Elementary Coordinate Geometry

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The Conic Section

There is geometry in the humming of the strings, there is music in the spacing of the spheres.

- Pythagoras

The Conic Section

Definition

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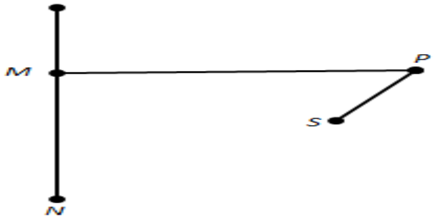
If a point moves so that its distance from a fixed point bears a constant ratio to its distance from a fixed line, the curve described is called a *conic*.

The Conic Section



In above figure, If S is a fixed point, MN is a fixed line and P is a point moving in such a way that $\frac{PS}{PM}=$ constant, the curve traced by P is conic.

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Directrix: The fixed line MN is called the *directrix*.

Axis: The straight line passing through the focus and perpendicular to the directrix is called the *axis* of conic.

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If $e < 1$, the conic is called an *ellipse*.

If $e > 1$, the conic is called a *hyperbola*.

Parabola

If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is.

- John von Neumann

Parabola

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A parabola is the locus of point which is equidistant from a fixed point (called the focus) and a fixed line (called directrix).

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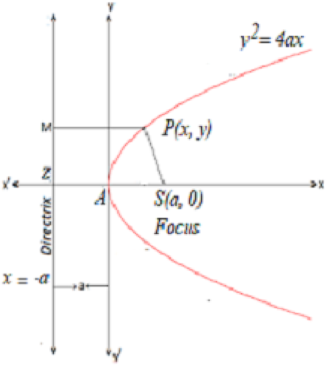

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Which is the standard equation of parabola

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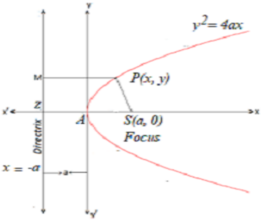

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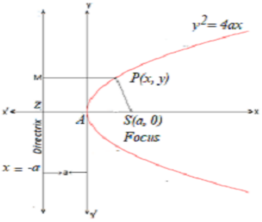

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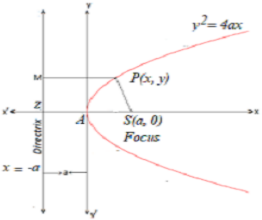

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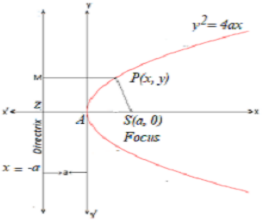

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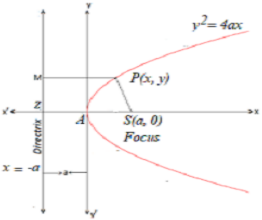

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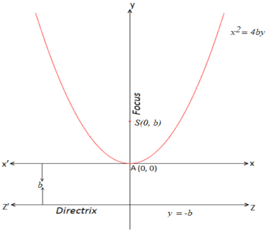

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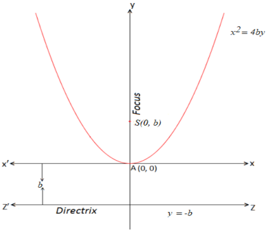

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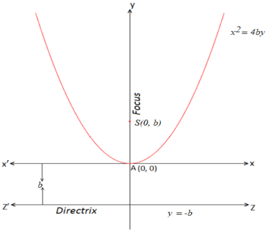

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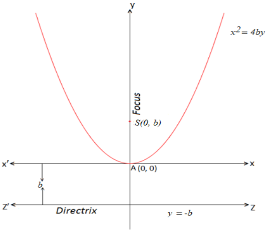

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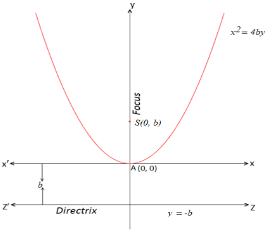

