



Electromagnetic waves

Lecture 2

System of Coordinates

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Tow stage

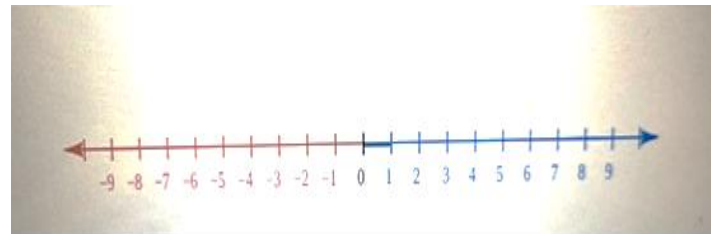
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❖ Coordinate System

- Used to describe the position of a point in space
- Coordinate System consists of
 - A fixed reference point called the origin
 - Specific axes with scales and labels
 - Instruction on how to label a point relative to the origin and the axes

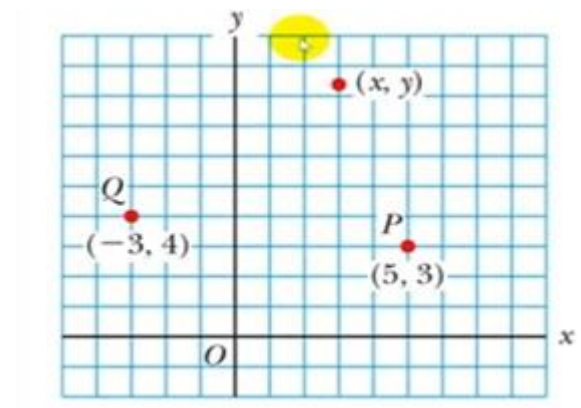
❖ Types of Coordinate Systems

- Number line.
- Cartesian coordinate system.
- Polar coordinate system.
- Cylindrical and spherical coordinate systems.
- Homogeneous coordinate system.
- Other commonly used systems.
- Relativistic coordinate systems.



❖ Cartesian Coordinate System

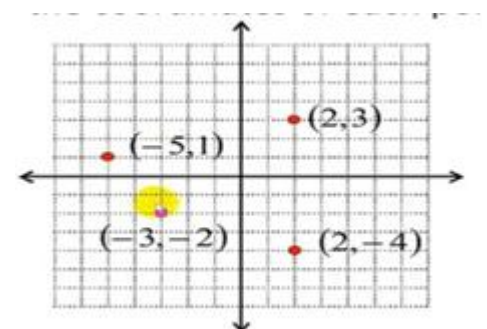
- Also called rectangular Coordinate System
- x- and y- axes intersect at the origin
- Points are labeled (x , y)
- The plural of axis is axes
- Ordered pair (x , y) with x-value first



Example /Determine the following points

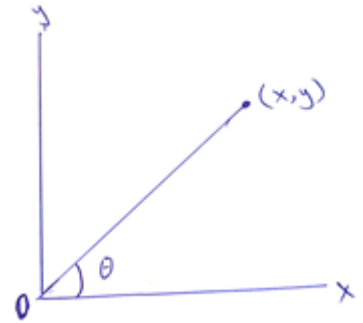
- (2 ,3)
- (-5 ,1)
- (-3,-2)
- (2,-4)

solution :



❖ Polar coordinate system

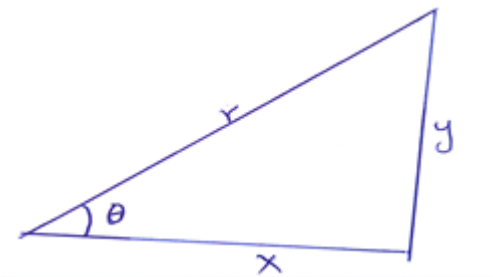
- Origin and reference line are noted.
- Point is distance r from the origin in the direction of angle θ , ccw from reference line.
- Points are labeled (r, θ) .



❖ Polar to Cartesian coordinates

$$\sin\theta = \frac{y}{r}, \cos\theta = \frac{x}{r}, \tan\theta = \frac{y}{x}$$

- Based on forming a right triangle from r and θ .
- $x = r \cos\theta$
- $y = r \sin\theta$



❖ Cartesian to Polar coordinates

- If the Cartesian coordinates are known :
 - r is the hypotenuse and θ an angle

$$\tan\theta = \frac{y}{x}$$

$$r = \sqrt{x^2 + y^2}$$

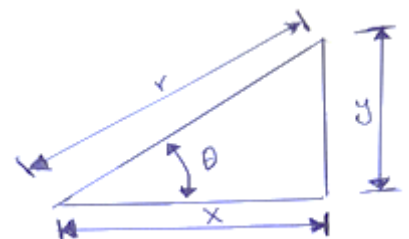
- θ must be ccw from positive x axis for these equations to be valid

Example : The Cartesian coordinates of a point in the xy Plane are $(x,y)=(12, 5)$. Find the polar coordinates of this point.

