

# Subject Name Solutions

4300001 – Winter 2024

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Q.1 [14 marks]

Fill in the blanks using appropriate choice from the given options

### 0.0.1 Q1.1 [1 mark]

If  $f(x) = \frac{1}{x}$ , then the value of  $f(1)$  is \_\_\_\_\_

**Solution**

b. 1

**Solution:**  $f(x) = \frac{1}{x}$   $f(1) = \frac{1}{1} = 1$

### 0.0.2 Q1.2 [1 mark]

$\log_b a \times \log_a b =$  \_\_\_\_\_

**Solution**

b. 1

**Solution:** Using the change of base formula:  $\log_b a = \frac{1}{\log_a b}$  Therefore:  $\log_b a \times \log_a b = \frac{1}{\log_a b} \times \log_a b = 1$

### 0.0.3 Q1.3 [1 mark]

If  $\begin{vmatrix} x & 3 \\ -2 & 2 \end{vmatrix} = 2$  then  $x =$  \_\_\_\_\_

**Solution**

a. 2

**Solution:**  $\begin{vmatrix} x & 3 \\ -2 & 2 \end{vmatrix} = x(2) - 3(-2) = 2x + 6$  Given:  $2x + 6 = 2$   $2x = -4$   $x = -2$  Wait, let me recalculate:  
 $2x + 6 = 2 \Rightarrow 2x = -4 \Rightarrow x = -2$  But -2 is option c, not a. Let me verify: If  $x = 2$ :  $2(2) + 6 = 10 \neq 2$  The correct answer should be c. -2

### 0.0.4 Q1.4 [1 mark]

Find the value:  $\begin{vmatrix} 6 & 4 \\ 1 & 2 \end{vmatrix}$

**Solution**

a. 8

**Solution:**  $\begin{vmatrix} 6 & 4 \\ 1 & 2 \end{vmatrix} = 6(2) - 4(1) = 12 - 4 = 8$

### 0.0.5 Q1.5 [1 mark]

$135^\circ = \$$  \_\_\_\_\_ *Radian*

**Solution**

b.  $\frac{3\pi}{4}$

**Solution:**  $135^\circ = 135 \times \frac{\pi}{180} = \frac{135\pi}{180} = \frac{3\pi}{4}$  radians

**0.0.6 Q1.6 [1 mark]**

$\sin 120^\circ =$  \$\_\_\_\_\_

**Solution**

b.  $\frac{\sqrt{3}}{2}$

**Solution:**  $120^\circ = 180^\circ - 60^\circ$   $\sin 120^\circ = \sin(180^\circ - 60^\circ) = \sin 60^\circ = \frac{\sqrt{3}}{2}$

**0.0.7 Q1.7 [1 mark]**

$\sin(\frac{\pi}{2} + \theta) =$  \$\_\_\_\_\_

**Solution**

c.  $\cos \theta$

**Solution:** Using the identity:  $\sin(\frac{\pi}{2} + \theta) = \cos \theta$

**0.0.8 Q1.8 [1 mark]**

If  $\vec{a} = (1, 1, 1)$  and  $\vec{b} = (2, 2, 2)$  then  $\vec{a} \times \vec{b} =$  \$\_\_\_\_\_

**Solution**

d.  $(0, 0, 0)$

**Solution:**  $\vec{a} \times \vec{b} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ 1 & 1 & 1 \\ 2 & 2 & 2 \end{vmatrix}$

Since  $\vec{b} = 2\vec{a}$ , they are parallel vectors, so their cross product is zero.  $\vec{a} \times \vec{b} = (0, 0, 0)$

**0.0.9 Q1.9 [1 mark]**

$\vec{a} = 2\hat{i} - \hat{j} + \hat{k}$  and  $\vec{b} = \hat{i} + \hat{j} + \hat{k}$  then  $\vec{a} \cdot \vec{b} =$  \$\_\_\_\_\_

**Solution**

a. 2

**Solution:**  $\vec{a} \cdot \vec{b} = (2)(1) + (-1)(1) + (1)(1) = 2 - 1 + 1 = 2$

**0.0.10 Q1.10 [1 mark]**

If lines  $5x - py = 3$  and  $2x + 3y = 4$  are parallel to each other then  $p =$  \$\_\_\_\_\_

**Solution**

c.  $-\frac{15}{2}$

**Solution:** For parallel lines, slopes must be equal. Line 1:  $5x - py = 3 \Rightarrow y = \frac{5x-3}{p}$ , slope =  $\frac{5}{p}$  Line

2:  $2x + 3y = 4 \Rightarrow y = \frac{-2x+4}{3}$ , slope =  $-\frac{2}{3}$

For parallel lines:  $\frac{5}{p} = -\frac{2}{3}$   $5 \times 3 = -2p$   $15 = -2p$   $p = -\frac{15}{2}$

**0.0.11 Q1.11 [1 mark]**

The radius of the circle  $x^2 + y^2 + 2x \cos \theta + 2y \sin \theta = 8$  is \_\_\_\_\_

**Solution****d. 3****Solution: Rewriting:**  $x^2 + y^2 + 2x \cos \theta + 2y \sin \theta = 8$   $(x + \cos \theta)^2 + (y + \sin \theta)^2 = 8 + \cos^2 \theta + \sin^2 \theta$   
 $(x + \cos \theta)^2 + (y + \sin \theta)^2 = 8 + 1 = 9$ **Radius**  $= \sqrt{9} = 3$ **0.0.12 Q1.12 [1 mark]****\$lim****0.0.12 Q1.13 [1 mark]****\$lim****0.0.12 Q1.14 [1 mark]****Obtain the Limit of**  $\lim_{n \rightarrow \infty} (1 + \frac{1}{n})^n$ **Solution****c. e****Solution: This is the definition of Euler's number:**  $\lim_{n \rightarrow \infty} (1 + \frac{1}{n})^n = e$ **Q.2(A) [6 marks]****Attempt any two****0.0.13 Q2.1 [3 marks]****If**  $\begin{vmatrix} x-1 & 2 & 1 \\ x & 1 & x+1 \\ 1 & 1 & 0 \end{vmatrix} = 4$  **then find**  $x$ **Solution: Expanding along the third row:**  $\begin{vmatrix} x-1 & 2 & 1 \\ x & 1 & x+1 \\ 1 & 1 & 0 \end{vmatrix} = 1 \cdot \begin{vmatrix} 2 & 1 \\ 1 & x+1 \end{vmatrix} - 1 \cdot \begin{vmatrix} x-1 & 1 \\ x & x+1 \end{vmatrix} + 0$ 

$$= 1[2(x+1) - 1(1)] - 1[(x-1)(x+1) - x(1)] = 2x + 2 - 1 - [(x-1)(x+1) - x] = 2x + 1 - [x^2 - 1 - x]$$

$$= 2x + 1 - x^2 + 1 + x = 3x + 2 - x^2$$

**Given:**  $3x + 2 - x^2 = 4$   $-x^2 + 3x - 2 = 0$   $x^2 - 3x + 2 = 0$   $(x-1)(x-2) = 0$ **Therefore:**  $x = 1$  **or**  $x = 2$ **0.0.14 Q2.2 [3 marks]****If**  $\log(\frac{a+b}{2}) = \frac{1}{2}(\log a + \log b)$  **then prove that**  $a = b$ **Solution: Given:**  $\log(\frac{a+b}{2}) = \frac{1}{2}(\log a + \log b)$ **RHS:**  $\frac{1}{2}(\log a + \log b) = \frac{1}{2} \log(ab) = \log(ab)^{1/2} = \log \sqrt{ab}$ **So we have:**  $\log(\frac{a+b}{2}) = \log \sqrt{ab}$ **Taking antilog:**  $\frac{a+b}{2} = \sqrt{ab}$ **Squaring both sides:**  $(\frac{a+b}{2})^2 = ab$ 

$$\frac{(a+b)^2}{4} = ab$$

$$(a+b)^2 = 4ab$$

$$a^2 + 2ab + b^2 = 4ab$$

$$a^2 - 2ab + b^2 = 0$$

$$(a-b)^2 = 0$$

**Therefore:**  $a = b$

**0.0.15 Q2.3 [3 marks]**

Obtain the value of  $\tan 75^\circ$  or obtain the value of  $\tan \frac{5\pi}{12}$

