1.

$x^3+4x^2+x-6=0$ Factors of $-6: \pm1, \pm2, \pm3, \pm6.$

$(1)^3+4(1)^2+(1)-6=0 \Rightarrow x=1$ is a root $\Rightarrow x-1$ is a factor.

$$x^2+5x+6$$

$$x-1 \quad \overline{)x^3+4x^2+x-6}$$

$$\underline{x^3-x^2}$$

$$5x^2+x$$

$$\underline{5x^2-5x}$$

$$6x-6$$

$$\underline{6x-6}$$

$$0$$

$x^2+5x+6=(x+2)(x+3)=0 \Rightarrow x=-2$ or $x=-3$

Ans. $x=1, x=-2$ or $x=-3$

2.

$2x^3-x^2-2x+1=0$ Factors of $+1: \pm1..$

$2(1)^3-(1)^2-2(1)+1=0 \Rightarrow x=1$ is a root $\Rightarrow x-1$ is a factor.

$$2x^2+x-1$$

$$x-1 \quad \overline{)2x^3-x^2-2x+1}$$

$$\underline{2x^3-2x^2}$$

$$x^2-2x$$

$$\underline{x^2-x}$$

$$-x+1$$

$$\underline{-x+1}$$

$$0$$

$2x^2+x-1=(2x-1)(x+1)=0 \Rightarrow x=\frac{1}{2}$ or $x=-1$

Ans. $x=1, x=-1$ or $x=\frac{1}{2}$

3.

$x^3+3x^2-4x-12=0$ Factors of $+12:\pm1,\pm2,\pm3,\pm4,\pm6,\pm12.$

$(-2)^3+3(-2)^2-4(-2)-12=0\Rightarrow x=-2$ is a root $\Rightarrow x+2$ is a factor.

$$\begin{array}{r|l} & x^2+x-6 \\ \hline x+2 & x^3+3x^2-4x-12 \\ & \underline{x^3+2x^2} \\ & \quad x^2-4x \\ & \quad \underline{x^2+2x} \\ & \qquad -6x-12 \\ & \qquad \underline{-6x-12} \\ & \qquad 0 \end{array}$$

$x^2+x-6=(x+3)(x-2)=0\Rightarrow x=-3$ or $x=2$

Ans. $x=-2, x=-3$ or $x=2$

4.

$x^3+x^2-5x+3=0$ Factors of $+3:\pm1,\pm3.$

$(1)^3+(1)^2-5(1)+3=0\Rightarrow x=1$ is a root $\Rightarrow x-1$ is a factor.

$$\begin{array}{r|l} & x^2+2x-3 \\ \hline x-1 & x^3+x^2-5x+3 \\ & \underline{x^3-x^2} \\ & \quad 2x^2-5x \\ & \quad \underline{2x^2-2x} \\ & \qquad -3x+3 \\ & \qquad \underline{-3x+3} \\ & \qquad 0 \end{array}$$

$x^2+2x-3=(x+3)(x-1)=0\Rightarrow x=-3$ or $x=1$

Ans. $x=1, x=-3$ or $x=1$

5.

$3x^3 - 11x^2 + x + 15 = 0$ Factors of $+15: \pm 1, \pm 3, \pm 5, \pm 15.$

$3(-1)^3 - 11(-1)^2 + (-1) + 15 = 0 \Rightarrow x = -1$ is a root $\Rightarrow x + 1$ is a factor.

$$\begin{array}{r l}
 & 3x^2 - 14x + 15 \\
x + 1 & \overline{)\,3x^3 - 11x^2 + x + 15} \\
 & \underline{3x^3 + 3x^2} \\
 & \quad -14x^2 + x \\
 & \quad \underline{-14x^2 - 14x} \\
 & \qquad\qquad 15x + 15 \\
 & \qquad\qquad \underline{15x + 15} \\
 & \qquad\qquad 0
\end{array}$$

