WELCOME

Physics 1 [Summer 2023 - 2024]

Department of Physics
Faculty of Science & Technology (FST)
American International University-Bangladesh

COURSE: PHYSICS 1 (PHY 1101)
SEMESTER: Summer [2023-2024]

CREDIT: 3 CREDIT HOURS

MARKS DISTRIBUTION

ATTENDANCE AND PERFORMANCE: 10 (10%)

ASSESSMENTS (QUIZZES) : BEST ONE OUT OF TWO : 20 (20 %)

ASSIGNMENT : 20 (20%)

MIDTERM ASSESSMENTS (COUNT ALL): 50 (50%)

TOTAL = 100 POINTS/MARKS

Outline up to Mid term

Reference Book: Fundamentals of Physics (10th Edition)

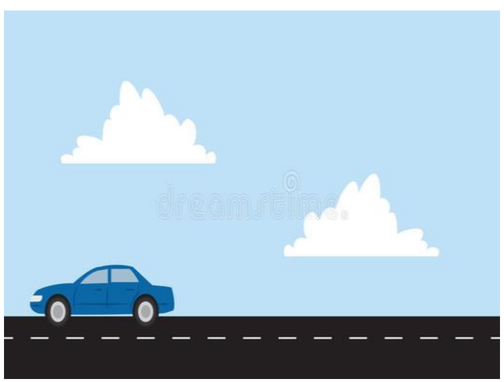
Written by Halliday, Resnick and Walker

Book chapter no	Chapter name
4	Motion in Two and Three Dimensions
5	Force and Motion-I
6	Force and Motion-II
7 and 8	Kinetic Energy and Work And Conservation of Energy
9	Center of Mass and Linear Momentum
10	Rotation
11	Rolling, Torque, and Angular Momentum

LESSON 1

BOOK CHAPTER 4

Motion in Two and Three Dimensions

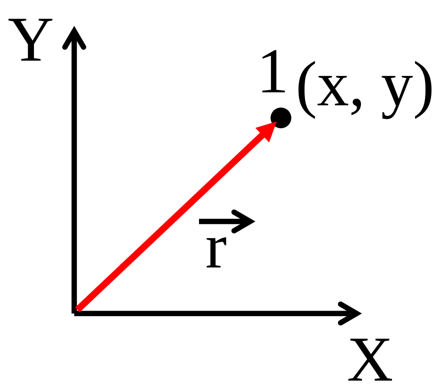



Outline of Lesson 1

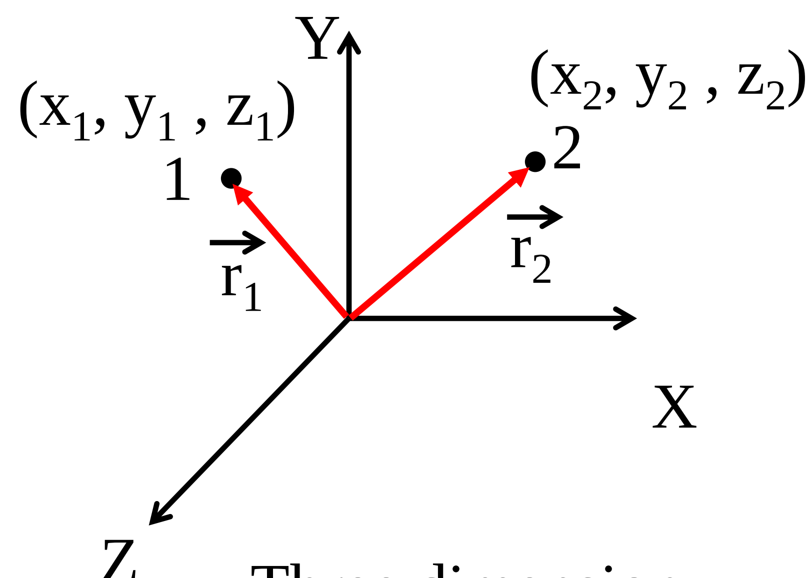
- Position and Displacement
- Average Velocity and Instantaneous Velocity
- Average Acceleration and Instantaneous Acceleration

Position:

