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M.Sc Math
0345-6510779

Transverse (Focal) Axis:-

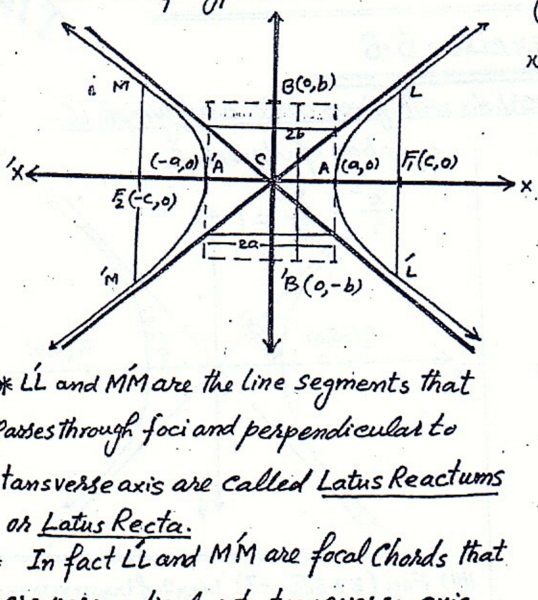
The line segment that joins the two points of hyperbola and passes through foci is called Transverse or focal Axis having length "2a". $|A'A| = 2a$

The points of intersection of hyperbola lying on transverse axis having Co-ordinates $A(a,0)$ and $A'(-a,0)$ are called Vertices.

Conjugate Axis:-

If Hyperbola meets the y-axis at $B(0,b)$ and $B'(0,-b)$ imaginarily then the line segment that joins B and B' is called Conjugate axis having length "2b" $|BB'| = 2b$

The mid point of Vertices is also called Centre of Hyperbola.



* $L'L$ and $M'M$ are the line segments that passes through foci and perpendicular to tansverse axis are called Latus Reactums or Latus Recta.
* In fact $L'L$ and $M'M$ are focal Chords that are perpendicular to transverse axis.
* Length of each Latus rectum is "$\frac{2b^2}{a}$".
* The +ve number "e" is ecentricity of hyperbola for $e > 1$.
  where $e = \frac{c}{a} > 1$ as $c > a$.

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* L_1 and L_2 are equations of directrices such as

$L_1: \frac{a}{e} = x$ and $L_2: x = \frac{-a}{e}$

or $L_1: x = \frac{c}{e^2}$ and $x = \frac{-c}{e^2}$

In Case of hyperbola

$$c^2 = a^2 + b^2 \text{ or } b^2 = c^2 - a^2.$$

* Ellipse and Hyperbola are both Central Conics having Centre.

* Equations of asymptotes are $y = \pm \frac{b}{a} x$

Equation of Hyperbola:-

Let $P(x,y)$ be any point on hyperbola then by defination $\big||PF_1| - |PF_2|\big| = 2a$ (Constant)

$$\sqrt{(x-c)^2+(y-0)^2} - \sqrt{(x+c)^2+(y-0)^2} = 2a$$

$$\sqrt{(x-c)^2+y^2} - \sqrt{(x+c)^2+y^2} = 2a$$

$$\left(\sqrt{(x-c)^2+y^2} - \sqrt{(x+c)^2+y^2}\right)^2 = (2a)^2$$

$$(x-c)^2+y^2+(x+c)^2+y^2-2\sqrt{(x+c)^2+y^2}\sqrt{(x-c)^2+y^2} = 4a^2$$

$$x^2+c^2-\cancel{2xc}+y^2+x^2+c^2+\cancel{2xc}+y^2-2\sqrt{x^2+c^2-2xc+y^2}\sqrt{x^2+c^2+2xc+y^2} = 4a^2$$

