

# Applied Mathematics (4320001) - Winter 2023 Solution

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## Question 1 [14 marks]

Fill in the blanks using appropriate choice from the given options.

### Question 1(1) [1 marks]

If  $A = \begin{bmatrix} 1 & 2 \\ 3 & -1 \end{bmatrix}$  then  $4A = \dots$  Answer: (b)  $\begin{bmatrix} 4 & 8 \\ 12 & -4 \end{bmatrix}$

#### Solution

$$4A = 4 \begin{bmatrix} 1 & 2 \\ 3 & -1 \end{bmatrix} = \begin{bmatrix} 4 & 8 \\ 12 & -4 \end{bmatrix}$$

### Question 1(2) [1 marks]

Order of the matrix  $\begin{bmatrix} 1 & 1 & 2 \\ -3 & 2 & 3 \end{bmatrix}$  is ... Answer: (a)  $2 \times 3$

#### Solution

Matrix has 2 rows and 3 columns, so order is  $2 \times 3$ .

### Question 1(3) [1 marks]

If  $A = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$  then  $A^2 = \dots$  Answer: (d)  $\begin{bmatrix} 2 & 2 \\ 2 & 2 \end{bmatrix}$

#### Solution

$$A^2 = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} = \begin{bmatrix} 2 & 2 \\ 2 & 2 \end{bmatrix}$$

**Question 1(4) [1 marks]**

If  $A = \begin{bmatrix} 2 & -1 \\ 3 & 4 \end{bmatrix}$  then adjoint of A = ... Answer: (c)  $\begin{bmatrix} 4 & 1 \\ -3 & 2 \end{bmatrix}$

**Solution**

For matrix  $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$ ,  $\text{adj}(A) = \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$   $\text{adj}(A) = \begin{bmatrix} 4 & 1 \\ -3 & 2 \end{bmatrix}$

**Question 1(5) [1 marks]**

$\frac{d}{dx}(\tan x) = \dots$  Answer: (d)  $\sec^2 x$

**Solution**

$$\frac{d}{dx}(\tan x) = \sec^2 x$$

**Question 1(6) [1 marks]**

$\frac{d}{dx}(\sin 5x) = \dots$  Answer: (b)  $5 \cos 5x$

**Solution**

$$\frac{d}{dx}(\sin 5x) = 5 \cos 5x \text{ (using chain rule)}$$

**Question 1(7) [1 marks]**

If function  $y = f(x)$  is maximum at  $x = a$  then  $f'(a) = \dots$  Answer: (c) 0

**Solution**

At maximum point, first derivative equals zero:  $f'(a) = 0$

**Question 1(8) [1 marks]**

$\int \sin x dx = \dots + C$  Answer: (a)  $-\cos x$

**Solution**

$$\int \sin x dx = -\cos x + C$$

**Question 1(9) [1 marks]**

$\int \frac{1}{x^2+4} dx = \dots + C$  Answer: (d)  $\frac{1}{2} \tan^{-1}\left(\frac{x}{2}\right)$

**Solution**

$$\int \frac{1}{x^2+4} dx = \frac{1}{2} \tan^{-1} \left( \frac{x}{2} \right) + C$$

**Question 1(10) [1 marks]**

$\int_1^2 x^2 dx = \dots$  Answer: (a)  $7/3$

**Solution**

$$\int_1^2 x^2 dx = \left[ \frac{x^3}{3} \right]_1^2 = \frac{8}{3} - \frac{1}{3} = \frac{7}{3}$$

**Question 1(11) [1 marks]**

Order of differential equation  $\left( \frac{d^3 y}{dx^3} \right)^4 + \frac{dy}{dx} + 5y = 0$  is ... Answer: (c) 3

**Solution**

Order is the highest derivative present = 3

**Question 1(12) [1 marks]**

Integrating factor of  $\frac{dy}{dx} + \frac{y}{x} = 1$  is ... Answer: (b)  $x$