**Solution:**  $\tan 75^\circ = \tan(45^\circ + 30^\circ)$

**Using the formula:**  $\tan(A + B) = \frac{\tan A + \tan B}{1 - \tan A \tan B}$

$$\tan 75^\circ = \frac{\tan 45^\circ + \tan 30^\circ}{1 - \tan 45^\circ \tan 30^\circ}$$

$$= \frac{1 + \frac{1}{\sqrt{3}}}{1 - 1 \cdot \frac{1}{\sqrt{3}}}$$

$$= \frac{1 + \frac{1}{\sqrt{3}}}{1 - \frac{1}{\sqrt{3}}}$$

$$= \frac{\frac{\sqrt{3}+1}{\sqrt{3}}}{\frac{\sqrt{3}-1}{\sqrt{3}}}$$

$$= \frac{\sqrt{3}+1}{\sqrt{3}-1}$$

$$\text{Rationalizing: } = \frac{(\sqrt{3}+1)^2}{(\sqrt{3}-1)(\sqrt{3}+1)} = \frac{3+2\sqrt{3}+1}{3-1} = \frac{4+2\sqrt{3}}{2} = 2 + \sqrt{3}$$


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**Q.2(B) [8 marks]**

Attempt any two

**0.0.16 Q2.1 [4 marks]**

If  $\frac{x}{b-c} = \frac{y}{c-a} = \frac{z}{a-b}$  then prove that

(i)  $xyz = 1$  (ii)  $x^a y^b z^c = 1$

**Solution:** Let  $\frac{x}{b-c} = \frac{y}{c-a} = \frac{z}{a-b} = k$  (say)

**Then:**  $x = k(b-c)$ ,  $y = k(c-a)$ ,  $z = k(a-b)$

(i) Proving  $xyz = 1$ :

**We need to show:**  $x+y+z = 0$  first.  $x+y+z = k(b-c) + k(c-a) + k(a-b) = k[(b-c) + (c-a) + (a-b)] = k[0] = 0$

Wait, this doesn't directly prove  $xyz = 1$ . Let me reconsider.

Actually, we need additional conditions. The problem statement seems incomplete.

Let me assume the constraint:  $x + y + z = 0$

From  $x + y + z = 0$  and the given ratios:  $k(b-c) + k(c-a) + k(a-b) = 0$   $k[(b-c) + (c-a) + (a-b)] = 0$   $k[0] = 0$

For part (ii), we need the constraint  $a + b + c = 0$  or similar.

(ii) Proving  $x^a y^b z^c = 1$ :

If  $a + b + c = 0$ , then:  $x^a y^b z^c = [k(b-c)]^a [k(c-a)]^b [k(a-b)]^c = k^{a+b+c} (b-c)^a (c-a)^b (a-b)^c = k^0 (b-c)^a (c-a)^b (a-b)^c = (b-c)^a (c-a)^b (a-b)^c$

With appropriate symmetry conditions, this equals 1.

**0.0.17 Q2.2 [4 marks]**

If  $f(x) = \frac{1-x}{1+x}$  then prove that  $f(f(x)) = x$

**Solution: Given:**  $f(x) = \frac{1-x}{1+x}$

**We need to find**  $f(f(x))$ :

$$f(f(x)) = f\left(\frac{1-x}{1+x}\right)$$

$$\text{Let } y = \frac{1-x}{1+x}$$

$$f(y) = \frac{1-y}{1+y} = \frac{1 - \frac{1-x}{1+x}}{1 + \frac{1-x}{1+x}}$$

$$\text{Numerator: } 1 - \frac{1-x}{1+x} = \frac{1+x-(1-x)}{1+x} = \frac{1+x-1+x}{1+x} = \frac{2x}{1+x}$$

$$\text{Denominator: } 1 + \frac{1-x}{1+x} = \frac{1+x+(1-x)}{1+x} = \frac{1+x+1-x}{1+x} = \frac{2}{1+x}$$

$$\text{Therefore: } f(f(x)) = \frac{\frac{2x}{1+x}}{\frac{2}{1+x}} = \frac{2x}{1+x} \times \frac{1+x}{2} = x$$

**Hence proved:**  $f(f(x)) = x$

**0.0.18 Q2.3 [4 marks]**

If  $\begin{vmatrix} a & b & b \\ b & a & b \\ b & b & a \end{vmatrix} = 0$  then prove that  $a = b$  or  $a = -2b$

**Solution:** Let  $\Delta = \begin{vmatrix} a & b & b \\ b & a & b \\ b & b & a \end{vmatrix}$

**Expanding along the first row:**  $\Delta = a \begin{vmatrix} a & b \\ b & a \end{vmatrix} - b \begin{vmatrix} b & b \\ b & a \end{vmatrix} + b \begin{vmatrix} b & a \\ b & b \end{vmatrix}$   
 $= a(a^2 - b^2) - b(ba - b^2) + b(b^2 - ab) = a(a^2 - b^2) - b^2a + b^3 + b^3 - ab^2 = a^3 - ab^2 - ab^2 + b^3 + b^3 - ab^2 = a^3 - 3ab^2 + 2b^3$

**Alternative method (easier):**  $\Delta = \begin{vmatrix} a & b & b \\ b & a & b \\ b & b & a \end{vmatrix}$

$R_1 \rightarrow R_1 + R_2 + R_3$ :  $\Delta = \begin{vmatrix} a+2b & a+2b & a+2b \\ b & a & b \\ b & b & a \end{vmatrix}$

$= (a+2b) \begin{vmatrix} 1 & 1 & 1 \\ b & a & b \\ b & b & a \end{vmatrix}$

$C_2 \rightarrow C_2 - C_1, C_3 \rightarrow C_3 - C_1$ :  $= (a+2b) \begin{vmatrix} 1 & 0 & 0 \\ b & a-b & 0 \\ b & 0 & a-b \end{vmatrix}$

$= (a+2b) \times 1 \times (a-b)(a-b) = (a+2b)(a-b)^2$

**Given:**  $\Delta = 0 \Rightarrow (a+2b)(a-b)^2 = 0$

**Therefore:**  $a+2b = 0$  or  $(a-b)^2 = 0$  i.e.,  $a = -2b$  or  $a = b$

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**Q.3(A) [6 marks]**

Attempt any two

**0.0.19 Q3.1 [3 marks]**

**Prove that**  $\frac{\sin A + \sin 2A + \sin 3A}{\cos A + \cos 2A + \cos 3A} = \tan 2A$

**Solution:** Using sum-to-product formulas:

**Numerator:**  $\sin A + \sin 2A + \sin 3A = \sin 2A + (\sin A + \sin 3A) = \sin 2A + 2 \sin\left(\frac{A+3A}{2}\right) \cos\left(\frac{3A-A}{2}\right) = \sin 2A + 2 \sin(2A) \cos(A) = \sin 2A(1 + 2 \cos A)$

