Date 30.11.23
Page No.

P-1

Pure Maths-1

Quadratics

Exercise-1 Solution (Revision)

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Quadratics Revision.

Example 1: The equation of a line is $y = mx + c$, where m and c are constants, and the equation of a curve is $xy = 16$.

(a) Given that the line is a tangent to the curve, express m in terms of c. ---[3]

(b) Given instead that $m = -4$, find the set of value of c for which the line intersects the curve at two distict points. ---[3]

$\boxed{S\text{-}20/11/Q5}$

Solution (a). $y = mx + c$ —— ①

Curve: $xy = 16$ —— ②

from ① and ② $x(mx + c) = 16$

$\Rightarrow mx^2 + cx - 16 = 0$ —— ③

for line be tangent to curve:

$B^2 - 4AC = 0$

for ③ $c^2 - 4 \times m \times (-16) = 0$

$\Rightarrow c^2 + 64m = 0$

$\Rightarrow m = \underline{-c^2/64}$ ✓

(b) Now $\begin{cases} y = -4x + c & \text{④ for } m = -4 \\ xy = 16 & \text{②} \end{cases}$

$\Rightarrow x(-4x + c) = 16$

$\Rightarrow -4x^2 + cx - 16 = 0$

$\Rightarrow 4x^2 - cx + 16 = 0$ —— ⑤

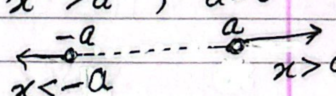
④ line intersects the curve ② in two different points $\Rightarrow B^2 - 4AC > 0$

from ⑤ $\Rightarrow c^2 - 4 \times 4 \times 16 > 0$

$c^2 - (16)^2 > 0$

$c^2 > (16)^2$

$\Rightarrow \underline{c > 16 \text{ or } c < -16}$ ✓ $\left(\because x^2 > a^2,\ a > 0\right.$



Example 2: The equation of a curve is $y = 2x^2 + kx + k - 1$, where k is a constant.

(a) Given that the line $y = 2x + 3$ is a tangent to the curve, find the value of k. --[3]

It is now given that $k = 2$

(b) Express the equation of the curve in the form $y = 2(x+a)^2 + b$, where a and b are constants, and state the coordinates of the vertex of the curve. [S-20/12/Q6] --[3]

Solution: curve: $y = 2x^2 + kx + k - 1$ —①

(a) line: $y = 2x + 3$ —②

from ① & ②

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

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

from line ② be tangent to curve ①
line should intersect exactly at one point to curve ②

$\therefore$ for $b^2 - 4ac = 0$

from ③ $\rightarrow (k-2)^2 - 4 \times 2 \times (k-4) = 0$

$\Rightarrow k^2 - 12k + 36 = 0$

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

$\Rightarrow k = 6$ ✓

(b) Now $k = 2$

from ① Curve: $y = 2x^2 + 2x + 1$

or $y = 2\left[x^2 + x + \frac{1}{2}\right]$

$= 2\left[x^2 + x + \left(\frac{1}{2}\right)^2 - \frac{1}{4} + \frac{1}{2}\right]$

$= 2\left[\left(x + \frac{1}{2}\right)^2 + \frac{1}{4}\right]$

$= 2\left(x + \frac{1}{2}\right)^2 + \frac{1}{2}$

$\therefore$ Vertex $\left(-\frac{1}{2}, \frac{1}{2}\right)$ ✓

$\because$ for a quad. function:
$y = a(x+b)^2 + c$
Vertex $(-b, c)$ ✓

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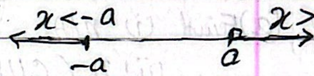
Example 3: Find the set of values of m for which the line with equation $y = mx+1$ and the curve with equation $y = 3x^2+2x+4$ intersect at two distinct points. ---[4]
[S-20/13/Q1]

Solution: line: $y = mx+1$ —— ①
curve: $y = 3x^2+2x+4$ —— ②
To find the point of intersection from ① & ②

$$3x^2+2x+4 = mx+1$$
or $3x^2+(2-m)x+3 = 0$ —— ③
from ① and ② intersect in two distict points,
for ③ $b^2-4ac > 0$
$\Rightarrow (2-m)^2 - 4\times 3\times 3 > 0$
$(2-m)^2 - 36 > 0$ —— ④
$(2-m)^2 > 6^2$

