Unit
03 Motion in a straight line

Introduction

In this chapter we study the simplest kind of motion: a single particle moving along a straight line. To describe the motion of a particle, we introduce the physical quantities velocity and acceleration.An important special case of straight-line motion is that when the acceleration is constant, a situation that we will encounter many times in our study of Physics. An example is the motion of a freely falling body.

Values and attitudes

- Selects and use appropriate visual, numeric, graphical and symbolic mode of representation to identify and represent relations.
- Develops the scientific skills like critical thinking, creative thinking and problem solving.
- Develops attitudes to wear helmets during riding two wheelers and seat belts during riding four wheelers.

Total Time : 11 periods

Concepts and Process skills	Process/Activity with assessment	Learning outcome
Frame of reference, Motion, Rectilinear motion and Kinematics • Observing • Comparing	• General Discussion • ICT for frame of reference	• Defines frame of reference, motion, rectilinear motion and Kinematics
Position, Pathlength, Displacement, Uniform motion, Position-time graphs • Observing • Identifying • Classifying • Infering	• General Discussion • Group Discussion • Graphical Method • ICT-PHET-Moving man Assessement:- Involvement in group discussion. Activity Log Book(Portfolio)	• Explains position, pathlength and displacement and Interprets position-time graph
Average velocity and Average Speed • Observing • Comparing • Predicting	• General Discussion • Drawing position-time graph and solving problems.	• Distinguishes average speed and velocity.
Instantaneous velocity and Speed • Observing • Comparing • Predicting	• General Discussion • Drawing position-time graph • solving numerical problems.	• Solves numerical problems of average speed and velocity. • Draws position-time graph and interprets it.
Acceleration • Observing • Identifying • Experimenting	• General Discussion • Drawing (a-t) and (x-t)graphs to discuss +ve, -ve accelerations. • Draws (v-t) graph and shows that area under the graph gives displacement • ICT • Ticker- Timer Expt- Project Assessement:- Involvement in group discussion. Activity Log Book-Project report (Portfolio)	• Solves numerical problems of instantaneous speed and velocity. • Formulates the concept that for uniform motion, velocity is same as the average velocity at all instants.

Concepts and Process skills	Process/Activity with assessment	Learning outcome
Kinematics equations for uniformly accelerated motion. • Observing • Infering • Problem solving	• General Discussion • Group Discussion • Drawing graphs	• Establishes the relation between velocity and distance. • Draws and interprets (a-t) and (x-t) graphs • Solves numerical problem related with acceleration. • Formulates equations of kinematics using (v-t) graph. • Solves problems related with kinematic equations. • Applies the kinematic equations to different cases of free fall • Develops Galileo's law of Odd numbers, stopping distances of vehicles, concept of reaction time and solves problems related with them.
Relative velocity • Observing • Comparing • Identifying • Interpreting	• General Discussion • Group Discussion • Drawing (x-t) graphs • Solve problems • ICT to get idea of relative Velocity Assesement:- Involvement in group discussion. Activity Log Book-Project report (Portfolio)	• Explains relative velocity, draws graphs and solves problems related to it.

TOWARDS THE UNIT

Content:-Frame of reference, Motion, Rectilinear Motion and Kinematics

Suggested Activity- 3.1 General Discussion

A student in the second bench is asked to stand up

Discussion points

- Whether the student is in motion or rest? Why?

  Hint:-If the position of the student changes with time, the student is in motion.
- What is the position of the student with respect to third bench?
- What is the position of the student with respect to first bench?
- What is the position of the student with respect to board?
- How is the position of the student described w.r.to the co-ordinate system?

  Hint:- The co-ordinates (x,y,z) describe the position of the student w.r.to the co-ordinate system.
- From where the distances along X, Y and Z axes measure λ

  Hint:-The point of intersection of the three mutually perpendicular axes in a cartesian co-ordinate system.

The teacher points out the necessity of the clock to measure time.