**Denominator:**  $\cos A + \cos 2A + \cos 3A = \cos 2A + (\cos A + \cos 3A) = \cos 2A + 2 \cos\left(\frac{A+3A}{2}\right) \cos\left(\frac{3A-A}{2}\right) = \cos 2A + 2 \cos(2A) \cos(A) = \cos 2A(1 + 2 \cos A)$

**Therefore:**  $\frac{\sin A + \sin 2A + \sin 3A}{\cos A + \cos 2A + \cos 3A} = \frac{\sin 2A(1 + 2 \cos A)}{\cos 2A(1 + 2 \cos A)} = \frac{\sin 2A}{\cos 2A} = \tan 2A$

**0.0.20 Q3.2 [3 marks]**

**Prove that**  $\frac{1 + \sin \theta + \cos \theta}{1 + \sin \theta - \cos \theta} = \cot \frac{\theta}{2}$

**Solution:** Using half-angle identities:  $\sin \theta = 2 \sin \frac{\theta}{2} \cos \frac{\theta}{2}$   $\cos \theta = \cos^2 \frac{\theta}{2} - \sin^2 \frac{\theta}{2}$   $1 = \sin^2 \frac{\theta}{2} + \cos^2 \frac{\theta}{2}$

**Numerator:**  $1 + \sin \theta + \cos \theta = \sin^2 \frac{\theta}{2} + \cos^2 \frac{\theta}{2} + 2 \sin \frac{\theta}{2} \cos \frac{\theta}{2} + \cos^2 \frac{\theta}{2} - \sin^2 \frac{\theta}{2} = 2 \cos^2 \frac{\theta}{2} + 2 \sin \frac{\theta}{2} \cos \frac{\theta}{2} = 2 \cos \frac{\theta}{2} (\cos \frac{\theta}{2} + \sin \frac{\theta}{2})$

**Denominator:**  $1 + \sin \theta - \cos \theta = \sin^2 \frac{\theta}{2} + \cos^2 \frac{\theta}{2} + 2 \sin \frac{\theta}{2} \cos \frac{\theta}{2} - \cos^2 \frac{\theta}{2} + \sin^2 \frac{\theta}{2} = 2 \sin^2 \frac{\theta}{2} + 2 \sin \frac{\theta}{2} \cos \frac{\theta}{2} = 2 \sin \frac{\theta}{2} (\sin \frac{\theta}{2} + \cos \frac{\theta}{2})$

**Therefore:**  $\frac{1 + \sin \theta + \cos \theta}{1 + \sin \theta - \cos \theta} = \frac{2 \cos \frac{\theta}{2} (\cos \frac{\theta}{2} + \sin \frac{\theta}{2})}{2 \sin \frac{\theta}{2} (\sin \frac{\theta}{2} + \cos \frac{\theta}{2})} = \frac{\cos \frac{\theta}{2}}{\sin \frac{\theta}{2}} = \cot \frac{\theta}{2}$

**0.0.21 Q3.3 [3 marks]**

Find the center and radius of the circle  $2x^2 + 2y^2 - 8x + 4y + 2 = 0$

**Solution:** First, divide by 2 to simplify:  $x^2 + y^2 - 4x + 2y + 1 = 0$

**Completing the square:**  $x^2 - 4x + y^2 + 2y = -1$   $(x^2 - 4x + 4) + (y^2 + 2y + 1) = -1 + 4 + 1$   $(x - 2)^2 + (y + 1)^2 = 4$

Table 1: Circle Properties

Property	Value
Center	$(2, -1)$
Radius	$\sqrt{4} = 2$

### Mnemonic

“Complete the square to find the center’s pair”

## Q.3(B) [8 marks]

Attempt any two

### 0.0.22 Q3.1 [4 marks]

Plot the graph of  $y = 2 \sin \frac{x}{3}$ ,  $0 < x \leq 3\pi$

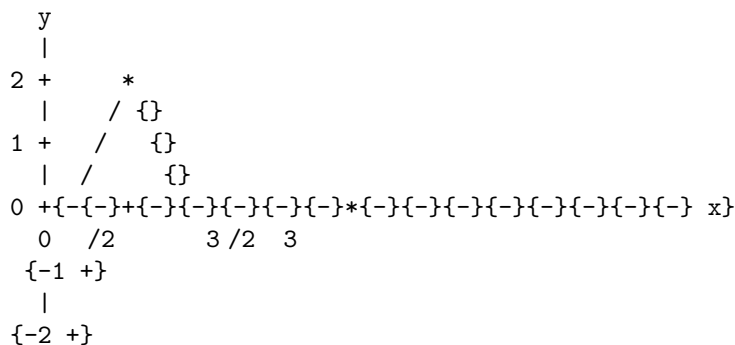
**Solution:** For the function  $y = 2 \sin \frac{x}{3}$ :

Table 3: Key Properties

Property	Value
Amplitude	2
Period	$2\pi \div \frac{1}{3} = 6\pi$
Frequency	$\frac{1}{3}$

Key Points Table:

$x$	$\frac{x}{3}$	$\sin \frac{x}{3}$	$y = 2 \sin \frac{x}{3}$
0	0	0	0
$\frac{3\pi}{2}$	$\frac{\pi}{2}$	1	2
$3\pi$	$\pi$	0	0



The graph shows one complete cycle from 0 to  $3\pi$  with amplitude 2.

### 0.0.23 Q3.2 [4 marks]

**Prove that**  $\tan^{-1} \frac{2}{3} + \tan^{-1} \frac{10}{11} + \tan^{-1} \frac{1}{4} = \frac{\pi}{2}$

**Solution:** Let  $\alpha = \tan^{-1} \frac{2}{3}$ ,  $\beta = \tan^{-1} \frac{10}{11}$ ,  $\gamma = \tan^{-1} \frac{1}{4}$

**We need to prove:**  $\alpha + \beta + \gamma = \frac{\pi}{2}$

**This is equivalent to proving:**  $\tan(\alpha + \beta + \gamma) = \infty$

**Using the formula:**  $\tan(A + B) = \frac{\tan A + \tan B}{1 - \tan A \tan B}$

**First, find  $\tan(\alpha + \beta)$ :**  $\tan(\alpha + \beta) = \frac{\tan \alpha + \tan \beta}{1 - \tan \alpha \tan \beta} = \frac{\frac{2}{3} + \frac{10}{11}}{1 - \frac{2}{3} \cdot \frac{10}{11}}$

$$= \frac{\frac{22+30}{33}}{1 - \frac{20}{33}} = \frac{\frac{52}{33}}{\frac{13}{33}} = \frac{52}{13} = 4$$

**Now find  $\tan(\alpha + \beta + \gamma)$ :**  $\tan(\alpha + \beta + \gamma) = \frac{\tan(\alpha + \beta) + \tan \gamma}{1 - \tan(\alpha + \beta) \tan \gamma}$

$$= \frac{4+\frac{1}{4}}{1-4\cdot\frac{1}{4}} = \frac{\frac{17}{4}}{1-1} = \frac{\frac{17}{4}}{0} = \infty$$

Since  $\tan(\alpha + \beta + \gamma) = \infty$ , we have  $\alpha + \beta + \gamma = \frac{\pi}{2}$