One dimension



Two dimension

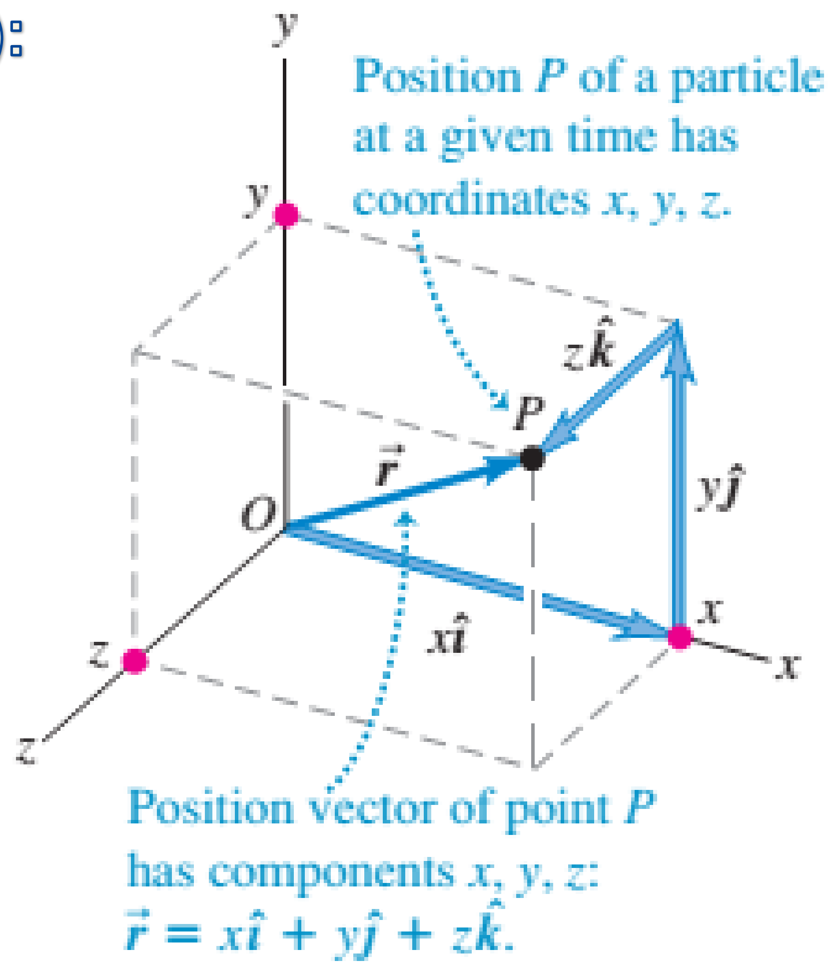


Three dimension

Position Vector (three-dimension):

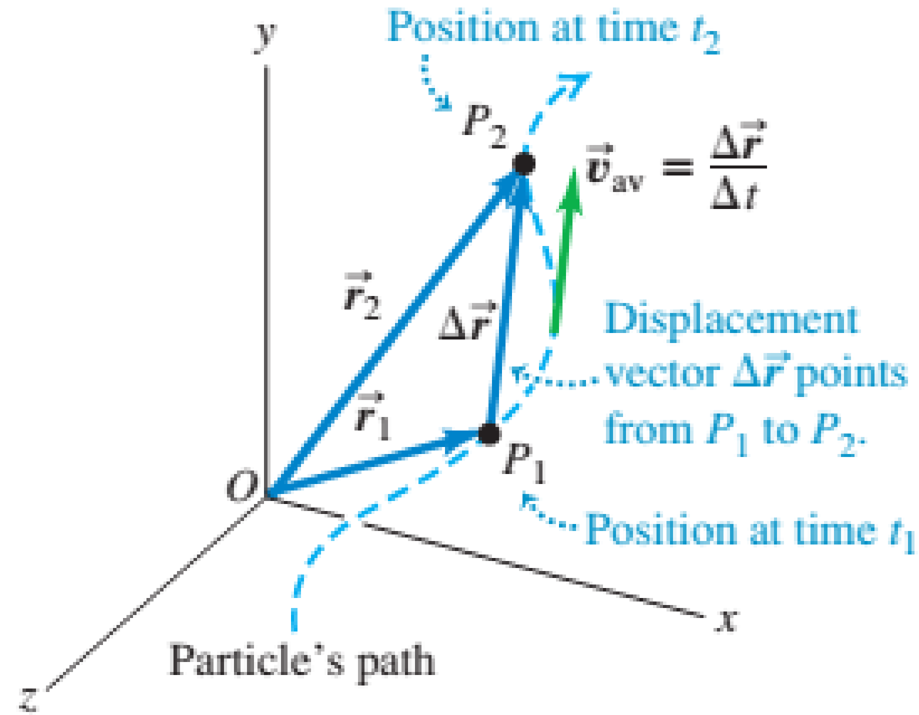
To describe the *motion* of a particle in space, we must first be able to describe the particle's *position.* Consider a particle that is at a point *P* at a certain instant. The **position vector** $\vec{r}$ of the particle at this instant is a vector that goes from the origin of the coordinate system to the point *P* (as shown in the figure). The Cartesian coordinates *x*, *y*, and *z* of point *P* are the *x*-, *y*-, and *z*-components of vector $\vec{r}$.Using the unit vectors we can write