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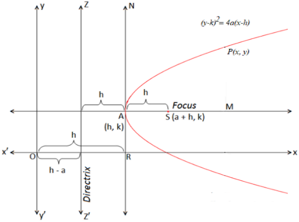

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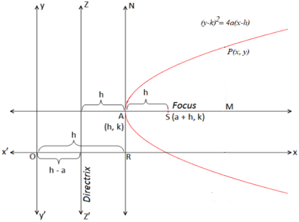

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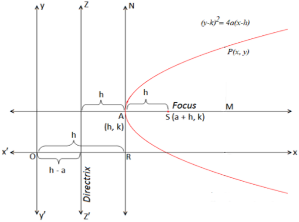

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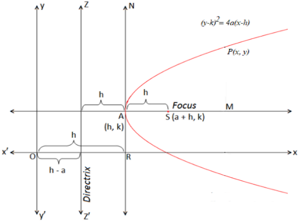

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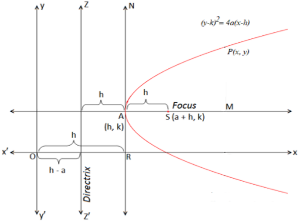

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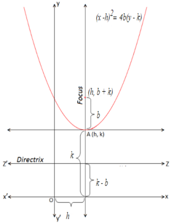

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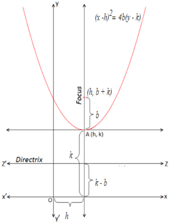

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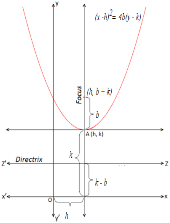

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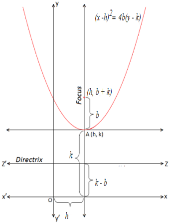

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Vertex of the parabola $= (h, k) = (4, -1)$
Equation of directrix is $x = h - a \Rightarrow x - 5 = 0$
Length of latus rectum $= 4a = 4$

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Q. Show that $y = mx + c$ will be tangent to the parabola $y^2 = 4ax$ if $c = \frac{a}{m}$. Also show that $yy_1 = 2a(x + x_1)$ is the equation of tangent at point (x_1, y_1).

If the line $y = mx + c$ intersects the parabola $y^2 = 4ax$, we have
$(mx + c)^2 = 4ax \Rightarrow m^2x^2 + 2x(mc - 2a) + c^2 = 0.$
If the line is tangent to the parabola, then two roots of above equation must coincide, and hence
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$yy_1 = 2a(x + x_1)$. Which is the required equation of tangent.

Some Solved Problems On Parabola

Q. The chain of a suspension bridge hangs in the form of a parabola, whose axis is vertical. In the case of a certain bridge, the chain hangs symmetrically with a span of $170m$ and a dip of $13m$. Find the latus rectum of the parabola and the angle of inclination to the horizon at each end of the chain.

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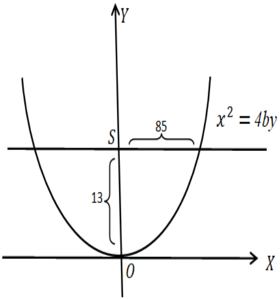

In this parabola we have $x = 85m$ and $y = 13m$.

Some Solved Problems On Parabola

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from which we obtain $\theta \approx 17°$.

Ellipse

Mathematics is the door and key to the Science.

- Roger Bacon

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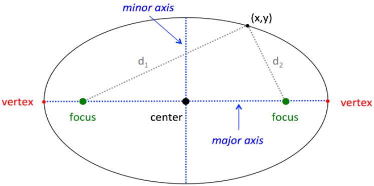

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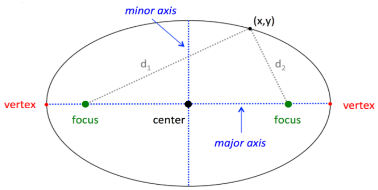

From this figure we can derive the standard equation of ellipse as $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$.