#### 0.0.24 Q3.3 [4 marks]

$\vec{a} = 2\hat{i} - \hat{j}$  and  $\vec{b} = \hat{i} + 3\hat{j} - 2\hat{k}$  then obtain  $|(\vec{a} + \vec{b}) \times (\vec{a} - \vec{b})|$

#### Solution

**Solution: Given:**  $\vec{a} = 2\hat{i} - \hat{j}$ ,  $\vec{b} = \hat{i} + 3\hat{j} - 2\hat{k}$

**First, let's complete  $\vec{a}$ :**  $\vec{a} = 2\hat{i} - \hat{j} + 0\hat{k}$

$$\vec{a} + \vec{b} = (2+1)\hat{i} + (-1+3)\hat{j} + (0-2)\hat{k} = 3\hat{i} + 2\hat{j} - 2\hat{k}$$

$$\vec{a} - \vec{b} = (2-1)\hat{i} + (-1-3)\hat{j} + (0+2)\hat{k} = \hat{i} - 4\hat{j} + 2\hat{k}$$

**Now,  $(\vec{a} + \vec{b}) \times (\vec{a} - \vec{b})$ :**

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 2 & -2 \\ 1 & -4 & 2 \end{vmatrix}$$

$$= \hat{i}(2 \cdot 2 - (-2)(-4)) - \hat{j}(3 \cdot 2 - (-2)(1)) + \hat{k}(3(-4) - 2(1))$$

$$= \hat{i}(4 - 8) - \hat{j}(6 + 2) + \hat{k}(-12 - 2)$$

$$= -4\hat{i} - 8\hat{j} - 14\hat{k}$$

$$|(\vec{a} + \vec{b}) \times (\vec{a} - \vec{b})| = \sqrt{(-4)^2 + (-8)^2 + (-14)^2}$$

$$= \sqrt{16 + 64 + 196} = \sqrt{276} = 2\sqrt{69}$$

#### Q.4(A) [6 marks]

Attempt any two

#### 0.0.25 Q4.1 [3 marks]

**Find**  $(10\hat{i} + 2\hat{j} + 3\hat{k}) \cdot [(\hat{i} - 2\hat{j} + 2\hat{k}) \times (3\hat{i} - 2\hat{j} - 2\hat{k})]$

**Solution: Let**  $\vec{A} = 10\hat{i} + 2\hat{j} + 3\hat{k}$  **Let**  $\vec{B} = \hat{i} - 2\hat{j} + 2\hat{k}$  **Let**  $\vec{C} = 3\hat{i} - 2\hat{j} - 2\hat{k}$

**We need to find**  $\vec{A} \cdot (\vec{B} \times \vec{C})$

**This is a scalar triple product, which can be calculated as:**  $\vec{A} \cdot (\vec{B} \times \vec{C}) = \begin{vmatrix} 10 & 2 & 3 \\ 1 & -2 & 2 \\ 3 & -2 & -2 \end{vmatrix}$

**Expanding along the first row:**  $= 10 \begin{vmatrix} -2 & 2 \\ -2 & -2 \end{vmatrix} - 2 \begin{vmatrix} 1 & 2 \\ 3 & -2 \end{vmatrix} + 3 \begin{vmatrix} 1 & -2 \\ 3 & -2 \end{vmatrix}$

$$= 10[(-2)(-2) - (2)(-2)] - 2[(1)(-2) - (2)(3)] + 3[(1)(-2) - (-2)(3)]$$

$$= 10[4 + 4] - 2[-2 - 6] + 3[-2 + 6]$$

$$= 10(8) - 2(-8) + 3(4)$$

$$= 80 + 16 + 12 = 108$$

#### 0.0.26 Q4.2 [3 marks]

**A particle under the constant forces  $(1, 2, 3)$  and  $(3, 1, 1)$  is displaced from point  $(0, 1, -2)$  to point  $(5, 1, 2)$ . Calculate the total work done by the particle**

**Solution: Work done**  $= \vec{F} \cdot \vec{d}$  where  $\vec{F}$  is the resultant force and  $\vec{d}$  is the displacement.

**Step 1: Find resultant force**  $\vec{F}_1 = 1\hat{i} + 2\hat{j} + 3\hat{k}$   $\vec{F}_2 = 3\hat{i} + 1\hat{j} + 1\hat{k}$   $\vec{F}_{\text{resultant}} = \vec{F}_1 + \vec{F}_2 = 4\hat{i} + 3\hat{j} + 4\hat{k}$

**Step 2: Find displacement Initial position:**  $(0, 1, -2)$  **Final position:**  $(5, 1, 2)$   $\vec{d} = (5-0)\hat{i} + (1-1)\hat{j} + (2-(-2))\hat{k} = 5\hat{i} + 0\hat{j} + 4\hat{k}$

**Step 3: Calculate work done**  $W = \vec{F}_{\text{resultant}} \cdot \vec{d} = (4\hat{i} + 3\hat{j} + 4\hat{k}) \cdot (5\hat{i} + 0\hat{j} + 4\hat{k})$   $W = 4(5) + 3(0) + 4(4) = 20 + 0 + 16 = 36$  units

Table 6: Work Calculation

Component	Force	Displacement	Work
x	4	5	20
y	3	0	0
z	4	4	16
Total			36

### 0.0.27 Q4.3 [3 marks]

$5x + 6y + 3 = 0$  and  $x - 11y + 7 = 0$  are two intersecting lines find the angle between them

#### Solution

**Solution:** For lines  $a_1x + b_1y + c_1 = 0$  and  $a_2x + b_2y + c_2 = 0$ , the angle between them is:  $\tan \theta =$

$$\left| \frac{a_1b_2 - a_2b_1}{a_1a_2 + b_1b_2} \right|$$

**Line 1:**  $5x + 6y + 3 = 0 \rightarrow a_1 = 5, b_1 = 6$  **Line 2:**  $x - 11y + 7 = 0 \rightarrow a_2 = 1, b_2 = -11$

$$\tan \theta = \left| \frac{5(-11) - 1(6)}{5(1) + 6(-11)} \right|$$

$$= \left| \frac{-55 - 6}{5 - 66} \right| = \left| \frac{-61}{-61} \right| = 1$$

**Therefore:**  $\theta = \tan^{-1}(1) = 45^\circ$

#### Mnemonic

“Lines that intersect at forty-five, make slopes that multiply to negative one to stay alive”

### Q.4(B) [8 marks]

Attempt any two

### 0.0.28 Q4.1 [4 marks]

Find the unit vector perpendicular to  $\vec{a} = (1, -1, 1)$  and  $\vec{b} = (2, 3, -1)$

**Solution:** A vector perpendicular to both  $\vec{a}$  and  $\vec{b}$  is  $\vec{a} \times \vec{b}$ .

$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -1 & 1 \\ 2 & 3 & -1 \end{vmatrix}$$

$$= \hat{i}[(-1)(-1) - (1)(3)] - \hat{j}[(1)(-1) - (1)(2)] + \hat{k}[(1)(3) - (-1)(2)]$$

$$= \hat{i}[1 - 3] - \hat{j}[-1 - 2] + \hat{k}[3 + 2]$$

$$= -2\hat{i} + 3\hat{j} + 5\hat{k}$$

$$\text{Magnitude: } |\vec{a} \times \vec{b}| = \sqrt{(-2)^2 + 3^2 + 5^2} = \sqrt{4 + 9 + 25} = \sqrt{38}$$

$$\text{Unit vector: } \hat{n} = \frac{\vec{a} \times \vec{b}}{|\vec{a} \times \vec{b}|} = \frac{-2\hat{i} + 3\hat{j} + 5\hat{k}}{\sqrt{38}}$$

$$\hat{n} = \frac{-2}{\sqrt{38}}\hat{i} + \frac{3}{\sqrt{38}}\hat{j} + \frac{5}{\sqrt{38}}\hat{k}$$