Solution : from equation

$$r = \sqrt{x^2 + y^2}$$

$$r = \sqrt{12^2 + 5^2}$$



$$r = 13$$

And from equation ,

$$\tan\theta = \frac{y}{x}$$

$$\tan\theta = \frac{5}{12}$$

$$\tan\theta = 12$$

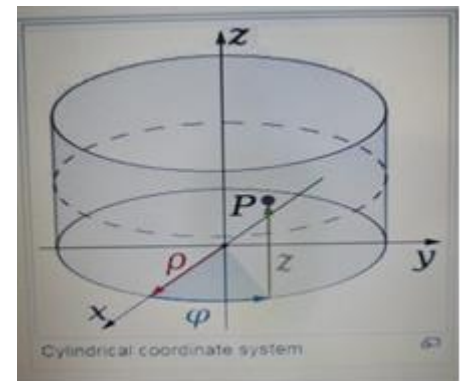
$$\theta = ??$$

$$\theta = \tan^{-1}\left(\frac{5}{12}\right)$$

$$\theta = 22,6^\circ$$

❖ Cylindrical coordinate systems

- There are two common methods for extending the polar coordinate system to three dimensions.
- In the cylindrical coordinate system, a z coordinate with the same meaning as in Cartesian coordinates is added to the r and θ polar coordinates giving a triple (r, θ, z) .



❖ Convert from Cartesian coordinates to cylindrical coordinates

$$(x, y, z) \rightarrow (r, \theta, z)$$

$$\theta = \tan^{-1}\left(\frac{y}{x}\right)$$

$$z = z$$

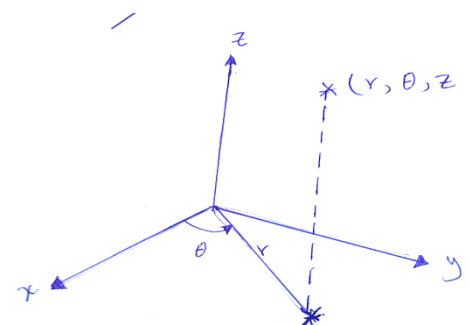
- ❖ Convert from cylindrical coordinates to Cartesian coordinates

$$(r, \theta, z) \rightarrow (x, y, z)$$

$$x = r \cos\theta$$

$$y = r \sin\theta$$

$$z = z$$



Example: Convert from cylindrical coordinates to Cartesian coordinates $(4, \frac{2\pi}{3}, -2)$

Solution : $x = r \cos \theta$

$$x = 4 \cos \frac{2\pi}{3}$$

$$x = -2$$

$$y = r \sin \theta$$

$$y = 4 \sin \frac{2\pi}{3}$$

$$y = 2\sqrt{3}$$

$$z = z$$

$$z = -2$$

$$p = (-2, 2\sqrt{3}, -2)$$

Example: Convert from Cartesian coordinates to cylindrical coordinates $(1, -3, 5)$

Solution :

$$r = \sqrt{x^2 + y^2}$$

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

$$r = \sqrt{10}$$

$$\theta = \tan^{-1} \left(\frac{y}{x} \right)$$

$$\theta = \tan^{-1} \left(\frac{-3}{1} \right)$$

$$\theta = -1.249$$

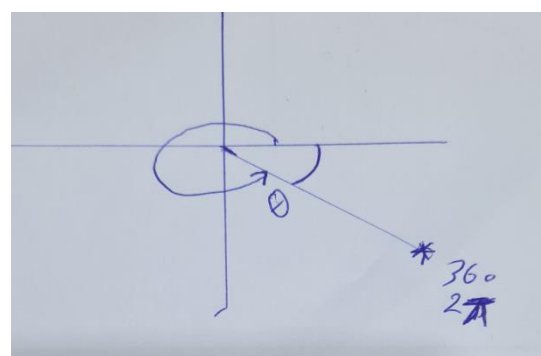
$$\theta = -1.249 + 2\pi$$

$$\theta = 5.03$$

$$z = z$$

$$z = 5$$

$$(r, \theta, z) = (\sqrt{10}, 5.03, 5)$$



Homework :

Convert from Cartesian coordinates to polar coordinates $(3,-3,-7)$.