$$\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$$



Position Vector and Displacement Vector:

During a time interval Δt the particle moves from P_1, where its position vector is $\vec{r}_1$ to P_2, where its position vector is $\vec{r}_2$.The change in position (the displacement) during this interval is



$$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$$

$$\Delta\vec{r} = x_2\hat{\imath} + y_2\hat{\jmath} + z_2\hat{k} - (x_1\hat{\imath} + y_1\hat{\jmath} + z_1\hat{k})$$

$$\Delta\vec{r} = (x_2 - x_1)\hat{\imath} + (y_2 - y_1)\hat{\jmath} + (z_2 - z_1)\hat{k}$$

$$\Delta\vec{r} = \Delta x\hat{\imath} + \Delta y\hat{\jmath} + \Delta z\hat{k}$$

Average Velocity and Instantaneous Velocity:

If a particle moves through a displacement $\Delta\vec{r}$ in a time interval Δt, then its **average velocity** $\vec{v}_{avg}$ is

$$\vec{v}_{avg} = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} = \frac{\Delta\vec{r}}{\Delta t}$$

Instantaneous velocity (simply, velocity $\vec{v}$) is the limit of the average velocity as the time interval approaches zero, and it equals the instantaneous rate of change of position with time. That is

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

The *magnitude* of the vector $\vec{v}$ at any instant is the *speed* of the particle at that instant. The *direction* of $\vec{v}$ at any instant is the same as the direction in which the particle is moving at that instant.

Note: At every point along the path, the instantaneous velocity vector is tangent to the path at that point.

- Create a particle's position vector as a function of time and evaluate its (instantaneous) velocity vector.

$$\vec{r}(t) = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$$

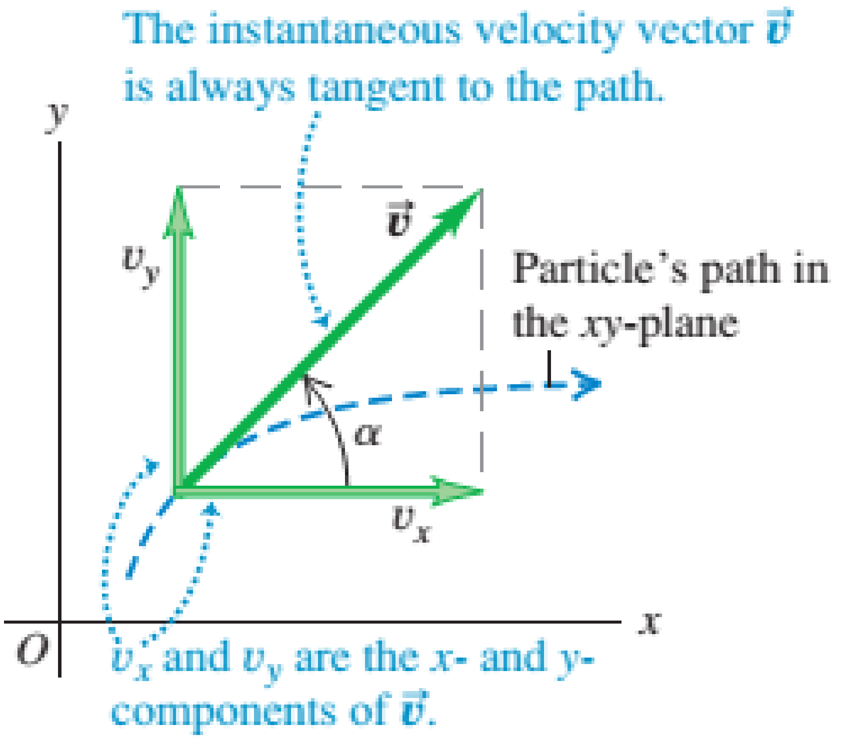
We have the definition of velocity vector,

