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ANALYTICAL GEOMETRY

By:
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QUESTION PAPER

(June – 2018)

(Solved)

ANALYTICAL GEOMETRY

Time: 1½ hours] *[Maximum Marks: 25*

Weightage: 70%

Note: *Question no. 1 is compulsory. Attempt any* ***three*** *questions from questions no. 2 to 5. Use of calculators is not allowed.*

Q. 1. Are the following statements *true* or *false?* Justify your answer with a short proof or a counter-example.

(a) **The line $ax + by = 0$ is tangent to the conic $x^2 + y^2 + 2ax + 2by = 1$, where a and b are non-zero constants.**

Ans. False: $x^2 + y^2 + 2ax + 2by = 1$ (1)

$ax + by = 0$ (2)

Comparing with equation (1) with $ax^2 + by^2 + 2bxy + 2yx$

$+ 2fy + c - 0$ and

Equation with $px = qy + r = 0$

$a = 1, b = 1, g = 2a, f = b, h = 0, c = 1$

$p - a, q = b, r = 0$

Equation tangent which parallel to $ax + by = 0$ is $ax + \text{by} + c = 0$ if only $(prh + pqg - aqx - p^2f)^2$

$= (aq^2 - 2hpq + 6p^2)\ (ar^2 - 2qpr + cp)^2$

$= (a \times 0 \times 0 + a \times b \times a - 1 \times bx0 - a^2b)^2$

$= (1 \times b^2 - 0 + 6a^2)\ (0 - 2 \times b \times ax0 + (-1)^2 \times a)^2$

$= (a^2b - a^2b)^2 = (6a^2 + b^2)\ (a^2)^2$

$$0 = (6a^2 + b_2)\ (a^4)$$

$$0 = 6a^6 + b^2$$

$$0 = 6 = 4$$

$$6\,a^6 = 0$$

$$\boxed{a^6 = 0}\ \boxed{a = 0}$$

$$b^2 = 0$$

$$\boxed{b = 0}.$$

(b) **The equation $x^2 + xy + \lambda\,(x + y) = 0$ represents a pair of straight lines for all $\lambda \in$ R.**

Ans. False: A pair of straigth line and through the point (α, λ)

$ax^2 + 2hxy + by^2 = 0$ – (1)

$x^2 + xy + \lambda\ (x + y) = 0$ – (2)

Compare Equation (1) and (2)

$$a = 1, h = ½, b = \lambda\ (x + 1)$$

$$\frac{x^2}{xy}\,y^2 = \frac{a - b}{h} = \frac{1 - \lambda\,(x + 1)}{½} = -2\,\lambda$$

(c) **The planes $x + y - z + 1 = 0$ and $3x + 3y - 3z = 0$ are parallel.**

Ans. True:

$x + y - z + 1 = 0$ $3x + 3y - 3z = 0$

$x + y - z = 1$

$-(x + y - z) = 1$

$-x - y + z = 1$ $\frac{A_1}{A_2} = \frac{B_1}{B_2} = \frac{C_1}{C_2}$

$$\frac{-1}{3} = \frac{-1}{3} = \frac{1}{-3}$$

parallel.

(d) **The *xy*-plane intersects the sphere $x^2 + y^2 + z^2 - 2x - 2y + 1 = 0$ in a great circle.**

Ans.True: $x^2 + y^2 + z^2 - 2x - 2y + 1 = 0$

because $z = 0, x^2 + y^2 - 2x - 2y = 1$.

So it is great circle.

(e) **The section of a paraboloid by a plane is a parabola.**

Ans. False: $ab = 1 \times -2 = -2$

$h^2 = 0 \quad \therefore ab \neq h^2$

So $ab - h^2 = -2 - 0 = -2 < 0$

$\therefore$ Given equation is central and can be either a hyperbola or a pair of strainght lines.