The teacher explains that in order to locate the position of the student, a co-ordinate system with a clock is required.This is called a frame of reference.

The teacher asks the students to imagine a rope tied across the class room and an ant is moving along the rope.

- How many co-ordinates require to locate the position of ant?
- What type of motion is this?
- Hint:-Rectilinear motion (One Dimensional Motion).
- If the ant is moving on the surface of the floor, how many co-ordinates are required to locate the position of ant?
- What type of motion is this?
- Hint:-Two Dimensional Motion.
- If a bird is flying in the sky, how many co-ordinates are required?
- what type of motion is this?

  Hint:-Three dimensional motion.

The teacher explains that the branch of mechanics which describe motion without describing the causes of motion is called kinematics.

The students are asked to write examples for one,two and three dimensional motions.

One Dimensional Motion	Two Dimensional Motion	Three Dimensional Motion
……	……	……
……	……	……
……	……	……
……	……	……

Consolidation

The teacher consolidates

- reference point
- frame of refernce
- motion
- rectilinear motion, two & three dimensional motion
- kinematics

Content:-Position, Path length and Displacement

Suggested Activity-3.2

Group Discussion, ICT

With the help of ICT, the students are shown the motion of a car along a straight line. The teacher explains that the x-axis is chosen such that it coincides with the path of the motion of the car and origin of the axis as the point from where the car started to move. The students are grouped, given data and are directed to draw x-axis, origin and positions of the car at different time (Fig.3.1 of NCERT Text).

The teacher draws a triangle ABC on the blackboard. The teacher says that a student walks from A to B and then from B to C

Discussion points

- What is the distance travelled by the student from A to B and then from B to C?

  Hint:- Path length
- What is the shortest distance between C (final position) and A(initial position) ?

Hint:- displacement

- What is the path length of the tip of the hour hand in a clock during 12hours?
- What is the displacement of the tip of the hour hand during this time interval?

  Hint:-zero
- When does pathlength of an object equal to its displacement?

  Hint:-If the object moves along a straight line in a particular direction
- When can we say that displacement is negative?
- With the help of a position-time graph, show that the magnitude of displacement may or may not be equal to the path length traversed by an object.

Consolidation

The teacher consolidates

- Path length
- Displacement
- Differences between distance and displcement.

Content:-UNIFORM MOTION ALONG A STRAIGHT LINE

Suggested Activity-3.3-Group Discussion, Graphical Method

The students are grouped and the teacher draws a table on the blackboard as shown and asked the students to draw time along x axis

Time in seconds	X in m
0	10
2	10
4	10
6	10
8	10
10	10

Discussion Points

- Whether the object is at rest or in motion?
- What is the shape of the graph?

  Hint:-straight line parallel to time axis

Again teacher draws a table as shown and asked the students to draw *x*-t graph

Time in seconds	X in m
0	0
2	3
4	6
6	9
8	12
10	15

- What is the nature of the graph?
  Hint:- Straight line inclined to X-axis
- What is the distance travelled by the body in each time interval?
  Hint:-equal distances
- What is the name of this type of motion?
  Hint:-Uniform motion

The teacher asks the students to draw the positin-time graph from the following data

Time in seconds	X_1 in m	X_2 in m	X_3
0	15	0	-10
2	12	-2	-8
4	9	-4	-6
6	6	-6	-4
8	3	-8	-2
10	0	-10	0

- What is the shape of x_1 -t graph?
  Hint:-Straight line parallel to time axis
- What is the shape of x_2 -t graph?
  Hint:- Positive slope
- What is the shape of x_3 -t graph?

Consolidation

The teacher consolidates

- Uniform motion

- *Position-time graph of (a) stationary object and (b) objects in motion in different situations.

Content:-Average Velocity and Average Speed

Suggested Activity-3.4-General Discussion and Graphical Method

Discussion Points

- What happens when an object is in motion?

  Hint:- Its position changes with time.