**Solution**

$$\text{I.F.} = e^{\int \frac{1}{x} dx} = e^{\ln x} = x$$

**Question 1(13) [1 marks]**

Mean of 39,23,58,47,50,16,61 is ... Answer: (b) 42

**Solution**

$$\text{Mean} = \frac{39+23+58+47+50+16+61}{7} = \frac{294}{7} = 42$$

**Question 1(14) [1 marks]**

Mean of first five natural numbers is ... Answer: (a) 3

**Solution**

$$\text{Mean} = \frac{1+2+3+4+5}{5} = \frac{15}{5} = 3$$

## Question 2 [14 marks]

Attempt any two

### Question 2(a) [6 marks]

#### Question 2(a)(1) [3 marks]

If  $A = \begin{bmatrix} 1 & 3 & 5 \\ -1 & 0 & 2 \\ 4 & 3 & 6 \end{bmatrix}$ ,  $B = \begin{bmatrix} 3 & 4 & 5 \\ 5 & 4 & 3 \\ 3 & 5 & 4 \end{bmatrix}$ ,  $C = \begin{bmatrix} 1 & 2 & 1 \\ 3 & 3 & 3 \\ 4 & 5 & 6 \end{bmatrix}$ , find  $3A + 2B - 4C$

**Solution**

$$3A = \begin{bmatrix} 3 & 9 & 15 \\ -3 & 0 & 6 \\ 12 & 9 & 18 \end{bmatrix}$$

$$2B = \begin{bmatrix} 6 & 8 & 10 \\ 10 & 8 & 6 \\ 6 & 10 & 8 \end{bmatrix}$$

$$4C = \begin{bmatrix} 4 & 8 & 4 \\ 12 & 12 & 12 \\ 16 & 20 & 24 \end{bmatrix}$$

$$3A + 2B - 4C = \begin{bmatrix} 5 & 9 & 21 \\ -5 & -4 & 0 \\ 2 & -1 & 2 \end{bmatrix}$$

#### Question 2(a)(2) [3 marks]

If  $A = \begin{bmatrix} 7 & 5 \\ -1 & 2 \end{bmatrix}$ ,  $B = \begin{bmatrix} 1 & -1 \\ 3 & 2 \end{bmatrix}$ , show that  $(A + B)^T = A^T + B^T$

**Solution**

$$A + B = \begin{bmatrix} 8 & 4 \\ 2 & 4 \end{bmatrix}$$

$$(A + B)^T = \begin{bmatrix} 8 & 2 \\ 4 & 4 \end{bmatrix}$$

$$A^T = \begin{bmatrix} 7 & -1 \\ 5 & 2 \end{bmatrix}, B^T = \begin{bmatrix} 1 & 3 \\ -1 & 2 \end{bmatrix}$$

$$A^T + B^T = \begin{bmatrix} 8 & 2 \\ 4 & 4 \end{bmatrix}$$

Hence proved:  $(A + B)^T = A^T + B^T$

### Question 2(a)(3) [3 marks]

Solve the differential equation  $xydy = (x+1)(y+1)dx$

#### Solution

Separating variables:  $\frac{y}{y+1}dy = \frac{x+1}{x}dx$

$$\left(1 - \frac{1}{y+1}\right) dy = \left(1 + \frac{1}{x}\right) dx$$

Integrating:  $y - \ln|y+1| = x + \ln|x| + C$

**Final answer:**  $y - x = \ln|y+1| + \ln|x| + C$

### Question 2(b) [8 marks]

#### Question 2(b)(1) [4 marks]

Find the inverse of matrix  $\begin{bmatrix} 3 & 1 & 2 \\ 2 & -3 & -1 \\ 1 & 2 & 1 \end{bmatrix}$

#### Solution

$$\text{Let } A = \begin{bmatrix} 3 & 1 & 2 \\ 2 & -3 & -1 \\ 1 & 2 & 1 \end{bmatrix}$$

$$|A| = 3(-3 - (-2)) - 1(2 - (-1)) + 2(4 - (-3)) = 3(-1) - 1(3) + 2(7) = -3 - 3 + 14 = 8$$

**Cofactors:**

- $C_{11} = -1, C_{12} = -3, C_{13} = 7$
- $C_{21} = 3, C_{22} = 1, C_{23} = -5$
- $C_{31} = 5, C_{32} = 7, C_{33} = -11$

$$\text{adj}(A) = \begin{bmatrix} -1 & 3 & 5 \\ -3 & 1 & 7 \\ 7 & -5 & -11 \end{bmatrix}$$

$$A^{-1} = \frac{1}{8} \begin{bmatrix} -1 & 3 & 5 \\ -3 & 1 & 7 \\ 7 & -5 & -11 \end{bmatrix}$$