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

$$\vec{v} = \frac{d}{dt}\,(x\hat{\imath} + y\hat{\jmath} + z\hat{k}) = \frac{dx}{dt}\hat{\imath} + \frac{dy}{dt}\hat{\jmath} + \frac{dz}{dt}\hat{k} = v_x\hat{\imath} + v_y\hat{\jmath} + v_z\hat{k}$$

The **magnitude** of the instantaneous velocity vector $\vec{v}$ —that is, the speed—is given in terms of the component v_x, v_y and v_z by the Pythagorean relation:

$$|\vec{v}| = v = \sqrt{v_x^2 + v_y^2 + v_z^2}$$



The adjacent Figure shows the situation when the particle moves in the *xy*-plane. In this case, *z* and v_z are zero. Then the speed (the magnitude of $\vec{v}$) is

$$v = \sqrt{v_x^2 + v_y^2}$$

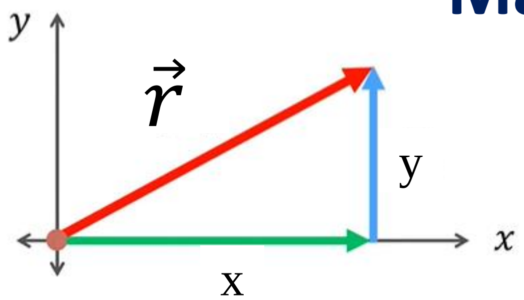
The **direction** of the instantaneous velocity is given by the angle α *(the* Greek letter alpha) in the figure.

$$\tan\alpha = \frac{v_y}{v_x}$$

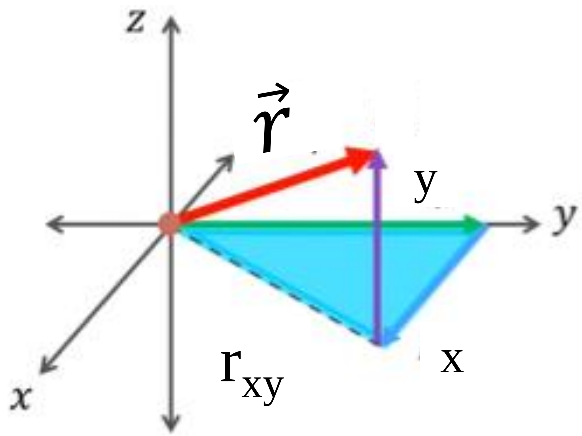
And

$$\alpha = \tan^{-1}\frac{v_y}{v_x}$$

Magnitude of a vector in 2D & 3D

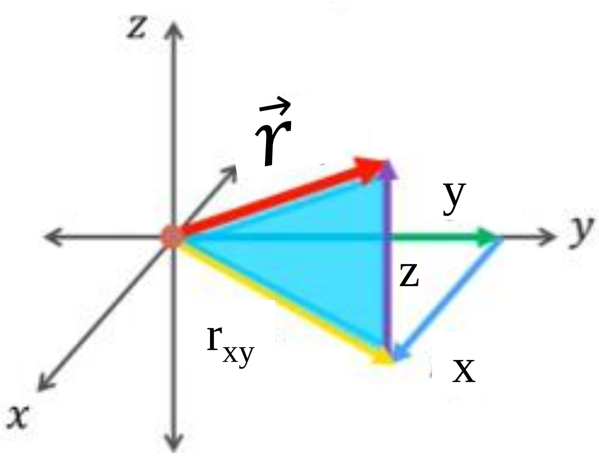


$$r = \sqrt{x^2 + y^2}$$



Triangle 1

$$r_{xy} = \sqrt{x^2 + y^2}$$



Triangle 2

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

Average acceleration and Instantaneous acceleration:

If a body's (or particle's) velocity changes from $\vec{v}_1$ to $\vec{v}_2$ in time interval Δt , its average acceleration during Δt is

$$\boxed{\vec{a}_{avg} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} = \frac{\Delta\vec{v}}{\Delta t}}$$