$3x^2 - 14x + 15 = (3x - 5)(x - 3) = 0 \Rightarrow x = \frac{5}{3}$ or $x = 3$

Ans. $x = -1, x = 3$ or $x = \frac{5}{3}$

6.(i)

$x^3 + 5x^2 - 4x - 20 = 0$ Factors of $-20: \pm 1, \pm 2, \pm 4, \pm 5, \pm 10, \pm 20.$

$(-2)^3 + 5(-2)^2 - 4(-2) - 20 = 0 \Rightarrow x = -2$ is a root $\Rightarrow x + 2$ is a factor.

$$\begin{array}{r l}
 & x^2 + 3x - 10 \\
x + 2 & \overline{)\,x^3 + 5x^2 - 4x - 20} \\
 & \underline{x^3 + 2x^2} \\
 & \quad 3x^2 - 4x \\
 & \quad \underline{3x^2 + 6x} \\
 & \qquad -10x - 20 \\
 & \qquad \underline{-10x - 20} \\
 & \qquad\quad 0
\end{array}$$

$x^2 + 3x - 10 = (x + 5)(x - 2) = 0$

Ans. $x^3 + 5x^2 - 4x - 20 = (x + 2)(x + 5)(x - 2)$

(ii)

$x^3 + 5x^2 - 4x - 20 = (x + 2)(x + 5)(x - 2) = 0$

$\Rightarrow x = -2, x = -5, x = 2.$

7.

$x-2$ is a factor $\Rightarrow x=2$ is a root.

$(2)^3+2(2)^2-5(2)+k=0 \Rightarrow 6+k=0 \Rightarrow k=-6$

$$
\begin{array}{r|l}
 & x^2+4x+3 \\
x-2 & x^3+2x^2-5x-6 \\
 & \underline{x^3-2x^2} \\
 & \quad 4x^2-5x \\
 & \quad \underline{4x^2-8x} \\
 & \qquad 3x-6 \\
 & \qquad \underline{3x-6} \\
 & \qquad 0
\end{array}
$$

$x^2+4x+3=(x+1)(x+3)$

$\therefore x^3+2x^2-5x-6=(x-2)(x+1)(x+3)$

8.

$x-3$ is a factor $\Rightarrow x=3$ is a root.

$3(3)^3-2(3)^2+k(3)-6=0 \Rightarrow 57+3k=0 \Rightarrow k=-19$

$$
\begin{array}{r|l}
 & 3x^2+7x+2 \\
x-3 & 3x^3-2x^2-19x-6 \\
 & \underline{3x^3-9x^2} \\
 & \quad 7x^2-19x \\
 & \quad \underline{7x^2-21x} \\
 & \qquad 2x-6 \\
 & \qquad \underline{2x-6} \\
 & \qquad 0
\end{array}
$$

$3x^2+7x+2=(3x+1)(x+2)$

$\therefore 3x^3-2x^2-19x-6=(x-3)(3x+1)(x+2)$

9.

$x+2$ is a factor $\Rightarrow x=-2$ is a root.

$(-2)^3+t(-2)^2+3(-2)-10=0 \Rightarrow -24+4t=0 \Rightarrow t=6$

$$x^2+4x-5$$
$$x+2 \enclose{longdiv}{x^3+6x^2+3x-10}$$
$$\underline{x^3+2x^2}$$
$$4x^2+3x$$
$$\underline{4x^2+8x}$$
$$-5x-10$$
$$\underline{-5x-10}$$
$$0$$

$x^2+4x-5=(x+5)(x-1) \Rightarrow x=-5$ or $x=1$

Ans. $x=-2$ or $x=-5$ or $x=1$

10.

$x-2$ is a factor $\Rightarrow x=2$ is a root.

$(2)^3+7(2)^2+a(2)+b=0 \Rightarrow 36+2a+b=0$

A: $2a+b=-36$

$x+2$ is a factor $\Rightarrow x=-2$ is a root.

