SOUTH SYDNEY HIGH SCHOOL
MATHEMATICS

POLYNOMIALS WORKSHEET

1. For the following polynomials, find the degree, the leading term, leading coefficient and constant term:
   (a) $P(x) = 3x^4 - 7x + 2$
   (b) $P(x) = 4 - 2x^5$
   (c) $P(x) = 3x^5 - 2x^3 + 4x$
   (d) $P(x) = 7$

2. Determine whether the following are polynomials in x:

   (a) $\frac{4}{x} - 3x + 2$

   (b) $\frac{5x^4 - x}{x}$

   (c) $\frac{3x}{4} + 2$

   (d) $4x^4 + \sqrt{x} - 2$

   (e) $(x+4)^2 - 2x + 3$

3. Complete the following:

   (a) $\begin{array}{r} 4x^4 - 2x^2 + 3 \\ \underline{3x^4 - 5x^2 - 7} \end{array} \; +$

   (b) $\begin{array}{r} 3x^2 - 4x + 1 \\ \underline{5x^2 + 2x - 5} \end{array} \; +$

   (c) $\begin{array}{r} 4x^3 + 12x^2 + 3x + 7 \\ \underline{5x^3 \qquad\quad + \; x + 3} \end{array} \; +$

   (d) $\begin{array}{r} 4x^5 - 21x + 2 \\ \underline{3x^5 + \;\; 2x - 1} \end{array} \; +$

   (e) $\begin{array}{r} 5x^3 + 2x^2 - x - 1 \\ \underline{3x^3 - \;\; x^2 - x + 5} \end{array} \; -$

   (f) $\begin{array}{r} 4x^4 - 2x^2 + 1 \\ \underline{x^4 - 5x^2 - 7} \end{array} \; -$

   (g) $\begin{array}{r} 4x^3 \qquad\quad - x + 2 \\ \underline{3x^3 + 2x^2 \qquad - 1} \end{array} \; -$

   (h) $\begin{array}{r} 5x^4 \qquad\quad - 2x^2 \qquad + 1 \\ \underline{3x^3 + \;\; x^2 - 5x + 2} \end{array} \; -$

4. Find the degree of $P(x).Q(x)$ if:

   (a) $P(x) = 3x^2 - 4x + 1$ and
   $Q(x) = 4 - x + x^2$

   (b) $P(x) = 5x^4 - 2x - 1$ and
   $Q(x) = 3x - 5x^2 + x^3$

5. Find the product of the following polynomials:

   (a) $2x^3 - 4$ and $5x^2 - x + 2$

   (b) $6x^2 - 4x$ and $x^3 + x - 1$

6. Complete the following divisions, leaving your answer in the form:
   dividend = divisor × quotient + remainder.

   (a) $(x^3 - 3x^2 + 7x - 5) \div (x - 3)$

   (b) $(-x^3 + 2x^2 - 5x - 1) \div (x + 2)$

   (c) $(x^5 + x^3 - x) \div (x^2 + x)$

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

7. If $P(x) = x^3 + 2x^2 - x + 1$ and $Q(x) = x - 1$, find

   (a) $P(x) + Q(x)$ (b) $P(x) - Q(x)$

   (c) $P(x) \cdot Q(x)$ (d) $\frac{P(x)}{Q(x)}$

8. Find the remainder after the following divisions:

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

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

9. If $x^3 + 3x^2 - 7x + k$ is divided by $(x + 2)$ the remainder is 5. Find the value of k.

10. When $3x^4 - 2x^3 + 2k$ is divided by $(x + 1)$, the remainder is 3. Find the value of k.

11. If $x^2 - 7x + 9$ is divided by $(x - k)$, the remainder is 3. Find the value of k.

12. If $(x - 5)$ is a factor of $x^3 + kx - 10$, find the value of k.

13. Show that $(x-1)$ is a factor of x^3-2x^2-5x+6, and hence solve the equation $x^3-2x^2-5x+6=0$.

14. Factorise $2x^3-5x^2-4x+3$.

15. Solve for x, the equation $x^3+2x^2-9x-18=0$.

16. If $x=-3$ and $x=1$ are roots of the equation x^3-2x^2-ax+b, find the values of a and b, and hence find the third root of the equation.