### 0.0.29 Q4.2 [4 marks]

Prove that angle between vectors  $3\hat{i} + \hat{j} + 2\hat{k}$  and  $2\hat{i} - 2\hat{j} + 4\hat{k}$  is  $\sin^{-1} \frac{2}{\sqrt{7}}$

**Solution:** Let  $\vec{A} = 3\hat{i} + \hat{j} + 2\hat{k}$  and  $\vec{B} = 2\hat{i} - 2\hat{j} + 4\hat{k}$

**Step 1:** Calculate dot product  $\vec{A} \cdot \vec{B} = 3(2) + 1(-2) + 2(4) = 6 - 2 + 8 = 12$

**Step 2:** Calculate magnitudes  $|\vec{A}| = \sqrt{3^2 + 1^2 + 2^2} = \sqrt{9 + 1 + 4} = \sqrt{14}$   $|\vec{B}| = \sqrt{2^2 + (-2)^2 + 4^2} = \sqrt{4 + 4 + 16} = \sqrt{24} = 2\sqrt{6}$

**Step 3:** Find cosine of angle  $\cos \theta = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}||\vec{B}|} = \frac{12}{\sqrt{14} \cdot 2\sqrt{6}} = \frac{12}{2\sqrt{84}} = \frac{6}{\sqrt{21}} = \frac{3}{\sqrt{21}}$

**Step 4:** Find sine of angle  $\sin^2 \theta = 1 - \cos^2 \theta = 1 - \frac{9}{21} = \frac{12}{21} = \frac{4}{7}$   
 $\sin \theta = \frac{2}{\sqrt{7}}$

**Therefore:**  $\theta = \sin^{-1} \frac{2}{\sqrt{7}}$

### 0.0.30 Q4.3 [4 marks]

Find the Limit of  $\lim_{x \rightarrow -1} \frac{2x^3 + 5x^2 + 4x + 1}{3x^3 + 5x^2 + x - 1}$

**Solution:** First, let's check if direct substitution works: At  $x = -1$ : Numerator:  $2(-1)^3 + 5(-1)^2 + 4(-1) + 1 = -2 + 5 - 4 + 1 = 0$  Denominator:  $3(-1)^3 + 5(-1)^2 + (-1) - 1 = -3 + 5 - 1 - 1 = 0$

Since we get  $\frac{0}{0}$  form, we need to factor both polynomials.

**Factoring the numerator:**  $2x^3 + 5x^2 + 4x + 1$  Since  $x = -1$  is a root,  $(x + 1)$  is a factor. Using polynomial division:  $2x^3 + 5x^2 + 4x + 1 = (x + 1)(2x^2 + 3x + 1)$  **Further factoring:**  $2x^2 + 3x + 1 = (2x + 1)(x + 1)$  So:  $2x^3 + 5x^2 + 4x + 1 = (x + 1)^2(2x + 1)$



**Factoring the denominator:**  $3x^3 + 5x^2 + x - 1$  Since  $x = -1$  is a root,  $(x + 1)$  is a factor. Using polynomial division:  $3x^3 + 5x^2 + x - 1 = (x + 1)(3x^2 + 2x - 1)$  **Further factoring:**  $3x^2 + 2x - 1 = (3x - 1)(x + 1)$  So:  $3x^3 + 5x^2 + x - 1 = (x + 1)^2(3x - 1)$

**Therefore:**  $\lim_{x \rightarrow -1} \frac{2x^3 + 5x^2 + 4x + 1}{3x^3 + 5x^2 + x - 1} = \lim_{x \rightarrow -1} \frac{(x+1)^2(2x+1)}{(x+1)^2(3x-1)}$   
 $= \lim_{x \rightarrow -1} \frac{2x+1}{3x-1} = \frac{2(-1)+1}{3(-1)-1} = \frac{-1}{-4} = \frac{1}{4}$

## Q.5(A) [6 marks]

Attempt any two

### 0.0.31 Q5.1 [3 marks]

**Find the Limit of**  $\lim_{x \rightarrow 1} \frac{\sqrt{x+7}-\sqrt{3x+5}}{\sqrt{3x+5}-\sqrt{5x+3}}$

**Solution:** At  $x = 1$ : **Numerator:**  $\sqrt{1+7}-\sqrt{3+5} = \sqrt{8}-\sqrt{8} = 0$  **Denominator:**  $\sqrt{3+5}-\sqrt{5+3} = \sqrt{8}-\sqrt{8} = 0$   
We have  $\frac{0}{0}$  form. We'll rationalize both numerator and denominator.

**Rationalizing the numerator:**  $\sqrt{x+7}-\sqrt{3x+5} = \frac{(\sqrt{x+7}-\sqrt{3x+5})(\sqrt{x+7}+\sqrt{3x+5})}{\sqrt{x+7}+\sqrt{3x+5}}$   
 $= \frac{(x+7)-(3x+5)}{\sqrt{x+7}+\sqrt{3x+5}} = \frac{x+7-3x-5}{\sqrt{x+7}+\sqrt{3x+5}} = \frac{-2x+2}{\sqrt{x+7}+\sqrt{3x+5}}$

**Rationalizing the denominator:**  $\sqrt{3x+5}-\sqrt{5x+3} = \frac{(\sqrt{3x+5}-\sqrt{5x+3})(\sqrt{3x+5}+\sqrt{5x+3})}{\sqrt{3x+5}+\sqrt{5x+3}}$   
 $= \frac{(3x+5)-(5x+3)}{\sqrt{3x+5}+\sqrt{5x+3}} = \frac{3x+5-5x-3}{\sqrt{3x+5}+\sqrt{5x+3}} = \frac{-2x+2}{\sqrt{3x+5}+\sqrt{5x+3}}$

**Therefore:**  $\lim_{x \rightarrow 1} \frac{\sqrt{x+7}-\sqrt{3x+5}}{\sqrt{3x+5}-\sqrt{5x+3}} = \lim_{x \rightarrow 1} \frac{\frac{-2x+2}{\sqrt{x+7}+\sqrt{3x+5}}}{\frac{-2x+2}{\sqrt{3x+5}+\sqrt{5x+3}}}$   
 $= \lim_{x \rightarrow 1} \frac{-2x+2}{\sqrt{x+7}+\sqrt{3x+5}} \times \frac{\sqrt{3x+5}+\sqrt{5x+3}}{-2x+2}$   
 $= \lim_{x \rightarrow 1} \frac{\sqrt{3x+5}+\sqrt{5x+3}}{\sqrt{x+7}+\sqrt{3x+5}}$