#### Question 2(b)(2) [4 marks]

Solve  $3x - 2y = 8, 5x + 4y = 6$  using matrix method

#### Solution

$$\begin{bmatrix} 3 & -2 \\ 5 & 4 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 8 \\ 6 \end{bmatrix}$$

$$|A| = 3(4) - (-2)(5) = 12 + 10 = 22$$

$$A^{-1} = \frac{1}{22} \begin{bmatrix} 4 & 2 \\ -5 & 3 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \frac{1}{22} \begin{bmatrix} 4 & 2 \\ -5 & 3 \end{bmatrix} \begin{bmatrix} 8 \\ 6 \end{bmatrix} = \frac{1}{22} \begin{bmatrix} 44 \\ -22 \end{bmatrix}$$

**Answer:**  $x = 2, y = -1$

### Question 2(b)(3) [4 marks]

If  $A = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 3 & 1 \\ 1 & 2 & 2 \end{bmatrix}$ , find  $A \cdot \text{adj}(A)$

#### Solution

$$|A| = 1(6 - 2) - 2(4 - 1) + 1(4 - 3) = 4 - 6 + 1 = -1$$

For any matrix A:  $A \cdot \text{adj}(A) = |A| \cdot I$

$$A \cdot \text{adj}(A) = (-1) \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

### Question 3 [14 marks]

Attempt any two

### Question 3(a) [6 marks]

#### Question 3(a)(1) [3 marks]

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

#### Solution

$$y = \log(\sin x) - \log(1 + \cos x)$$

$$\frac{dy}{dx} = \frac{1}{\sin x} \cdot \cos x - \frac{1}{1 + \cos x} \cdot (-\sin x)$$

$$= \frac{\cos x}{\sin x} + \frac{\sin x}{1 + \cos x}$$

$$= \cot x + \frac{\sin x}{1 + \cos x}$$

Using identity:  $\frac{\sin x}{1 + \cos x} = \tan\left(\frac{x}{2}\right)$

**Answer:**  $\frac{dy}{dx} = \cot x + \tan\left(\frac{x}{2}\right)$

#### Question 3(a)(2) [3 marks]

If  $y = \sin(x + y)$ , find  $\frac{dy}{dx}$

**Solution**

Differentiating both sides:  $\frac{dy}{dx} = \cos(x+y) \cdot \left(1 + \frac{dy}{dx}\right)$

$$\frac{dy}{dx} = \cos(x+y) + \cos(x+y) \cdot \frac{dy}{dx}$$

$$\frac{dy}{dx} - \cos(x+y) \cdot \frac{dy}{dx} = \cos(x+y)$$

$$\frac{dy}{dx} [1 - \cos(x+y)] = \cos(x+y)$$

**Answer:**  $\frac{dy}{dx} = \frac{\cos(x+y)}{1 - \cos(x+y)}$

**Question 3(a)(3) [3 marks]**

Obtain  $\int x^2 \log x dx$

**Solution**

Using integration by parts:  $\int u dv = uv - \int v du$

Let  $u = \log x$ ,  $dv = x^2 dx$  Then  $du = \frac{1}{x} dx$ ,  $v = \frac{x^3}{3}$

$$\int x^2 \log x dx = \log x \cdot \frac{x^3}{3} - \int \frac{x^3}{3} \cdot \frac{1}{x} dx$$

$$= \frac{x^3 \log x}{3} - \int \frac{x^2}{3} dx$$

$$= \frac{x^3 \log x}{3} - \frac{x^3}{9} + C$$

**Answer:**  $\frac{x^3}{3} (\log x - \frac{1}{3}) + C$

**Question 3(b) [8 marks]****Question 3(b)(1) [4 marks]**

Motion equation  $s = 2t^3 - 3t^2 - 12t + 7$ . Find  $s$  and  $t$  when acceleration is zero

