# CAMA 15C : Mathematics - I





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$$f(x) = a_0 x^n + a_1 x^{n-1} + a_2 x^{n-2} + \ldots + a_{n-1} x + a_n.$$

This a polynomial in x of degree *n* provided  $a_0 \neq 0$ .

The equation is obtained by putting f(x) = 0 is called an

algebraic equation of degree n.

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real or complex.

2. Every polynomial equation f(x) = 0 of  $n^{th}$  degree has n roots and only n roots.

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- 1. Relation between the roots and coefficient of equations.
- 2. Imaginary roots and irrational roots.
- 3. Transformation of equations.
- 4. Reciprocal equations.
- 5. Newton's method.

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# Given equation be

 $a_0x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_{n-1}x + a_n = 0.$ 

Divide the equation by  $a_0$ , then

 $x^{n} + \frac{a_{1}}{a_{0}}x^{n-1} + \frac{a_{2}}{a_{0}}x^{n-2} + \ldots + \frac{a_{n-1}}{a_{0}}x + \frac{a_{n}}{a_{0}} = 0.$ 

i.e.,  $x^n + p_1 x^{n-1} + p_2 x^{n-2} + \ldots + p_{n-1} x + p_n = 0$ . (say  $p_i = \frac{a_i}{a_0}$ )

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Then, we have

 $S_1 = \sum \alpha_1 = -p_1$ 

 $S_2 = \sum \alpha_1 \, \alpha_2 = p_2$ 

 $S_3 = \sum \alpha_1 \, \alpha_2 \, \alpha_3 = -p_3$ 

 $S_n = \alpha_1 \alpha_2 \alpha_3 \ldots \alpha_n = (-1)^n p_n$ 

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If  $\alpha$  and  $\beta$  are the roots of  $2x^2 + 3x + 5 = 0$ , then

find  $\alpha + \beta, \alpha\beta$ .

Solution.

Given  $2x^2 + 3x + 5 = 0$ .  $x^2 + \frac{3}{2}x + \frac{5}{2} = 0$ . Here  $p_1 = \frac{3}{2}$  and  $p_2 = \frac{5}{2}$ We know that  $\alpha + \beta = -p_1 = -p_1$ 

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#### Problem 1.

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If  $\alpha$  and  $\beta$  are the roots of  $x^2 + 5x + 6 = 0$ , then

find  $\alpha + \beta, \alpha\beta$ .

Solution.

Given  $x^2 + 5x + 6 = 0$ .

Here  $p_1 = 5$  and  $p_2 = 6$ 

We know that  $\alpha + \beta = -p_1 = -5$  and

$$\alpha\beta = p_2 = 6$$

$$(\alpha = -3 \text{ and } \beta = -2)$$

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# Solution.

Given  $x^2 + 5x + 6 = 0$ .

Here  $p_1 = 5$  and  $p_2 = 6$ 

We know that  $\alpha + \beta = -p_1 = -5$  and

$$\alpha\beta = p_2 = 6$$

$$(\alpha = -3 \text{ and } \beta = -2)$$

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Given  $ax^3 + bx^2 + cx + d = 0$ .  $x^3 + \frac{b}{a}x^2 + \frac{c}{a}x + \frac{d}{a} = 0$ We know that  $\alpha + \beta + \gamma = -p_1 = -p_1$ 

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# 1. In an equation with rational coefficients, imaginary roots

occur in pairs.

2. In an equation with rational coefficients, irrational roots

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2. In an equation with rational coefficients, irrational roots occur in pairs.



Solution.

Given  $\sqrt{3} + \sqrt{5}$  is one of whose root of the required equation.

The other root of the same equation are

 $-\sqrt{3} + \sqrt{5}, \quad \sqrt{3} - \sqrt{5}, \text{ and } -\sqrt{3} - \sqrt{5}$ 

Therefore, the required equation is

 $[x - (\sqrt{3} + \sqrt{5})][x - (\sqrt{3} - \sqrt{5})][x - (-\sqrt{3} + \sqrt{5})][x - (-\sqrt{3} - \sqrt{5})] = 0$ 

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$$[(x - \sqrt{3}) + \sqrt{5}][(x - \sqrt{3}) - \sqrt{5}][(x + \sqrt{3}) + \sqrt{5}][(x + \sqrt{3}) - \sqrt{5}] = 0$$
  

$$[(x - \sqrt{3})^2 - (\sqrt{5})^2] [(x + \sqrt{3})^2 - (\sqrt{5})^2] = 0$$
  

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

$$(x^2 - 2x\sqrt{3} + 3 - 5) (x^2 + 2x\sqrt{3} + 3 - 5) = 0$$
  

$$(x^2 - 2x\sqrt{3} - 2) (x^2 + 2x\sqrt{3} - 2) = 0$$
  

$$[(x^2 - 2) - 2x\sqrt{3}] [(x^2 - 2) + 2x\sqrt{3}] = 0$$
  

$$[(x^2 - 2)^2 - (2x\sqrt{3})^2] = 0$$
  

$$x^4 - 4x^2 + 4 - 12x^2 = 0$$
  

$$\therefore x^4 - 16x^2 + 4 = 0$$

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 $[(x - \sqrt{3}) + \sqrt{5}][(x - \sqrt{3}) - \sqrt{5}][(x + \sqrt{3}) + \sqrt{5}][(x + \sqrt{3}) - \sqrt{5}] = 0$  $[(x - \sqrt{3})^2 - (\sqrt{5})^2] [(x + \sqrt{3})^2 - (\sqrt{5})^2] = 0$  $((a+b)(a-b) = a^2 - b^2)$ 

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Solution.

