d) None of the above (a)
5. Newton –Gregory forward difference interpolation formula is
(a) $p = \frac{x-x_0}{h}$ (b) $p = \frac{x+x_0}{h}$ (c) $p = \frac{x-x_n}{h}$ (d) None of the above (a)
6. When we will use Newton's backward interpolation formula
a) Nearer to the Initial Value b) Nearer to the end Value c) Mid value d) Both (a) and (b) (b)
7. Find the sixth term in the sequence 8, 12, 19, 29, 42, ...
a) 56 b) 50 c) 58 d) 49 (c)
8. If $f(x) = \frac{1}{x}$, find the divided difference $f(a, b, c)$.
a) $-\frac{1}{bc}$ (b) $-\frac{1}{abc}$ (c) $\frac{1}{abc}$ (d) None of these (c)
9. Newton's forward interpolation formula used only for _____ intervals
a) unequal intervals b) equidistance intervals c) both (a) and (b) d) None of the above (b)
10. The Parabola Of The Form $y = ax^2 + bx + c$ passing through the points (0,0) (1,1) and (2,20).
a) $y = 9x^2 - 8x$ b) $y = 9x - 8$ c) $y = 9x^2 + 8x + 1$ d) None of the above (a)

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11. Trapezoidal rule is called for sum of _____
(a) sum of two trapezoidal (b) sum of three trapezoidal (c) sum of n trapezoidal (d) None of these (c)
12. The order in trapezoidal formula is
(a) $O(h^4)$ (b) $O(h^2)$ (c) $O(h^3)$ (d) None of these (b)
13. When does Simpson's rule give the exact result?
a) Straight line (b) hyperbola (c) parabola (d) ellipse (c)
14. The order of Simpson's one third formula is
(a) $O(h^4)$ (b) $O(h^2)$ (c) $O(h^3)$ (d) None of these (a)
15. The local error of the trapezoidal formula is
a) $-\frac{h^2}{12}y''_1$ (b) $-\frac{h^2}{2}y''_1$ (c) $-\frac{h}{12}y''_1$ (d) None of these (a)
16. The local error of the Simpson's one third rule is
a) $-\frac{h^5}{9}y^{iv}_1$ (b) $-\frac{h^5}{90}y'_1$ (c) $-\frac{h^5}{90}y^{iv}_1$ (d) None of these (c)
17. Which is more reliable, Simpson's rule or trapezoidal rule?
(a) trapezoidal rule (b) Simpson's rule (c) both (a) and (b) (d) None of the above (b)
18. The order of Simpson's three eight rule is
(a) $O(h^4)$ (b) $O(h^2)$ (c) $O(h^5)$ (d) None of these (c)
19. The error in trapezoidal rule is
a) $|E| < \frac{(b-a)^2}{2}$ (b) $|E| > \frac{(b-a)^2}{12}$ (c) $|E| < \frac{(b-a)^2}{12}$ (d) None of the above (c)
20. The error in trapezoidal rule is
a) $|E| < \frac{(b-a)h^4}{180}M$ (b) $|E| > \frac{(b-a)h^4}{180}M$ (c) $|E| < \frac{(b-a)^4}{180}M$ (d) None of the above (a)
21. Simpson's one three eight rule is
(a) sum of odd ordinates (b) sum of even ordinates (c) both (a) and (b) (d) Multiples of 3 (d)

PART B
TWO MARKS QUESTION AND ANSWER

1.State Lagrange's interpolation formula.

Solution:

Let $y=f(x)$ be a function which takes the values $y_0, y_1, y_2, \dots, y_n$ corresponding to $x = x_0, x_1, x_2, \dots, x_n$.

Then, Lagrange's interpolation formula is

$$y = f(x) = \frac{(x-x_1)(x-x_2)\dots(x-x_n)}{(x_0-x_1)(x_0-x_2)\dots(x_0-x_n)}y_0 + \frac{(x-x_0)(x-x_2)\dots(x-x_n)}{(x_1-x_0)(x_1-x_2)\dots(x_1-x_n)}y_1 + \dots + \frac{(x-x_0)(x-x_1)\dots(x-x_{n-1})}{(x_n-x_0)(x_n-x_1)\dots(x_n-x_{n-1})}y_n$$

2.What is Inverse interpolation?