[$x^2 > a^2$, $a > 0$

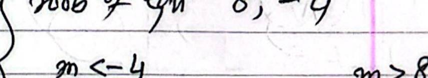


$\Rightarrow 2-m > 6$ or $2-m < -6$
$\Rightarrow m < -4$ or $m > 8$ ✓

Note: $a > b$
$(x-a)(x-b) > 0$

$\Rightarrow x > a$ or $x < b$

Alternate method to solve ④
$(2-m)^2 - 36 > 0$
$m^2 - 4m + 4 - 36 > 0$
$m^2 - 4m - 32 > 0$
$(m-8)(m+4) > 0$ → roots of eqn 8, −4
$\Rightarrow m > 8$ or $m < -4$ ✓



4. Find the set of values of m for which the line with equation $y = mx - 3$ and the curve with equation, $y = 2x^2 + 5$ do not meet. [W-20/11/Q1] ---[3]

Solution: Line: $y = mx - 3$ --- ①

Curve: $y = 2x^2 + 5$ --- ②

for intersection of ① & ②

$2x^2 + 5 = mx - 3$

$\Rightarrow 2x^2 - mx + 8 = 0$ — ③

Given that ① & ② do not intersect.

$B^2 - 4AC < 0$ for ③

$\Rightarrow (-m)^2 - 4 \times 2 \times 8 < 0$

$\Rightarrow m^2 - 64 < 0$

$(m+8)(m-8) < 0$

$\Rightarrow -8 < m < 8$ ✓ [for $m = -8, 8$]

4⁺. The equation of a curve is $y = 2x^2 + m(2x+1)$, where m is a constant, and the equation of a line is $y = 6x + 4$. Show that for all value of m, the line intersects the curve at two distinct points. [W-20/12/Q3] ---[5]

Solution: Curve: $y = 2x^2 + m(2x+1)$ — ①

Line: $y = 6x + 4$ --- ②

for ① and ② to intersect,

$2x^2 + 2mx + m = 6x + 4$

$\Rightarrow 2x^2 + (2m-6)x + (m-4) = 0$ — ③

$B^2 - 4AC$

$= (2m-6)^2 - 4 \times 2 \times (m-4)$

$= 4m^2 - 24m + 36 - 8m + 32$

$= 4m^2 - 32m + 68$

$= 4[m^2 - 8m + 17]$

$= 4[(m-4)^2 + 1] > 0$ for all value of m.

For nature of roots of ③ to prove the two distinct points of intersection $\Rightarrow B^2 - 4AC > 0$

$\therefore$ line ② intersects the curve ① at two distinct points for all values of m.

$\because (m-4)^2 \geq 0$

$\Rightarrow (m-4)^2 + 1 > 0$

$\Rightarrow 4[(m-4)^2 + 1] > 0$

5.(a) Express x^2+6x+5 in the form $(x+a)^2+b$, where a and b are constants. ---[2]

(b) The curve with equation $y=x^2$ is transformed to the curve with equation $y=x^2+6x+5$. describe fully the transformations involved. [W-20/13/Q1] --[2]

Solution (a) $x^2+6x+5 = x^2+6x+3^2-9+5$

$= (x+3)^2-4$ ✓ —— ①

(b) Translation (or shift) $\begin{pmatrix}-3\\-4\end{pmatrix}$.

[or translation -3 units in x-direction and translation -4 units in y-direction.]

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6. A curve has equation $y=3x^2-4x+4$ and a straight line has equation $y=mx+m-1$, where m is a constant. Find the set of values of m for which the curve and the line have two distinct points of intersection. ---[5]

[W-20/13/Q4]

Solution: Curve: $y=3x^2-4x+4$ ---①

Line: $y=mx+m-1$ ---②

for the points of intersection of ① & ②

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

$\Rightarrow 3x^2-(4+m)x+(5-m)=0$ —— ③

To check the nature the roots of ③ find B^2-4AC for two distinct roots $B^2-4AC>0$

$B^2-4AC=(-(4+m))^2-4\times3(5-m)$

$=16+m^2+8m-60+12m$

$=m^2+20m-44$

$=m^2+22m-2m-44$

$=(m+22)(m-2)>0$ for two distinct roots

$\Rightarrow$ $\underline{m>2}$ or $\underline{m<-22}$ ✓

7. By using a suitable substitution, solve the equation:

$$(2x-3)^2 - \frac{4}{(2x-3)^2} - 3 = 0 \quad ---① \qquad ---[4]$$

[M-21/12/Q2]