If Δt approaches to zero about some instant, then in the limit $\vec{a}_{avg}$ approaches the **instantaneous acceleration** (or **acceleration**) at that instant; that is,

$$\boxed{\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}}$$

- Create a particle's velocity vector as a function of time and evaluate its (Instantaneous) acceleration vector.

$$\boxed{\vec{\boldsymbol{v}}(\boldsymbol{t}) = v_x\hat{\boldsymbol{\imath}} + v_y\hat{\boldsymbol{\jmath}} + v_z\widehat{\boldsymbol{k}}}$$

$$\boxed{\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}\left(v_x\hat{\boldsymbol{\imath}} + v_y\hat{\boldsymbol{\jmath}} + v_z\widehat{\boldsymbol{k}}\right) = \frac{dv_x}{dt}\hat{\imath} + \frac{dv_y}{dt}\hat{\jmath} + \frac{dv_z}{dt}\hat{k}}$$

$$\boxed{\vec{a} = a_x\hat{\imath} + a_y\hat{\jmath} + a_z\hat{k}}$$

Problem 3 (Book chapter 4)

A positron undergoes a displacement $\Delta\vec{r} = 2\hat{\imath} - 3\hat{\jmath} + 6\hat{k}$, ending with the position vector $\vec{r} = 3\hat{\jmath} - 4\hat{k}$, in meters. What was the positron's initial position vector?

Answer:

We have $\Delta\vec{r} = \vec{r} - \vec{r}_1$

$$\boxed{\vec{r}_1 = \vec{r} - \Delta\vec{r} = 3\hat{\jmath} - 4\hat{k} - \left(2\hat{\imath} - 3\hat{\jmath} + 6\hat{k}\right) = 3\hat{\jmath} - 4\hat{k} - 2\hat{\imath} + 3\hat{\jmath} - 6\hat{k}}$$

$$\boxed{\vec{r}_1 = -2\hat{\imath} + 6\hat{\jmath} - 10\hat{k}}$$

Problem 13 (Book chapter 4)

A particle moves so that its position (in meters) as a function of time (in seconds) is $\vec{r} = \hat{\imath} + 4t^2\hat{\jmath} + t\hat{k}$. Write expressions for (a) its velocity and (b) its acceleration as functions of time.

Answer:

We have
$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{v} = \frac{d}{dt}\left(\hat{\imath} + 4t^2\hat{\jmath} + t\hat{k}\right) = 0 + 8t\,\hat{\jmath} + \hat{k} = 8t\,\hat{\jmath} + \hat{k}$$

Again, we have
$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{a} = \frac{d}{dt}\left(8t\,\hat{\jmath} + \hat{k}\right) = 8\,\hat{\jmath} + 0 = 8\,m/s^2\,\hat{\jmath}$$

Let's practice

1. A train at a constant 60.0 km/h moves east for 40.0 min, then in a direction 50.0° east of due north for 20.0 min, and then west for 50.0 min. What are the (a) magnitude and (b) angle of its average velocity during this trip?
2. [Chap 4 - problem 7]: An ion's position vector is initially $\vec{r} = 5\,\hat{\imath} - 6\hat{\jmath} + 2\,\hat{k}$, and 10 s later it is $\vec{r} = -2\,\hat{\imath} + 8\hat{\jmath} - 2\,\hat{k}$, all in meters. In unit vector notation, what is its $\vec{v}_{avg}$ during the 10 s?
3. [Chap 4 - problem 11]: The position of a particle moving in an r xy plane is given by $\vec{r} = (5t^3 - 5t)\hat{\imath} + (6 - 7t^4)\hat{\jmath}$, with $\vec{r}$ in meters and t in seconds. In unit-vector notation, calculate (a) $\vec{r}$, (b) $\vec{v}$, and (c) $\vec{a}$ for t = 2.00 s.
4. [Chap 4 - problem 14]: A proton initially has $\vec{v} = 4\,\hat{\imath} - 2\hat{\jmath} + 3\,\hat{k}$ and then 4.0 s later has $\vec{v} = -2\,\hat{\imath} - 2\hat{\jmath} + 5\,\hat{k}$ (in meters per second). For that 4.0 s, what are (a) the proton's average acceleration $\vec{a}_{avg}$ in unit vector notation, (b) the magnitude of $\vec{a}_{avg}$, and (c) the angle between $\vec{a}_{avg}$ and the positive direction of the x axis?

Thank you