17. Sketch the graphs of the following polynomials:

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

    (b) $y=x(x-2)^2(4-x)$

    (c) $y=(3-x)(x+1)^3(4-x)$

    (d) $y=x^2(1-x)^2$

    (e) $y=(1+x)^3$

18. Factorise the following and then sketch their graphs, showing clearly the zeros of each function:

    (a) $y=x^3-4x^2+x+6$

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

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

    (d) $y=-x^3+12x+16$

19. Match the polynomial function to the correct sketch:

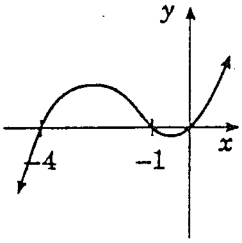
    (a) $y=x(x-1)^2(4-x)$

    (b) $y=x^2(x-1)(x+4)$

    (c) $y=x(x-1)^3(4-x)$

    (d) $y=x(x+1)(4+x)$

(i)



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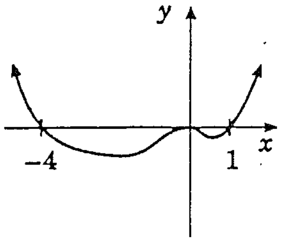

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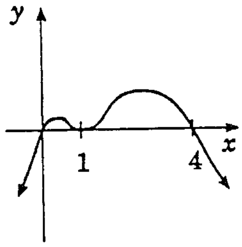

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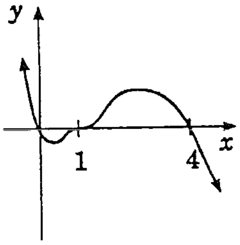


WORKED SOLUTIONS

1. (a) $P(x) = 3x^4 - 7x + 2$
   deg: 4, lead t: $3x^4$, lead c = 3
   const t: 2
   (b) $P(x) = 4 - 2x^5$
   deg: 5, lead t: $-2x^5$, lead c = −2
   const t: 4
   (c) $P(x) = 3x^5 - 2x^3 + 4x$
   deg: 5, lead t: $3x^5$, lead c = 3
   const t: 0
   (d) $P(x) = 7$
   deg: 0, lead t: 7, lead c = 7
   const t: 7

2. (a) $\dfrac{4}{x} - 3x + 2 = 4x^{-1} - 3x + 2$
   ∴ not polynomial [power of − 1]

   (b) $\dfrac{5x^4 - x}{x} = 5x^3 - 1$
   ∴ polynomial.

   (c) $\dfrac{3x}{4} + 2 = \tfrac{3}{4}x + 2$
   ∴ polynomial.

   (d) $4x^4 + \sqrt{x} - 2 = 4x^4 + x^{\frac{1}{2}} - 2$
   ∴ not polynomial [power of $\frac{1}{2}$]

   (e) $(x+4)^2 - 2x + 3$
   $= x^2 + 8x + 16 - 2x + 3$
   $= x^2 + 6x + 19$
   ∴ polynomial.