Solution: Let $(2x-3)^2 = y$

from ① $\rightarrow$ $y - \frac{4}{y} - 3 = 0 \Rightarrow y^2 - 3y - 4 = 0$

$\Rightarrow (y-4)(y+1) = 0$

$\Rightarrow y = 4 \; ; \; y = -1$

$\Rightarrow (2x-3)^2 = 4 \; ; \; (2x-3)^2 = -1^{\times}$

$\Rightarrow 2x-3 = \pm 2 \Rightarrow 2x-3 = 2 \; ; \; 2x-3 = -2$

$x = 5/2 \checkmark \; ; \; x = \frac{1}{2} \checkmark$

8. A line line has equation $y = 3x + k$ and a curve has equation $y = x^2 + kx + 6$, where k is a constant. Find the set of values of k for which the line and curve have two distinct points of intersection. --- [5]

[M-21/12/Q4]

Solution: Line: $y = 3x + k$ ——①

Curve: $y = x^2 + kx + 6$ ---②

from ① and ②

$x^2 + kx + 6 = 3x + k$

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

for two points of intersection $\Rightarrow$

$B^2 - 4AC > 0$

$\Rightarrow (k-3)^2 - 4 \times 1 \times (6-k) > 0$

$k^2 - 6k + 9 - 24 + k > 0$

$k^2 - 2k - 15 > 0$

$(k-5)(k+3) > 0$ [$k = 5, -3$]

$\therefore k < -3 \; ; \; k > 5 \checkmark$

9. The equation of curve is $y=(2k-3)x^2-kx-(k-2)$, where k is a constant. The line $y=3x-4$ is a tangent to the curve. Find the value of k. [S-21/11/Q6] [5]

Solution: curve: $y=(2k-3)x^2-kx-(k-2)$ ---(i)
line: $y=3x-4$ ---(ii)

Solving ① & (ii) $\Rightarrow (2k-3)x^2-kx-(k-2)=3x-4$
$\Rightarrow (2k-3)x^2-(k+3)x-(k-6)=0$
for line (ii) be tangent to curve ① $\Rightarrow B^2-4AC=0$
$\Rightarrow (k+3)^2+4(2k-3)(k-6)=0$
$k^2+6k+9+4(2k^2-15k+18)=0$
$\Rightarrow 9k^2-54k+81=0$
$\Rightarrow k^2-6k+9=0 \Rightarrow (k-3)^2=0$
$= k=3$ ✓

10. (a) Express $16x^2-24x+10$ in the form $(4x+a)^2+b$. ---[2]
(b) It is given that the equation $16x^2-24x+10=k$; where k is a constant, has exactly one root. Find the value of this root. ---[2]
[S-21/12/Q1]

Solution (a) $16x^2-24x+10$
$= (4x)^2-2\times4x\cdot3+3^2-9+10$
$= (4x-3)^2+1$ ✓ [$\because b=1$]

(b) $16x^2-24x+10=k$ (Given)
from Part (a) $\Rightarrow (4x-3)^2+1=k$ has exactly one root $\Rightarrow k=1$
$\Rightarrow (4x-3)^2=0 \Rightarrow 4x-3=0 \Rightarrow x=3/4$ (or 0.75) ✓

11. A line with equation $y=mx-6$, is a tangent to the curve with equation $y=x^2-4x+3$. Find the possible values of the constant m, and the corresponding coordinate of the points at which the line touches the curve. [S-21/13/Q3] ---[6]

Solution: line: $y=mx-6$ — ①
Curve: $y=x^2-4x+3$ — ②
from ① & ② $x^2-4x+3=mx-6$
$\Rightarrow x^2-(4+m)x+9=0$ — ③

for line ① is tangent to curve ② $\Rightarrow$ In ③ $B^2-4AC=0$
$\Rightarrow (4+m)^2-4\times9=0 \Rightarrow 4+m=\pm6 \Rightarrow m=2$, or -10
from ① $m=2 \Rightarrow$ from ③ $x^2-6x+9=0 \Rightarrow (x-3)^2=0 \Rightarrow x=3$
for $m=-10$ in ③ $\Rightarrow x^2+6x+9=0$, $(x+3)^2=0 \Rightarrow x=-3$
$\therefore$ Required Points are $(3,0)$, ✓ $(-3,24)$ ✓ from ②