$(-2)^3+7(-2)^2+a(-2)+b=0 \Rightarrow 20-2a+b=0$

B: $-2a+b=-20$

A + B: $2b=-56 \Rightarrow b=-28$

Substitute in A: $2a+(-28)=-36 \Rightarrow 2a=-8 \Rightarrow a=-4$

$x-2$, $x+2$ are factors $\Rightarrow (x-2)(x+2)=x^2-4$ is a factor

$$x+7$$
$$x^2-4 \enclose{longdiv}{x^3+7x^2\cancel{-4x}-28}$$
$$\underline{x^3\cancel{-4x}}$$
$$7x^2-28$$
$$\underline{7x^2-28}$$
$$0$$

$\therefore x^3+7x^2-4x-28=(x-2)(x+2)(x+7)$

11.

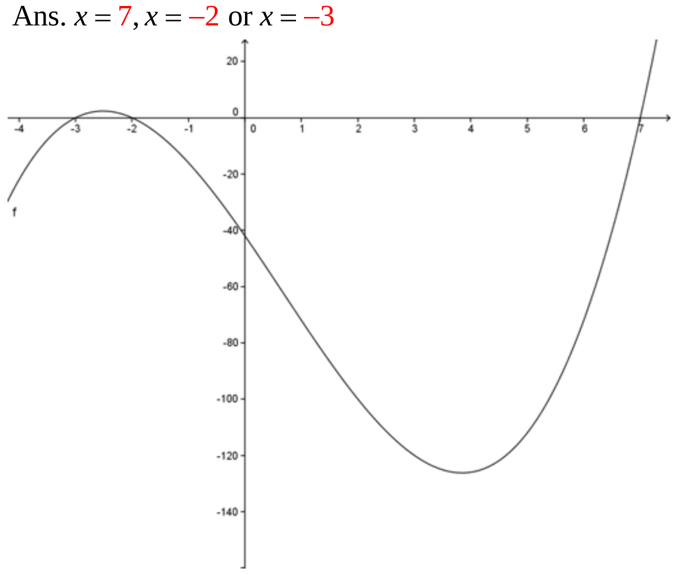
$x^3 - 2x^2 - 29x - 42 = 0$

$(7)^3 - 2(7)^2 - 29(7) - 42 = 0 \Rightarrow x = 7$ is a root $\Rightarrow x - 7$ is a factor.

$$\begin{array}{rl} & x^2 + 5x + 6 \\ x - 7 & \overline{\big) x^3 - 2x^2 - 29x - 42} \\ & \underline{x^3 - 7x^2} \\ & \quad 5x^2 - 29x \\ & \quad \underline{5x^2 - 35x} \\ & \qquad 6x - 42 \\ & \qquad \underline{6x - 42} \\ & \qquad 0 \end{array}$$

$x^2 + 5x + 6 = (x+2)(x+3) = 0 \Rightarrow x = -2$ or $x = -3$

Ans. $x = 7, x = -2$ or $x = -3$



12.

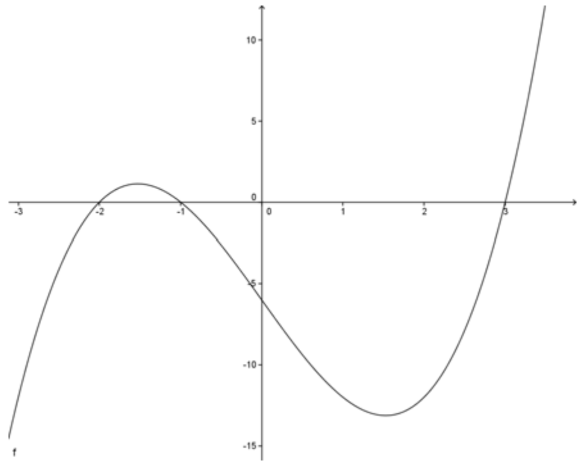
$x^3 - 7x - 6 = 0$

$(-1)^3 - 7(-1) - 6 = 0 \Rightarrow x = -1$ is a root $\Rightarrow x + 1$ is a factor.

