1. Details of Module and its structure

Module Detail	
Subject Name	Physics
Course Name	Physics 01 (Physics - Part 1, Class XI)
Module Name/Title	Unit 2, Module 1, Rest and Motion Chapter 3, Motion in a Straight Line
Module Id	Keph_10301_eContent
Pre-requisites	Knowledge of objects, Speed, displacement, Cartesian plane.
Objectives	**After going through this module, the learners will be able to :** • Understand the meaning of rest and motion • Recognize the involvement of time to describe moving objects • Conceptualize the idea of frame of reference, • Develop an understanding of limitations of our study • Appreciate the advantage of considering real objects as point objects
Keywords	Frame of reference, point object, rest, motion, point object, inertial frame of reference, non-inertial frame of reference

2. Development Team

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TABLE OF CONTENTS:

1. UNIT SYLLABUS

This unit will be covered in two parts

Chapter 3: Motion in a straight line

Frame of reference, motion in straight line, motion, position –time graph Speed and velocity Elementary concepts of differentiation and integration for describing motion, uniform and non-uniform motion, average speed and instantaneous velocity, uniformly accelerated motion, velocity –time and position time graphs relations for uniformly accelerated motion - equations of motion (graphical method).

Chapter 4: Motion in a plane

Scalar and vector quantities, position and displacement vectors, general vectors and their notations, multiplication of vectors by a real number, addition and subtraction of vectors, relative velocity, unit vector, resolution of a vector in a plane, rectangular components, scalar and vector product of vectors

Motion in a plane, cases of uniform velocity and uniform acceleration projectile motion uniform circular motion.

2. MODULE-WISE DISTRIBUTION OF UNIT SYLLABUS 10 Modules

The above unit is divided into 10 modules for better understanding

Module 1	• Introduction to moving objects • Frame of reference, • limitations of our study • treating bodies as point objects
Module 2	• Motion as change of position with time • Distance travelled unit of measurement • Displacement negative, zero and positive • Difference between distance travelled and displacement • Describing motion by position time and displacement time graphs
Module 3	• Rate of change of position • Speed • Velocity • Zero , negative and positive velocity • Unit of velocity • Uniform and non-uniform motion • Average speed • Instantaneous velocity • Velocity time graphs • Relating position time and velocity time graphs
Module 4	• Accelerated motion • Rate of change of speed, velocity • Derivation of Equations of motion
Module 5	• Application of equations of motion • Graphical representation of motion • Numerical
Module 6	• Vectors

	• Vectors and physical quantities • Vector algebra • Relative velocity • Problems
Module 7	• Motion in a plane • Using vectors to understand motion in 2 dimensions' projectiles • Projectiles as special case of 2 D motion • Constant acceleration due to gravity in the vertical direction zero acceleration in the horizontal direction • Derivation of equations relating horizontal range vertical range velocity of projection angle of projection
Module 8	• Circular motion • Uniform circular motion • Constant speed yet accelerating • Derivation of $a = \frac{v^2}{r}$ $or\ \omega^2 r$ • direction of acceleration • If the speed is not constant? • Net acceleration
Module 9	• Numerical problems on motion in two dimensions • Projectile problems
Module 10	• Differentiation and integration • Using logarithm tables

Module 1

3. WORDS YOU MUST KNOW

- **Rigid body-** If distance between any pair of particles does not change then body is said to be rigid body.
- **Point object-** If distance travelled by a body is much greater than the size of the body then the object is considered as point object.

4. INTRODUCTION

This module serves as an introduction to motion. We will develop the concept of position of an object, change in position of an object in certain duration of time and relative nature of motion. We will limit ourselves to objects moving in a straight line as rigid point objects.

In kinematics, we study ways to describe the motion without going into the causes of motion. We will study causes of motion of objects in another unit.

We will also visualize real life situations related to the above concept mathematically and graphically. The module includes videos, film clips, graph analysis and problems.

Motion is common to everything in the universe. The earth rotates around the sun and the sun itself is in motion in the Milky Way galaxy, which is again moving in the local group of galaxies. We walk, run, ride a bicycle or sit in a bus and go. Even while sleeping air moves in and out of our systems at all times.

When we say a body has moved, it is with respect to its original position. What needs to be considered is that the body changes its position and sometime must elapse for this activity.