Q. 2. *(a)* Find the points of intersection of the conics $a^2x^2 - b^2y^2 = 1$ and $b^2x^2 + a^2y^2 = 1$.

Ans. $a^2 x^2 - b^2y^2 = 1$ –(1)

$$b^2x^2 + a^2y_2 = 1 \quad -(2)$$

$$a^2x^2 = 1 + b^2y^2$$

$$\boxed{x^2 = \frac{1+b^2y^2}{a^2}}$$

We put the x^2 value in equation (2)

$$b^2 x^2 + a^2 y^2 = 1$$

$$b^2\left(\frac{1+b^2y^2}{a^2}\right) + a^2y^2 = 1$$

$$\frac{b^2}{a^2}\left(1+b^2y^2\right) + a^2y^2 = 1$$

$$1 - \frac{b^2}{a^2}\left(1+b^2y^2\right) = a^2y^2$$

$$\frac{b^2+b^4y^2}{a^2} + a^2y^2 - 1$$

$$\frac{b^4y^2+a^4y^2}{a^2} = 1 - \frac{b^2}{a^2}$$

$$y^2\left(\frac{b^4+a^4}{a^2}\right) = 1 - \frac{b^2}{a^2}$$

$$\boxed{y^2 = \frac{a^2-b^2}{b^4+a^4}}.$$

***(b)* Find the centre and radius of the sphere passing through (1, 0, 0), (0, 1, 1), (0, 0, 1) and $\left(\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{\ }}, \frac{1}{\sqrt{2}}\right)$.**

Ans. Given four points on a sphere, viz.,

$$A(1,0,0), B(0,1,1), C(0,0,1), D\left(\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}\right)$$

Let the sphere be,

$x^2 + y^2 + z^2 + 2ux + ex + 2vy + 2\omega z + d = 0$ –(1)

As A, B, C, D lie on (1), so

$1^2 + 0^2 + 0^2 + 2u + 0 + 0 + d = 0$

$\Rightarrow \quad 2u + d + 1 = 0$ –(2)

$0^2 + 1^2 + 0^2 + 0 + 2v + 0 + d = 0$

$\Rightarrow \quad 2v + d + 1 = 0$ –(3)

$0^2 + 1^2 + 1^2 + 0 + 2v + 2\omega + d = 0$

$\Rightarrow \quad 2v + 2\omega + d + 2 = 0$ –(4)

and $$\left(\frac{1}{\sqrt{2}}\right)^2 + \left(\frac{1}{\sqrt{2}}\right)^2 + \left(\frac{1}{\sqrt{2}}\right)^2 + \frac{2u}{\sqrt{2}} + \frac{2v}{\sqrt{2}} + \frac{2\omega}{\sqrt{2}} + d = 0$$

$$\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \sqrt{2u} + \sqrt{2v} + \sqrt{2}\,\omega + d = 0$$

$$\frac{3}{2} + \sqrt{2u} + \sqrt{2v} + \sqrt{2}\,\omega + d = 0$$

$$3 + 2\sqrt{2u} + 2\sqrt{2v} + 2\sqrt{2}\,\omega + 2d = 0 \quad -(5)$$

Now subtracting (3) from (2) and (4) from (3)

$2u - 2v = 0$ and $-2\omega - 1 = 0$

$$u = v \text{ and } \omega = \frac{1}{2}$$

Putting in (5)

$$3 + 2\sqrt{2u} + 2\sqrt{2v} + 2\sqrt{2} \times \frac{1}{2} + 2d = 0$$

$$3 + 4\sqrt{2u} + \sqrt{2} + 2d = 0$$

$$2d = -3 - 4\sqrt{2u} - \sqrt{2}$$

$$\Rightarrow d = \frac{-3 - 4\sqrt{2}u - \sqrt{2}}{2}$$

Putting this in (2), we get

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

$$2u = \left(\frac{3 + 4\sqrt{2u} + \sqrt{2}}{2}\right) - 1$$

$$2u = \frac{3 + 4\sqrt{2}u + \sqrt{2} - 2}{2}$$

$$4u = 3 + 4\sqrt{2}u + \sqrt{2} - 2$$

$$4u = 4\sqrt{2}u = 1 + \sqrt{2}$$

$$4u\left(1 - \sqrt{2}\right) = 1 + \sqrt{2}$$

$$4u = \frac{1+\sqrt{2}}{1-\sqrt{2}}$$

Sample Preview
of
The Chapter

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ANALYTICAL GEOMETRY

CONICS

Preliminaries in Plane Geometry

1

Let us review two-dimensional geometry and study the polar form of a point in the plane. Then we shall study transformations of coordinate systems, viz, symmetry with respect to either coordinate axis or the origin. And then polar form of an equation.