$$2x^2+2c^2+2y^2-2\sqrt{(x^2+y^2+c^2)^2-(2xc)^2} = 4a^2$$

$$x^2+y^2+c^2-\sqrt{(x^2+y^2+c^2)^2-(2xc)^2} = 2a^2$$

$$(x^2+y^2+c^2)-2a^2 = \sqrt{(x^2+y^2+c^2)^2-(2xc)^2}$$

Squaring both sides

$$\cancel{(x^2+y^2+c^2)^2}+(2a^2)^2-4a^2(x^2+y^2+c^2) = \cancel{(x^2+y^2+c^2)^2}-(2xc)^2$$

$$4a^4-4a^2x^2-4a^2y^2-4a^2c^2 = -4x^2c^2$$

$$4x^2c^2-4a^2x^2-4a^2y^2 = 4a^2c^2-4a^4$$

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

Dividing by $4a^2(c^2-a^2)$

$$\frac{x^2}{a^2} - \frac{y^2}{c^2-a^2} = 1$$

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1 \quad \text{where } b^2 = c^2 - a^2$$

which is required.

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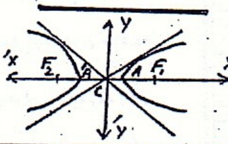
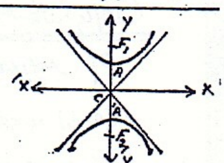
* Parametric Equations of hyperbola are $x = a\sec\theta$ and $y = b\tan\theta$

Standard Hyperbolas:

Equations.	Foci.	Vertices.	Latus Rectum	Directrices	Graphs.
$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$	$F_1(c,0)$ $F_2(-c,0)$	$A(a,0)$. $A'(-a,0)$.	$\frac{2b^2}{a}$	$x = \pm\frac{c}{e^2} = \pm\frac{a}{e}$	
$\frac{y^2}{a^2} - \frac{x^2}{b^2} = 1$	$F_1(0,c)$ $F_2(0,-c)$	$A(0,a)$. $A'(0,-a)$.	$\frac{2b^2}{a}$	$y = \pm\frac{c}{e^2} = \pm\frac{a}{e}$	

When centre of Hyperbola is (h,k) then equations are:

$$\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1 \quad \text{and} \quad \frac{(y-k)^2}{a^2} - \frac{(x-h)^2}{b^2} = 1$$

If $a=b$ then hyperbola is called Rectangular hyperbola. In this case assymptotes are perpendicular.

Exercise: 6.6

Q.1. Find an equation of hyperbola with given data and graph it.

(i) Centre(0,0), Focus (6,0), Vertex(4,0).

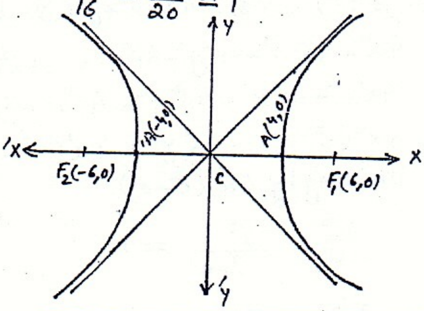
$\Rightarrow a = 4 \quad c = 6$

$b^2 = c^2 - a^2 = 36 - 16 = 20$

$\Rightarrow b^2 = 20$ and $a^2 = 16$

Now equation of Hyperbola

$$\frac{x^2}{16} - \frac{y^2}{20} = 1$$



(ii) Foci $(\pm 5, 0)$, Vertex $(3,0)$

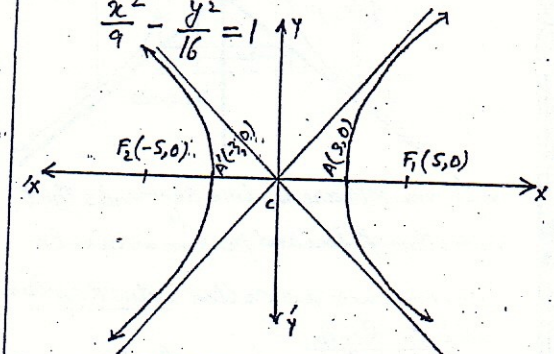
Centre: $\left(\frac{5-5}{2}, \frac{0-0}{2}\right) = (0,0)$