3. (a)
$$\begin{array}{l} 4x^4-2x^2+3 \;\; + \\ \underline{3x^4-5x^2-7} \\ 7x^4-7x^2-4 \end{array}$$
   (b)
$$\begin{array}{l} 3x^2-4x+1 \;\; + \\ \underline{5x^2+2x-5} \\ 8x^2-2x-4 \end{array}$$
   (c)
$$\begin{array}{l} 4x^3+12x^2+3x+\;7 \;\; + \\ \underline{5x^3+\;0x^2+\;x+\;3} \\ 9x^3+12x^2+4x+10 \end{array}$$
   (d)
$$\begin{array}{l} 4x^5-21x+2 \;\; + \\ \underline{3x^5+\;2x-1} \\ 7x^5-19x+1 \end{array}$$
   (e)
$$\begin{array}{l} 5x^3+2x^2-x-1 \;\; - \\ \underline{3x^3-\;x^2-x-5} \\ 2x^3+3x^2\qquad+4 \end{array}$$
   (f)
$$\begin{array}{l} 4x^4-2x^2+1 \;\; - \\ \underline{\;x^4-5x^2-7} \\ 3x^4+3x^2+8 \end{array}$$
   (g)
$$\begin{array}{l} 4x^3+0x^2-\;x+2 \;\; - \\ \underline{3x^3+2x^2+0x-1} \\ x^3-2x^2-\;x+3 \end{array}$$
   (h)
$$\begin{array}{r} 5x^4+0x^3-2x^2+0x+1 \;\; - \\ \underline{3x^3+\;x^2-5x+2} \\ 5x^4-3x^3-3x^2+5x-1 \end{array}$$

4. (a) $P(x)\cdot Q(x)$
   $= (3x^2-4x+1)(4-x+x^2)$
   $= \ldots + 3x^4 + \ldots$
   ∴ degree is 4
   [only need leading term]

   (b) $P(x)\cdot Q(x)$
   $= (5x^4-2x-1)(3x-5x^2+x^3)$
   $= \ldots + 5x^7 + \ldots$
   ∴ degree is 7.

5. (a) $(2x^3-4)(5x^2-x+2)$
   $= 10x^5 - 2x^4 + 4x^3 - 20x^2 + 4x - 8$

   (b) $(6x^2-4x)(x^3+x-1)$
   $= 6x^5 + 6x^3 - 6x^2 - 4x^4 - 4x^2 + 4x$
   $= 6x^5 - 4x^4 + 6x^3 - 10x^2 + 4x$

6. (a)
$$\begin{array}{r} x^2+7 \\ x-3\overline{)\,x^3-3x^2+7\underset{\times}{x}-\underset{\times}{5}} \\ \underline{x^3-3x^2}\qquad\qquad \\ 0\;+7x-\;5 \\ \underline{7x-21} \\ 16 \end{array}$$
   $\therefore\; x^3-3x^2+7x-5$
   $= (x-3)(x^2+7)+16$

   (b)
$$\begin{array}{r} -x^2+4x-13 \\ x+2\overline{)\,-x^3+2x^2-5\underset{\times}{x}-\underset{\times}{1}} \\ \underline{-x^3-2x^2}\qquad\qquad \\ 4x^2-5x\quad \\ \underline{4x^2+8x}\quad \\ -13x-\;1 \\ \underline{-13x-26} \\ 25 \end{array}$$
   $\therefore\; -x^3+2x^2-5x-1$
   $= (x+2)(-x^2+4x-13)+25$

(c)
$$\begin{array}{rl} & \quad\quad\quad x^3-x^2+2x-2 \\ x^2+x & \overline{\big)\,x^5+0x^4+\underset{\times}{x^3}+0\underset{\times}{x^2}-\underset{\times}{x}} \\ & \underline{x^5+\;x^4} \\ & \quad -x^4+x^3 \\ & \quad \underline{-x^4-x^3} \\ & \quad\quad 2x^3+0x^2 \\ & \quad\quad \underline{2x^3+2x^2} \\ & \quad\quad\quad -2x^2-\;x \\ & \quad\quad\quad \underline{-2x^2-2x} \\ & \quad\quad\quad\quad\quad\quad x \end{array}$$

$\therefore\ x^5+x^3-x$

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

(d) $\left(x^4-1\right)\div\left(x^2-3\right)$

$$\begin{array}{rl} & \quad\quad\quad x^2+3 \\ x^2-3 & \overline{\big)\,x^4+0x^3+0x^2+0x-1} \\ & \underline{x^4\quad\quad -3x^2} \\ & \quad\quad\quad 3x^2-1 \\ & \quad\quad\quad \underline{3x^2-9} \\ & \quad\quad\quad\quad\quad 8 \end{array}$$

