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# Dynamics (Quickstudy: Academic)

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**Quick Study ACADEMIC** **DYNAMICS**

**NOTATIONS**

A. All scalar quantities are denoted by normal print, e.g., time,  $t$ . Also, the magnitude of vector quantities is denoted by normal print, e.g., velocity magnitude,  $v = |\mathbf{v}|$ .

B. All vector quantities are denoted by italicized bold print, e.g., velocity vector or acceleration vector,  $\mathbf{a}$ .

**DEFINITIONS**

A. **Vector Components.** Any vector can be decomposed to a certain number of components based on the reference coordinate system.

1. **Cartesian (Rectangular) Coordinate System,  $x, y, z$ .**  
 $\mathbf{a} = a_x \mathbf{i} + a_y \mathbf{j} + a_z \mathbf{k}$  where  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  are the unit vectors along the axes,  $x, y, z$ , respectively.  
 $a_x, a_y, a_z$  are the vector components and  $a_x, a_y, a_z$  are the scalar components along the axes,  $x, y, z$ , respectively.

2. **Polar Coordinate System,  $r, \theta$ .**  
 $\mathbf{a} = a_r \mathbf{e}_r + a_\theta \mathbf{e}_\theta$  where  $\mathbf{e}_r, \mathbf{e}_\theta$  are the unit vectors and  $a_r, a_\theta$  are the scalar and transverse unit vectors respectively.

3. **Spherical Coordinate System,  $\rho, \theta, \phi$ .**  
 $\mathbf{a} = a_\rho \mathbf{e}_\rho + a_\theta \mathbf{e}_\theta + a_\phi \mathbf{e}_\phi$   
 $a_\rho = a$  radial  
 $a_\theta = a$  latitudinal  
 $a_\phi = a$  azimuthal

4. **Cylindrical Coordinate System,  $\rho, \theta, z$ .**  
 $\mathbf{a} = a_\rho \mathbf{e}_\rho + a_\theta \mathbf{e}_\theta + a_z \mathbf{e}_z$   
 $a_\rho = a$  radial  
 $a_\theta = a$  tangential  
 $a_z = a$  axial

B. **Scalar product.** Between two vectors  $\mathbf{a}$  and  $\mathbf{b}$  is defined as:  
 $\mathbf{a} \cdot \mathbf{b} = ab \cos \alpha$  where  $\alpha$  is the angle between the two vectors.

C. **Vector product.** Between two vectors  $\mathbf{a}$  and  $\mathbf{b}$  is defined as:  
 $\mathbf{c} = \mathbf{a} \times \mathbf{b} = |\mathbf{a}||\mathbf{b}| \sin \alpha \mathbf{e}_n$  where  $\mathbf{e}_n$  is the unit vector perpendicular to the plane defined by the vectors  $\mathbf{a}$  and  $\mathbf{b}$ . Using a Cartesian coordinate system the vector product can be defined as:  
 $(\mathbf{a} \times \mathbf{b})_x = a_y b_z - a_z b_y, (\mathbf{a} \times \mathbf{b})_y = a_z b_x - a_x b_z, (\mathbf{a} \times \mathbf{b})_z = a_x b_y - a_y b_x$

D. **Particles** are hypothetical bodies that do not possess any rotational characteristics. All points of a particle have the same displacement, velocity, and acceleration.

E. **Rigid bodies** are objects whose points may have different displacements, velocities, and accelerations.

F. **Kinematics** is the study of motion without considering the forces that cause the motion. Kinematics involve displacement, velocity, acceleration, and time.

G. **Kinetics** is the study of motion as related to the forces causing the motion. Kinetics involve force, mass, and acceleration.

H. **Path** is the curve that a particle follows as it moves through the space. The path can be a space curve called **trajectory** or a plane curve called **plane path**.

**KINEMATICS PARTICLE MOTION**

**RECTILINEAR MOTION**

**Rectilinear motion** is when a particle moves along a straight line. The governing equations regarding acceleration,  $a$ , velocity,  $v$ , and displacement,  $s$ , as a function of time,  $t$ , for rectilinear motion are:  
 $a = dv/dt = ds/dt$   
 $v = \int a dt = v_0 + at$   
 $s = \int v dt = s_0 + v_0 t + \frac{1}{2} at^2$

Generally, all three variables,  $a, v$ , and  $s$ , are vectors. However, in the above equations these variables are treated as scalars, since the motion is rectilinear and their direction can be defined only by their sign (positive or negative).