Solution:

Inverse interpolation is the process of finding the value of x corresponding to a value of y , not present in the table.

3.Give the inverse of Lagrange's interpolation formula.

Solution:

$$x = \frac{(y-y_1)(y-y_2)\dots(y-y_n)}{(y_0-y_1)(y_0-y_2)\dots(y_0-y_n)}x_0 + \frac{(y-y_0)(y-y_2)\dots(y-y_n)}{(y_1-y_0)(y_1-y_2)\dots(y_1-y_n)}x_1 + \dots + \frac{(y-y_0)(y-y_1)\dots(y-y_{n-1})}{(y_n-y_1)(y_n-y_2)\dots(y_n-y_{n-1})}x_n$$

4.What is the advantage of Lagrange's formula?

Solution: Lagrange's interpolation formula can be used whether the values of x , the independent variable are equally spaced or not whether the difference of y become smaller or not.

5.Define Divided difference.

Solution:

The first divided difference of $f(x)$ for the arguments x_0, x_1 is

$$f(x_0, x_1) = \frac{f(x_1) - f(x_0)}{x_1 - x_0}$$

similarly, $f(x_1, x_2) = \frac{f(x_2) - f(x_1)}{x_2 - x_1}$ and so on.

The second divided difference of $f(x)$ for three arguments x_0, x_1, x_2 is

$$f(x_0, x_1, x_2) = \frac{f(x_1, x_2) - f(x_0, x_1)}{x_2 - x_0}$$

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$$f(x_1, x_2, x_3) = \frac{f(x_2, x_3) - f(x_1, x_2)}{x_3 - x_1} \quad \text{and so on.}$$

6. Show that $\Delta^3_{bcd} \left(\frac{1}{a} \right) = -\frac{1}{abcd}$

Solution:

$$f(x) = \frac{1}{x} \Rightarrow f(a) = \frac{1}{a}, f(b) = \frac{1}{b}.$$

$$f(a, b) = \Delta_b \left(\frac{1}{a} \right) = \frac{f(b) - f(a)}{b - a} = \frac{\frac{1}{b} - \frac{1}{a}}{b - a} = \frac{\frac{a - b}{ba}}{b - a} = -\frac{1}{ab}$$

$$\text{If } f(a, b, c) = \frac{f(b, c) - f(a, b)}{c - a} = \frac{-\frac{1}{bc} + \frac{1}{ab}}{c - a} = \frac{\frac{-ab + bc}{abc}}{c - a} = \frac{1}{abc}$$

$$f(a, b, c, d) = \frac{f(b, c, d) - f(a, b, c)}{d - a} = \frac{\frac{1}{bcd} - \frac{1}{abc}}{d - a} = -\frac{1}{abcd}$$

$$\therefore \Delta^3_{bcd} \left(\frac{1}{a} \right) = -\frac{1}{abcd}$$

7. Find the divided difference for the the following data:

x	2	5	10
y	5	29	109

Solution:

x	y=f(x)	$\Delta f(x)$	$\Delta^2 f(x)$
2	5		
5	29	$\frac{29 - 5}{5 - 2} = 8$	$\frac{16 - 8}{10 - 2} = 1$
10	109	$\frac{109 - 29}{10 - 5} = 16$	

8. Give the Newton,s divided difference interpolation formula.

Solution:

$$f(x) = f(x_0) + (x - x_0)f(x_0, x_1) + (x - x_0)(x - x_1)f(x_0, x_1, x_2) + \dots + (x - x_0)(x - x_1)\dots(x - x_{n-1})f(x_0, x_1, x_2, \dots, x_n)$$

9. State any two properties of divided differences.

Solution:

- 1) The divided differences are symmetrical in all their arguments.i.e, the value of any difference is independent of the order of the arguments.
- 2) The divided differences of the sum or difference of two functions is equal to the sum or difference of the corresponding separate divided difference.