The teacher explains that to understand how fast is the position of an object change with time and in what direction, average velocity is introduced.

- What is average velocity?

  Hint:-Definition, equation, unit and dimensions

The teacher draws x-t graph on the blackboard and shows that average velocity is the slope of the x-t graph.

Hint:- graph 3.4 in the NCERT Text

- To what physical quantity, average velocity is related?

  Hint:-Displacement

- Is the magnitude of displacement always equal to the actual path length?

  The teacher explains that average velocity involves only displacement of the object. The magnitude of displacement may be different from the actual path length. To describe the rate of motion over the actual path, average speed is to be introduced.

- What is average speed?

  The teacher helps the students to Illustrate with a problem that speed is greater than or equal to the magnitude of the velocity.

  Hint:- refer example 3.1 in the NCERT Text.

- What are the differences between Speed and Velocity?

Consolidation

The teacher consolidates

- Average velocity
- Average speed
- Problem to illustrate that speed is greater than or equal to the magnitude of the velocity
- Distinguishes between Speed and Velocity

Content:-Instantaneous Velocity and Speed

Suggested Activity-3.5-General Discussion

The teacher explains that the average velocity of a particle during a time interval can't tell us how fast, or in what direction , the particle was moving at any given time during the interval. The teacher points out that in Physics an instant has no duration at all, it refers to a single value of time.

Discussion Points

- Why instantaneous velocity is to be introduced?

  Hint:-To explain how fast an object moves at different instants of time, instantaneous velocity is introduced.
- What is instantaneous velocity?

  The teacher draws position-time graph (Fig. 3.7 in the NCERT Text) and helps the students to determine velocity from position-time graph.
- How can we draw velocity-time graph corresponding to the motion in the position-time graph?

  Hint:-Fig. 3.7 in the NCERT Text.

The teacher helps the students to Illustrate with a problem that for uniform motion, velocity is same as the average velocity at all instants.

Hint:-Example 3.2 in the NCERT Text.

- What is instantaneous speed?

Consolidation

The teacher consolidates

- Need for the introduction of instantaneous velocity.
- Instantaneous velocity
- Velocity from Position-Time graph
- Velocity-time graph corresponding to the motion in the position-time graph
- Problem to illustrate that for uniform motion, velocity is same as the average velocity at all instants.
- Instantaneous speed.

Content:-Acceleration

Suggested Activity-3.6-General Discussion and Graphical Method

Discussion Points

- Why the concept of acceleration is to be introduced?
- The velocity of an object, in general, changes during its course of motion. To describe this change, acceleration is to be introduced.
- What is average acceleration?
- What is negative acceration?

The teacher helps the students to show that average velocity is the slope of the straight line connecting different points in the velocity-time graph.

Hint:-Fig. 3.8 in the NCERT Text.

- What is instantaneous acceleration?
- Teacher helps the students to draw position-time graph for motion with (a)positive acceleration; (b) negative acceleration and (c) zero acceleration.

  Hint:-Fig. 3.9 in the NCERT Text.
- The teacher asks the students to draw velocity-time graph for motion with constant acceleration for the following cases

  (a)An object is moving in a positive direction with positive acceleration.

  (b)An object is moving in a positive direction with negative acceleration.

  (c))An object is moving in a negative direction with negative acceleration.

  (d))An object is moving in a positive direction till time t, and then turns back and moves with the same acceleration.

  Hint:_ Fig. 3.10 in the NCERT Text.
- Show that the area under the curve of velocity-time graph represents the displacement over a given time interval.

  Hint:_ Fig. 3.11 in the NCERT Text.

Consolidation

The teacher consolidates

- Acceleration
- Negative acceleration (Retardation)

- Average acceleration
- Average velocity is the slope of the straight line connecting different points in the velocity-time graph.
- Instantaneous acceleration
- Position-time graph for motion with (a)positive acceleration; (b) negative acceleration and (c) zero acceleration.
- Velocity-time graph for motion with constant acceleration for the following cases

  (a)An object is moving in a positive direction with positive acceleration.