Equation of a Line: We are familiar with distance, formula i.e., if $P(x_1, y_1)$, $Q(x_2, y_2)$ be two points in a plane then distance PQ is given by:

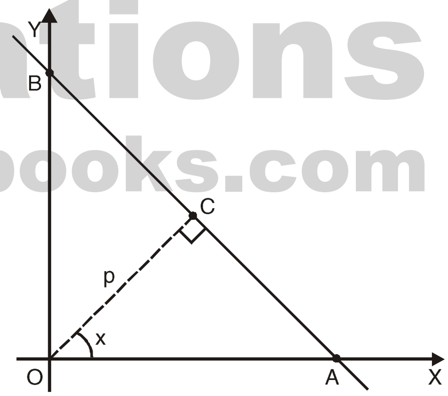
$$PQ = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Also by section formula. The distance PQ can be divided by a point $R(x, y)$ is ratio $m : n$, then

$$x = \frac{mx_2 + nx_1}{m+n}, \qquad y = \frac{my_2 + ny_1}{m+n}$$

We have various forms of equations of line, viz.,

1. $y = mx + c$
   where m = slope and $c = y$ – intercept.
2. $y - y_1 = m(x - x_1)$
   m = slope and (x_1, y_1) is a point on line.
3. $y - y_1 = \frac{(y_2 - y_1)}{(x_2 - x_1)}(x - x_1)$,
   (x_1, y_1), (x_2, y_2) are two points on line.
4. $\frac{x}{a} + \frac{y}{b} = 1$,
   a, b are intercepts on x and y-axis respectively.
5. $x \cos\alpha + y \sin\alpha = p$,
   α = Angle subtended to line from origin by perpendicular and p = length of that perpendicular.



***$x \cos \alpha + y \sin \alpha = p$* is the normal form of AB**

6. $Ax + By + C = 0$ (General form)
   $\perp$ Distance of line $Ax + By + C$

from $(x_1, y_1) = \left| \frac{Ax_1 + By_1 + C}{\sqrt{A^2 + B^2}} \right|$

Symmetry: If $F(x_1, y_2) = 0 \Rightarrow F(-x, y) = 0$, then curve $F(x, y)$ is called symmetrical about x-axis.

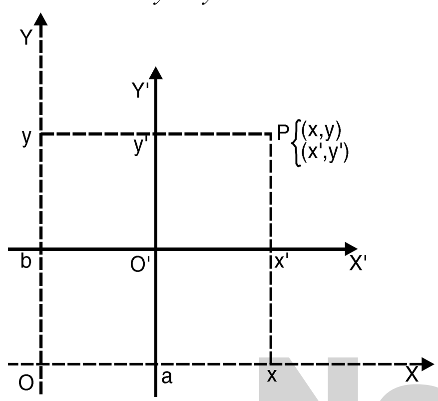
If $F(x, y) = 0 \Rightarrow F(x, -y) = 0$ then curve $F(x, y) = 0$ is called symmetrical about y-axis.

If $F(x, y) = 0 \Rightarrow F(-x, -y) = 0$ then curve $F(x, y) = 0$ is called symmetrical about origin.

CHANGE OF AXES

Translation: Let a point P has coordinates (x, y) in one coordinate system $x - y$ with origin O. Another point O′ has its coordinates (a, b) in this system, then we can draw x'–y' coordinate system parallel to axes of $x - y$ system through O′ and obtain new coordinates of P viz. (x', y') by:

$$x' = x + a$$
$$y' = y + b$$



Translation of axes through (a, b).

This gives required translation of axes. (see fig ....)