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Q. Find centre, vertex, foci, length of latus rectum, length of major and minor axis, equation of directrix of ellipse
$9x^2 + 4y^2 - 18x - 16y - 11 = 0.$

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Vertex $= (h, k \pm b) = (1, 2 \pm 3) = (1, 5)$ and $(1, -1)$

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Length of latus rectum

Some Solved Problems of an Ellipse

Eccentricity is given by
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Some Solved Problems of an Ellipse

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Since $b > a$. SO major axis of the ellipse is parallel to $y-$axis.

Some Solved Problems of an Ellipse

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The coordinate of centre

Some Solved Problems of an Ellipse

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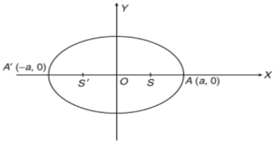
The coordinate of foci is given by:
$(h, k \pm be) = (0, 3 \pm 3 \times \frac{2}{3}) = (0, 3 \pm 2)$.

Some Solved Problems of an Ellipse

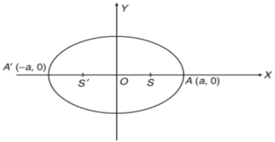
Q. A satellite is to be placed into an elliptical orbit about the earth having a minimum altitude of $640km$ and a maximum altitude of $3520km$. Assuming that the centre of the earth is located at one focus and that the radius of earth is $6400km$, find the equation describing the path followed by the satellite.

Some Solved Problems of an Ellipse



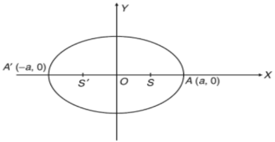
Let the orbit of the satellite be as shown in above figure.

Some Solved Problems of an Ellipse



Let the orbit of the satellite be as shown in above figure.
Let S' be the centre of the earth.

Some Solved Problems of an Ellipse



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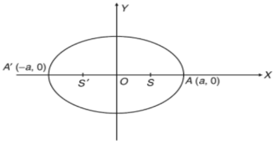
Then the distance between S' and the closest vertex A' is

Some Solved Problems of an Ellipse



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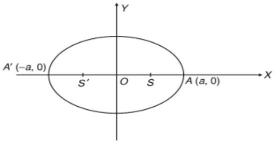
Some Solved Problems of an Ellipse



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Let S' be the centre of the earth.
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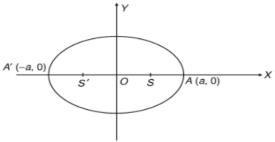

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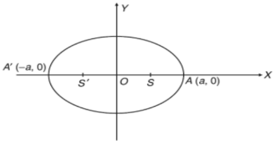

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Let S' be the centre of the earth.
Then the distance between S' and the closest vertex A' is
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Also, $2a =$ major axis of the ellipse
$= 640 + 12800 + 3520 = 16960km$.

Some Solved Problems of an Ellipse

Thus, $a = 8480$

Some Solved Problems of an Ellipse

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We know,
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Hyperbola

Mathematics is the language with which God wrote the universe.

- Galileo

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A *hyperbola* is the locus of a point which moves such that the difference of the distance from two fixed point is always a constant.

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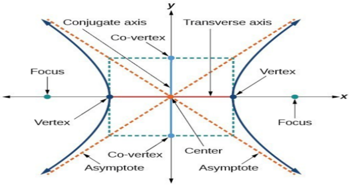
Labled Diagram of Hyperbola



Some Important Result on Hyperbola

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Some Solved Problems on Hyperbola

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Comparing with the equation $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$

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Some Solved Problems on Hyperbola

Q. Find the centre, vertices, eccentricity, foci, equation of directrix, length of latus rectum, length of transverse axis and conjugate axis of the hyperbola: $9x^2 - 16y^2 - 18x - 64y - 199 = 0$.