If there is no time elapsed, we cannot say the object moved because time is continuously changing.

Motion is change in position of an object with time. How does the position change with time? In this module, we shall learn how to describe motion. For this, we develop concepts of object, position of an object. We shall first confine ourselves to the study of motion of objects along a straight line, also known as rectilinear motion. This is because in real life we see complex motions. For example, a boy playing football in the field, his legs are moving, hands are moving, his head is moving etc.

In our discussions, we shall treat the objects in motion as point objects. This approximation is valid so far as the size of the object is much smaller than the distance it moves in a reasonable duration of time. In a good number of situations in real-life, the size of objects can be neglected and they can be considered as point-like objects without much error.

In kinematics, we study ways to describe motion without going into the causes of motion.

5. OBJECT

In physics we refer to all concerned bodies, for which we are observing any motion. So in our example of a boy in the football game we will treat him as an object and so is the football .This is being done in order to focus on the motion of the boy or the motion of the ball. Regardless of why they moved, that is what caused them to move.

So, in the physics course, we often say 'an object is' or 'a body is'….

6. NEED TO CONSIDER BODIES AS POINT OBJECTS

Consider a red dot on the car. The motion of the car as a whole can be described as the motion of the red dot. This is especially true if the distance travelled by the car is much larger than the size of the car.

Bodies in real life may be rigid or non-rigid. They may be of any size and shape.

We can say that **a rigid body is**

- **A body with a perfectly definite and unchanging shape, the distance between any pair of particles does not change.**
- **If all points in an object move in the same way, that they may be represented by any one of them we can treat the big body as a point object in many real life situations.**
- **In general, a rigid body may be referred to as point object**
- **Whenever we consider the motion of a body, we generally deal with it as a point object. In reality, however, there is nothing like a point object. Even the simplest bodies consist of a large number of particles.**

The advantage of idealizing a body as a point object is that the mathematical calculations become simple.


https://pixabay.com/images/search/motorcycle/

https://www.maxpixel.net/Couple-Travel-Old-Couple-Village-Road-Bicycle-2448478

watch: This video shows a swimmer under water.

https://www.youtube.com/watch?v=5fg95DojzTE

In all the cases, it is easier to take the moving object as a point object if we are only studying the motion - change in its position as a whole.

EXAMPLE:

In which of the following examples of motion, can the body be considered approximately a point object:

(a) a railway carriage moving without jerks between two stations.

(b) a monkey sitting on top of a man cycling smoothly on a circular track.

(c) a spinning cricket ball that turns sharply on hitting the ground.

(d) a tumbling beaker that has slipped off the edge of a table.

SOLUTION: Only (a) and (b), because in others the size of object is comparable to the distance.

So, now we can generalize that when the size of a body is small compared with the relevant dimensions of the system, the body may be considered as a point object

- When we discuss the motion of the earth round the sun, the earth can be considered as a point object.
- Motion of stars in the Galaxy can be studied as if they were point objects.
- A cricket ball can be taken as a point object when its trajectory is considered on a cricket field.
- A bus with all the passengers can be taken as a point object.

However, when we consider the motion of the earth on its axis, it cannot be considered a point object or a swinging water bottle cannot be considered a point object.

But we can say that even a big aircraft or a long train, or a car can be treated a point objects.

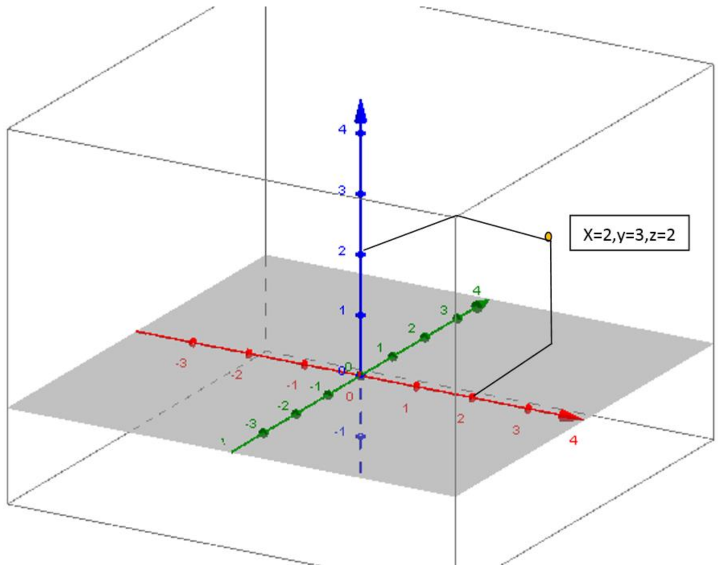
7. POSITION OF AN OBJECT

In daily life, we need to know where things are with respect to their surroundings.