$\therefore\ x^4-1=\left(x^2-3\right)\left(x^2+3\right)+8$

7. $p(x)=x^3+2x^2-x+1$

$q(x)=x-1$

(a) $p(x)+q(x)$

$$\therefore\ \begin{array}{r} x^3+2x^2-x+1 \\ \underline{x-1} \\ x^3+2x^2\quad\quad\quad \end{array}\ +$$

$\therefore\ p(x)+q(x)=x^3+2x^2$

(b) $p(x)-q(x)$

$$\therefore\ \begin{array}{r} x^3+2x^2-\ x+1 \\ \underline{x-1} \\ x^3+2x^2-2x+2 \end{array}\ -$$

$\therefore\ p(x)-q(x)=x^3+2x^2-2x+2$

(c) $p(x)\cdot q(x)$

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

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

$+x+x-1$

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

(d) $\dfrac{p(x)}{q(x)}$

$$\therefore\ \begin{array}{rl} & \quad\quad\quad x^2+3x+2 \\ x-1 & \overline{\big)\,x^3+2x^2-x+1} \\ & \underline{x^3-\ x^2} \\ & \quad\quad 3x^2-\ x \\ & \quad\quad \underline{3x^2-3x} \\ & \quad\quad\quad\quad 2x+1 \\ & \quad\quad\quad\quad \underline{2x-2} \\ & \quad\quad\quad\quad\quad\quad 3 \end{array}$$

$\therefore\ p(x)\div q(x)=\left(x^2+3x+2\right)\div 3$

8. (a) Let $P(x)=x^3+4x^2+x-1$

Dividing by $(x+2)$, $\therefore$ find $P(-2)$

$\therefore\ P(-2)=(-2)^3+4(-2)^2+(-2)-1$

$=-8+16-2-1=5$

$\therefore$ remainder is 5.

(b) Let $P(x)=x^3-4x+2$

Dividing by $(x-1)$, $\therefore$ find $P(1)$

$\therefore\ P(1)=1^3-4(1)+2$

$=1-4+2=-1$

$\therefore$ remainder is -1.

9. Let $P(x)=x^3+3x^2-7x+k$

Dividing by $(x+2)$, $\therefore\ P(-2)=5$

$\therefore\ P(-2)=(-2)^3+3(-2)^2-7(-2)+k=5$

$-8+12+14+k=5$

$18+k=5$

$k=5-18$

$k=-13$

$\therefore$ value of k is -13.

10. Let $P(x)=3x^4-2x^3-2k$

Dividing by $(x+1)$, $\therefore\ P(-1)=3$

$\therefore\ P(-1)=3(-1)^4-2(-1)^3+2k=3$

$3+2+2k=3$

$5+2k=3$

$2k=3-5$

$2k=-2$

$k=-1$

$\therefore$ value of k is -1.

11. Let $P(x)=x^2-7x+9$

Dividing by $(x-k)$, $\therefore\ P(k)=3$

$\therefore P(k)=k^2-7k+9=3,$

that is, $k^2-7k+6=0$

$$(k-6)(k-1)=0$$
$$k=6 \text{ or } 1$$

$\therefore$ k is 6 or 1.

12. Let $P(x)=x^3+kx-10$

Dividing by $(x-5)$, $\therefore\ P(5)=0$

$\therefore P(5)=5^3+5k-10=0$

$$\begin{aligned}125+5k-10&=0\\ 5k+115&=0\\ 5k&=-115\\ \frac{5k}{5}&=-\frac{115}{5}\\ k&=-23\end{aligned}$$

$\therefore$ value of k is -23.