A. **Variable or Uniformly Accelerated Rectilinear Motion.** Denoting the initial conditions to be of the various variables by the subscript 0, the relationships between position, coordinate,  $s$ , velocity,  $v$ , acceleration,  $a$ , and time,  $t$ , are given as follows:

**Given:**  $a, v_0, s_0$  **Estimate:**  
 $v = v_0 + at$   
 $s = s_0 + v_0 t + \frac{1}{2} at^2$   
 $v^2 = v_0^2 + 2as$   
 $s = s_0 + v_0 t + \frac{1}{2} at^2$   
 $v = v_0 + at$   
 $v^2 = v_0^2 + 2as$   
 $s = s_0 + v_0 t + \frac{1}{2} at^2$   
 $v = v_0 + at$   
 $v^2 = v_0^2 + 2as$   
 $s = s_0 + v_0 t + \frac{1}{2} at^2$   
 $v = v_0 + at$   
 $v^2 = v_0^2 + 2as$   
 $s = s_0 + v_0 t + \frac{1}{2} at^2$

**Free Fall:**  
 $a = -g$   
 $v = v_0 - gt$   
 $s = s_0 + v_0 t - \frac{1}{2} gt^2$   
 $v^2 = v_0^2 - 2gs$

**Relative Motion Between Two Particles A and B.**  
 $\mathbf{r}_{B/A} = \mathbf{r}_B - \mathbf{r}_A$   
 $\mathbf{v}_{B/A} = \mathbf{v}_B - \mathbf{v}_A$   
 $\mathbf{a}_{B/A} = \mathbf{a}_B - \mathbf{a}_A$

**CURVILINEAR MOTION**

**Curvilinear motion** is the motion where particles move along a curved path. The position of a particle is given by the position vector,  $\mathbf{r}$ . The velocity,  $\mathbf{v}$ , and the acceleration,  $\mathbf{a}$ , for curvilinear motion are defined as:  
 $\mathbf{v} = d\mathbf{r}/dt = v \mathbf{e}_t$  where  $\mathbf{e}_t$  is tangent to the particle's path,  $\mathbf{e}_n$  is normal to the particle's path,  $\mathbf{e}_\theta$  is tangential to the particle's path,  $\mathbf{e}_r$  is radial to the particle's path,  $\mathbf{e}_\phi$  is azimuthal to the particle's path.

1. **Two-Dimensional Motion.** For plane motion, the particle's acceleration can be separated into two components, one tangential,  $a_t$ , and one normal,  $a_n$ .  $a_t = dv/dt$ ,  $a_n = v^2/\rho$  where  $\rho$  is the radius of curvature,  $\mathbf{e}_t$  is the tangential unit vector, and  $\mathbf{e}_n$  is the normal unit vector to the curved path of the particle.

2. **Three-Dimensional Motion.** Considering plane or a three-dimensional motion in the plane in the neighborhood of the starting particle that includes the unit vectors  $\mathbf{e}_t$ , tangential and  $\mathbf{e}_n$ , normal to the path. The tangential unit vector,  $\mathbf{e}_t$ , is perpendicular to the osculating plane.

C. **Polar Coordinate System (Radial and Transverse Components in Plane Motion)**

1. **Particle Velocity:**  
 $\mathbf{v} = v_r \mathbf{e}_r + v_\theta \mathbf{e}_\theta$   
 $v_r = \dot{\rho}$ ,  $v_\theta = \rho \dot{\theta}$

2. **Particle Acceleration:**  
 $\mathbf{a} = a_r \mathbf{e}_r + a_\theta \mathbf{e}_\theta$   
 $a_r = \ddot{\rho} - \rho \dot{\theta}^2$ ,  $a_\theta = 2\dot{\rho}\dot{\theta} + \rho \ddot{\theta}$   
 $a_r = \ddot{\rho} - \rho \dot{\theta}^2$ ,  $a_\theta = 2\dot{\rho}\dot{\theta} + \rho \ddot{\theta}$

**Concise Material**



## Synopsis

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