It is only then we say that a body continues to be at rest or in motion with respect to its surroundings.

Physics defines the location of an object by assigning a position to it. We can use the idea of coordinate system from mathematics, and take zero point or origin as reference to any position where the object may be located.

We have used (x, y, z) as the position coordinates.



In the fig, the yellow dot is located at (2,3,2), we notice we will say it moved only when the coordinates change, also the body can only be at one location at an instant of time, to be at another location it would take some time which we refer as time elapsed, time interval duration of motion etc

The change in coordinates gives an idea about the motion of the body. These coordinates are also called dimensions

So if out of the three x, y, z if only one changes, then the motion is in one dimension, if any two change, then motion is in two dimension, and if all three change, then the motion would be in three dimension.

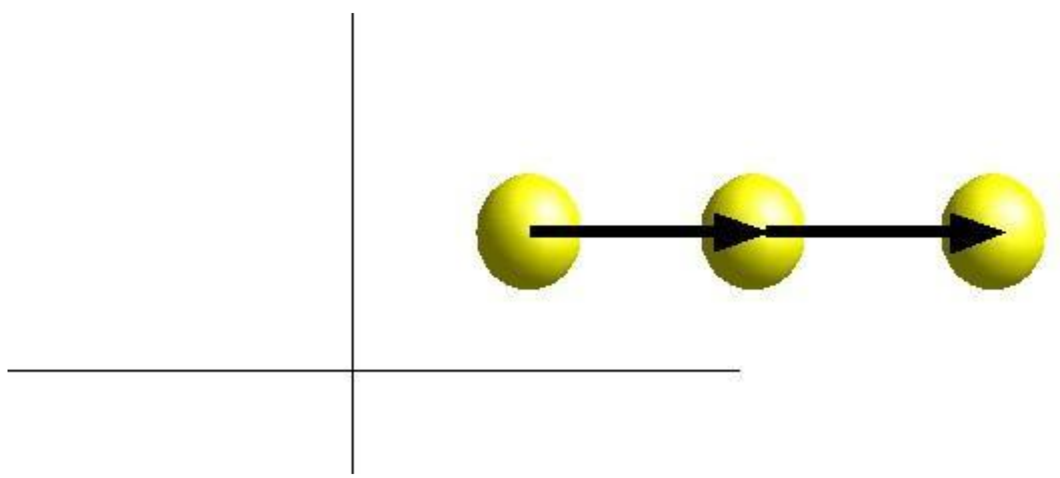
Dimension

We have learnt earlier
Dimension is - a measurable extent of a particular kind, such as length, breadth, depth, or height.
"The final dimensions of the pond were 14m x10m x 5 m

Dimension of a physical quantity is the powers to which M L T should be raised to determine its dimensional; formula
"Dimensions of area are $M^0L^2\,T^0$"
Dimension also means spatial extent, here in this module it implies change in position in one dimension so for coordinates (x, y z) only one of them changes while the others remains the same for two dimension any two of x, y or z change likewise for movement in three dimension x, y and z change to indicate the position of an object at any instant.

EXAMPLE

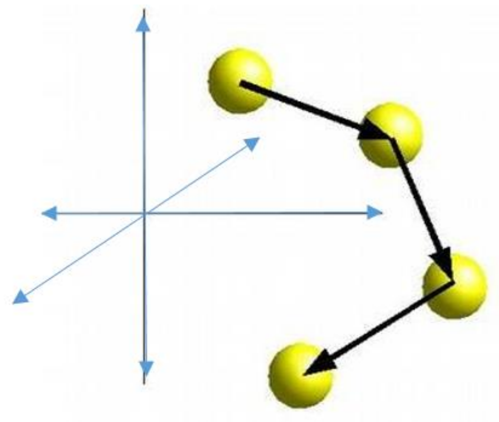
The ball moves along a straight line in the positive x direction