$\because c = 5 \quad a = 3$ so $b^2 = c^2 - a^2$

$b^2 = 25 - 9 = 16$ and $a^2 = 9$

Equation of Hyperbola

$$\frac{x^2}{9} - \frac{y^2}{16} = 1$$



(iii) Foci $(2 \pm 5\sqrt{2}, -7)$, Length of transverse axis $= 10$

$2a = 10 \Rightarrow a = 5$

Centre: $\left(\frac{2+5\sqrt{2}+2-5\sqrt{2}}{2}, \frac{-7-7}{2}\right) = \left(\frac{4}{2}, \frac{-14}{2}\right)$

Centre: $(2,-7)$

$c = |CF_1| = \sqrt{(2+5\sqrt{2}-2)^2 + (-7+7)^2} = 5\sqrt{2}$

$b^2 = c^2 - a^2 = (5\sqrt{2})^2 - 5^2 = 50 - 25$

$b^2 = 25$ also $a^2 = 25$

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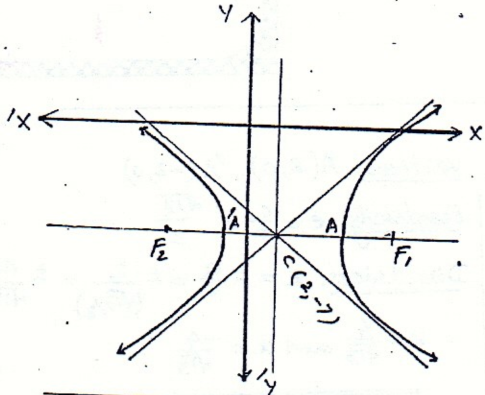


(iv) Foci $(0, \pm 9)$, Directrices $y = \pm 4$

$\Rightarrow c = 9 \quad \because y = \pm \frac{a}{e} = \pm 4$

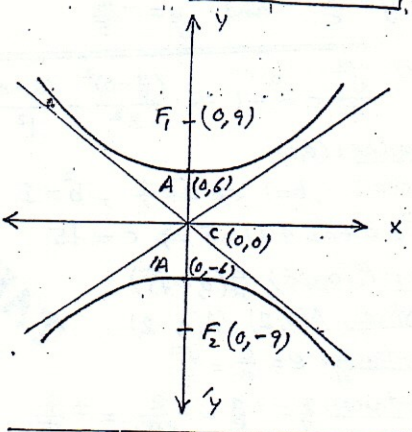
$\Rightarrow a = 4e \Rightarrow e = 4/a$ Centre $(0,0)$

$\because c = ae = 9 \Rightarrow a(a/4) = 9$

$a^2 = 36$

$b^2 = c^2 - a^2 = 81 - 36 = 45$

So Equation is $\boxed{\frac{y^2}{36} - \frac{x^2}{45} = 1}$



(V) Centre $(2,2)$, Eccentricity $= 2$

Horizontal transverse axis of length 6

$\because 2a = 6 \Rightarrow a = 3 \Rightarrow a^2 = 9$

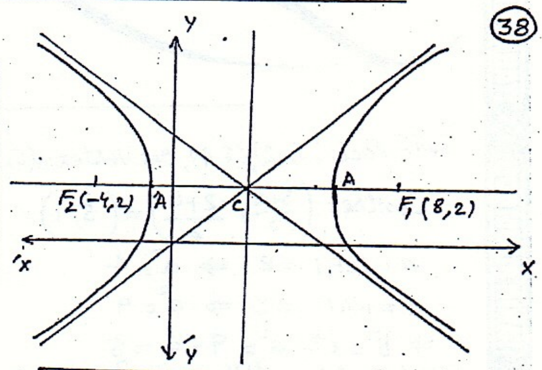
Now $c = ae = 3(2) = 6$

$b^2 = c^2 - a^2 = 36 - 9 = 27$

$F_1(2+6, 2)$, $F_2(2-6, 2)$

$F_1(8,2)$, $F_2(-4,2)$

So Equation $\boxed{\frac{(x-2)^2}{9} - \frac{(y-2)^2}{27} = 1}$



(vi) Vertices $(2, \pm 3)$, $(0,5)$ lies on the Curve.