  (b)An object is moving in a positive direction with negative acceleration.

  (c))An object is moving in a negative direction with negative acceleration.

  (d))An object is moving in a positive direction till time t_1, and then turns back with the same acceleration.
- The area under the curve of velocity-time graph represents the displacement over a given time interval.
- Differentiate between retardation and deceleration.

Content:-Kinematic Equations For Uniformly Accelerated Motion

Suggested Activity-3.7-General Discussion and Graphical Method

Discussion Points

- What is the relation between final and initial velocities v_0 and v of an object moving with uniform acceleration a?

  Hint:- $v = v_0 + at$

The teacher helps the students to represent this relation graphically

Hint:- Fig. 3.12 in the NCERT Text.

- What is the area under this curve?
- The area under this v-t graph represents ……..

Hint:- Displacement

- Now, what is the displacement of thisobject?

Hint:- $x = \frac{1}{2}(v - v_0)t + v_0 t$

- How we can simplyfy this relation using the relation $v - v_0 = at$?

  Hint:- $x = v_0 t + \frac{1}{2}at^2$ .....(1)

- How we can convert this relation using $\bar{v} = \frac{v + v_0}{2}$, the average velocity for constant acceleration?

  Hint:- $= \frac{1}{2}(v + v_0)t = \bar{v}t$

The teacher helps the students to rewrite this relation by substituting t from the equation $v = v_0 + at$

Hint:- $t = \frac{v - v_0}{a}$

$$x = \frac{1}{2}(v + v_0)t \quad = \quad x = \frac{1}{2}(v + v_0)\frac{(v - v_0)}{a}$$

$$x = \frac{v^2 - v_o^{\,2}}{2a}$$

$$v^2 - v_0^{\,2} = 2ax$$

$$v^2 = v_0^{\,2} + 2ax$$

- What are the kinematics equations of rectilinear motion for constant acceleration?

  Hint:- (1) $v = v_0 + at$

  (2) $x = v_0 t + \frac{1}{2}at^2$

  (3) $v^2 = v_0^{\,2} + 2ax$

- The teacher introduces the concept of integration and helps the students to obtain equations of motion for constant acceleration using the method of calculus.

The students are given Example 3.4 of NCERT Text and are asked to solve the probem.

The teacher explains that the most familiar example of motion with (nearly) constant acceleration is that of a body falling under the influence of the earth's gravitational attraction. When the effects of air can be neglected, all bodies at a particular location fall with the same downward acceleration, regardless of their size or weight. If the distance of fall is small compare to the radius of earth, the acceleration is constant.

The students are given the idea of acceleration due to gravity, 'g'.

- What is the value of 'g' near the surface of earth?
- If the upward direction is taken as positive, in which direction, the acceleration is?

Hint:- Negative y-direction. The acceleration is taken as -g

The teacher helps the students to write down the equations of motion in the case of an object released from rest at y = o and $v_0 = 0$ and to draw the graph showing the variation of acceleration, velocity and distance with time.

The teacher explains the Galileo's law of Odd numbers, stopping distances of vehicles and concept of reaction time with the help of Examples 3.6, 3.7& 3.8 of NCERT Text.

The students are given a project of Ticker-Timer Experiment

Consolidation

The teacher consolidates

- The Derivation of Kinematic equations
- Advantages of integration method

  Hint:- It can also be used for motion with non-uniform acceleration
- Free fall and acceleration due to gravity
- The graph showing the variation of acceleration, velocity and distance with time
- The Galileo's law of odd numbers, stopping distances of vehicles and concept of reaction time.

Content:-Relative Velocity

Suggeted Activity-3.8-General Discussion

The students recalls the experience of traveling in a train and being overtaken by another train moving in the same direction.