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We obtain, $h = 1, k = -2, a^2 = 16, b^2 = 9$ and $a = 4, b = 3$

Some Solved Problems on Hyperbola

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Some Solved Problems on Hyperbola

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Coordinates of vertices

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$x = h \pm \frac{a}{e} \Rightarrow x = 1 \pm \frac{4}{\frac{5}{4}}$

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Length of latus rectum

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Length of latus rectum $= \frac{2b^2}{a} = \frac{2 \times 9}{4}$

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length of transverse axis $= 2a = 2 \times 4 = 8$
length of conjugate axis $= 2b = 2 \times 3 = 6$

Translation of Axes

Mathematics is the Supreme Judge: from its decision there is no appeal.

- Tobias Dantzig

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- Rotation of axes without changing the origin
- Change of Origin and rotation of axis

Translation of Axes

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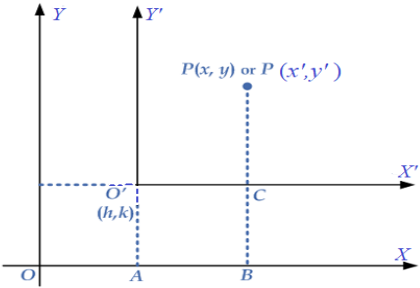

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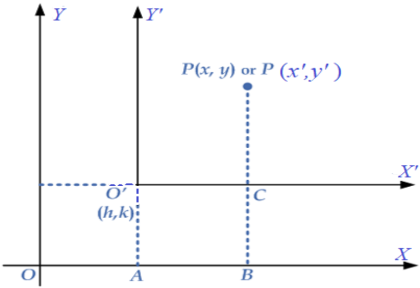

Let (x, y) be the coordinates of P referred to OX and OY as axes.

Translation of Axes

Let O be shifted to the new origin O' whose coordinates are (h, k) ,

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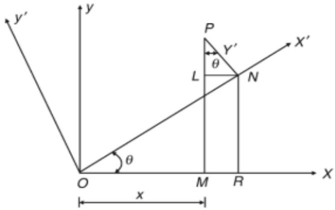

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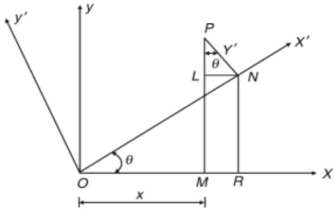

Let OX' and OY' be the new axes inclined at an angle θ to the old axes and let (x', y') be the coordinates of P referred to OX' and OY'.

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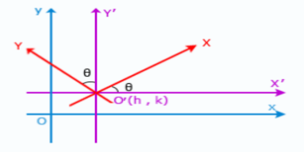

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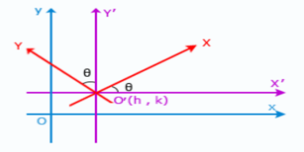

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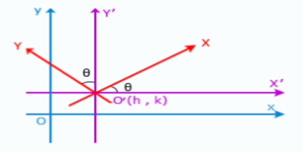

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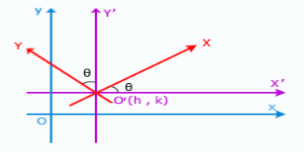

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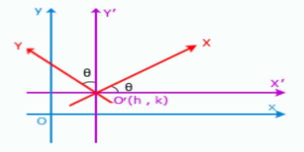

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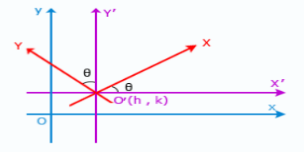

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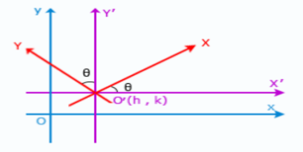