Rotating the Axes: Let us rotate coordinate system through an angle θ so that XOY becomes X′OY′.

Let a point P has (x, y) coordinates in XOY and (x', y') in X′OY′ system. Drop perpendiculars PA and PB from P to OX′ and OX respectively. Also draw AC ⊥ OX and AD ⊥ PB. Then x = OB, y = OB, x' = OA, y' = PA

Also ∠DAO = ∠AOC = θ

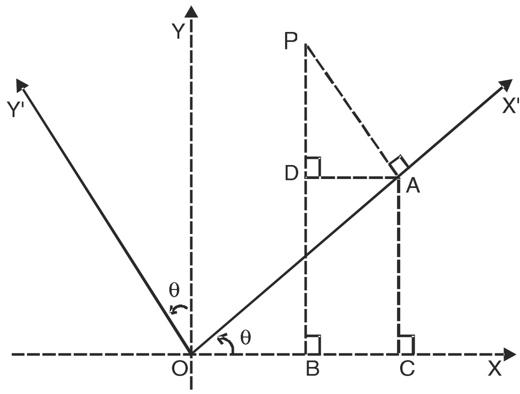
∴ ∠DPA = θ.

Thus
$$x = \text{OB}$$
$$= \text{OC} - \text{AD}$$
$$= \text{OA}\left(\frac{\text{OC}}{\text{OA}}\right) - \text{PA}\left(\frac{\text{AD}}{\text{PA}}\right)$$
$$= \text{OA}\cos\theta - \text{PA}\sin\theta$$

∴ $$x = x'\cos\theta - y'\sin\theta$$

and
$$y = \text{PB} = \text{PD} + \text{AC}$$
$$= \text{PA}\left(\frac{\text{PD}}{\text{PA}}\right) + \text{OA}\left(\frac{\text{AC}}{\text{OA}}\right)$$
$$= \text{PA}\cos\theta + \text{OA}\sin\theta$$

i.e. $$y = x'\sin\theta + y'\cos\theta$$



The axes OX' and OY' are obtained by rotating the axes OX and OY through

Thus by $x = x'\cos\theta - y\sin\theta$

and $y = x'\sin\theta + y'\cos\theta$

or otherwise or solving for x', y', we can get

$$x' = x\cos\theta + y\sin\theta$$

and $$y' = -x\sin\theta + y\cos\theta$$

How do you translate and rotate together? We shall see from the following example:

Let us rotate the equation $11x^2 + 2\sqrt{3}\,xy + 9y^2 = 12\left(x\sqrt{3} + y + 1\right)$ through 30° and then translate the system through $\left(\frac{1}{2}, 0\right)$, what do we get?

We write

$$x = x'\cos 30° - y'\sin 30° = \left(\frac{x'\sqrt{3} - y'}{2}\right)$$

and $$y = x'\sin 30° - y'\cos 30° = \left(\frac{x'\,y'\sqrt{3}}{2}\right)$$

Then equation becomes

$$11\left(\frac{x'\sqrt{3} - y'}{2}\right)^2 + 2\sqrt{3}\left(\frac{x'\sqrt{3} - y'}{2}\right)\left(\frac{x' + y'\sqrt{3}}{2}\right)$$
$$+ 9\left(\frac{x'\,y'\sqrt{3}}{2}\right)^2 = 12\left[\sqrt{3}\frac{\left(x'\sqrt{3} - y'\right)}{2} + \frac{\left(x' + y'\sqrt{3}\right)}{2} + 1\right]$$

$$\Rightarrow \quad \frac{1}{4}\left[11\left(3x'^2 + y'^2 - 2\sqrt{x'y'}\right)\right]$$
$$+ \frac{2\sqrt{3}}{4}\left(\sqrt{3}x'^2 + \sqrt{3}y'^2 - x'y' + 3x'y'\right)$$
$$+ \frac{9}{4}\left(x'^2 + 3y'^2 - 2\sqrt{3}x'y'\right)$$