12. A curve has equation $y = kx^2 + 2x - k$ and a line has equation $y = kx - 2$, where k is a constant. Find the set of values of k for which the curve and line do not intersection. ---[5]
W-21/Q11/Q2

Solution: Line: $y = kx - 2$ ---(i)
Curve: $y = kx^2 + 2x - k$ ---(ii)
for (i) and (ii) to intersect:
$kx^2 + 2x - k = kx - 2$
$\Rightarrow kx^2 + (2-k)x + (2-k) = 0$ ---③

for ① & ⑪ do not intersection: In ③
$B^2 - 4AC < 0 \Rightarrow (2-k)^2 - 4k(2-k) < 0$
$\Rightarrow 5k^2 - 12k + 4 < 0$
$(5k-2)(k-2) < 0$ {critical values are $k = \frac{2}{5}; 2$
$\Rightarrow \frac{2}{5} < k < 2$ ✓

13. Express $5y^2 - 30y + 50$ in the form $5(y+a)^2 + b$, where a and b are constants. [W-21/13/Q3(a)] --[2]

Solution: $5y^2 - 30y + 50 = 5[y^2 - 6y + 10] = 5[y^2 - 6y + 3^2 - 9 + 10]$
$= 5[(y-3)^2 + 1]$
$= 5(y-3)^2 + 5$ ✓

14. A curve has equation $y = x^2 + 2cx + 4$ and a straight line has equation $y = 4x + c$, where c is a constant. Find the set of values of c for which the curve and line intersect at two distinct points. ---[5]
M-22/12/Q2

Solution: Curve: $y = x^2 + 2cx + 4$ ---①
line: $y = 4x + c$ ---②
To line and curve intersect; from ① & ② $4x + c = x^2 + 2cx + 4$
$\Rightarrow x^2 + (4-2c)x + (4-c) = 0$ ---③
for ③ $B^2 - 4AC$
$= (4-2c)^2 - 4 \times 1(4-c)$
$= 16 + 4c^2 - 16c - 16 + 4c$
$B^2 - 4AC = 4c^2 - 12c$ ---④
for ① & ② to intersect in two disint points → $B^2 - 4AC > 0$

from ④ $4c^2 - 12c > 0$
$4c(c-3) > 0$ {critical values are 0, 3
$\Rightarrow$ $c < 0$ or $c > 3$ ✓

15(a) Express $2x^2-8x+14$ in the form $2[(x-a)^2+b]$ --- [2]

[M-22/12/Q5(a)]

Solution: $2x^2-8x+14 = 2[x^2-4x+7]$
$= 2[x^2-4x+2^2-4+7]$
$= 2[(x-2)^2+3]$ ✓

15⁺(a) Express $x^2-8x+11$ in the form $(x+p)^2+q$, where p and q are constants. --- [2]
(b) Hence find the exact solutions of the equation $x^2-8x+11=1$ --- [2]

[S-22/11/Q1]

Solution: (a) $x^2-8x+11$
$= x^2-8x+4^2-16+11$
$= (x-4)^2-5$ ✓

(b) $x^2-8x+11=1$
$\Rightarrow (x-4)^2-5=1$ (from Part (a))
$\Rightarrow (x-4)^2=6 \Rightarrow x-4=\pm\sqrt{6}$
$\therefore x = 4\pm\sqrt{6}$ ✓

16. Solve the equation $6\sqrt{y}+\frac{2}{\sqrt{y}}-7=0$ --[4]

[S-22/13/Q5(a)]

Solution: $6\sqrt{y}+\frac{2}{\sqrt{y}}-7=0$ Put $\left.\begin{array}{l}\sqrt{y}=x\\ y=x^2\end{array}\right\}$ ---- (1)
$\Rightarrow 6x+\frac{2}{x}-7=0$
$\Rightarrow 6x^2-7x+2=0 \Rightarrow 6x^2-4x-3x+2=0$
$2x(3x-2)-1(3x-2)=0$
$\Rightarrow (3x-2)(2x-1)=0 \Rightarrow x=\frac{1}{2}, \frac{2}{3}$
$\Rightarrow \sqrt{y}=\frac{1}{2}, \frac{2}{3} \Rightarrow y=\frac{1}{4}; \frac{4}{9}$ ✓

