KINEMATICS

L1: 1/12/26

Chapter 1 — Lecturebook
Chapter 2 — Meriam

Kinematics Motion of objects w/o reference to forces that cause it.

- Particle
  - 2D
  - 3D
- Rigid Body
  - 2D $\longrightarrow$ Motion 2D
  - 2D $\longrightarrow$ Motion 3D
  - 3D $\longrightarrow$ Motion 3D

KINETICS Motion and its causes (i.e., Forces)

Why things move (impact, applied force, applied moments)

- Particle motion
  - Newton's Laws
  - Work energy
  - Linear impulse momentum
  - Angular impulse momentum
- 2D rigid body motion
  - Newton's Laws
  - Work energy
  - Linear impulse & L. momentum
  - Angular impulse & A. momentum
- 3D rigid body motion

Why Dynamics is important?

It's not just important, it's **FUNDAMENTAL** in the analysis of engineering systems

Basic in the analysis of

→ Moving structures (e.g., aircraft moving parts, robotic arms, airport luggage carrousels,...)

→ Fixed structures subjected to dynamic loads (e.g., earthquake @ building, wind load @ turbine)

→ Automatic control systems need the dynamics equations to function properly

→ Robotic & Autonomous systems. Rockets, missiles, aircraft spacecraft, transportation vehicles, all types of machinery

🔗Boston Dynamics 🔗Space X 🔗Organifarms

Definition of motion any ideas?

Motion can be described by monitoring the position, velocity and acceleration of a particle or body at any time.

where is it? with respect to a reference
where was it previously?] Position $\vec{r}$

how fast?
which direction?] velocity $\vec{v}$

change of speed
change of direction] acceleration $\vec{a}$

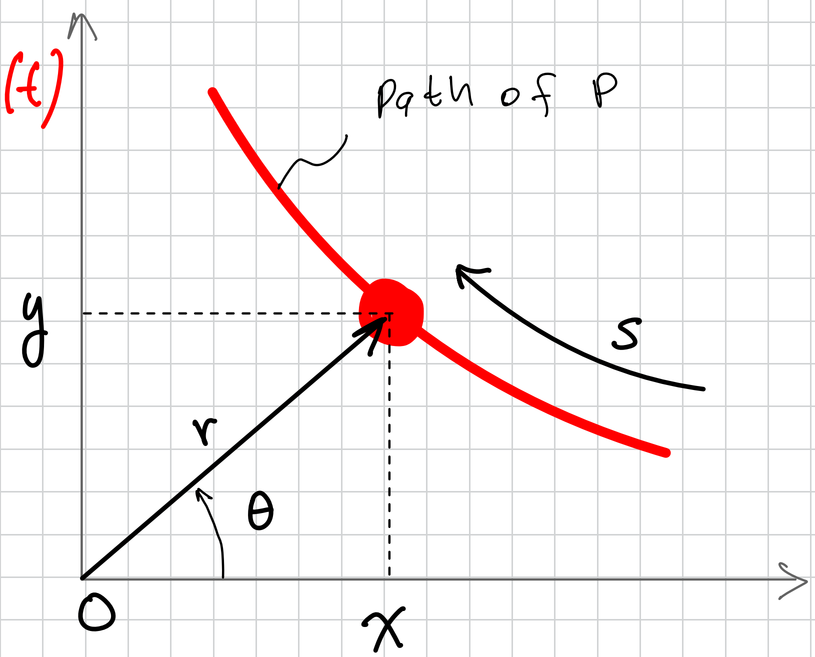
PLANAR KINEMATICS: Cartesian, Path and Polar description of motion

Consider a point P moving on a curvilinear path in the plane (e.g. over a table). Depending on convenience, we will describe the motion of P using three different coordinate systems (descriptions)

Cartesian – Path in terms of x-y coordinates. Typically, $y = x(t)$

path – Position in terms of distance S along path

Polar – Position in terms of radial distance r (from O) and θ. Typically $r = r(\theta)$



Let's write the velocity and acceleration for the planar motion of a point in terms of Cartesian, path, and polar descriptions.

Let's find out the pros & cons of each!