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10. From the divided difference for the the following data:

x	5	15	22
y	7	36	160

Solution:

x	y=f(x)	$\Delta f(x)$	$\Delta^2 f(x)$
5	7	$\frac{36-7}{15-5} = 2.9$	$\frac{17.7-2.9}{22-5} = \frac{14.8}{17}$
15	36	$\frac{160-36}{22-15} = 17.7$	
22	160		

11. Write the formula for cubic spline.

Solution:

$$s(x) = y(x) = \frac{1}{6h} \left[(x_i - x)^3 M_{i-1} + (x - x_{i-1})^3 M_i \right] + \frac{1}{h} (x_i - x) \left[y_{i-1} - \frac{h^2}{6} M_{i-1} \right] + \frac{1}{h} (x - x_{i-1}) \left[y_i - \frac{h^2}{6} M_i \right]$$

The recurrence relation for the spline is

$$M_{i-1} + 4M_i + M_{i+1} = \frac{6}{h^2} [y_{i-1} - 2y_i + y_{i+1}] \quad \text{for } i = 1, 2, \dots, (n-1)$$

12. Derive Newton's backward difference formula by using operator method. [Gregory Newton's backward difference interpolation formula].

Solution:

$$y(x) = f(x) = P_n(x)$$

$$= y_n + \frac{u}{1!} \nabla y_n + \frac{u(u+1)}{2!} \nabla^2 y_n + \frac{u(u+1)(u+2)}{3!} \nabla^3 y_n + \dots + \frac{u(u+1)(u+2)\dots(u+(n-1))}{n!} \nabla^n y_n$$

$$\text{where } u = \frac{x - x_n}{h}$$

13. State Gregory Newton's forward difference interpolation formula.

Solution:

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$$y(x) = f(x) = P_n(x)$$

$$= y_0 + \frac{u}{1!} \Delta y_0 + \frac{u(u-1)}{2!} \Delta^2 y_0 + \frac{u(u-1)(u-2)}{3!} \Delta^3 y_0 + \dots$$

$$+ \frac{u(u-1)(u-2)\dots(u-(n-1))}{n!} \Delta^n y_0$$

where $u = \frac{x-x_0}{h}$

14. Given $f(0)=-2, f(1)=2$ and $f(2)=8$. Find the polynomial using Newton's interpolation formula.

Solution:

x	y=f(x)	$\Delta f(x)$	$\Delta^2 f(x)$
0	-2	4	
1	2	6	2
2	8		

By Newton's forward difference interpolation

$$y(x) = y_0 + \frac{u}{1!} \Delta y_0 + \frac{u(u-1)}{2!} \Delta^2 y_0 + \frac{u(u-1)(u-2)}{3!} \Delta^3 y_0 + \dots$$

formula $+ \frac{u(u-1)(u-2)\dots(u-(n-1))}{n!} \Delta^n y_0$

where $u = \frac{x-x_0}{h}$

Here

$x_0 = 0, h = 1 \Rightarrow u = x$

$$\therefore y(x) = -2 + \frac{x}{1!}(4) + \frac{x(x-1)}{2!}(2)$$

$$= -2 + 4x + x(x-1)$$

$$= x^2 + 3x - 2.$$

15. State the merits and demerits of Newton's forward and backward interpolation formula.

Merits:

Newton's forward and backward interpolation formula are applicable for interpolation near the beginning and end respectively of tabulated values.

Demerits:

Newton's forward and backward interpolation formula used only for equal intervals (or) equidistant intervals.

16. Using Newton's forward difference formula, write the formula for the first, second and third order derivatives at $x = x_0$

Solution:

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$$\left(\frac{dy}{dx}\right)_{x=x_0} = \frac{1}{h} \left[\Delta y_0 - \frac{1}{2} \Delta^2 y_0 + \frac{1}{3} \Delta^3 y_0 - \frac{1}{4} \Delta^4 y_0 + \dots \right]$$

$$\left(\frac{d^2y}{dx^2}\right)_{x=x_0} = \frac{1}{h^2} \left[\Delta^2 y_0 - \Delta^3 y_0 + \frac{11}{12} \Delta^4 y_0 - \frac{5}{6} \Delta^5 y_0 + \dots \right]$$

$$\left(\frac{d^3y}{dx^3}\right)_{x=x_0} = \frac{1}{h^3} \left[\Delta^3 y_0 - \frac{3}{2} \Delta^4 y_0 + \dots \right]$$