Centre : $\left(\frac{2+2}{2}, \frac{3-3}{2}\right) = (2,0)$

$\Rightarrow a = 3 \Rightarrow a^2 = 9$

So Equation is $\frac{y^2}{9} - \frac{(x-2)^2}{b^2} = 1$

$\because (0,5)$ lies on hyperbola.

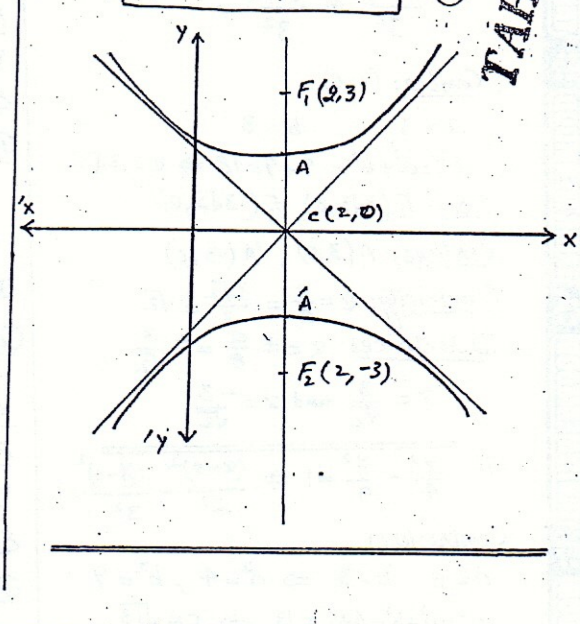
$\Rightarrow \frac{25}{9} - \frac{(-2)^2}{b^2} = 1 \Rightarrow \frac{25}{9} - 1 = \frac{4}{b^2}$

$\Rightarrow \frac{25-9}{9} = \frac{4}{b^2} \Rightarrow \frac{16}{9} = \frac{4}{b^2}$ or $b^2 = \frac{9 \times 4}{16}$

$b^2 = \frac{9}{4} \Rightarrow b^2 = 9/4$

So $\frac{y^2}{9} - \frac{(x-2)^2}{9/4} = 1$

or $\boxed{\frac{y^2}{9} - \frac{4(x-2)^2}{9} = 1}$



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(vii) Foci: $(5,-2),(5,4)$, One Vertex: $A(5,3)$

Centre: $\left(\frac{5+5}{2}, \frac{-2+4}{2}\right) = (5,1)$

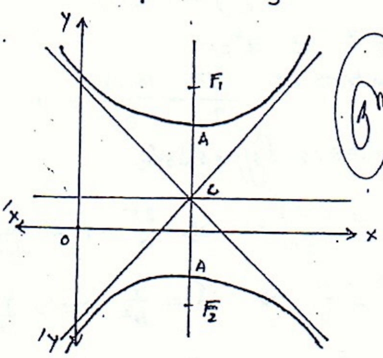
$a = |CF_1| = 2 \Rightarrow a^2 = 4$

$c = |CA| = 3 \Rightarrow c^2 = 9$

$\Rightarrow b^2 = c^2 - a^2 = 9 - 4 = 5$

So Equation of Hyperbola:

$$\frac{(y-1)^2}{4} - \frac{(x-5)^2}{5} = 1$$



Q.2:- Find the centre, foci, ecentricity, vertices and Directrices of:

(i) $x^2 - y^2 = 9 \Rightarrow \frac{x^2}{9} - \frac{y^2}{9} = 1$

$\Rightarrow \frac{(x-0)^2}{3^2} - \frac{(y-0)^2}{3^2} = 1$

Centre: $(0,0)$

$a = 3 \quad b = 3$

$c^2 = a^2 + b^2 = 9 + 9 = 18 \Rightarrow c = 3\sqrt{2}$

Foci: $F_1(3\sqrt{2}, 0)$, $F_2(-3\sqrt{2}, 0)$

Vertices: $A(3,0)$, $A'(-3,0)$

Ecentricity: $e = \frac{c}{a} = \frac{3\sqrt{2}}{3} = \sqrt{2}$

Directrices: $x = \pm \frac{a}{e} = \pm \frac{3}{\sqrt{2}}$

$x = \frac{3}{\sqrt{2}}$ and $x = \frac{-3}{\sqrt{2}}$

(ii) $\frac{x^2}{4} - \frac{y^2}{9} = 1 \Rightarrow \frac{(x-0)^2}{2^2} - \frac{(y-0)^2}{3^2} = 1$

Centre: $(0,0)$

$a = 2 \quad b = 3 \Rightarrow a^2 = 4, \ b^2 = 9$

$c^2 = a^2 + b^2 = 4 + 9 = 13 \Rightarrow c = \sqrt{13}$

Foci: $F_1(\sqrt{13}, 0)$, $F_2(-\sqrt{13}, 0)$

Vertices: $A(2,0)$, $A'(-2,0)$

Ecentricity: $e = \frac{c}{a} = \frac{\sqrt{13}}{2}$

Directrices: $x = \pm \frac{a}{e} = \pm \frac{2}{(\sqrt{13}/2)} = \pm \frac{4}{\sqrt{13}}$

$x = \frac{4}{\sqrt{13}}$ and $x = \frac{-4}{\sqrt{13}}$

(iii) $\frac{y^2}{16} - \frac{x^2}{9} = 1 \Rightarrow \frac{(y-0)^2}{4^2} - \frac{(x-0)^2}{3^2} = 1$

Centre: $(0,0)$

$a = 4 \quad b = 3 \Rightarrow a^2 = 16 \quad b^2 = 9$

$c^2 = a^2 + b^2 = 16 + 9 = 25 \Rightarrow c = 5$

Foci: $F_1(0,5)$, $F_2(0,-5)$

Vertices: $A(0,4)$, $A'(0,-4)$

Ecentricity: $e = \frac{c}{a} = \frac{5}{4}$

Directrices: $y = \pm \frac{a}{e} = \pm 4/(5/4) = \pm \frac{16}{5}$

$y = \frac{16}{5}$ and $y = -\frac{16}{5}$

(iv) $\frac{y^2}{4} - x^2 = 1 \Rightarrow \frac{(y-0)^2}{2^2} - \frac{(x-0)^2}{1^2} = 1.$

Centre: $(0,0)$

$a = 2, \ b = 1 \Rightarrow a^2 = 4, \ b^2 = 1$

$c^2 = a^2 + b^2 = 4 + 1 = 5 \Rightarrow c = \sqrt{5}$

Foci: $F_1(0, \sqrt{5})$, $F_2(0, -\sqrt{5})$

Vertices: $A(0,2)$, $A'(0,-2)$

Ecentricity: $e = \frac{c}{a} = \frac{\sqrt{5}}{2}$

Directrices: $y = \pm \frac{a}{e} = \pm \frac{2}{(\sqrt{5}/2)} = \pm \frac{4}{\sqrt{5}}$

$y = \frac{4}{\sqrt{5}}$ and $y = \frac{-4}{\sqrt{5}}$

(v) $\frac{(x-1)^2}{2} - \frac{(y-1)^2}{9} = 1$

Centre: $(1,1)$

$a^2 = 2, \ b^2 = 9 \Rightarrow a = \sqrt{2}, \ b = 3$

$c^2 = a^2 + b^2 = 2 + 9 = 11 \Rightarrow c = \sqrt{11}$

Foci: $(1 \pm \sqrt{11}, 1) \Rightarrow F_1(1+\sqrt{11}, 1)$ and $F_2(1-\sqrt{11}, 1)$