Since -1 + 2i is a root, -1 - 2i will also be a root of the equation.

The factor corresponding to the two roots is

$$(x + 1 - 2i) (x + 1 + 2i) = 0$$
$$(x + 1)^{2} - (2i)^{2} = 0$$
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Now divide 
$$x^4 - 12x - 5 = 0$$
 by  $x^2 + 2x + 5 = 0$ 

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Now divide 
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$$\begin{array}{r} x^2 - 2x - 1 \\ x^2 + 2x + 5 \end{array} \underbrace{\begin{array}{r} x^4 & -12x - 5 \\ -x^4 - 2x^3 - 5x^2 \\ -2x^3 - 5x^2 - 12x \\ 2x^3 + 4x^2 + 10x \\ \hline -x^2 & -2x - 5 \\ x^2 & +2x + 5 \\ \hline 0 \end{array}}$$

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 $x^2 - 2x - 1 = 0 \qquad (ax^2 + bx + c = 0)$ 

$$x = \frac{2 \pm \sqrt{4+4}}{2} \qquad \left(x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\right)$$

$$x = \frac{2 \pm 2\sqrt{2}}{2}$$
$$x = 1 \pm \sqrt{2}$$

 $\therefore$  The roots are  $-1 \pm 2i$ ,  $1 \pm \sqrt{2}$ .

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Now divide 
$$x^4 - 4x^2 + 8x + 35 = 0$$
 by  $x^2 - 4x + 7 = 0$ 

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Now divide 
$$x^4 - 4x^2 + 8x + 35 = 0$$
 by  $x^2 - 4x + 7 = 0$ 

$$\begin{array}{r} x^{2} + 4x + 5 \\
 x^{2} - 4x + 7) \hline x^{4} - 4x^{2} + 8x + 35 \\
 -x^{4} + 4x^{3} - 7x^{2} \\
 4x^{3} - 11x^{2} + 8x \\
 -4x^{3} + 16x^{2} - 28x \\
 5x^{2} - 20x + 35 \\
 -5x^{2} + 20x - 35 \\
 0
 \end{array}$$

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 $x^2 + 4x + 5 = 0 \qquad (ax^2 + bx + c = 0)$ 

$$x = \frac{-4 \pm \sqrt{16 - 20}}{2} \qquad \left(x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\right)$$

$$x = \frac{-4 \pm 2i}{2}$$
$$x = -2 \pm i$$

 $\therefore$  The roots are  $2 \pm i\sqrt{3}$ ,  $-2 \pm i$ .

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$$\sqrt{5}-1$$
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Solution.

Since  $\sqrt{5} - 1$  is a root,  $-\sqrt{5} - 1$  will also be a root of the equation.

The factor corresponding to the two roots is

$$(x+1-\sqrt{5})(x+1+\sqrt{5}) = 0$$

 $(x+1)^2 - (\sqrt{5})^2 = 0$ 

 $x^2 + 2x + 1 - 5 = 0$ 

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Now divide 
$$x^4 - 11x^2 + 2x + 12 = 0$$
 by  $x^2 + 2x - 4 = 0$ 

$$\begin{array}{r} x^{2} - 2x - 3 \\ x^{2} + 2x - 4 \end{array} \xrightarrow{x^{4} - 11x^{2} + 2x + 12} \\ - x^{4} - 2x^{3} + 4x^{2} \\ \hline - 2x^{3} - 7x^{2} + 2x \\ 2x^{3} + 4x^{2} - 8x \\ \hline - 3x^{2} - 6x + 12 \\ 3x^{2} + 6x - 12 \\ \hline 0 \end{array}$$

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Now divide 
$$x^4 - 11x^2 + 2x + 12 = 0$$
 by  $x^2 + 2x - 4 = 0$ 

$$\begin{array}{r} x^2 - 2x - 3 \\ x^2 + 2x - 4 \end{array} \underbrace{\begin{array}{r} x^4 & -11x^2 + 2x + 12 \\ -x^4 - 2x^3 & +4x^2 \\ \hline -2x^3 & -7x^2 + 2x \\ 2x^3 & +4x^2 - 8x \\ \hline -3x^2 - 6x + 12 \\ 3x^2 + 6x - 12 \\ \hline 0 \end{array}}$$

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$$x^{2} - 2x - 3 = 0 \qquad (x^{2} - (\alpha + \beta)x + \alpha\beta = 0)$$
$$(x - 3)(x + 1) = 0 \qquad (\alpha\beta = c; \ \alpha + \beta = -b)$$
$$x = -1, 3 \qquad (\alpha = -1; \ \beta = 3)$$

 $\therefore$  The roots are  $\pm\sqrt{5}-1$ , -1, 3.

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: The roots are  $\pm\sqrt{5}-1$  , -1, 3.

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# Problems.



5. Solve the equation  $x^4 - 5x^3 + 4x^2 + 8x - 8 = 0$  given that

$$1-\sqrt{5}$$
 is a root.

6. Solve the equation  $x^4 + 2x^3 - 5x^2 + 6x + 2 = 0$  given that

 $1+\sqrt{-1}$  is a root.

7. Solve the equation  $x^4 + 2x^2 - 16x + 77 = 0$  given that

 $-2 + \sqrt{-7}$  is a root.

8. Solve the equation  $3x^5 - 4x^4 - 42x^3 + 52x^2 + 27x - 36 = 0$ 

given that  $\sqrt{2} + \sqrt{5}$  is a root.

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