17 Given $f(x)=2x^2-16x+23$,
Express $f(x)$ in the form $2(x+a)^2+b$ ---[2]

[S-22/13/Q6(a)]

Solution: $2x^2-16x+23$
$= 2[x^2-8x]+23$
$= 2[x^2-8x+4^2-16]+23$
$= 2(x-4)^2-32+23$
$= 2(x-4)^2-9$ ✓

$\left\{\begin{array}{l} x^2-ax = x^2-ax+\left(\frac{a}{2}\right)^2-\frac{a^2}{4} \\ \quad = \left(x-\frac{a}{2}\right)^2-\frac{a^2}{4}\end{array}\right.$

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18. Solve the equation: $3x+2=\frac{2}{x-1}$ ---[3]

[W-22/11/Q1]

Solution: $3x+2=\frac{2}{x-1} \Rightarrow (3x+2)(x-1)=2$

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

$\Rightarrow (3x-4)(x+1)=0 \Rightarrow x=-1, \frac{4}{3}$ ✓

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19. Find the set of values of k for which the equation $8x^2+kx+2=0$ has no real roots. --[2]

[W-22/12/Q3(a)]

Solution: $8x^2+kx+2=0$ has no real roots.

{ $ax^2+bx+c=0$ has no real roots if $b^2-4ac<0$

$\Rightarrow k^2-4\times8\times2<0$

$\Rightarrow k^2-64<0 \Rightarrow (k+8)(k-8)<0$

{ as critical values of $k=8,-8$

$\Rightarrow -8<k<8$ ✓

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20. The equation of a curve is $y=4x^2+20x+6$ ---[3]

(a) Express the equation in the form $y=a(x+b)^2+c$; a, b, c are constants

(b) Hence solve the equation $4x^2+20x+6=45$ ---[3]

(c) Sketch the graph of $y=4x^2+20x+6$, showing the coordinates of stationary point.

[W-22/12/Q6] --[3]

Solution:

(a) $y=4x^2+20x+6$

$=4\left(x^2+5x+\left(\frac{5}{2}\right)^2-\frac{25}{4}\right)+6$

$=4\left(x+\frac{5}{2}\right)^2-25+6$

$\Rightarrow y=4\left(x+\frac{5}{2}\right)^2-19$ ✓

(b) Solve $4x^2+20x+6=45$

$\Rightarrow 4\left(x+\frac{5}{2}\right)^2-19=45$ [from Part (a)]

$\Rightarrow 4\left(x+\frac{5}{2}\right)^2=45+19=64$

$\left(x+\frac{5}{2}\right)^2=16$

$\Rightarrow x+\frac{5}{2}=\pm4$

$\Rightarrow x+\frac{5}{2}=4$ or $x+\frac{5}{2}=-4$

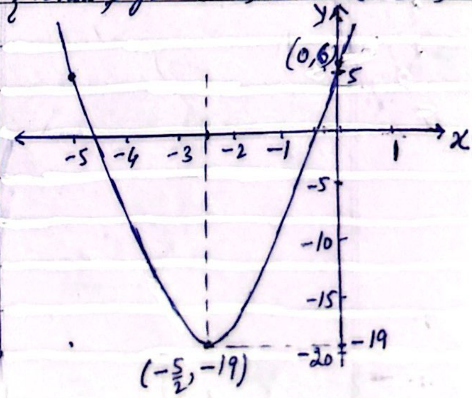
$x=\frac{3}{2}$ or $-\frac{13}{2}$ ✓

(c) $y=4x^2+20x+6$

$y=4\left(x+\frac{5}{2}\right)^2-19$ [from last (a)]

Stationary point (vertex) $\left(-\frac{5}{2},-19\right)$ ✓

{ Vertex of $y=a(x+b)^2+c$ is $(-b,-c)$



21. Find the coordinates of the minimum point on the curve $y=\frac{9}{4}x^2-12x+18$

[W-22/12/Q11(a)] ---[3]

Solution: $y=\frac{9}{4}x^2-12x+18$

$=\frac{9}{4}\left(x^2-\frac{16}{3}x+\left(\frac{8}{3}\right)^2-\frac{64}{9}\right)+18$

$=\frac{9}{4}\left(x-\frac{8}{3}\right)^2-16+18$

$=\frac{9}{4}\left(x-\frac{8}{3}\right)^2+2 \Rightarrow$ minimum point is at Vertex $\left(\frac{8}{3},2\right)$ ✓