**Solution**

$$s = 2t^3 - 3t^2 - 12t + 7$$

Velocity:  $v = \frac{ds}{dt} = 6t^2 - 6t - 12$

Acceleration:  $a = \frac{dv}{dt} = 12t - 6$

When acceleration = 0:  $12t - 6 = 0$   $t = \frac{1}{2}$

At  $t = 1/2$ :  $s = 2(\frac{1}{2})^3 - 3(\frac{1}{2})^2 - 12(\frac{1}{2}) + 7 = \frac{1}{4} - \frac{3}{4} - 6 + 7 = \frac{1}{2}$

**Answer:**  $t = 1/2, s = 1/2$

**Question 3(b)(2) [4 marks]**

If  $y = 2e^{3x} + 3e^{-2x}$ , prove  $\frac{d^2y}{dx^2} - \frac{dy}{dx} - 6y = 0$

**Solution**

$$y = 2e^{3x} + 3e^{-2x}$$

$$\frac{dy}{dx} = 6e^{3x} - 6e^{-2x}$$

$$\frac{d^2y}{dx^2} = 18e^{3x} + 12e^{-2x}$$

Now:  $\frac{d^2y}{dx^2} - \frac{dy}{dx} - 6y$   
 $= (18e^{3x} + 12e^{-2x}) - (6e^{3x} - 6e^{-2x}) - 6(2e^{3x} + 3e^{-2x})$   
 $= 18e^{3x} + 12e^{-2x} - 6e^{3x} + 6e^{-2x} - 12e^{3x} - 18e^{-2x}$   
 $= (18 - 6 - 12)e^{3x} + (12 + 6 - 18)e^{-2x} = 0$   
**Hence proved**

### Question 3(b)(3) [4 marks]

Find maximum and minimum values of  $f(x) = x^3 - 3x + 11$

#### Solution

$f(x) = x^3 - 3x + 11$   
 $f'(x) = 3x^2 - 3 = 3(x^2 - 1) = 3(x - 1)(x + 1)$   
Critical points:  $x = 1, x = -1$   
 $f''(x) = 6x$   
At  $x = 1$ :  $f''(1) = 6 > 0 \rightarrow$  Local minimum At  $x = -1$ :  $f''(-1) = -6 < 0 \rightarrow$  Local maximum  
 $f(1) = 1 - 3 + 11 = 9$  (minimum)  $f(-1) = -1 + 3 + 11 = 13$  (maximum)  
**Answer:** Maximum = 13 at  $x = -1$ , Minimum = 9 at  $x = 1$

### Question 4 [14 marks]

Attempt any two

### Question 4(a) [6 marks]

### Question 4(a)(1) [3 marks]

Obtain  $\int \sin 5x \sin 6x dx$

#### Solution

Using identity:  $\sin A \sin B = \frac{1}{2}[\cos(A - B) - \cos(A + B)]$   
 $\sin 5x \sin 6x = \frac{1}{2}[\cos(5x - 6x) - \cos(5x + 6x)]$   
 $= \frac{1}{2}[\cos(-x) - \cos(11x)] = \frac{1}{2}[\cos x - \cos(11x)]$   
 $\int \sin 5x \sin 6x dx = \frac{1}{2} \int [\cos x - \cos(11x)] dx$   
 $= \frac{1}{2}[\sin x - \frac{\sin(11x)}{11}] + C$   
**Answer:**  $\frac{1}{2} \sin x - \frac{\sin(11x)}{22} + C$

### Question 4(a)(2) [3 marks]

Obtain  $\int \frac{(1+x)e^x}{\cos^2(xe^x)} dx$



**Solution**

Let  $u = xe^x$ , then  $du = (1+x)e^x dx$

The integral becomes:  $\int \frac{du}{\cos^2 u} = \int \sec^2 u du = \tan u + C$

Substituting back:  $= \tan(xe^x) + C$

**Answer:**  $\tan(xe^x) + C$

**Question 4(a)(3) [3 marks]**

Find standard deviation for data: 6,7,10,12,13,4,8,12

**Solution**

Data: 6, 7, 10, 12, 13, 4, 8, 12  $n = 8$

Mean  $= \frac{6+7+10+12+13+4+8+12}{8} = \frac{72}{8} = 9$

**Table 1.** Standard Deviation Calculation

x	x-9	(x-9) <sup>2</sup>
6	-3	9
7	-2	4
10	1	1
12	3	9
13	4	16
4	-5	25
8	-1	1
12	3	9

$$\sum (x - 9)^2 = 74$$

$$\text{Standard deviation} = \sqrt{\frac{\sum (x - \bar{x})^2}{n}} = \sqrt{\frac{74}{8}} = \sqrt{9.25} = 3.04$$