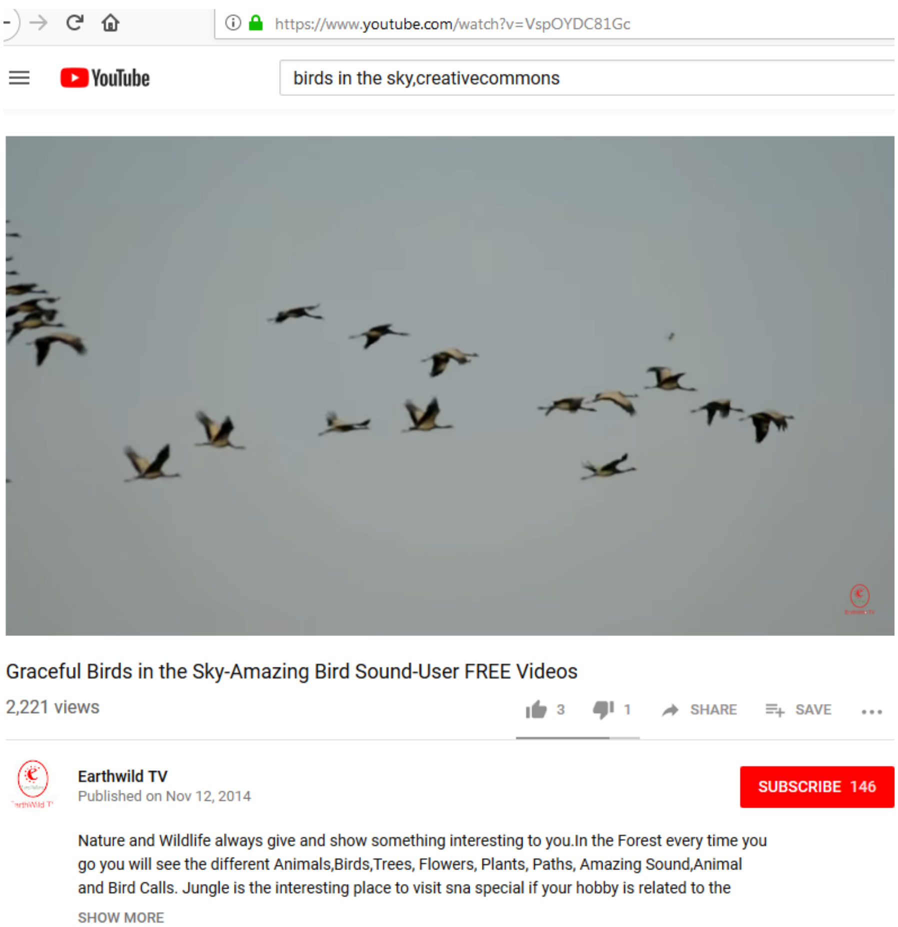


Here the only coordinate that will change will be x this is referred as motion in one dimension.

EXAMPLE

The ball moves in straight paths between each position shown but as a whole the motion is not along a straight line.





Watch the video

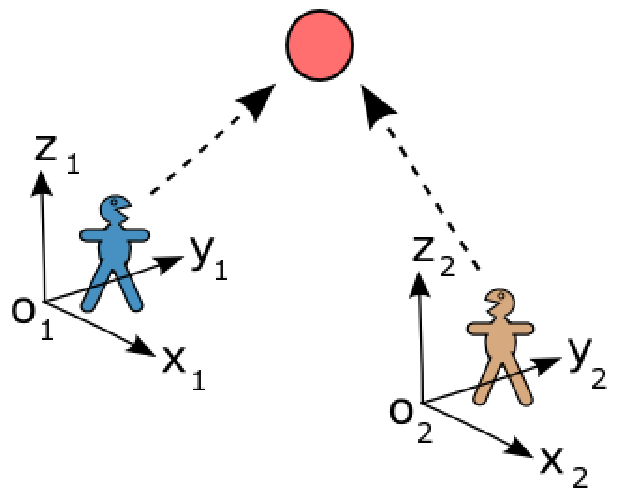
https://www.youtube.com/watch?v=VspOYDC81Gc

Here all three coordinates are changing as the birds fly.