13. Let $P(x)=x^3-2x^2-5x+6$

If $(x-1)$ is a factor, then $P(1)=0$

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

$=1-2-5+6$

$=0$

$\therefore$ as $P(1)=0$, then $(x-1)$ is a factor of $P(x)$.

$$\begin{array}{r l}
 & x^2-\ x-6 \\ \cline{2-2}
x-1\big) & x^3-2x^2-5x+6 \\
 & \underline{x^3-\ x^2} \\
 & \quad -\ x^2-5x \\
 & \quad \underline{-\ x^2+\ x} \\
 & \qquad\quad -6x+6 \\
 & \qquad\quad \underline{-6x+6} \\
 & \qquad\qquad\quad 0
\end{array}$$

$\therefore$ as $x^3-2x^2-5x+6=0$

$\therefore$ $(x-1)(x^2-x-6)=0$

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

$\therefore$ $x=1,\ 3,\ -2,$

$\therefore$ the roots of the equation are $x=1,\ 3$ and -2.

14. Let $P(x)=2x^3-5x^2-4x+3$

Now find a, where $P(a)=0$,

that is, try

$P(1)=2(1)^3-5(1)^2-4(1)+3$

$=2-5-4+3$

$\neq 0$

Try

$P(-1)=2(-1)^3-5(-1)^2-4(-1)+3$

$=-2-5+4+3$

$=0$

$\therefore$ $P(-1)=0$, $\therefore$ $(x+1)$ is a factor.

$$\begin{array}{r l}
 & 2x^2-7x+3 \\ \cline{2-2}
x+1\big) & 2x^3-5x^2-4x+3 \\
 & \underline{2x^3+2x^2} \\
 & \quad -7x^2-4x \\
 & \quad \underline{-7x^2-7x} \\
 & \qquad\qquad 3x+3 \\
 & \qquad\qquad \underline{3x+3} \\
 & \qquad\qquad\quad 0
\end{array}$$

$\therefore$ $2x^3-5x^2-4x+3$

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

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

15. Let $P(x)=x^3+2x^2-9x-18$

Try $P(1)=1^3+2(1)^2-9(1)-18\neq 0$

$P(-1)=(-1)^3+2(-1)^2-9(-1)-18\neq 0$

$P(2)=(2)^3+2(2)^2-9(2)-18$

$=8+8-18-18\neq 0$

$P(-2)=(-2)^3+2(-2)^2-9(-2)-18$

$=-8+8+18-18=0,$

$\therefore$ as $P(-2)=0$, $(x+2)$ is a factor,

$$\therefore\quad \begin{array}{r l}
 & x^2-9 \\ \cline{2-2}
x+2\big) & x^3+2x^2-9x-18 \\
 & \underline{x^3+2x^2} \\
 & \qquad\quad -9x-18 \\
 & \qquad\quad \underline{-9x-18} \\
 & \qquad\qquad\quad 0
\end{array}$$

As $x^3+2x^2-9x-18=0$

$(x+2)(x^2-9)=0$

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

$\therefore$ $x=-2,\ 3,\ -3.$

16. Let $P(x)=x^3-2x^2-ax+b$

As $x=-3$ is a root, $P(-3)=0$

$\therefore$ $P(-3)=(-3)^3-2(-3)^2-a(-3)+b$

$=0$

$-27-18+3a+b=0$

$-45+3a+b=0$

$\therefore$ $3a+b=45.$

Also, as $x=1$ is a root, $P(1)=0.$

$\therefore$ $P(1)=(1)^3-2(1)^2-a(1)+b=0$

$1-2-a+b=0$

$-1-a+b=0$

$\therefore$ $a-b=-1$

$\therefore\quad 3a+b=45 \qquad (1)$

$a-b=-1 \qquad (2)$

$(1)+(2)$

$4a=44$

$a=11$

Substitute $a=11$ in (2)