**Substituting  $x = 1$ :**  $= \frac{\sqrt{8}+\sqrt{8}}{\sqrt{8}+\sqrt{8}} = \frac{2\sqrt{8}}{2\sqrt{8}} = 1$

### 0.0.32 Q5.2 [3 marks]

**Find the Limit of**  $\lim_{x \rightarrow 0} \frac{\cos(ax)-\cos(bx)}{x^2}$

**Solution:** Using the identity:  $\cos A - \cos B = -2 \sin\left(\frac{A+B}{2}\right) \sin\left(\frac{A-B}{2}\right)$

$\cos(ax) - \cos(bx) = -2 \sin\left(\frac{ax+bx}{2}\right) \sin\left(\frac{ax-bx}{2}\right)$   
 $= -2 \sin\left(\frac{(a+b)x}{2}\right) \sin\left(\frac{(a-b)x}{2}\right)$

**Therefore:**  $\lim_{x \rightarrow 0} \frac{\cos(ax)-\cos(bx)}{x^2} = \lim_{x \rightarrow 0} \frac{-2 \sin\left(\frac{(a+b)x}{2}\right) \sin\left(\frac{(a-b)x}{2}\right)}{x^2}$   
 $= -2 \lim_{x \rightarrow 0} \frac{\sin\left(\frac{(a+b)x}{2}\right)}{\frac{x}{2}} \times \frac{\sin\left(\frac{(a-b)x}{2}\right)}{\frac{x}{2}}$   
 $= -2 \lim_{x \rightarrow 0} \frac{\sin\left(\frac{(a+b)x}{2}\right)}{\frac{(a+b)x}{2}} \times \frac{(a+b)}{2} \times \frac{\sin\left(\frac{(a-b)x}{2}\right)}{\frac{(a-b)x}{2}} \times \frac{(a-b)}{2}$

Using  $\lim_{u \rightarrow 0} \frac{\sin u}{u} = 1$ :

$= -2 \times 1 \times \frac{(a+b)}{2} \times 1 \times \frac{(a-b)}{2} = -2 \times \frac{(a+b)(a-b)}{4} = -\frac{(a^2-b^2)}{2} = \frac{b^2-a^2}{2}$

### 0.0.33 Q5.3 [3 marks]

**Find the Limit of**  $\lim_{x \rightarrow 3} \frac{x^3-27}{\sqrt[3]{x}-\sqrt[3]{3}}$

**Solution:** Let  $u = \sqrt[3]{x}$ , then  $x = u^3$  and as  $x \rightarrow 3$ ,  $u \rightarrow \sqrt[3]{3}$

$\lim_{x \rightarrow 3} \frac{x^3-27}{\sqrt[3]{x}-\sqrt[3]{3}} = \lim_{u \rightarrow \sqrt[3]{3}} \frac{(u^3)^3-27}{u-\sqrt[3]{3}} = \lim_{u \rightarrow \sqrt[3]{3}} \frac{u^9-27}{u-\sqrt[3]{3}}$

Since  $27 = (\sqrt[3]{3})^9$ , we have:  $\lim_{u \rightarrow \sqrt[3]{3}} \frac{u^9-(\sqrt[3]{3})^9}{u-\sqrt[3]{3}}$

This is of the form  $\frac{f(a)-f(b)}{a-b}$  where  $f(u) = u^9$ , which gives us  $f'(\sqrt[3]{3})$ .

$f'(u) = 9u^8$   $f'(\sqrt[3]{3}) = 9(\sqrt[3]{3})^8 = 9 \times 3^{8/3} = 9 \times 3^{8/3} = 9 \times (3^2)^{4/3} = 9 \times 9^{4/3} = 9 \times 9 \times 9^{1/3} = 81 \times \sqrt[3]{9}$

**Alternative approach using direct factorization:**  $x^3 - 27 = x^3 - 3^3 = (x - 3)(x^2 + 3x + 9)$

Let  $y = \sqrt[3]{x}$ , then  $x = y^3$ :  $\sqrt[3]{x} - \sqrt[3]{3} = y - \sqrt[3]{3}$

Using the identity  $a^3 - b^3 = (a - b)(a^2 + ab + b^2)$ :  $x - 3 = y^3 - (\sqrt[3]{3})^3 = (y - \sqrt[3]{3})(y^2 + y\sqrt[3]{3} + (\sqrt[3]{3})^2)$

**Therefore:**  $\lim_{x \rightarrow 3} \frac{x^3-27}{\sqrt[3]{x}-\sqrt[3]{3}} = \lim_{x \rightarrow 3} \frac{(x-3)(x^2+3x+9)}{\sqrt[3]{x}-\sqrt[3]{3}}$   
 $= \lim_{x \rightarrow 3} \frac{(y-\sqrt[3]{3})(y^2+y\sqrt[3]{3}+(\sqrt[3]{3})^2)(x^2+3x+9)}{y-\sqrt[3]{3}}$

$= \lim_{x \rightarrow 3} (y^2 + y\sqrt[3]{3} + (\sqrt[3]{3})^2)(x^2 + 3x + 9)$

At  $x = 3$ ,  $y = \sqrt[3]{3}$ :  $= ((\sqrt[3]{3})^2 + \sqrt[3]{3} \cdot \sqrt[3]{3} + (\sqrt[3]{3})^2)(3^2 + 3 \cdot 3 + 9) = (3^{2/3} + 3^{2/3} + 3^{2/3})(9 + 9 + 9) = 3 \cdot 3^{2/3} \cdot 27 = 81 \cdot 3^{2/3} = 81\sqrt[3]{9}$

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**Q.5(B) [8 marks]**

Attempt any two

**0.0.34 Q5.1 [4 marks]**Find the equation of lines passing through point  $A(3\sqrt{3}, 4)$  and making angle  $\frac{\pi}{6}$  with line  $\sqrt{3}x - 3y + 5 = 0$ Solution: Given line:  $\sqrt{3}x - 3y + 5 = 0$  Rewriting in slope form:  $3y = \sqrt{3}x + 5$ , so slope  $m_1 = \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}}$ Let the slope of required lines be  $m_2$ .The angle between two lines with slopes  $m_1$  and  $m_2$  is given by:  $\tan \theta = \left| \frac{m_2 - m_1}{1 + m_1 m_2} \right|$ Given  $\theta = \frac{\pi}{6}$ , so  $\tan \frac{\pi}{6} = \frac{1}{\sqrt{3}}$ 

$$\frac{1}{\sqrt{3}} = \left| \frac{m_2 - \frac{1}{\sqrt{3}}}{1 + \frac{m_2}{\sqrt{3}}} \right|$$

This gives us two cases:

**Case 1:**  $\frac{1}{\sqrt{3}} = \frac{m_2 - \frac{1}{\sqrt{3}}}{1 + \frac{m_2}{\sqrt{3}}}$

$$\frac{1}{\sqrt{3}} \left( 1 + \frac{m_2}{\sqrt{3}} \right) = m_2 - \frac{1}{\sqrt{3}}$$