$$\begin{array}{rl} & x^2 - x - 6 \\ x + 1 & \overline{\big) x^3 - 7x - 6} \\ & \underline{x^3 + x^2} \\ & \quad -x^2 - 7x \\ & \quad \underline{-x^2 - 1x} \\ & \qquad -6x - 6 \\ & \qquad \underline{-6x - 6} \\ & \qquad 0 \end{array}$$

$x^2 - x - 6 = (x+2)(x-3) = 0 \Rightarrow x = -2$ or $x = 3$

Ans. $x = -1, x = -2$ or $x = 3$



13.

$x=\frac{1}{2}=0 \Rightarrow x-\frac{1}{2}=0 \Rightarrow 2x-1=0$

$$\begin{array}{r|l} & x^2-9x+20 \\ 2x-1 & 2x^3-19x^2+49x-20 \\ & \underline{2x^3-x^2} \\ & \quad -18x^2+49x \\ & \quad \underline{-18x^2+9x} \\ & \qquad\quad 40x-20 \\ & \qquad\quad \underline{40x-20} \\ & \qquad\quad 0 \end{array}$$

$x^2-9x+20=(x-4)(x-5)$

$\therefore 2x^3-19x^2+49x-20=(2x-1)(x-4)(x-5)$

The roots are $x=\frac{1}{2}, x=4, x=5$.

14.(i)

$-1,2,5$ roots $\Rightarrow (x+1)(x-2)(x-5)=0$

$\Rightarrow (x+1)(x^2-7x+10)=0$

$\Rightarrow x(x^2-7x+10)+1(x^2-7x+10)=0$

$\Rightarrow x^3-7x^2+10x+x^2-7x+10=0$

$\Rightarrow x^3-6x^2+3x+10=0$

14.(i) (Alternative method)

p,q,r roots $\Rightarrow (x-p)(x-q)(x-r)=0$

$\Rightarrow (x-p)(x^2-qx-rx+qr)=0$

$\Rightarrow x(x^2-qx-rx+qr)-p(x^2-qx-rx+qr)=0$

$\Rightarrow x^3-qx^2-rx^2+qrx-px^2+pqx+prx-pqr=0$

$\Rightarrow x^3-(p+q+r)x^2+(pq+qr+pr)x-pqr=0$

(ii)

$3, \frac{1}{2}, -7$ roots $\Rightarrow (x-3)\left(x-\frac{1}{2}\right)(x+7)=0$

$\Rightarrow (x-3)(2x-1)(x+7)=0$

$\Rightarrow (x-3)(2x^2+13x-7)=0$

$\Rightarrow x(2x^2+13x-7)-3(2x^2+13x-7)=0$

$\Rightarrow 2x^3+13x^2-7x-6x^2-39x+21=0$

$\Rightarrow 2x^3+7x^2-46x+21=0$

(iii)

$1, -1, -\frac{1}{3}$ roots $\Rightarrow (x-1)(x+1)\left(x+\frac{1}{3}\right)=0$

$\Rightarrow (x-1)(x+1)(3x+1)=0$

$\Rightarrow (x-1)(3x^2+4x+1)=0$

$\Rightarrow x(3x^2+4x+1)-1(3x^2+4x+1)=0$

$\Rightarrow 3x^3+4x^2+x-3x^2-4x-1=0$

$\Rightarrow 3x^3+x^2-3x-1=0$

(iv)

$0, 5, -2$ roots $\Rightarrow x(x-5)(x+2)=0$

$\Rightarrow x(x^2-3x-10)=0 \Rightarrow x^3-3x^2-10x=0$

(v)