$11-b=-1$

$-b=-1-11$

$-b=-12$

$\therefore\quad b=12,$

$\therefore\quad a=11,\ b=12,$

$\therefore\quad P(x)=x^3-2x^2-11x+12.$

Now as $x=-3,\ x=1$ are roots,

$\therefore\quad (x+3),\ (x-1)$ are factors,

$\therefore\quad (x+3)(x-1)$ is also a factor,

$\therefore\quad (x^2+2x-3)$ is a factor,

$$\therefore\quad \begin{array}{r} x-4 \\ x^2+2x-3\overline{)x^3-2x^2-11x+12} \\ \underline{x^3+2x^2-\ 3x} \\ -4x^2-\ 8x+12 \\ \underline{-4x^2-\ 8x+12} \\ 0 \end{array}$$

$\therefore\quad x^3-2x^2-11x+12$

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

$=(x+3)(x-1)(x-4),$

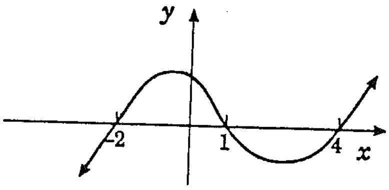
$\therefore$ as $P(x)=0$

$(x+3)(x-1)(x-4)=0,$

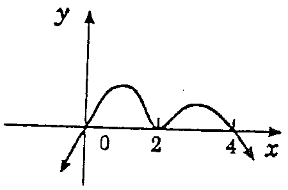
$\therefore\quad x=-3,\ 1,\ 4$

$\therefore$ the other root is $x=4.$

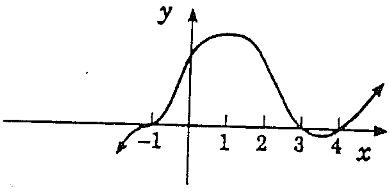
17. (a) $y=(x-4)(x-1)(x+2)$



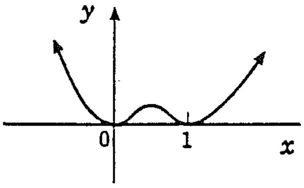
(b) $y=x(x-2)^2(4-x)$



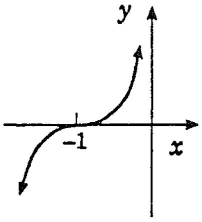
(c) $y=(3-x)(x+1)^3(4-x)$



(d) $y=x^2(1-x)^2$



(e) $y=(1+x)^3$



18. (a) $y=x^3-4x^2+x+6$

Let $y=P(x)$

$\therefore\quad P(x)=x^3-4x^2+x+6.$

Try $\quad P(1)=1^3-4(1)^2+1+6$

$=1-4+1+6\neq 0$

$P(-1)=(-1)^3-4(-1)^2-1+6$

$=-1-4-1+6=0$

$\therefore$ as $P(-1)=0,\quad x+1$ is a factor,

$$\therefore\quad \begin{array}{r} x^2-5x+6 \\ x+1\overline{)x^3-4x^2+x+6} \\ \underline{x^3+\ x^2} \\ -5x^2+x \\ \underline{-5x^2-5x} \\ 6x+6 \\ \underline{6x+6} \\ 0 \end{array}$$

$\therefore\quad P(x)=x^3-4x^2+x+6$

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

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

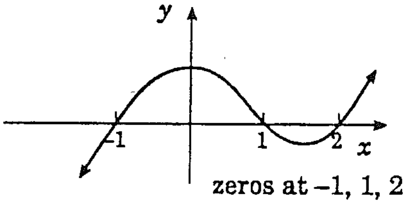
$\therefore\quad y=(x+1)(x-3)(x-2)$

Substitute $x=4$ in y,

that is, $\ y(4)=(4+1)(4-3)(4-1)$

$=(5)(1)(3)>0$

$\therefore$ above the x-axis at $x=4.$



zeros at −1, 1, 2

(b) $y=x^3-x^2-x+1.$

Let $y=P(x)$

$\therefore\quad P(x)=x^3-x^2-x+1.$

Try $P(1)=1^3-1^2-1+1$

$=0$

$\therefore$ as $P(1)=0,\quad x-1$ is a factor,

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

$$\begin{aligned} \therefore\quad P(x)&=x^3-x^2-x+1 \\ &=(x-1)(x^2-1) \\ &=(x-1)(x-1)(x+1) \\ &=(x-1)^2(x+1) \end{aligned}$$