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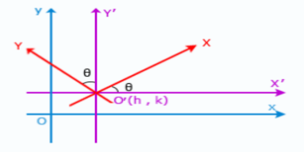

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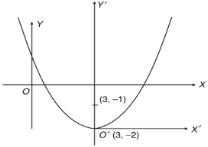

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Equation of a Conic in Polar Coordinates

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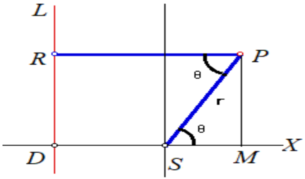

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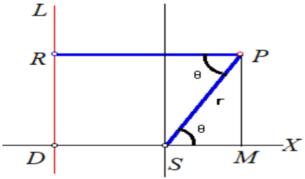

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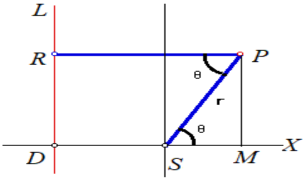

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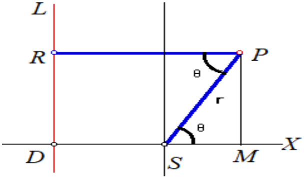

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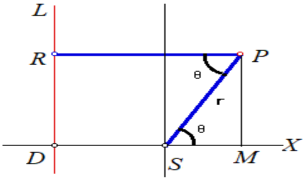

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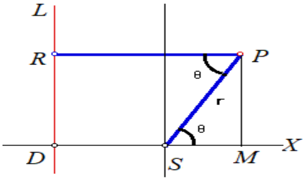

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Equation of a Conic in Polar Coordinates

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Which is the polar equation of the Conic.

Equation of a Conic in Polar Coordinates

Equation of Conic in in Polar Coordinates

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- For a conic with a focus at the origin, if the directrix is $x = \pm 2p$, where p is a positive real number, and the eccentricity is a positive real number e , the conic has a polar equation

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Some Solved Problems on Equation of a Conic in Polar Coordinates

Q. For the equation $r = \frac{6}{3+2\sin\theta}$, identify the conic with focus at the origin, the directrix, and the eccentricity.

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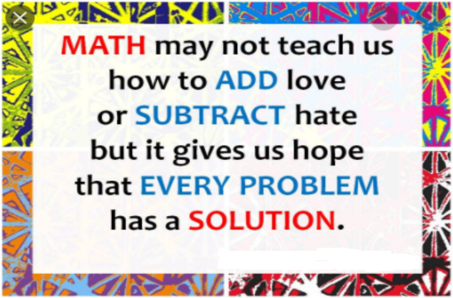
MATH may not teach us
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but it gives us hope
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has a SOLUTION.

Self Exercise:1

Parabola

Self Exercise:1

Parabola

1. Define conic. When does it becomes parabola?

Self Exercise:1

Parabola

1. Define conic. When does it becomes parabola?
2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 = 16x$.

Self Exercise:1

Parabola

1. Define conic. When does it becomes parabola?
2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 = 16x$.
3. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $x^2 = 12y$.

Self Exercise:1

Parabola

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2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 = 16x$.
3. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $x^2 = 12y$.
4. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 + 4x + 8 = 0$.

Self Exercise:2

Parabola

Self Exercise:2

Parabola

1. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 + 4x + 2y - 15 = 0$.

Self Exercise:2

Parabola

1. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 + 4x + 2y - 15 = 0$.
2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $(x + 1)^2 + 8y - 16 = 0$.

Self Exercise:2

Parabola

1. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 + 4x + 2y - 15 = 0$.
2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $(x + 1)^2 + 8y - 16 = 0$.
3. The chain of a suspension bridge hangs in the form of a parabola, whose axis is vertical. In the case of a certain bridge, the chain hangs symmetrically with a span of $170m$ and a dip of $13m$. Find the latus rectum of the parabola and the angle of inclination to the horizon at each end of the chain.