Discussion Points

- If that train travels faster than your train, what will you feel?
  Hint:-The train in which you are travelling is moving back.
- If that train travels slower than your train, what will you feel?
  Hint:- The other train is moving back.
- If both trains travel with the same velocity, what will you feel?
  Hint:-Both trains are stationary.
- If both trains travel in opposite directions with the same velocity, what will you feel?

The teacher introduces the concept of relative velocity (the velocity seen by a particular observer is called the velocity relative to that observer or simply relative velocity) to understand the above situations properly.

The teacher discusses the movement of two objects A and B moving uniformly with average velocities v and v_0 in one dimension. The teacher helps the students to draws Position-time graphs of two objects with equal and unequal velocities.

Consolidation

The teacher consolidates

- Relative velocity
- Position-time graphs related with relative velocity
- Solves numerical problems related with relative velocity

Work Sheets

Appendix-3.1

Time:10minutes

Name of the student……..

Class……..

Content:- Motion, Position, Pathlength and Displacement

1. The change in position of an object with time is called ……

   a.position b.pathlength c.motion d.displacement

2. The point of intersection of three mutually perpendicular axes in a cartesian co-ordinate system is …..

   a.frame of reference b.reference point

   c.rectilinear motion d.displacement

3.Which of the following is a vector quantity

   a.pathlength b.distance c.displacement d.both b and c

4. Comment on the statement "the magnitude of displacement is always equal to the pathlength travelled by an object".

5. If the displacement for a course of motion is zero, then the corresponding pathlength is

   a.zero b.not necessarily zero

   c.not zero d.none of these.

6.Draw position -time graphs of

   (a)stationary object (b)an object in uniform motion
   (c) an object in non-uniform motion

7. Distinguish between distance and displacement?

   Hints:-

   1.c 2.b 3.c 5.c

Appendix -3.2

Time:15minutes

Name of the student……..

Class……..

Content:- Average Velocity, Average Speed, Instantaneous Velocity and Speed

1. The quantity which describes, "how fast is the position of an object changing with time and in what direction", is

   a.Velocity b.Speed

   c.average velocity d.average speed

2. Distinguish between average speed and average velocity?
3. Suggest a situation such that the magnitude of average velocity is equal to the average speed.
4. What is the significance of instantaneous velocity?
5. Define instantaneous velocity.
6. Define instantaneous speed.
7. For ……., velocity is the same as the average velocity at all instants.

   a.rectilinear motion b.two dimensional motion
   c.uniform motion d.non-uniform motion

Hints:-

1.c 3.If the motion of an object is along a straight line and in the same direction, then the magnitude of displacement is equal to the total pathlength. 4. instantaneous velocity tell us how fast an object moves at different instants of time. 7.c

Appendix -3.3

Time:25minutes

Name of the student……..

Class……..

Content:- Acceleration, Kinematic equations for uniformly accelerated motion and relative velocity

1. A particle starts from rest and has an acceleration of $2m/s_2$ for 10seconds. After that, it travels for 30 seconds with constant speed and then undergoes a retardation of $4m/s_2$ and comes to rest. The total distance overed by the particle is

   a.650m b.700m c.750m d.800m

2. A body when released from the top of inclined plane of length 1m, reaches the bottom after 4 seconds. How much distance will it cover in the first two seconds?

   a.25cm b.40cm c.60cm d.75cm

3. Obtain equations of motion for constant acceleration using the method of calculus.

4. Prove that the distances traversed, during equal intervals of time, by a body falling from rest, stand to one another in the same ratio as the odd numbers beginning with unity.

5. Two trains A and B move in opposite directions along the same track with speeds 108km/h along north and 90km/h along south respectively. Find (a)velocity of A with respect to B (b)velocity of A with respect to ground (c)velocity of a monkey running on the roof of the train A against its motion (with a velocity of 18km/h with respect to the train A) as observed by a man standing on the ground.