$$= \frac{12}{2}\left(3x'+\sqrt{3}y'+x'+\sqrt{3}y'+2\right)$$

$$\Rightarrow \quad 33x'^2 + 11y'^2 - 22\sqrt{3x'y'} + 6x'^2 - 6y'^2$$

$$+ 4\sqrt{3x'y'} + 9x'^2 + 27y'^2 + 18\sqrt{3x'y'}$$

$$= 24\,(4x' + 2)$$

$$\Rightarrow \quad 48x'^2 + 32y'^2 = 2(48x' + 24)$$

$$\Rightarrow \quad 16(3x'^2 + 2y'^2) = 16(6x' + 3)$$

$$\Rightarrow \quad 3x'^2 - 6x' + 2y'^2 = 3$$

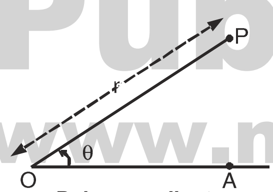
$$\Rightarrow \quad 3\left(x'^2 - x' + \frac{1}{4}\right) + 2y'^2 = 3 + \frac{3}{4}$$

$$\Rightarrow \quad 3\left(x' - \frac{1}{2}\right)^2 + 2y'^2 = \frac{15}{4},$$

Now shifting origin to $\left(\frac{1}{2}, 0\right)$, we get

$\Rightarrow \quad 3x^2 + 2y^2 = \frac{15}{4}$, which is required equation.

Polar Coordiante: If a line OA, known as polar line (initial line) rotates through angle θ, then length OP (= OA), taken as r and angle θ can give (r, θ) where r, θ are both variables. This defines every point in the plane.



Polar coordinates

SOLVED EXERCISE

Q. 1. What are the coordinates of mid-point of the line segment with end points

***(a)* A (5, –4) and B(–3, 2) ?**

***(b)* A (a_1, a_2) and B(b_1, b_2).**

Sol. *(a)* Mid-point of AB, given A(5, –4), B(–3, 2)

is $\left(\frac{5-3}{2}, \frac{-4+2}{2}\right) = (1, -1)$

(b) $\quad A(a_1, a_2), \quad B(b_1, b_2)$

$\therefore$ Mid-point of AB $= \left(\frac{a_1 + a_1}{2}, \frac{a_2 + b_2}{2}\right)$

Q. 2. Check if the triangle PQR, where P, Q, and R are represented by (1, 0) (–2, 3) and (1, 3), is an equilateral triangle.

Sol. Given: P(1, 0), Q(–2, 3), R(1, 3)

$$\therefore \quad PQ = \sqrt{(-2-1)^2 + (3-0)^2}$$

$$= \sqrt{9+9}$$

$$\therefore \quad PQ = \sqrt{18} = 3\sqrt{2}$$

$$QR = \sqrt{(1+2)^2 + (3-3)^2}$$

$$= \sqrt{9+0}$$

$$\therefore \quad QR = 3$$

$$\text{and} \quad RP = \sqrt{(1-1)^2 + (3-0)^2}$$

$$= \sqrt{0+9}$$

$$= \sqrt{9}$$

$$\therefore \quad RP = 3$$

$$\therefore \quad QR = RP = 3 \neq PQ.$$

$\therefore$ PQR is not an equilateral triangle.

Q. 3. What are the equations of the coordinate axes?

Sol. Equation of x-axis is $y = 0$

and Equation of y-axis is $x = 0$.

Q. 4. Find the equation of the line that cuts off an intercept of 1 from the negative direction of the *y*-axis, and is inclined at 120° to the *x*-axis.