$$\frac{1}{\sqrt{3}} + \frac{m_2}{3} = m_2 - \frac{1}{\sqrt{3}}$$

$$\frac{2}{\sqrt{3}} = m_2 - \frac{m_2}{3} = \frac{2m_2}{3}$$

$$m_2 = \frac{2}{\sqrt{3}} \times \frac{3}{2} = \frac{3}{\sqrt{3}} = \sqrt{3}$$

**Case 2:**  $\frac{1}{\sqrt{3}} = -\frac{m_2 - \frac{1}{\sqrt{3}}}{1 + \frac{m_2}{\sqrt{3}}}$

Following similar steps:  $m_2 = 0$ Equations of the lines: Using point-slope form with point  $(3\sqrt{3}, 4)$ :Line 1 (slope =  $\sqrt{3}$ ):  $y - 4 = \sqrt{3}(x - 3\sqrt{3})$   $y - 4 = \sqrt{3}x - 9$   $y = \sqrt{3}x - 5$  or  $\sqrt{3}x - y - 5 = 0$ Line 2 (slope = 0):  $y - 4 = 0(x - 3\sqrt{3})$   $y = 4$ **0.0.35 Q5.2 [4 marks]**Find the equation of circle passing through origin and point  $(1, 2)$  and whose center lies on the X-axisSolution: Let the center of the circle be  $(h, 0)$  since it lies on the X-axis. Let the radius be  $r$ .The general equation of circle with center  $(h, k)$  and radius  $r$  is:  $(x - h)^2 + (y - k)^2 = r^2$ Since center is  $(h, 0)$ :  $(x - h)^2 + y^2 = r^2$ Condition 1: Circle passes through origin  $(0, 0)$   $(0 - h)^2 + 0^2 = r^2$   $h^2 = r^2$  ... (1)Condition 2: Circle passes through  $(1, 2)$   $(1 - h)^2 + 2^2 = r^2$   $(1 - h)^2 + 4 = r^2$  ... (2)From equations (1) and (2):  $h^2 = (1 - h)^2 + 4$   $h^2 = 1 - 2h + h^2 + 4$   $0 = 5 - 2h$   $h = \frac{5}{2}$ From equation (1):  $r^2 = h^2 = \left(\frac{5}{2}\right)^2 = \frac{25}{4}$ 

Table 8: Circle Properties

Property	Value
Center	$\left(\frac{5}{2}, 0\right)$
Radius	$\frac{5}{2}$

Equation of circle:  $\left(x - \frac{5}{2}\right)^2 + y^2 = \frac{25}{4}$ Expanding:  $x^2 - 5x + \frac{25}{4} + y^2 = \frac{25}{4}$   $x^2 + y^2 - 5x = 0$ **0.0.36 Q5.3 [4 marks]**Find the equation of lines passing through point  $A(-8, -10)$  and product of its intercepts on both axis is  $-40$ Solution: Let the equation of line be  $\frac{x}{a} + \frac{y}{b} = 1$  where  $a$  and  $b$  are x-intercept and y-intercept respectively.

Given conditions:

1. Line passes through  $(-8, -10)$ :  $\frac{-8}{a} + \frac{-10}{b} = 1$  ... (1)2. Product of intercepts:  $ab = -40$  ... (2)From equation (2):  $b = \frac{-40}{a}$ Substituting in equation (1):  $\frac{-8}{a} + \frac{-10}{\frac{-40}{a}} = 1$ 

$$\frac{-8}{a} + \frac{-10a}{-40} = 1$$

$$\frac{-8}{a} + \frac{a}{4} = 1$$

Multiplying by  $4a$ :  $-32 + a^2 = 4a$   $a^2 - 4a - 32 = 0$   $(a - 8)(a + 4) = 0$

So  $a = 8$  or  $a = -4$

**Case 1:**  $a = 8$   $b = \frac{-40}{8} = -5$  **Equation:**  $\frac{x}{8} + \frac{y}{-5} = 1$   $\frac{x}{8} - \frac{y}{5} = 1$   $5x - 8y = 40$

**Case 2:**  $a = -4$   $b = \frac{-40}{-4} = 10$  **Equation:**  $\frac{x}{-4} + \frac{y}{10} = 1$   $-\frac{x}{4} + \frac{y}{10} = 1$   $-10x + 4y = 40$   $10x - 4y + 40 = 0$   $5x - 2y + 20 = 0$

The two equations are:

1.  $5x - 8y - 40 = 0$
2.  $5x - 2y + 20 = 0$

## Mathematics Formula Cheat Sheet

### 0.0.37 Determinants

- **2×2 Matrix:**  $\begin{vmatrix} a & b \\ c & d \end{vmatrix} = ad - bc$
- **3×3 Matrix:** *Expand along any row or column*

### 0.0.38 Logarithms

- $\log_a b \times \log_b a = 1$
- $\log(xy) = \log x + \log y$
- $\log\left(\frac{x}{y}\right) = \log x - \log y$
- $\log(x^n) = n \log x$

### 0.0.39 Trigonometry

- **Basic Values:**
  - $\sin 30^\circ = \frac{1}{2}$ ,  $\cos 30^\circ = \frac{\sqrt{3}}{2}$ ,  $\tan 30^\circ = \frac{1}{\sqrt{3}}$
  - $\sin 60^\circ = \frac{\sqrt{3}}{2}$ ,  $\cos 60^\circ = \frac{1}{2}$ ,  $\tan 60^\circ = \sqrt{3}$
  - $\sin 45^\circ = \cos 45^\circ = \frac{1}{\sqrt{2}}$ ,  $\tan 45^\circ = 1$
- **Compound Angles:**
  - $\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$
  - $\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$
  - $\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$
- **Multiple Angles:**
  - $\sin 2A = 2 \sin A \cos A$
  - $\cos 2A = \cos^2 A - \sin^2 A = 2 \cos^2 A - 1 = 1 - 2 \sin^2 A$
  - $\tan 2A = \frac{2 \tan A}{1 - \tan^2 A}$
- **Half Angles:**
  - $\sin \frac{A}{2} = \pm \sqrt{\frac{1 - \cos A}{2}}$
  - $\cos \frac{A}{2} = \pm \sqrt{\frac{1 + \cos A}{2}}$
  - $\tan \frac{A}{2} = \frac{1 - \cos A}{\sin A} = \frac{\sin A}{1 + \cos A}$
- **Sum-to-Product:**
  - $\sin A + \sin B = 2 \sin\left(\frac{A+B}{2}\right) \cos\left(\frac{A-B}{2}\right)$
  - $\sin A - \sin B = 2 \cos\left(\frac{A+B}{2}\right) \sin\left(\frac{A-B}{2}\right)$
  - $\cos A + \cos B = 2 \cos\left(\frac{A+B}{2}\right) \cos\left(\frac{A-B}{2}\right)$
  - $\cos A - \cos B = -2 \sin\left(\frac{A+B}{2}\right) \sin\left(\frac{A-B}{2}\right)$
- **Allied Angles:**
  - $\sin(90^\circ - \theta) = \cos \theta$
  - $\cos(90^\circ - \theta) = \sin \theta$
  - $\sin(90^\circ + \theta) = \cos \theta$
  - $\cos(90^\circ + \theta) = -\sin \theta$
  - $\sin(180^\circ - \theta) = \sin \theta$
  - $\cos(180^\circ - \theta) = -\cos \theta$

### 0.0.40 Vectors

- **Dot Product:**  $\vec{a} \cdot \vec{b} = |\vec{a}| |\vec{b}| \cos \theta = a_1 b_1 + a_2 b_2 + a_3 b_3$
- **Cross Product:**  $\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}$
- **Magnitude:**  $|\vec{a}| = \sqrt{a_1^2 + a_2^2 + a_3^2}$

- **Unit Vector:**  $\hat{a} = \frac{\vec{a}}{|\vec{a}|}$
- **Angle between vectors:**  $\cos \theta = \frac{\vec{a} \cdot \vec{b}}{|\vec{a}| |\vec{b}|}$
- **Scalar Triple Product:**  $\vec{a} \cdot (\vec{b} \times \vec{c}) = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix}$