Vertices: $A(1+\sqrt{2}, 1)$ and $A'(1-\sqrt{2}, 1)$

Ecentricity: $e = \frac{c}{a} = \frac{\sqrt{11}}{\sqrt{2}} = \sqrt{\frac{11}{2}}$

Directrices: $x - 1 = \pm \frac{a}{e} = \pm \sqrt{2}/\left(\sqrt{\frac{11}{2}}\right) = \pm \frac{2}{\sqrt{11}}$

$\Rightarrow x = 1 + \frac{2}{\sqrt{11}}$ and $x = 1 - \frac{2}{\sqrt{11}}$

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(vi) $\dfrac{(y+2)^2}{9} - \dfrac{(x-2)^2}{16} = 1$

Centre: $C(+2,-2) = C(h,k)$

$a^2=9,\ b^2=16 \Rightarrow a=3,\ b=4$

$c^2=a^2+b^2=9+16=25 \Rightarrow c=5$

Foci: $F_2(+2,-2+5),\ F_1(+2,-2-5) \because F(h,k\pm c)$

$F_1(+2,-7),\ F_2(+2,+3)$

Vertices: $A(2,-2+3),\ A'(2,-2-3) \because A(h,k\pm a)$

$A(2,1),\ A'(2,-5)$

Ecentricity: $e=\dfrac{c}{a}=\dfrac{5}{3}$

Directrices: $y+2=\pm\dfrac{a}{e}=\pm\dfrac{3}{(5/3)}=\pm\dfrac{9}{5}$

$y+2=\dfrac{9}{5}$ and $y+2=-\dfrac{9}{5}$

$y=-2+\dfrac{9}{5}$ and $y=-2-\dfrac{9}{5}$

$y=\dfrac{-1}{5}$ and $y=\dfrac{-19}{5}$

(vii) $9x^2-12x-y^2-2y+2=0$

$(9x^2-12x)-(y^2+2y)=-2$

$(9x^2-12x+4)-(y^2+2y+1)=-2+4-1$

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

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

$\dfrac{(x-2/3)^2}{1/9}-\dfrac{(y+1)^2}{1}=1$

Centre: $\left(\dfrac{2}{3},-1\right)$

$a^2=\dfrac{1}{9},\ b^2=1 \Rightarrow a=1/3,\ b=1$

$c^2=a^2+b^2=\dfrac{1}{9}+1=\dfrac{10}{9} \Rightarrow c=\dfrac{\sqrt{10}}{3}$

Foci: $F_1\left(\dfrac{2}{3}+\dfrac{\sqrt{10}}{3},-1\right),\ F_2\left(\dfrac{2}{3}-\dfrac{\sqrt{10}}{3},-1\right)$

Vertices: $A\left(\dfrac{2}{3}+\dfrac{1}{3},-1\right),\ A'\left(\dfrac{2}{3}-\dfrac{1}{3},-1\right)$