**Answer:**  $\sigma = 3.04$

**Question 4(b) [8 marks]****Question 4(b)(1) [4 marks]**

Obtain  $\int \frac{2x+1}{(x+1)(x-3)} dx$

**Solution**

Using partial fractions:  $\frac{2x+1}{(x+1)(x-3)} = \frac{A}{x+1} + \frac{B}{x-3}$

$$2x + 1 = A(x - 3) + B(x + 1)$$

$$\text{When } x = -1: 2(-1) + 1 = A(-4) \Rightarrow -1 = -4A \Rightarrow A = \frac{1}{4}$$

$$\text{When } x = 3: 2(3) + 1 = B(4) \Rightarrow 7 = 4B \Rightarrow B = \frac{7}{4}$$

$$\int \frac{2x+1}{(x+1)(x-3)} dx = \frac{1}{4} \int \frac{1}{x+1} dx + \frac{7}{4} \int \frac{1}{x-3} dx$$

$$= \frac{1}{4} \ln |x+1| + \frac{7}{4} \ln |x-3| + C$$

**Answer:**  $\frac{1}{4} \ln |x+1| + \frac{7}{4} \ln |x-3| + C$

### Question 4(b)(2) [4 marks]

Obtain  $\int_0^{\pi/2} \frac{\sqrt{\cot x}}{\sqrt{\cot x} + \sqrt{\tan x}} dx$

#### Solution

Let  $I = \int_0^{\pi/2} \frac{\sqrt{\cot x}}{\sqrt{\cot x} + \sqrt{\tan x}} dx$

Using property:  $\int_0^a f(x) dx = \int_0^a f(a-x) dx$

$I = \int_0^{\pi/2} \frac{\sqrt{\cot(\pi/2-x)}}{\sqrt{\cot(\pi/2-x)} + \sqrt{\tan(\pi/2-x)}} dx$

Since  $\cot(\pi/2-x) = \tan x$  and  $\tan(\pi/2-x) = \cot x$ :

$I = \int_0^{\pi/2} \frac{\sqrt{\tan x}}{\sqrt{\tan x} + \sqrt{\cot x}} dx$

Adding both expressions:  $2I = \int_0^{\pi/2} \frac{\sqrt{\cot x} + \sqrt{\tan x}}{\sqrt{\cot x} + \sqrt{\tan x}} dx = \int_0^{\pi/2} 1 dx = \frac{\pi}{2}$

**Answer:**  $I = \frac{\pi}{4}$

### Question 4(b)(3) [4 marks]

Find mean deviation for grouped data

#### Solution

**Table 2.** Grouped Data

$x_i$	4	8	11	17	20	24	32
$f_i$	3	5	9	5	4	3	1

$N = \sum f_i = 3 + 5 + 9 + 5 + 4 + 3 + 1 = 30$

Mean =  $\frac{\sum f_i x_i}{N} = \frac{3(4) + 5(8) + 9(11) + 5(17) + 4(20) + 3(24) + 1(32)}{30}$   
 $= \frac{12 + 40 + 99 + 85 + 80 + 72 + 32}{30} = \frac{420}{30} = 14$

**Table 3.** Mean Deviation Calculation

$x_i$	$f_i$	$ x_i - 14 $	$f_i  x_i - 14 $
4	3	10	30
8	5	6	30
11	9	3	27
17	5	3	15
20	4	6	24
24	3	10	30
32	1	18	18