Hints:-

1.c

2. $l = \frac{1}{2} g \sin\theta \, T^2$, $l_1 = \frac{1}{2} g \sin\theta \times (\frac{T}{2})^2$ and $l1 = l/4 = 25cm$

REPOSITORY CE ACTIVITIES

1. Process Assessment
   - General Discussion
   - Group Discussion on distance, displacement and uniform motion along a straight line
   - Project of Ticker-Timer experiment
   - Assignment of examples for one, two and three dimensional motions

2. Portfolio Assessment

3. Unit based Assessment
   - Unit Test
   - Quiz
   - Debate
   - Open Text Examination

   Draw Position-time graph as in Fig.3.3 of NCERT Text and

   (a) find average velocity in between t=8s and t=14s

   (b) find the instantaneous velocity at t=6s

   (c) find the instantaneous acceleration at t=6s

   (d) draw velocity-time graph between t=6s to t=18s

4. ICT Possibilites
   - frame of reference
   - PHET-moving man
   - Relative velocity

5. Sample TE Items:-

   1. Two bodies start moving in the same straight line at the same instant of time from the same origin. The first body moves with a constant velocity of 40m/s, and the second starts from rest with a constant acceleration of $4m/s^2$.

   (a) What is uniform speed?

   (b) Find the time that elapses before the second catches the first body.

   (c) Find the greatest distance between them prior to t and the time at which this occurs.

   Hint:- (b)When the second body catches the first, the distance travelled by each is the same.

$$\therefore 40t = \frac{1}{2}(4)\,t^2$$

$$t = 20s$$

(c)Now, the distance x between the two bodies at any time t is $x = ut - \frac{1}{2}at^2$

For x to be maximum, $\frac{dx}{dt} = 0$ or $u - at = 0$ or $t = \frac{u}{a} = \frac{40}{4} = 10s$

:. Maximum distance = $40\times10 - \frac{1}{2}\times4\times10^2 = 200m$

2. A particle thrown down from the top of a tower takes time t_1 to reach the ground. It takes time t_2 if thrown from the same point with the same speed in the upward direction.

(a) What happens to the velocity of the particle when thrown downwards and thrown upwards?

(b) Explain the concept of free fall

(c) Find the time it will take to fall freely to the ground from the top of the tower?

Hint:- (c)Taking downward direction as positive,

$$h = ut_1 + \frac{1}{2}gt_1^2 \quad \ldots\ldots\ldots\ldots\ldots(1)$$

and $h = -ut_2 + \frac{1}{2}gt_2^2$ ……..(2)

Muliplying eq. (1) by t_2 and eq. (2) by t_1 and adding the two, we get

$$h(t_1 + t_2) = \frac{1}{2}gt_1t_2(t_1 + t_2)$$

$$h = \frac{1}{2}gt_1t_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

If t is the time taken for free fall, then

$$h = \frac{1}{2}gt^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Comparing eq. (3) and eq. (4) $t = \sqrt{t_1t_2}$:

3. A balloon is rising vertically upwards with uniform acceleration 15.7m/s^2. A stone is dropped from it. After 4s, another stone is

dropped from it.

(a) What is acceleration?

(b) Name the velocity of the stone with respect to the balloon?

(c) Find the distance between the two stones 6s after the second stone is dropped.

Hint:- (b)relative velocity.

(c) If a is the upward acceleration of the balloon, then the acceleration of the stones relative to the balloon is (a+g). The initial velocity of each stone w.r.to the balloon is zero.