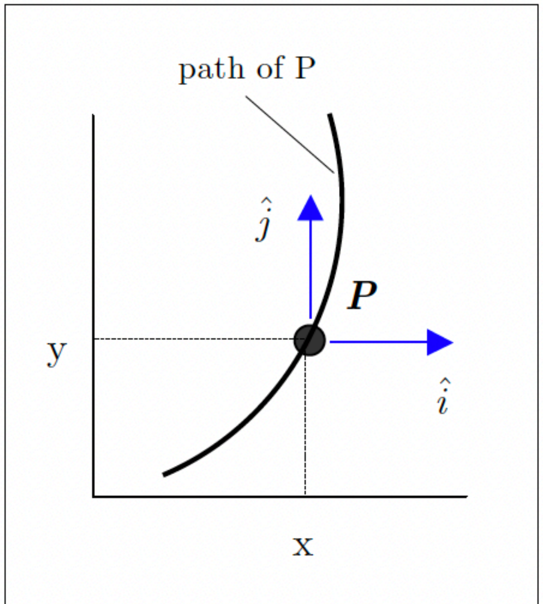
FUNDAMENTALS:

Velocity and acceleration of P are given by the first and second time derivatives of the position

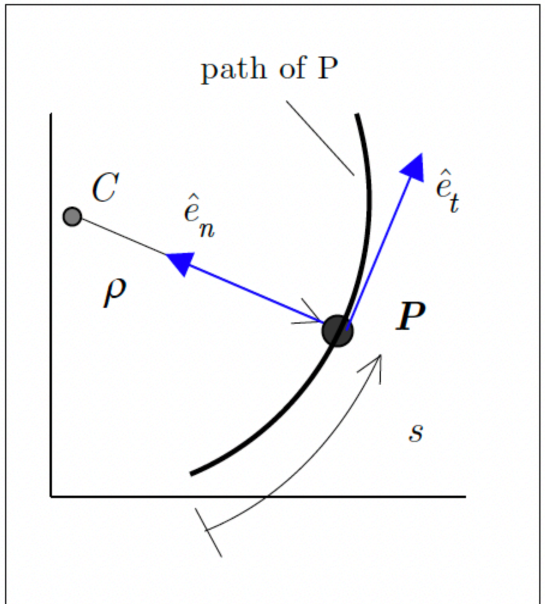
$$\vec{v} = \frac{d\vec{r}}{dt} = \dot{\vec{r}}$$

$$\vec{a} = \frac{d}{dt}(\vec{v}) = \ddot{\vec{r}}$$

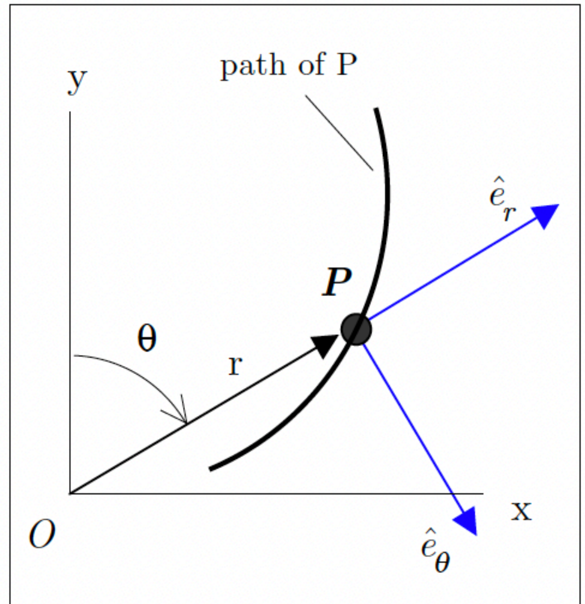
Do not think of these $(\vec{r}, \vec{v}, \vec{a})$ as individual quantities. Know one, and you know them all with $\frac{d}{dt}(\cdot)$ and $\int(\cdot)dt$



Cartesian description



Path description



Polar description

Position measured through x and y components

→ intuitive

$$\vec{r} = \begin{cases} x(t) & [m] \\ y(t) & [m] \end{cases}$$

Position measured through s along path

eg. race track

$$\vec{r} \begin{cases} \text{path geometry} & \\ \text{distance } s(t) & [m] \end{cases}$$

Position described through radial distance r and angle of $\overline{OP}$

eg. rotating and telescopic shaft

$$\vec{r} \begin{cases} r(t) & [m] \\ \theta(t) & [rad] \end{cases}$$