$1, 1, 1$ roots $\Rightarrow (x-1)(x-1)(x-1)=0$

$\Rightarrow (x-1)(x^2-2x+1)=0$

$\Rightarrow x(x^2-2x+1)-1(x^2-2x+1)=0$

$\Rightarrow x^3-2x^2+x-x^2+2x-1=0$

$\Rightarrow x^3-3x^2+3x-1=0$

15.(i)

x^3+ax^2+bx+c has root $x=-3$

$\Rightarrow (-3)^3+a(-3)^2+b(-3)+c=0 \Rightarrow -27+9a-3b+c=0$

A: $9a-3b+c=27$

$x=-1$ a root $\Rightarrow (-1)^3+a(-1)^2+b(-1)+c=0$

B: $a-b+c=1$

$x=3$ a root $\Rightarrow (3)^3+a(3)^2+b(3)+c=0$

C: $9a+3b+c=-27$

C − A: $6b=-54 \Rightarrow b=-9$

A − B: $8a-2b=26 \Rightarrow 8a-2(-9)=26 \Rightarrow 8a=26-18=8 \Rightarrow a=1$

B: $(1)-(-9)+c=1 \Rightarrow 10+c=1 \Rightarrow c=-9$

Ans: $a=1, b=-9, c=-9$.

15.(i) Alternative method.

$-3,-1,3$ roots $\Rightarrow y=(x+3)(x+1)(x-3)$

$=(x+3)(x^2-2x-3)$

$=x(x^2-2x-3)+3(x^2-2x-3)$

$=x^3-2x^2-3x+3x^2-6x-9$

$=x^3+x^2-9x-9$

$=x^3+ax^2+bx+c$

Ans: $a=1, b=-9, c=-9$.

(ii)

$-1,4,4$ roots $\Rightarrow y=(x+1)(x-4)(x-4)$

$=(x+1)(x^2-8x+16)$

$=x(x^2-8x+16)+1(x^2-8x+16)$

$=x^3-8x^2+16x+x^2-8x+16$

$=x^3-7x^2+8x+16$

$=x^3+ax^2+bx+c$

Ans: $a=-7, b=8, c=16$.

(iii)

$-1,-1,4$ roots $\Rightarrow y=(x+1)(x+1)(x-4)$

$=(x+1)(x^2-3x-4)$

$=x(x^2-3x-4)+1(x^2-3x-4)$

$=x^3-3x^2-4x+x^2-3x-4$

$=x^3-2x^2-7x-4$

$=x^3+ax^2+bx+c$

Ans: $a=-2, b=-7, c=-4$.

(iv)

$-2,1,1$ roots $\Rightarrow y=(x+2)(x-1)(x-1)$

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

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

$$=x^3-2x^2+x+2x^2-4x+2$$

$$=x^3+0x^2-3x+2$$

$$=x^3+ax^2+bx+c$$

Ans: $a=0, b=-3, c=2.$

16.

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

$\Rightarrow x^2-6x+9-5=0 \Rightarrow x^2-6x+4=0$

$(x-4)(x^2-6x+4)=x(x^2-6x+4)-4(x^2-6x+4)$

$$=x^3-6x^2+4x-4x^2+24x-16$$

$$=x^3-10x^2+28x-16=0$$

17.

$x^2-(\alpha+\beta)x+\alpha\beta=0 \Rightarrow x^2-(1-\sqrt{2}+1+\sqrt{2})x+(1-\sqrt{2})(1+\sqrt{2})=0$

$\Rightarrow x^2-2x+1-2=0 \Rightarrow x^2-2x-1=0$

$x=\frac{1}{4}$ a root $\Rightarrow x-\frac{1}{4}=0 \Rightarrow 4x-1=0$

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

$$=4x^3-8x^2-4x-x^2+2x+1$$

$$=4x^3-9x^2-2x+1=0$$

18.