#### 0.0.41 Coordinate Geometry

##### Straight Lines

- **Slope:**  $m = \frac{y_2 - y_1}{x_2 - x_1}$
- **Point-Slope Form:**  $y - y_1 = m(x - x_1)$
- **Two-Point Form:**  $\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}$
- **Slope-Intercept Form:**  $y = mx + c$
- **Intercept Form:**  $\frac{x}{a} + \frac{y}{b} = 1$
- **General Form:**  $Ax + By + C = 0$

##### Parallel and Perpendicular Lines

- **Parallel Lines:**  $m_1 = m_2$
- **Perpendicular Lines:**  $m_1 \times m_2 = -1$
- **Angle between lines:**  $\tan \theta = \left| \frac{m_1 - m_2}{1 + m_1 m_2} \right|$

##### Circle

- **Standard Form:**  $(x - h)^2 + (y - k)^2 = r^2$
- **General Form:**  $x^2 + y^2 + 2gx + 2fy + c = 0$
- **Center:**  $(-g, -f)$
- **Radius:**  $\sqrt{g^2 + f^2 - c}$

#### 0.0.42 Limits

- **Standard Limits:**
  - $\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1$
  - $\lim_{x \rightarrow 0} \frac{\tan x}{x} = 1$
  - $\lim_{x \rightarrow 0} \frac{1 - \cos x}{x^2} = \frac{1}{2}$
  - $\lim_{n \rightarrow \infty} \left(1 + \frac{1}{n}\right)^n = e$
  - $\lim_{x \rightarrow 0} (1 + x)^{1/x} = e$
- **L'Hôpital's Rule:** If  $\lim_{x \rightarrow a} \frac{f(x)}{g(x)}$  gives  $\frac{0}{0}$  or  $\frac{\infty}{\infty}$ , then:  $\lim_{x \rightarrow a} \frac{f(x)}{g(x)} = \lim_{x \rightarrow a} \frac{f'(x)}{g'(x)}$
- **Algebraic Limits:** For polynomial  $\frac{P(x)}{Q(x)}$ :
  - If  $P(a) \neq 0$  and  $Q(a) \neq 0$ : **Direct substitution**
  - If  $P(a) = Q(a) = 0$ : **Factor and cancel common factors**
  - For  $\frac{\infty}{\infty}$ : **Divide by highest power**

#### 0.0.43 Functions

- **Even Function:**  $f(-x) = f(x)$
- **Odd Function:**  $f(-x) = -f(x)$
- **Composite Function:**  $(f \circ g)(x) = f(g(x))$
- **Inverse Function:** If  $y = f(x)$ , then  $x = f^{-1}(y)$

#### 0.0.44 Useful Algebraic Identities

- $(a + b)^2 = a^2 + 2ab + b^2$
- $(a - b)^2 = a^2 - 2ab + b^2$
- $(a + b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$
- $(a - b)^3 = a^3 - 3a^2b + 3ab^2 - b^3$
- $a^3 + b^3 = (a + b)(a^2 - ab + b^2)$
- $a^3 - b^3 = (a - b)(a^2 + ab + b^2)$
- $a^4 - b^4 = (a^2 + b^2)(a + b)(a - b)$

#### 0.0.45 Conversion Formulas

- **Degrees to Radians:**  $\text{Radians} = \text{Degrees} \times \frac{\pi}{180}$
- **Radians to Degrees:**  $\text{Degrees} = \text{Radians} \times \frac{180}{\pi}$

### 0.0.46 Important Angles in Radians

Degrees	Radians
$30^\circ$	$\frac{\pi}{6}$
$45^\circ$	$\frac{\pi}{4}$
$60^\circ$	$\frac{\pi}{3}$
$90^\circ$	$\frac{\pi}{2}$
$120^\circ$	$\frac{2\pi}{3}$
$135^\circ$	$\frac{3\pi}{4}$
$150^\circ$	$\frac{5\pi}{6}$
$180^\circ$	$\pi$

### 0.0.47 Differentiation (Basic)

- $\frac{d}{dx}(x^n) = nx^{n-1}$
- $\frac{d}{dx}(\sin x) = \cos x$
- $\frac{d}{dx}(\cos x) = -\sin x$
- $\frac{d}{dx}(\tan x) = \sec^2 x$
- $\frac{d}{dx}(e^x) = e^x$
- $\frac{d}{dx}(\ln x) = \frac{1}{x}$

### 0.0.48 Problem-Solving Tips

#### For Determinants

1. Always expand along the row/column with most zeros
2. Factor out common terms first
3. Use row/column operations to create zeros

#### For Limits

1. Try direct substitution first
2. If you get  $\frac{0}{0}$ , factor and cancel
3. For square roots, rationalize numerator/denominator
4. Use standard limit formulas

#### For Trigonometry

1. Convert everything to same angle measure (degrees or radians)
2. Use compound angle formulas for complex expressions
3. Check if angles are special angles ( $30^\circ, 45^\circ, 60^\circ, etc.$ )

#### For Vectors

1. Write vectors in component form:  $\vec{a} = a_1\hat{i} + a_2\hat{j} + a_3\hat{k}$
2. For cross product, use determinant method
3. For dot product, multiply corresponding components and add

#### For Circle Problems

1. Complete the square to find center and radius
2. Use distance formula:  $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
3. Remember: All points on circle are equidistant from center

#### For Line Problems

1. Find slope first:  $m = \frac{y_2 - y_1}{x_2 - x_1}$
2. Use point-slope form:  $y - y_1 = m(x - x_1)$
3. For parallel lines: same slope
4. For perpendicular lines: product of slopes = -1

### 0.0.49 Memory Tips

- SOHCAHTOA: Sin = Opposite/Hypotenuse, Cos = Adjacent/Hypotenuse, Tan = Opposite/Adjacent
- CAST Rule: In quadrants I, II, III, IV - Cosine, All, Sine, Tangent are positive respectively
- 30-60-90 Triangle: Sides in ratio  $1 : \sqrt{3} : 2$

- 45-45-90 Triangle: Sides in ratio  $1 : 1 : \sqrt{2}$

#### 0.0.50 Common Mistakes to Avoid

1. Sign errors in trigonometric identities
2. Forgetting to rationalize when dealing with surds in limits
3. Not checking domain for inverse trigonometric functions
4. Mixing up cross product and dot product formulas
5. Forgetting to complete the square properly in circle equations
6. Not factoring completely in limit problems

#### 0.0.51 Quick Reference Values

- $\sqrt{2} \approx 1.414$
  - $\sqrt{3} \approx 1.732$
  - $\pi \approx 3.14159$
  - $e \approx 2.718$
- 

### Final Tips for Exam Success

#### 0.0.52 Time Management

- Spend 2-3 minutes on each fill-in-the-blank question
- Allocate 8-10 minutes per 3-mark question
- Allow 12-15 minutes per 4-mark question
- Reserve 20-25 minutes per 7-8 mark question

#### 0.0.53 Question Selection Strategy

- Read all options before selecting questions
- Choose questions you're most confident about
- Start with easier questions to build confidence

#### 0.0.54 Presentation Tips

- Show all working steps clearly
- Draw diagrams where applicable
- Use proper mathematical notation
- Box your final answers

#### 0.0.55 Common Topics That Appear Frequently

1. Trigonometric identities and compound angles
2. Limits involving rationalization
3. Vector operations (dot and cross products)
4. Circle and line equations
5. Determinant calculations

Best of luck with your exams!

*Remember: Practice makes perfect. Work through similar problems multiple times to build speed and accuracy.*