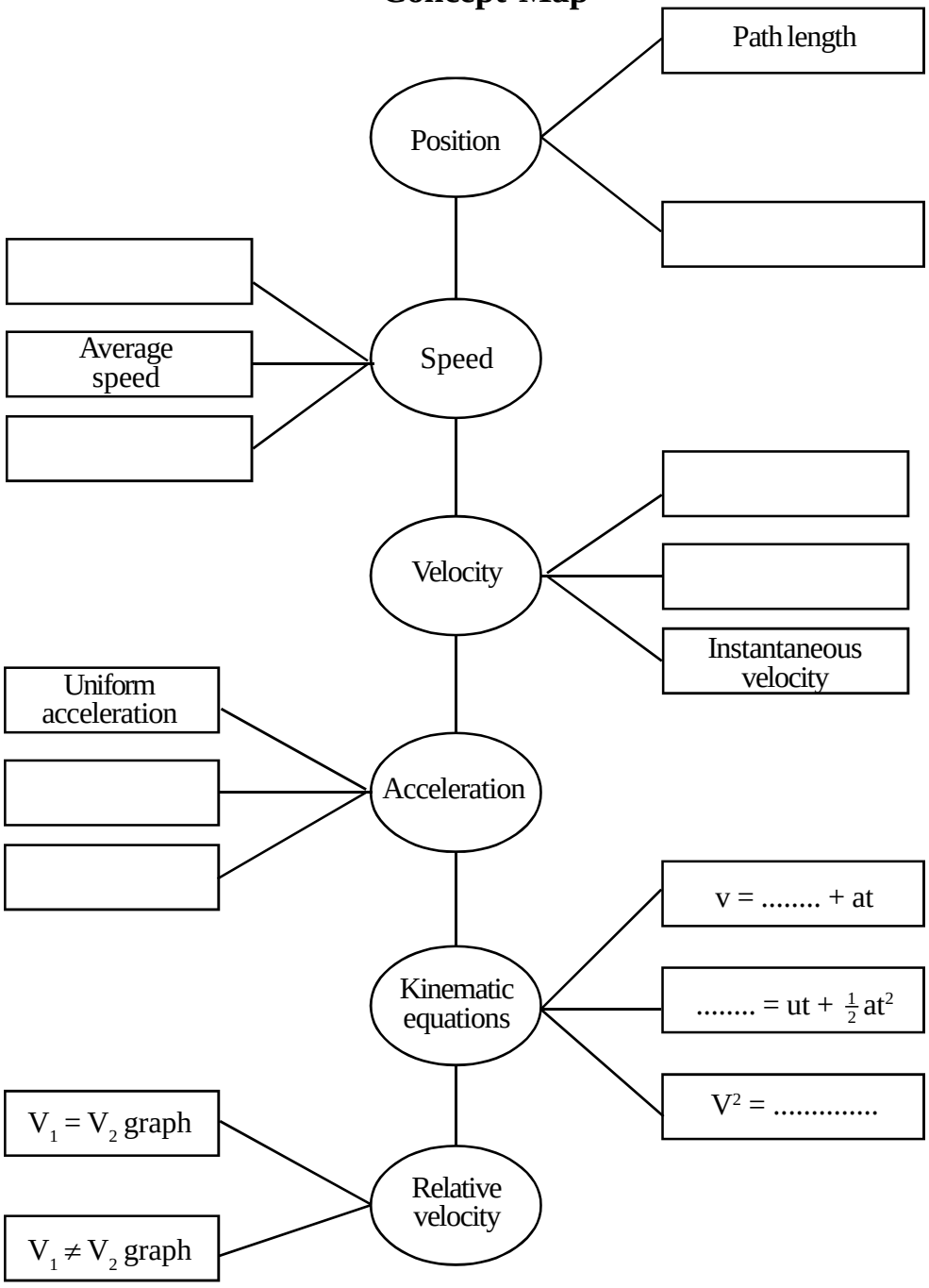
Let $x1$ and $x2$ be the distances of the two stones from the balloon after 10 and 6s, respectively, then

$$x_1 = \frac{1}{2}(a+g)\,10^2 = 25.5\times 50$$

$$x_3 = \frac{1}{2}(a+g)\,6^2 = 25.5\times 18$$

$$x_1 - x_2 = 25.5 \times 32 = 816\text{m}.$$

Concept Map



6.References

(1) NCERT Text

(2) Sears and Zemansky's University Physics

(3) Fundamentals of Physics by Haliday, Resnick and Walker