$\left\{ \begin{array}{l} y=a(x-h)^2+k \\ \text{Vertex is } (h,k) \end{array} \right.$

22. A line has equation $y=3x-2k$ and a curve has equation $y=x^2-kx+2$, where k is a constant. Show that the line and the curve meet for all values of k. [4]

[M-23/12/Q1]

Solution: line: $y=3x-2k$ ---①

Curve: $y=x^2-kx+2$ --②

for the intersection of ① and ②

$x^2-kx+2=3x-2k$

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

$b^2-4ac=(k+3)^2-4\times1\times(2+2k)$

$=k^2+6k+9-8-8k$

$b^2-4ac=k^2-2k+1$

$=(k-1)^2\geqslant 0$ for all values of k.

$\therefore$ line and curve meets for all values of k.

23. The line with equation $y=kx-k$, where k is a positive constant, is a tangent to the curve with equation $y=-\frac{1}{2x}$.
Find, in any order, the value of k and the coordinates of the point where the tangent meets the curve. ---[5]

[S-23/11/Q5]

Solution: Line: $y=kx-k$ ---①

Curve: $y=-\frac{1}{2x}$ ---②

Solving ① and ②

$kx-k=-\frac{1}{2x} \Rightarrow 2kx^2-2kx+1=0$ ---③

for line ① is tangent to curve ②, has only one point of intersection $\Rightarrow B^2-4AC=0$ in ③

$\Rightarrow (-2k)^2-4\times2k\times1=0$

$\Rightarrow 4k^2-8k=0 \Rightarrow 4k(k-2)=0$

$\Rightarrow k=2$ ✓ (as $k>0$)

from ③ put $k=2$

$2\times2x^2-2\times2x+1=0$

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

$\Rightarrow x=\frac{1}{2}$ ✓

from ② $y=-\frac{1}{2\times\frac{1}{2}}=-1$

$\therefore$ Req. point of contact is:

$\left(\frac{1}{2},-1\right)$ ✓

24. (a) Express $4x^2-24x+p$ in the form $a(x+b)^2+c$, where a and b are integers and c is to be given in term of the constant p. ---[2]
(b) Hence or otherwise find the set of value of p for which the equation $4x^2-24x+p=0$ has no real roots. --[1]

[S-23/12/Q3]

Solution (a) $4x^2-24x+p$
$= 4(x^2-6x+3^2-9)+p$
$= 4(x-3)^2-36+p$
$\therefore$ $a=4$, $b=-3$ $[a(x+b)^2+c$
and $c=p-36$

(b) $4x^2-24x+p=0$ --①
$= 4(x-3)^2+(p-36)=0$ $[4(x-3)^2\geq 0$
has no real roots for $p-36>0$
or $p>36$

Alternate method: $B^2-4AC<0$ for ①
$\Rightarrow (-24)^2-4\times 4\times p<0 \Rightarrow 576-16p<0$
$\Rightarrow 36-p<0 \Rightarrow p>36$

25. Solve the equation. $8x^6+215x^3-27=0$ ---[3]

[S-23/12/Q4]

Solution: $8x^6+215x^3-27=0$
$8(x^3)^2+215x^3-27=0$ Put $x^3=y$
$8y^2+215y-27=0$ $(-8\times 27=-216$, factors $+216\times(-1))$
$8y^2+216y-y-27=0$
$8y(y+27)-1(y-27)=0 \Rightarrow (y+27)(8y-1)=0$
$\Rightarrow y=-27,\ 8y=1$ $[y=x^3$
$\Rightarrow x^3=-27$ or $x^3=\frac{1}{8} \Rightarrow x=-3,\ x=\frac{1}{2}$

26. The function f is defined for $x\in R$ by $f(x)=x^2-6x+c$, where c is a constant. It is given that $f(x)>2$ for all values of x. Find the set of values of c. ---[4]

[S-23/13/Q2]

Solution: Given $f(x)>2 \Rightarrow x^2-6x+c>2$
$\Rightarrow x^2-6x+c-2>0$ $[\Rightarrow x^2-6x+(c-2)=0$ has no real roots$]$
$\Rightarrow B^2-4AC<0$
$(-6)^2-4\times 1\times(c-2)<0$
$36-4c+8<0$
$4c>44 \Rightarrow c>11$