$\therefore\ y=(x-1)^2(x+1).$

Substitute $x=2$ in y,

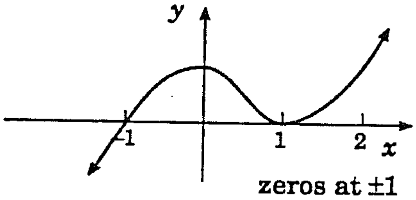
that is, $y(2)=(2-1)^2(2+1)$

$=(1)^2(3)>0,$

$\therefore$ above x - axis at $x=4$,

that is, $y>0$ when $x=4$,

(that is, $y>0$ for $x>1$).



zeros at ±1

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

Let $y=P(x)$

$\therefore\quad P(x)=x^3-3x^2+3x-1.$

Try $P(1)=1^3-3(1)^2+3(1)-1$

$=1-3+3-1$

$=0$

$\therefore$ as $P(1)=0,\quad (x-1)$ is a factor,

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

$$\begin{aligned} \therefore \text{ as } P(x)&=x^3-3x^2+3x-1 \\ &=(x-1)(x^2-2x+1) \\ &=(x-1)(x-1)(x-1) \\ &=(x-1)^3 \end{aligned}$$

$\therefore\ y=(x-1)^3$

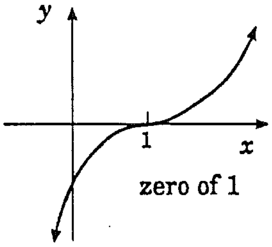
Substitute $x=2$ in y,

that is, $y(2)=(2-1)^3$

$=1^3>0,$

$\therefore$ above x - axis at $x=2$,

$\therefore\ y>0$ when $x>1$.



zero of 1

(d) $y=-x^3+12x+16$

Let $y=P(x)$

$\therefore\quad P(x)=-x^3+12x+16.$

Try $P(1)=-1^3+12(1)+16$

$\neq 0$

$P(-1)=-(-1)^3+12(-1)+16$

$\neq 0$

$P(2)=-2^3+12(2)+16$

$=-8+24+16$

$\neq 0$

$P(-2)=-(-2)^3+12(-2)+16$

$=8-24+16$

$=0,$

$\therefore$ as $P(-2)=0,\quad (x+2)$ is a factor,

$$\begin{array}{rl} & \qquad -x^2+2x+8 \\ \therefore\ x+2 & \overline{)\,-x^3+0x^2+12x+16} \\ & \underline{-x^3-2x^2} \\ & \qquad\quad 2x^2+12x \\ & \qquad\quad \underline{2x^2+\ 4x} \\ & \qquad\qquad\qquad 8x+16 \\ & \qquad\qquad\qquad \underline{8x+16} \\ & \qquad\qquad\qquad\qquad 0 \end{array}$$

$$\begin{aligned} \therefore \text{ as } P(x)&=-x^3+12x+16 \\ &=(x+2)(-x^2+2x+8) \\ &=-(x+2)(x^2-2x-8) \\ \therefore\qquad y&=-(x+2)(x+2)(x-4) \\ &=-(x+2)^2(x-4) \end{aligned}$$

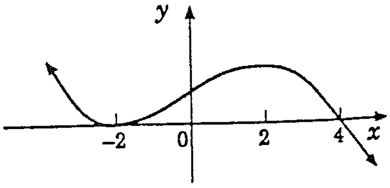
$\therefore$ zeros at $-2,\ 4$

Substitute $x=0$ in y,

that is, $y(0)=-(2)^2(-4)$

$=-4(-4)>0,$

$\therefore$ below axis when $x=0$.



19. (a) (iii)

(b) (ii)

(c) (iv)

(d) (i)