$\sum f_i |x_i - 14| = 174$

Mean deviation =  $\frac{\sum f_i |x_i - \bar{x}|}{N} = \frac{174}{30} = 5.8$

**Answer:** Mean deviation = 5.8

### Question 5 [14 marks]

Attempt any two

## Question 5(a) [6 marks]

### Question 5(a)(1) [3 marks]

Find mean deviation for grouped data

#### Solution

**Table 4.** Grouped Data

Class	30-40	40-50	50-60	60-70	70-80	80-90	90-100
Freq	3	7	12	15	8	3	2

$$N = 50, \sum f_i x_i = 3100$$

$$\text{Mean} = 3100/50 = 62$$

**Table 5.** Mean Deviation Calculation

Class	$x_i$	$f_i$	$ x_i - 62 $	$f_i  x_i - 62 $
30-40	35	3	27	81
40-50	45	7	17	119
50-60	55	12	7	84
60-70	65	15	3	45
70-80	75	8	13	104
80-90	85	3	23	69
90-100	95	2	33	66

$$\text{Mean deviation} = 568/50 = 11.36$$

**Answer:** Mean deviation = 11.36

### Question 5(a)(2) [3 marks]

Find standard deviation for given data

#### Solution

**Table 6.** Grouped Data

Class	60	61	62	63	64	65	66	67	68
Freq	2	1	12	29	25	12	10	4	5

$$N = 100, \text{Mean} = 63.8$$

**Table 7.** Standard Deviation Calculation

$x_i$	$f_i$	$(x_i - 63.8)$	$(x_i - 63.8)^2$	$f_i(x_i - 63.8)^2$
60	2	-3.8	14.44	28.88
61	1	-2.8	7.84	7.84
62	12	-1.8	3.24	38.88
63	29	-0.8	0.64	18.56
64	25	0.2	0.04	1.00
65	12	1.2	1.44	17.28
66	10	2.2	4.84	48.40
67	4	3.2	10.24	40.96
68	5	4.2	17.64	88.20

$$\sum f_i(x_i - \bar{x})^2 = 290$$

$$\text{Standard deviation} = \sqrt{290/100} = \sqrt{2.9} = 1.70$$

**Answer:**  $\sigma = 1.70$

### Question 5(a)(3) [3 marks]

Find mean for grouped data

#### Solution

**Table 8.** Grouped Data

Class	0-20	20-40	40-60	60-80	80-100	100-120
Freq	26	31	35	42	82	71

**Table 9.** Mean Calculation

Class	Mid-value	$f_i$	$f_i x_i$
0-20	10	26	260
20-40	30	31	930
40-60	50	35	1750
60-80	70	42	2940
80-100	90	82	7380
100-120	110	71	7810

$$N = 287, \sum f_i x_i = 21070$$

$$\text{Mean} = \frac{\sum f_i x_i}{N} = \frac{21070}{287} = 73.42$$

**Answer:** Mean = 73.42

### Question 5(b) [8 marks]

### Question 5(b)(1) [4 marks]

Solve differential equation  $(x + y + 1)^2 \frac{dy}{dx} = 1$

**Solution**

Let  $z = x + y + 1$ , then  $\frac{dz}{dx} = 1 + \frac{dy}{dx}$  So  $\frac{dy}{dx} = \frac{dz}{dx} - 1$

Substituting:  $z^2 \left( \frac{dz}{dx} - 1 \right) = 1$   $z^2 \frac{dz}{dx} - z^2 = 1$   $z^2 \frac{dz}{dx} = 1 + z^2$   $\frac{z^2}{1+z^2} dz = dx$

Integrating:  $\int \frac{z^2}{1+z^2} dz = \int dx$

$\int \left( 1 - \frac{1}{1+z^2} \right) dz = x + C$

$z - \tan^{-1} z = x + C$

Substituting back  $z = x + y + 1$ :  $(x + y + 1) - \tan^{-1}(x + y + 1) = x + C$

**Answer:**  $y + 1 = \tan^{-1}(x + y + 1) + C$

**Question 5(b)(2) [4 marks]**

Solve  $\frac{dy}{dx} + \frac{y}{x} = e^x$ ,  $y(0) = 2$

**Solution**

This is a linear differential equation of the form  $\frac{dy}{dx} + P(x)y = Q(x)$

Here  $P(x) = \frac{1}{x}$ ,  $Q(x) = e^x$

Integrating factor:  $I.F. = e^{\int \frac{1}{x} dx} = e^{\ln|x|} = |x| = x$  (for  $x > 0$ )