$A(1,-1),\ A'\left(\dfrac{1}{3},-1\right)$

Ecentricity: $e=\dfrac{c}{a}=\dfrac{\sqrt{10}/3}{1/3}=\sqrt{10}$

Directrices: $x-\dfrac{2}{3}=\pm\dfrac{a}{e}=\dfrac{\pm1}{3\sqrt{10}}$

$x=\dfrac{2}{3}\pm\dfrac{1}{3\sqrt{10}}$

(viii) $4y^2+12y-x^2+4x+1=0$

$(4y^2+12y)-(x^2-4x)=-1$

$(4y^2+12y+9)-(x^2-4x+4)=-1+9-4$

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

$\dfrac{2^2[y+3/2]^2}{4}-\dfrac{(x-2)^2}{4}=1$

$\dfrac{(y+3/2)^2}{1^2}-\dfrac{(x-2)^2}{2^2}=1$

Centre: $(2,-3/2)$

$a=1,\ b=2 \Rightarrow a^2=1,\ b^2=4$

$c^2=a^2+b^2=1+4=5 \Rightarrow c=\sqrt{5}$

Foci: $F_1\left(2,-\dfrac{3}{2}+\sqrt{5}\right),\ F_2\left(2,\dfrac{-3}{2}-\sqrt{5}\right)$

Vertices: $A\left(2,-\dfrac{3}{2}\pm1\right)=\left(2,\dfrac{-3\pm2}{2}\right)$

$A(2,-1/2)$ and $A'(2,-5/2)$

Ecentricity: $e=\dfrac{c}{a}=\dfrac{\sqrt{5}}{1}=\sqrt{5}$

Directrices:- $y+\dfrac{3}{2}=\pm\dfrac{a}{e}=\pm\dfrac{1}{\sqrt{5}}$

$y=\dfrac{-3}{2}\pm\dfrac{1}{\sqrt{5}}$

(ix) $x^2-y^2+8x-2y-10=0$

$(x^2+8x)-(y^2+2y)=10$

$(x^2+8x+16)-(y^2+2y+1)=10+16-1$

$(x+4)^2-(y+1)^2=25$

$\Rightarrow \dfrac{(x+4)^2}{25}-\dfrac{(y+1)^2}{25}=1$

Centre: $(-4,-1)$

$a^2=25,\ b^2=25 \Rightarrow a=5,\ b=5$

$c^2=a^2+b^2=25+25=50 \Rightarrow c=5\sqrt{2}$

Foci: $F_1(-4+5\sqrt{2},-1),\ F_2(-4-5\sqrt{2},-1)$

Vertices:- $A(-4+5,-1)$ and $A'(-4-5,-1)$

$A(1,-1),\ A'(-9,-1)$

Ecentricity:- $e=\dfrac{c}{a}=\dfrac{5\sqrt{2}}{5}=\sqrt{2}$

Directrices:- $(x+4)=\pm\dfrac{a}{e}=\pm\dfrac{5}{\sqrt{2}}$

$x=-4\pm\dfrac{5}{\sqrt{2}}$

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(x) $9x^2 - y^2 - 36x - 6y + 18 = 0$

$(9x^2 - 36x) - (y^2 + 6y) = -18$

$(9x^2 - 36x + 36) - (y^2 + 6y + 9) = -18 + 36 - 9$

$(3x-6)^2 - (y+3)^2 = 9$

$\dfrac{3^2(x-2)^2}{9} - \dfrac{(y+3)^2}{9} = 1$

$\dfrac{(x-2)^2}{1} - \dfrac{(y+3)^2}{9} = 1$

Centre:- $(2,-3)$

$a^2 = 1$, $b^2 = 9 \Rightarrow a = 1, b = 3$

$c^2 = a^2 + b^2 = 1 + 9 = 10 \Rightarrow c = \sqrt{10}$

Foci: $F_1(2+\sqrt{10}, -3)$, $F_2(2-\sqrt{10}, -3)$

Vertices:- $A(2+1, -3)$, $A'(2-1\ -3)$

$A(3,-3)$, $A'(1,-3)$

Ecentricity: $e = \frac{c}{a} = \frac{\sqrt{10}}{1} = \sqrt{10}$

Directrices: $(x-2) = \pm \frac{a}{e} = \frac{\pm 1}{\sqrt{10}}$

$x = 2 \pm \frac{1}{\sqrt{10}}$

Q.3 is already solved as proof of Equation of hyperbola.