Sol. Given: y = intercept on negative side,

i.e. $C = -1$

and Slope $m = \tan\theta$

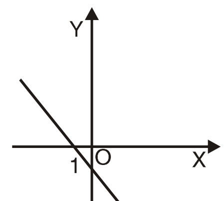
$= \tan 120$ as $\theta = 120°$ (given)

$\therefore \quad m = -\sqrt{3}$

$\therefore$ Required line is,

$$y = -\sqrt{3}x - 1$$

i.e. $\sqrt{3}x + y + 1 = 0$ using $y = mx + c$



$y = -(\sqrt{3}x + 1)$

Q. 5. What is the equation of a line passing through the origin and making an angle θ with the *x*-axis?

Sol. Given: Line passes through origin, i.e. (0, 0) amd it makes an angle θ with x-axis

∴ Its slope $m = \tan\theta$

∴ Equation of line by

$$y - y_1 = m(x - x_1) \text{ is}$$
$$y - 0 = \tan\theta(x - 0)$$
$$\Rightarrow \quad y = x\tan\theta$$

Q. 6. *(a)* Suppose we know that the intercept of a line on the *x*-axis is 2 and on the *y*-axis is –3. Then show that its equation is:

$$\frac{x}{2} - \frac{y}{3} = 1.$$

***(b)* More generally, if a line L cuts off an intercept *a* (≠ 0) on the *x*-axis and *b*(≠ 0) on the *y*-axis, then show that its equation is:**

$$\frac{x}{a} + \frac{y}{b} = 1$$

is called the intercept form of the equation of L.

Sol. *(a)* Given:

Line makes x intercept = 2

i.e. it passes through (2, 0)

It makes y intercept = –3

i.e. it passes through (0, –3)

∴ Using two point form, *viz.*,

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}, \text{ we get}$$
$$\frac{y - 0}{-3 - 0} = \frac{x - 2}{0 - 2}$$
$$\Rightarrow \quad y = \frac{-3}{-2}(x - 2)$$
$$\Rightarrow \quad \frac{y}{3} = \frac{x}{2} - \frac{2}{2}$$
$$\Rightarrow \quad \frac{x}{2} - \frac{y}{3} = 1$$

(b) Given:

x-intercept = a

and y-intercept = b

$a, b \neq 0$

Then it passes through $(a, 0)$ and $(0, b)$

∴ Using two point form, *viz.*

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}, \text{ we get}$$
$$\frac{y - 0}{b - 0} = \frac{x - a}{0 - a}$$
$$\Rightarrow \quad \frac{y}{b} = \frac{x}{-a} - \frac{a}{-a}$$
$$\Rightarrow \quad \frac{x}{a} + \frac{y}{b} = 1.$$

Q. 7. Find the distance of (1, 1) from the line which has slope –1 and intercept $\frac{1}{2}$ on the *y*-axis.

Sol. Given: Slope of line

$m = -1$

It cut $\frac{1}{2}$ intercept on y axis i.e.,

$$c = \frac{1}{2}$$

∴ E*qn*. of line is

$$y = mx + c$$
$$\Rightarrow \quad y = -1x + \frac{1}{2}$$
$$2y = -2x + 1$$
$$2x + 2y - 1 = 0$$

∴ Its distance from (1, 1) is, by using,

$$\left|\frac{Ax_1 + By_1 + C}{\sqrt{A^2 + B^2}}\right|$$
$$\text{Distance} = \left|\frac{2.1 + 2.1 - 1}{\sqrt{2^2 + 2^2}}\right|$$
$$= \left|\frac{3}{\sqrt{8}}\right| = \left|\frac{3}{2\sqrt{2}}\right| \times \frac{\sqrt{2}}{\sqrt{2}}$$
$$= \frac{3\sqrt{2}}{4}$$

Q. 8. What is the distance of:

(a) **$y = mx + c$ from (0, 0)?**

(b) **$x = 5$ from (1, 1)?**

(c) **$x\cos\alpha + y\sin\alpha = p$ from $(\cos\alpha, \sin\alpha)$?**

(d) **(0, 0) from $2x + 3y = 0$?**

Sol. *(a)* To find distance of $y = mx + c$ from (0, 0) i.e. of $mx - y + c = 0$ from (0, 0)

$$\text{Using distance} = \left|\frac{Ax_1 + By_1 + C}{\sqrt{A^2 + B^2}}\right|$$

We get,

$$= \left|\frac{m.0 - 0 + c}{\sqrt{m^2 + 1}}\right| = \frac{c}{\sqrt{m^2 + 1}}$$