8. FRAME OF REFERENCE

'Imagination is more important than knowledge' Albert Einstein

So when a body moves we need to imagine its surroundings like we said earlier, a co-ordinate system consisting of three mutually perpendicular X,Y and Z axes with their point of intersection O (0,0,0) as reference point . Location of body at any instant can be described by (x, y, z) coordinates. What if the coordinate system was attached to the body or was moving or starts rotating or oscillating?

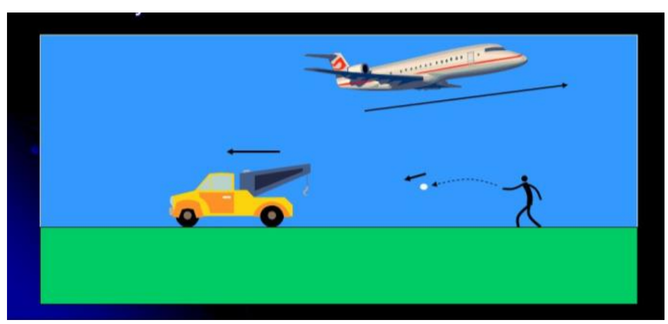


The position coordinates as seen by the two persons will be different.

Watch the animation

https://www.youtube.com/watch?v=aZAthZq9OfE

The animation shows two carts moving in different directions, like cars or vehicles on the road, our observation of road side stalls, vehicles, or tress depends upon whether we are standing on the pavement, are in a bus or a car. Observe the picture you may be in the plane flying at low height, in the van, or you may be the person throwing the ball or may be sitting on the ball (hypothetically): For each one, the motion of the ball is different.

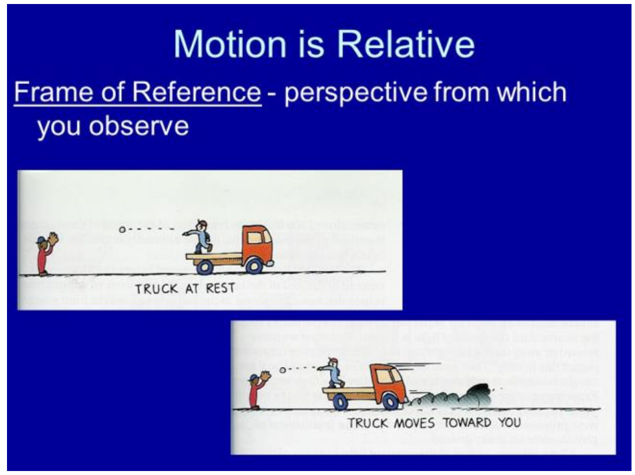


Frame of reference is the perspective from which an observer views the situation; there is no absolute frame of reference in our universe, no stationary platform from which we can observe all other motions. The only constant measurement as of now is the speed of light.

If one or more coordinates of an object change with time, we say that the object is in motion. Otherwise, the object is said to be at rest with respect to this frame of reference. **The choice of a set of axes in a frame of reference depends upon the situation**.

For example, **for describing motion in one dimension, we need only one axis. To describe motion in two/three dimensions, we need a set of two/three axes**.

Description of an event depends on the frame of reference chosen for the description. For example, when you say that a car is moving on a road, you are describing the car with respect to a frame of reference attached to you or to the ground. But with respect to a frame of reference attached with a person sitting in the car, the car is at rest.



http://slideplayer.com/slide/6083835/

Watch the animation to understand frame of reference

https://www.youtube.com/watch?v=XhTKqmaUP5k

Video lesson to understand reference frame, video uses animation.

https://www.youtube.com/watch?v=XcdJjGk-M58

Animation of a video game to show motion is always described in terms of a reference frame.

MOVING AND STATIONARY INERTIAL FRAMES:

There are endless examples of relative motion. Suppose that you are in an elevator that is rising with a constant speed of 2 m/s relative to the ground. If you released a ball while in this reference frame, how will the motion of the ball differ than had you dropped the ball while standing on the ground? After the brief acceleration period, you can no longer sense the motion of the elevator. The ball will move as if it has been released in the reference frame of Earth.

Had you been asleep in a moving train and woke up after the compartment was in motion. You would have no idea you were in motion. There is no experiment that can be performed to detect constant motion.