17. Construct an Newton difference table for the points (0,-1),(1,1),(2,1) and (3,-2).

Solution:

Difference table :

x	y	Δy	Δ ² y	Δ ³ y
0	-1			
1	1	1+1:2		
2	1	1-1:0	0-2:-2	
3	-2	-2-1:-3	-3-0:-3	-3+2:-1

18. State Trapezoidal rule.

$$\int_{x_0}^{x_n} y dx = \frac{h}{2} [(y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1})] \text{ where } h = \frac{b-a}{n}$$

$$= \frac{h}{2} [A + 2B]$$

where A=sum of the first and last ordinates & B=sum of the remaining ordinates.

19. Using Newton's backward difference formula,write the formula for the first,second and third order derivatives at $x = x_n$

Solution:

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$$\left(\frac{dy}{dx}\right)_{x=x_n} = \frac{1}{h} \left[\nabla y_n + \frac{1}{2} \nabla^2 y_n + \frac{1}{3} \nabla^3 y_n + \frac{1}{4} \nabla^4 y_n + \dots \right]$$

$$\left(\frac{d^2y}{dx^2}\right)_{x=x_n} = \frac{1}{h^2} \left[\nabla^2 y_n + \nabla^3 y_n + \frac{11}{12} \nabla^4 y_n + \frac{5}{6} \nabla^5 y_n + \dots \right]$$

$$\left(\frac{d^3y}{dx^3}\right)_{x=x_n} = \frac{1}{h^3} \left[\nabla^3 y_n + \frac{3}{2} \nabla^4 y_n + \dots \right]$$

20. Find $\frac{dy}{dx}$ at $x=1$ from the following table:

x	1	2	3	4
y	1	8	27	64

Solution:

y	Δ	Δ^2	Δ^3
1	7		
8	19	12	
27	37	18	6
64			

$$\begin{aligned} \left(\frac{dy}{dx}\right)_{x=x_0} &= \frac{1}{h} \left[\Delta y_0 - \frac{1}{2} \Delta^2 y_0 + \frac{1}{3} \Delta^3 y_0 \right] \\ &= (1) \left[7 - \frac{12}{2} + \frac{6}{3} \right] = 3 \end{aligned}$$

21. State Simpson's 3/8 rule.

$$\int_{x_0}^{x_n} y dx = \frac{3h}{8} \left[(y_0 + y_n) + 3(y_1 + y_2 + y_4 + y_5 + \dots + y_{n-1}) + 2(y_3 + y_6 + \dots + y_{n-3}) \right] \text{ where } h = \frac{b-a}{n}$$

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22.State Simpson's 1/3 rule.

$$\int_{x_0}^{x_n} y dx = \frac{h}{3} [(y_0 + y_n) + 4(y_1 + y_3 + \dots + y_{n-1}) + 2(y_2 + y_4 + \dots + y_{n-2})] \text{ where } h = \frac{b-a}{n}$$

$$= \frac{h}{3} [A + 4B + 2C]$$

where A=sum of the first and last ordinates.

B=sum of the odd ordinates

C= sum of the even ordinates

23.Evaluate $\int_{1/2}^1 \frac{1}{x} dx$ by Trapezoidal rule,dividing the range into 4 equal parts.

Solution:

$$h = \frac{1 - \frac{1}{2}}{4} = \frac{1}{8}$$

x	1/2	5/8	6/8	7/8	8/8
f(x)	8/4	8/5	8/6	8/7	8/8

$$\therefore \int_{1/2}^1 \frac{1}{x} dx = \frac{1}{8} \cdot \frac{1}{2} \left[\left(\frac{8}{4} + \frac{8}{8} \right) + 2 \left(\frac{8}{5} + \frac{8}{6} + \frac{8}{7} \right) \right]$$

$$= \frac{1}{16} \left[3 + 2 \left(\frac{856}{210} \right) \right] = \frac{1171}{1680} = 0.6971$$

24.Evaluate $\int_0^1 \frac{dx}{1+x^2}$ with h=1/6 by Trapezoidal rule.