Self Exercise:3

Parabola

Self Exercise:3

Parabola

1. Show that $y = mx + c$ will be tangent to the parabola $y^2 = 4ax$ if $c = \frac{a}{m}$. Also show that $yy_1 = 2a(x + x_1)$ is the equation of tangent at point (x_1, y_1).

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2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 + 4x + 2y - 15 = 0$.

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Parabola

1. Show that $y = mx + c$ will be tangent to the parabola $y^2 = 4ax$ if $c = \frac{a}{m}$. Also show that $yy_1 = 2a(x + x_1)$ is the equation of tangent at point (x_1, y_1).
2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 + 4x + 2y - 15 = 0$.
3. Find the equation of parabola whose vertex is at $(3, 2)$ and the focus is at $(5, 2)$.

Self Exercise:3

Parabola

1. Show that $y = mx + c$ will be tangent to the parabola $y^2 = 4ax$ if $c = \frac{a}{m}$. Also show that $yy_1 = 2a(x + x_1)$ is the equation of tangent at point (x_1, y_1).
2. Find the coordinates of the focus, the vertex, the equation of the directrix, the length of the latus rectum and axis of the parabola: $y^2 + 4x + 2y - 15 = 0$.
3. Find the equation of parabola whose vertex is at $(3, 2)$ and the focus is at $(5, 2)$.
4. Find the equation of the parabola with focus at $(-1, 2)$ and directrix $x = -5$.

Self Exercise:4

Ellipse

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1. Define conic. When does it becomes an Ellipse?

Self Exercise:4

Ellipse

1. Define conic. When does it becomes an Ellipse?
2. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major axis, length of the minor axis, length of latus rectum and equation of directrix of ellipse: $9x^2 + 25y^2 - 18x - 100y - 116 = 0$

Self Exercise:4

Ellipse

1. Define conic. When does it becomes an Ellipse?
2. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major axis, length of the minor axis, length of latus rectum and equation of directrix of ellipse: $9x^2 + 25y^2 - 18x - 100y - 116 = 0$
3. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major axis, length of the minor axis, length of latus rectum and equation of directrix of ellipse: $9x^2 + 4y^2 - 18x - 16y - 11 = 0$

Self Exercise:5

Ellipse

Self Exercise:5

Ellipse

1. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major axis, length of the minor axis, length of latus rectum and equation of directrix of ellipse: $9x^2 + 5y^2 - 30y = 0$
2. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci and equation of directrix of ellipse: $x^2 + 4y^2 - 4x + 24y + 24 = 0$

Self Exercise:5

Ellipse

1. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major axis, length of the minor axis, length of latus rectum and equation of directrix of ellipse: $9x^2 + 5y^2 - 30y = 0$
2. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci and equation of directrix of ellipse: $x^2 + 4y^2 - 4x + 24y + 24 = 0$
3. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major and minor axis, and equation of directrix of ellipse: $\frac{x^2}{25} + \frac{y^2}{16} = 1$

Self Exercise:6

Ellipse

Self Exercise:6

Ellipse

1. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major axis, length of the minor axis, length of latus rectum and equation of directrix of ellipse: $\frac{x^2}{9} + \frac{y^2}{25} = 1$

Self Exercise:6

Ellipse

1. Find the coordinates of the centre, vertices, eccentricity, coordinates of the foci, length of the major axis, length of the minor axis, length of latus rectum and equation of directrix of ellipse: $\frac{x^2}{9} + \frac{y^2}{25} = 1$
2. A satellite is to be placed into an elliptical orbit about the earth having a minimum altitude of $640km$ and a maximum altitude of $3520km$. Assuming that the centre of the earth is located at one focus and that the radius of the earth is $6400km$, find the equation describing the path followed by the satellite.

Self Exercise:7

Hyperbola

Self Exercise:7

Hyperbola

1. Define conic. When does it becomes hyperbola?

Self Exercise:7

Hyperbola

1. Define conic. When does it becomes hyperbola?
2. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $9x^2 - 16y^2 + 72x - 32y - 16 = 0$.