$x^3 - 14x + 8 = 0$

$(-4)^3 - 14(-4) + 8 = -64 + 56 + 8 = 0 \Rightarrow x = -4$ is a root $\Rightarrow x + 4$ is a factor.

$$\begin{array}{r|l} & x^2 - 4x + 2 \\ x+4 & x^3 - 14x + 8 \\ & \underline{x^3 + 4x^2} \\ & \quad -4x^2 - 14x \\ & \quad \underline{-4x^2 - 16x} \\ & \qquad\quad 2x + 8 \\ & \qquad\quad \underline{2x + 8} \\ & \qquad\quad 0 \end{array}$$

$$\left\{\begin{array}{c} ax^2 + bx + c = 0 \\ x^2 - 4x + 2 = 0 \end{array}\right\} \quad a = 1,\ b = -4,\ c = 2$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-(-4) \pm \sqrt{(-4)^2 - 4(1)(2)}}{2(1)}$$

$$x = \frac{4 \pm \sqrt{8}}{2} = \frac{4 \pm \sqrt{4}\sqrt{2}}{2} = \frac{4 \pm 2\sqrt{2}}{2} = 2 \pm \sqrt{2}$$

Ans. $x = 2 + \sqrt{2}$ or $x = 2 - \sqrt{2}$

19.

$5x^3+7x^2-kx+3=0,\ x=\frac{3}{5}$ a root $\Rightarrow$

$5\left(\frac{3}{5}\right)^3+7\left(\frac{3}{5}\right)^2-k\left(\frac{3}{5}\right)+3=0\Rightarrow\frac{33}{3}-\frac{3k}{5}=0\Rightarrow k=11$

Now, $x=\frac{3}{5}$ a root $\Rightarrow x-\frac{3}{5}=0\Rightarrow 5x-3$ is a factor

$$\begin{array}{r|l} & x^2+2x-1 \\ 5x-3 & 5x^3+7x^2-11x+3 \\ & \underline{5x^3-3x^2} \\ & \quad 10x^2-11x \\ & \quad \underline{10x^2-6x} \\ & \qquad -5x+3 \\ & \qquad \underline{-5x+3} \\ & \qquad\quad 0 \end{array}$$

$\left\{\begin{array}{l} ax^2+bx+c=0 \\ x^2+2x-1=0 \end{array}\right\}\ a=1,\ b=2,\ c=-1$

$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}=\frac{-(2)\pm\sqrt{(2)^2-4(1)(-1)}}{2(1)}$

$x=\frac{-2\pm\sqrt{8}}{2}=\frac{-2\pm\sqrt{4}\sqrt{2}}{2}=\frac{-2\pm2\sqrt{2}}{2}=-1\pm\sqrt{2}$

20.(i)

$x^3-4x=x\left(x^2-4\right)=x(x-2)(x+2)=0$

$\Rightarrow x=0,\ x=2$ or $x=-2$

(ii)

$x^3-4x^2=x^2(x-4)=0$

$\Rightarrow x=0,\ x=0$ or $x=4$

(iii)

$4x^3-x=x\left(4x^2-1\right)=x(2x-1)(2x+1)=0$

$\Rightarrow x=0,\ x=\frac{1}{2}$ or $x=-\frac{1}{2}$

(iv)

$x^3-2x^2=x^2(x-2)=0$

$\Rightarrow x=0,\ x=0$ or $x=2$

(v)

$x^3-2x^2+x=x\left(x^2-2x+1\right)=x(x-1)(x-1)=0$

$\Rightarrow x=0,\ x=1$ or $x=1$.

21.

$2x^3 - 3x^2 + 6x + 4 = 0,\ x = -\frac{1}{2}$

$2\left(-\frac{1}{2}\right)^3 - 3\left(-\frac{1}{2}\right)^2 + 6\left(-\frac{1}{2}\right) + 4 = -\frac{1}{4} - \frac{3}{4} - 3 + 4 = 0$