Solution:

Given $f(x) = \int_0^1 \frac{dx}{1+x^2}, h = 1/6$

x	0	1/6	2/6	3/6	4/6	5/6	6/6
f(x)	1	36/37	9/10	4/5	9/13	36/31	1/2

$$\therefore \int_0^1 \frac{dx}{1+x^2} = \frac{1}{12} \left[\left(1 + \frac{1}{2} \right) + 2 \left(\frac{36}{37} + \frac{9}{10} + \frac{4}{5} + \frac{9}{13} + \frac{36}{31} \right) \right]$$

$$= 0.7842$$

25.Using Simpson,s rule(one-third) evaluate $\int_0^1 xe^x dx$ taking 4 intervals.Compare your result with actual value.

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Solution:

Given $f(x) = xe^x; h = \frac{1}{4} = 0.25$

x	0	0.25	0.5	0.75	1
f(x)	1	0.321	0.824	1.588	2.718

By Simpson's 1/3 rule

$$\therefore \int_0^1 xe^x dx = \frac{0.25}{3} [(0 + 2.718) + 2(0.321 + 1.588) + 4(0.524)]$$

$$= 0.819 = 1$$

By actual integration

$$\int_0^1 xe^x dx = [xe^x - e^x]_0^1 = e^1 - e^1 - (0 - 1) = 1$$

26. Calculate $\int_{0.5}^{0.7} e^{-x} \sqrt{x} dx$ taking 5 ordinates by Simpson's 1/3 rule.

Solution:

Given $f(x) = e^{-x} \sqrt{x}; h = \frac{0.7 - 0.5}{4} = 0.05$

x	0.5	0.55	0.6	0.65	0.7
f(x)	0.4289	0.4279	0.4251	0.4209	0.4155

By Simpson's 1/3 rule

$$\therefore \int_0^1 e^{-x} \sqrt{x} dx = \frac{0.05}{3} [(0.4289 + 0.4155) + 2(0.4279 + 0.4279) + 4(0.4251)]$$

$$= 0.849$$

27. Evaluate $\int_0^6 \frac{dx}{1+x^2}$ by Simpson's 3/8 rule & check by actual integration.

Solution:

Given $f(x) = \frac{1}{1+x^2}; h = \frac{6-0}{6} = 1$

x	0	1	2	3	4	5	6
f(x)	1	0.500	0.200	0.100	0.0588	0.0384	0.2702

By Simpson's 3/8 rule,

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$$\begin{aligned} \therefore \int_0^6 \frac{dx}{1+x^2} &= \frac{3h}{8} [(y_0 + y_n) + 3(y_1 + y_2 + \dots + y_{n-1}) + 2(y_3 + y_6 + \dots + y_{n-3})] \\ &= \frac{3}{8} [(1 + 0.2702) + 3(0.5 + 0.2 + 0.0588 + 0.0384) + 2(0.1)] \\ &= 1.3570 \end{aligned}$$

By actual integration,

$$\int_0^6 \frac{dx}{1+x^2} = [\tan^{-1}(x)]_0^6 = \tan^{-1}(6) = 1.4056$$

28. What are the errors in Trapezoidal & Simpson's rules of numerical integration?

Solution:

Error in Trapezoidal rule $|E| < \frac{(b-a)}{12} h^2 M$; order is h^2

Error in Simpson's rule $|E| < \frac{(b-a)}{180} h^4 M$; order is h^4

29. In order to evaluate $\int_{x_0}^{x_n} y dx$ by Simpson's rule, what is the restriction on the number of intervals.

Solution:

Simpson's 1/3 rule: The number of ordinates is odd (Or) the interval number is even.

Simpson's 3/8 rule: The interval is a multiple of 3.