Multiplying the equation by  $x$ :  $x \frac{dy}{dx} + y = x e^x$

$\frac{d}{dx}(xy) = x e^x$

Integrating both sides:  $xy = \int x e^x dx$

Using integration by parts for  $\int x e^x dx$ : Let  $u = x$ ,  $dv = e^x dx$  Then  $du = dx$ ,  $v = e^x$

$\int x e^x dx = x e^x - \int e^x dx = x e^x - e^x = e^x(x - 1)$

So:  $xy = e^x(x - 1) + C$   $y = \frac{e^x(x-1)+C}{x}$

Using initial condition  $y(0) = 2$ : As  $x \rightarrow 0$ , we need to use L'Hôpital's rule or series expansion.

From the original equation at  $x = 0$ :  $\frac{dy}{dx} = e^x - \frac{y}{x}$  This suggests we need to be more careful with the initial condition.

**Alternative approach:** Since the equation has a singularity at  $x = 0$ , we solve in the neighborhood where  $x \neq 0$ .

**Answer:**  $y = \frac{e^x(x-1)+C}{x}$  where  $C$  is determined by boundary conditions.

**Question 5(b)(3) [4 marks]**

Solve  $y \frac{dy}{dx} = \sqrt{1 + x^2 + y^2 + x^2 y^2}$

**Solution**

$y \frac{dy}{dx} = \sqrt{1 + x^2 + y^2 + x^2 y^2}$

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

$\frac{y dy}{\sqrt{1+y^2}} = \sqrt{1+x^2} dx$

Integrating both sides:  $\int \frac{y dy}{\sqrt{1+y^2}} = \int \sqrt{1+x^2} dx$

For the left side, let  $u = 1 + y^2$ , then  $du = 2y dy$ :  $\int \frac{y dy}{\sqrt{1+y^2}} = \frac{1}{2} \int \frac{du}{\sqrt{u}} = \sqrt{u} = \sqrt{1+y^2}$

For the right side:  $\int \sqrt{1+x^2} dx = \frac{x\sqrt{1+x^2}}{2} + \frac{1}{2} \ln|x + \sqrt{1+x^2}| + C$

Therefore: **Answer:**  $\sqrt{1+y^2} = \frac{x\sqrt{1+x^2}}{2} + \frac{1}{2} \ln|x + \sqrt{1+x^2}| + C$

**Formula Cheat Sheet**

## Matrix Operations

- $(A + B)^T = A^T + B^T$
- $(AB)^T = B^T A^T$
- $A \cdot \text{adj}(A) = |A| \cdot I$
- For  $2 \times 2$  matrix  $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$ :  $\text{adj} = \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$

## Differentiation Formulas

- $\frac{d}{dx}(\sin x) = \cos x$
- $\frac{d}{dx}(\cos x) = -\sin x$
- $\frac{d}{dx}(\tan x) = \sec^2 x$
- $\frac{d}{dx}(\log x) = \frac{1}{x}$
- $\frac{d}{dx}(e^x) = e^x$
- Chain rule:  $\frac{d}{dx}f(g(x)) = f'(g(x)) \cdot g'(x)$

## Integration Formulas

- $\int \sin x \, dx = -\cos x + C$
- $\int \cos x \, dx = \sin x + C$
- $\int \sec^2 x \, dx = \tan x + C$
- $\int \frac{1}{x} dx = \ln |x| + C$
- $\int e^x dx = e^x + C$
- $\int \frac{1}{x^2 + a^2} dx = \frac{1}{a} \tan^{-1}\left(\frac{x}{a}\right) + C$

## Differential Equations

- **Linear DE:**  $\frac{dy}{dx} + P(x)y = Q(x)$
- **Integrating Factor:**  $I.F. = e^{\int P(x)dx}$
- **Variable Separable:**  $\frac{dy}{dx} = f(x)g(y) \Rightarrow \frac{dy}{g(y)} = f(x)dx$

## Statistics

- **Mean:**  $\bar{x} = \frac{\sum x_i}{n}$  (ungrouped),  $\bar{x} = \frac{\sum f_i x_i}{\sum f_i}$  (grouped)
- **Mean Deviation:**  $M.D. = \frac{\sum |x_i - \bar{x}|}{n}$
- **Standard Deviation:**  $\sigma = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n}}$