Q.4 Foci: $F_1(-5,-5)$, $F_2(5,5)$

vertices: $A(-3\sqrt{2}, -3\sqrt{2})$, $A'(3\sqrt{2}, 3\sqrt{2})$

Now $2a = |AA'| = \sqrt{(3\sqrt{2}+3\sqrt{2})^2 + (3\sqrt{2}+3\sqrt{2})^2}$

$2a = \sqrt{72+72} = \sqrt{144} = 12$

By def. $|PF_1| - |PF_2| = 2a$

or $|PF_1| = 2a + |PF_2|$

$\sqrt{(x+5)^2 + (y+5)^2} = 12 + \sqrt{(x-5)^2 + (y-5)^2}$

Squaring both sides, we have

$(x+5)^2 + (y+5)^2 = 144 + (x-5)^2 + (y-5)^2 + 24\sqrt{(x-5)^2 + (y-5)^2}$

$\left[(x+5)^2 - (x-5)^2\right] + \left[(y+5)^2 - (y-5)^2\right] - 144 = 24\sqrt{(x-5)^2 + (y-5)^2}$

$20x + 20y - 144 = 24\sqrt{(x-5)^2 + (y-5)^2}$

$5x + 5y - 36 = 6\sqrt{(x-5)^2 + (y-5)^2}$

Squaring again, we have

$(5x + 5y - 36)^2 = 36\left[(x-5)^2 + (y-5)^2\right]$

$25x^2 + 25y^2 + 1296 + 50xy - 360x - 360y = 36\left[x^2 + 25 - 10x + y^2 + 25 - 10y\right]$

$25x^2 + 25y^2 + 50xy - \cancel{360x} - \cancel{360y} + 1296 = 36x^2 - \cancel{360x} - \cancel{360y} + 36y^2 + 1800$

$36x^2 - 25x^2 + 36y^2 - 25y^2 - 50xy + 1800 - 1296 = 0$

$11x^2 + 11y^2 - 50xy + 504 = 0$

which is required Equation.

Q.5 $2a = 6$ (Given)

$F_1(2,2)$, $F_2(10,2)$

By defination $|PF_1| - |PF_2| = 2a$

$\Rightarrow \quad |PF_1| = 2a + |PF_2|$

$\sqrt{(x-2)^2 + (y-2)^2} = 6 + \sqrt{(x-10)^2 + (y-2)^2}$

Squaring both sides, we have

$(x-2)^2 + \cancel{(y-2)^2} = 36 + (x-10)^2 + \cancel{(y-2)^2} + 12\sqrt{(x-10)^2 + (y-2)^2}$

$\cancel{x^2} + 4 - 4x - 36 - \cancel{x^2} + 20x - 100 = 12\sqrt{(x-10)^2 + (y-2)^2}$

$16x - 132 = 12\sqrt{x^2 + 100 - 20x + y^2 + 4 - 4y}$

$4x - 33 = 3\sqrt{x^2 + y^2 - 20x - 4y + 104}$

Squaring again, we have:

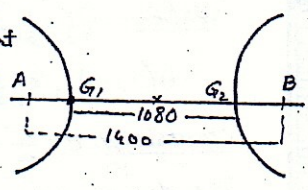
$16x^2 + 1089 - 264x = 9x^2 + 9y^2 - 180x - 36y + 936$

$16x^2 - 9x^2 - 9y^2 - 264x + 180x + 36y + 1089 - 936$

$7x^2 - 9y^2 - 84x + 36y + 153 = 0$

which is required.

Q.6 Suppose G_1 and G_2 be the guns 1080 ft apart and A, B are the posts 1400 feet apart. then by diagram arrangement



$2a = 1080$ and $2c = 1400$

$a = 540$ $\quad c = 700$

Now $c^2 = a^2 + b^2 \Rightarrow b^2 = c^2 - a^2 = (700)^2 - (540)^2$

$b^2 = 198400$ and $a^2 = 291600$

Equation of Hyperbola is

$$\frac{x^2}{291,600} - \frac{y^2}{191,600} = 1.$$