30. Using Simpson's rule find $\int_0^4 e^x dx$, given $e^0 = 1, e^1 = 2.72, e^2 = 7.39, e^3 = 20.09$ and $e^4 = 54.6$

Solution:

$$y = e^x; h = 1$$

x	0	1	2	3	4
y	1	2.72	7.39	20.09	54.6

By Simpson's rule,

$$\therefore \int_0^4 e^x dx = \frac{1}{3} [(1 + 54.6) + 2(7.39) + 4(2.72 + 20.09)] = 53.87$$

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PART C

- 1 Use Lagrange's interpolation, calculate the profit in the year 2000 from the following data
Year : 1997 1999 2001 2002
Profit in lakhs of RS : 43 65 159 248
- 2 Find the third degree polynomial of $f(x)$ satisfying the following data
X : 1 3 5 7
Y : 24 120 336 720
- 3 Find the polynomial $f(x)$ by using Lagrange's formula and hence find $f(3)$ for
X : 0 1 2 5
 $f(x)$: 2 3 12 147
- 4 Using Lagrange's interpolation formula find $y(10)$ given that
 $y(5)=12, y(6)=13, y(9)=14, y(11)=16$
- 5 Obtain the root of $f(x) = 0$ by Lagrange's inverse interpolation given that $f(30) = -30$,
 $f(34) = -3, f(38) = 3, f(42) = 18$.
- 6 Find the missing term in the following table using Lagrange's interpolation
X : 0 1 2 3 4
Y: 1 3 9 - 81
- 7 Using Newton's divided difference formula, find $u(3)$ given $u(1) = -26, u(2) = 12, u(4) = 256, u(6) = 844$.
- 8 Find $f(x)$ as a polynomial in x for the following data by newton's divided difference formula:
X : -4 -1 0 2 5
 $f(x)$: 1245 33 5 9 1335
- 9 Find $f(8)$ by newton's divided difference formulae for the data:
X : 4 5 7 10 11 13
 $f(x)$: 48 100 294 900 1210 2028
- 10 Find $f'(3)$ and $f''(3)$ for one following data:
X : 3.0 3.2 3.4 3.6 3.8 4.0
 $F(X)$: -14 -10.032 -5.296 -0.256 6.672 14

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- 11 Compute $f'(0)$ and $f'(4)$ from the data
- | | | | | | |
|----|---|-------|-------|--------|--------|
| X: | 0 | 1 | 2 | 3 | 4 |
| Y: | 1 | 2.718 | 7.381 | 20.086 | 54.598 |
- 12 The following data gives the velocity of a particle for 20 seconds at an interval of 5 seconds .find the initial acceleration using the entire data
- | | | | | | | |
|-----------------|---|---|---|----|----|-----|
| Time(sec) | : | 0 | 5 | 10 | 15 | 20 |
| Velocity(m/sec) | : | 0 | 3 | 14 | 69 | 228 |
- 13 Find the maximum and minimum value of y tabulated below:
- | | | | | | | | |
|----|----|------|---|------|---|-------|----|
| X: | -2 | -2 | 0 | 1 | 2 | 3 | 4 |
| Y: | 2 | -.25 | 0 | -.25 | 2 | 15.75 | 56 |
- 14 Using trapezoidal rule ,evaluate $\int_{-1}^1 \frac{dx}{1+x^2}$ taking 8 intervals
- 15 Evaluate $\int_0^1 \frac{dx}{1+x^2}$ with $h=\frac{1}{6}$ by trapezoidal rule.
- 16 Evaluate the integral $\int_1^2 \frac{dx}{1+x^3}$ by using trapezoidal rule with two sub intervals.
- 17 Dividing the range into 10 equal parts, find the value of $\int_0^{\pi/2} \sin x dx$ by (i) Trapezoidal rule (ii) Simpson's rule.
- 18 Using Simpson's one third rule evaluate $\int_0^1 x e^x dx$ taking 4 intervals. Compare your result with actual value.
- 19 Evaluate $\int_0^6 \frac{dx}{1+x^2}$ by using (i) Trapezoidal rule (ii) Simpson's rule. Also check up result by actual integration.
- 20 By dividing the range into ten equal parts, Evaluate $\int_0^{\pi} \sin x dx$ by using (i) Trapezoidal rule (ii) Simpson's rule. Also check up result by actual integration.