Now, $x = -\frac{1}{2}$ a root $\Rightarrow x + \frac{1}{2} = 0 \Rightarrow 2x + 1$ is a factor

$$\begin{array}{r|l} & x^2 - 2x + 4 \\ \hline 2x+1 & 2x^3 - 3x^2 + 6x + 4 \\ & \underline{2x^3 + x^2} \\ & \quad -4x^2 + 6x \\ & \quad \underline{-4x^2 - 2x} \\ & \qquad\quad 8x + 4 \\ & \qquad\quad \underline{8x + 4} \\ & \qquad\quad\ 0 \end{array}$$

$\left.\begin{cases} ax^2 + bx + c = 0 \\ x^2 - 2x + 4 = 0 \end{cases}\right\}\ a = 1,\ b = -2,\ c = 4$

$b^2 - 4ac = (-2)^2 - 4(1)(4) = -12 < 0$ thus the roots are unreal.

22.(i)

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

(ii)

$x^3 - 1 = (x-1)(x^2 + x + 1) = 0$

$\Rightarrow x - 1 = 0$ i.e. $x = 1$

or $x^2 + x + 1 = 0$

$\left.\begin{cases} ax^2 + bx + c = 0 \\ x^2 + x + 1 = 0 \end{cases}\right\}\ a = 1,\ b = 1,\ c = 1$

$b^2 - 4ac = (1)^2 - 4(1)(1) = -3 < 0$ thus the roots of the quadratic are unreal.

Thus, $x^3 - 1 = 0$ has only one real root, $x = 1$.

23.

$f(x) = x^3 + ax + b$

$f(2) = (2)^3 + a(2) + b = 0 \Rightarrow 2a + b = -8$ A

$f(3) = (3)^3 + a(3) + b = -20 \Rightarrow 3a + b = -47$ B

B: $3a + b = -47$

−A: $\underline{-2a - b = 8}$

$a \qquad = -39$

Substitute in A: $2(-39) + b = -8 \Rightarrow b = -8 + 78 = 70$

Now, $x = 2$ is a root $\Rightarrow x - 2$ is a factor.

$$
\begin{array}{r|l}
 & x^2 - 2x - 35 \\
x - 2 & x^3 - 39x + 70 \\
 & \underline{x^3 - 2x^2} \\
 & -2x^2 - 39x \\
 & \underline{-2x^2 - 4x} \\
 & -35x + 70 \\
 & \underline{-35x + 70} \\
 & 0
\end{array}
$$

$x^2 - 2x - 35 = (x-7)(x+5) = 0$

Ans. the roots are $x = 2, x = 7$ and $x = -5$

24.

$f(x-)=x^3+ax^2+bx+c=0$

$f(3)=(3)^3+a(3)^2+b(3)+c=0$

$\Rightarrow 9a+3b+c=-27$ A

$f(-2)=(-2)^3+a(-2)^2+b(-2)+c=0$

$4a-2b+c=8$ B

$f(1)=(1)^3+a(1)^2+b(1)+c=-36$

$a+b+c=-37$ C

A $\quad 9a+3b+c=-27$

$-$B $\quad \underline{-4a+2b-c=-8}$

$\quad 5a+5b=-35 \Rightarrow a+b=-7$ D

B $\quad 4a-2b+c=8$

$-$C $\quad -a-b-c=37$

$\quad 3a-3b=45 \Rightarrow a-b=15$ E

D + E $\quad 2a=8 \Rightarrow a=4$

Substitute in D: $(4)+b=-7 \Rightarrow b=-11$

Substitute in C: $(4)+(-11)+c=-37 \Rightarrow c=-30$

3, $-$2 roots $\Rightarrow (x-3)(x+2)=x^2-x-6$ is a factor

$$\begin{array}{r l}
 & x+5 \\
x^2-x-6 & \overline{\big)\, x^3+4x^2-11x-30} \\
 & \underline{x^3-x^2-6x} \\
 & \quad 5x^2-5x-30 \\
 & \quad \underline{5x^2-5x-30} \\
 & \quad 0
\end{array}$$

Thus, $f(x)=0$ has solutions $x=-2$, $x=3$ and $x=-5$