If you have ever travelled in a jet moving 1000 km/h with no air turbulence, then you know from firsthand experience that you felt as though you were stationary.

As a general statement, we consider all constant velocity reference frames to be equivalent. This idea is known as the Galilean principal of relativity. Constant velocity reference frames are called **inertial frames of reference.**

An **"at – rest' or stationary reference frame** is an arbitrary idea. If you are travelling with a constant velocity in your car, the reference frame of the car is an 'at rest' frame. When in an elevator (lift) moving at 2 m/s, you are 'at rest' with respect to the lift. You who are sitting and reading this firmly placed on the earth- consider yourself to be in at rest reference frame.

But you know the earth itself is in motion.

It rotates about its axis with a speed of about **1600 km/h at the equator**, and it orbits the sun with an average speed of 108,000 km/h. In fact, the earth is not even an inertial frame of reference, since it rotates about its axis and its orbital speed varies. (Remember, velocity is constant only if its magnitude and direction do not change- objects in circular motion do not qualify!) we usually approximate the earth as an inertial frame since we do not readily sense the earth's motion **Objects on earth's surface have a maximum acceleration due to its rotation of about 0.03 m/s^2 which we don't typically concern ourselves with since the acceleration due to gravity of 10 m/s^2.**

So, **the reference frame may be assumed to be:**

- **Stationary or**
- **Moving with constant velocity** with respect to the moving object. These are called **inertial frame of reference.**

Accelerating or rotating frames are called **non- inertial frames of reference**.

We will imagine and deal with ideal inertial frame for simplicity.

9. IMPORTANCE OF TIME ELAPSED

Just think about these:

A boy ran from his school gate at 12 noon and he reached the bus stop at 12 noon

A lady left her home for the market at 4:15pm and she reached the market at 4:15pm

The two statements are not possible because some time will be needed for any motion of the object with respect to the surroundings.

Hence we need to use terms like **'in time'', 'time elapsed', or 'time interval'** .

This is represented by Δ**t = (t_2-t_1) or (t_f –t_i) indicating the time interval between when we start observing an object to time when we decide to stop looking at it.**

During this interval it may remain in its place with respect to its surroundings or may change its position.

We can say **'at an instant'**, this would mean just then as the clock or watch strikes that time.

In such a situation we cannot speak about motion at all. Because at an instant the object would be at one position only and will have only one set of coordinates. For any of the three (x, y, z) to remain the same or change time should pass or elapse.

10. REST AND MOTION

If the position of an object with respect to its surroundings changes with time, the object is said to be in motion which implies:

- **If the position co-ordinates of an object do not change with respect to an inertial frame of reference with time, the body is said to be at rest.**
- **If the position co-ordinates of an object change with respect to an inertial frame of reference with time, the body is said to be in motion.**
- **Motion is always relative; it is meaningful when expressed with reference to a frame of reference**

THINK ABOUT THESE

- **Two friends are sitting in a moving bus:**

i. **Are they moving when observed by each other?**

ii. **Are they moving when observed by a third friend outside the bus?**

iii. **If the bus stops, are they still in motion?**

- **Is our school building moving? If so with respect to which frame of reference?**

- **A book is lying on a table:**

i. **Describe the state of rest or motion as observed by you sitting on a chair next to the table.**

ii. **Describe its state of rest or motion as observed by you walking in a straight line near the table.**

iii. **Describe its state of rest or motion as observed by a moving satellite camera.**

iv. **When will the book be at absolute rest?**

11. SUMMARY

In this module you have learnt:

- A finite body may be described as appoint object
- A body is said to be at rest when it does not change its position with respect to its surrounding
- A body is said to be in motion when it changes its position with respect to its surrounding
  - Motion is relative and we need a frame of reference to describe motion as well as rest
  - Frame of reference can be the Cartesian coordinate system. in this system the position of an object is given by (x, y, z) its coordinates with respect to the origin (0, 0, 0).
- Frame of reference is called Inertial if it is stationary or moving with constant velocity (constant speed and same direction) and non- inertial frame of reference in case the frame of reference is rotating or accelerating
- An object can move in one dimension, two or three dimension. This is identified by how many coordinates are changing from one position to another.
- Some time is always elapsed when an object moves from one position to another. This is called time interval between final and initial positions.