Self Exercise:7

Hyperbola

1. Define conic. When does it becomes hyperbola?
2. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $9x^2 - 16y^2 + 72x - 32y - 16 = 0$.
3. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $9x^2 - 16y^2 - 18x - 64y - 199 = 0$.

Self Exercise:8

Hyperbola

Self Exercise:8

Hyperbola

1. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $9x^2 - 16y^2 + 36x + 32y - 124 = 0$.

Self Exercise:8

Hyperbola

1. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $9x^2 - 16y^2 + 36x + 32y - 124 = 0$.
2. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $5x^2 - 20y^2 - 20x = 0$.

Self Exercise:8

Hyperbola

1. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $9x^2 - 16y^2 + 36x + 32y - 124 = 0$.
2. Find the centre,vertex, eccentricity, foci, length of transverse axis, length of conjugate axis, length of latus rectum and equation of directrix of the hyperbola: $5x^2 - 20y^2 - 20x = 0$.
3. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $3x^2 - 4y^2 = 36$.

Self Exercise:9

Hyperbola

Self Exercise:9

Hyperbola

1. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $\frac{x^2}{16} - \frac{y^2}{4} = 1$.

Self Exercise:9

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1. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $\frac{x^2}{16} - \frac{y^2}{4} = 1$.
2. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $\frac{x^2}{9} - \frac{y^2}{16} = -1$.

Self Exercise:9

Hyperbola

1. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $\frac{x^2}{16} - \frac{y^2}{4} = 1$.
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3. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $\frac{x^2}{9} - \frac{y^2}{16} = 1$.
4. Determine the equation of the hyperbola with a focus at $(6, 0)$ and a vertex at $(4, 0)$.

Self Exercise:9

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1. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $\frac{x^2}{16} - \frac{y^2}{4} = 1.$
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3. Find the centre,vertex, eccentricity, foci and equation of directrix of the hyperbola: $\frac{x^2}{9} - \frac{y^2}{16} = 1.$
4. Determine the equation of the hyperbola with a focus at $(6, 0)$ and a vertex at $(4, 0)$.
5. Find the equation of the hyperbola with foci $(\pm 5, 0)$ and vertices $(\pm 4, 0)$.

Self Exercise:10

Translation of Axes

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1. Transform the equation $x^2 + 4xy + y^2 + 2x = 12$ by rotating the axes through an angle of 45^0.

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1. Transform the equation $x^2 + 4xy + y^2 + 2x = 12$ by rotating the axes through an angle of 45^0.
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2. Transform the equation $x^2 - 6x - 4y + 1 = 0$ by a proper translation of axes and then draw it's graph.
3. Transform the equation $ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$ into another of the same degree but without the xy term.
   Hint:Rotate through an angle θ without changing the origin.

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   Hint:Rotate through an angle θ without changing the origin.
4. Transform the equation $y^2 - x^2 = 4$ by rotating the coordinate axes through an angle of 45^0

Self Exercise:11

Equation of a Conic in Polar Coordinates

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3. For the equation $r = \frac{7}{2-2\sin\theta}$, identify the conic with focus at the origin, the directrix, and the eccentricity.

Self Exercise:11

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3. For the equation $r = \frac{7}{2-2\sin\theta}$, identify the conic with focus at the origin, the directrix, and the eccentricity.
4. For the equation $r = \frac{10}{3\cos\theta+4\sin\theta+5}$, identify the conic with focus at the origin, the directrix, and the eccentricity. Also sketch the graph of the equation. Hint: choose $\cos\alpha = \frac{3}{5}$ and $\sin\alpha = \frac{4}{5}$ to change into standard form.

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If you have any queries regarding to this material, content or you need any help on this content; please feel free to contact me at any time.

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THANK YOU

JN Chalise