Kinematics (Equations of Motion)

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Contents of Curriculum Unit

Overview

Kinematics is an important tool in understanding the motion of objects, whether translational, oscillatory, or circular. The behavior of variables such as speed, velocity, acceleration, and deceleration is described by the equations of motion. Apart from the equations, some other tools to study kinematics are graphs, diagrams and vectors. Velocity versus time graphs and displacement time graphs (distance time graphs) relate equations of motion in a very simple way.

The main purpose of this curriculum unit is to familiarize physical science and physics students with the basic concepts used in equations of motion (kinematics). Students will gain knowledge and understanding of the fundamental physical quantities such as distance, time, speed, velocity, displacement, acceleration etc. The unit will also help students understand mathematical concepts such as scientific notation and significant digits (or figures) used in calculations. The curriculum unit will also boost the understanding of graphs and calculations of different physical quantities such as velocity, acceleration, and distance/displacement. Mathematical concepts such as finding slope of a line and area under the curve are illustrated and their connections with physical quantities are discussed through numerical problems. The subject areas to which this unit is useful are Physical Science (9th grade); Physics (11th-12th grade), AP-Physics (critical-thinking questions). However unit is also useful for assisting Algebra (I), Algebra (II), Geometry and discrete math students in understanding linear and quadratic equations.

In this unit, my idea is to introduce kinematics in one dimension only, because to study motion in two dimensions and three dimensions would require a much more solid mathematical background.

Rationale

Kinematics plays a very important role in everyday life; be it a sports field, rocket launch or racetrack; calculation of speed is the most important factor. As a high school teacher, my teaching experience in Math, Physics, Chemistry and Physical Science through different curricula has made me aware that most students are afraid to take Physics as a Science course. It may be because of its difficult connections with mathematics and students' lack of strong foundation in basic mathematics. So an attempt in this unit is made to cross these hurdles in a simple and lucid way. The basic reason for creating this unit is to help my high school students acquire interest in physics through an easy mathematical approach. The unit is different because difficult problems are deleted or left for critical thinking. It fits into the curriculum set by School District of Philadelphia. The unit "Equations of Motion" is very helpful to (Algebra - I and II) teachers and students in establishing connections between physics, linear equations and quadratic equations. Even the students with basic algebra knowledge of substituting values can manage the kinematics equations.

The curriculum unit is based on lesson plans and classroom/laboratory activities in my physics class. The whole unit along with the definitions of physical quantities (key – vocabulary) and problems based on equations of motion can be completed in 2-3 weeks with a regular class period per day. Distance, speed, time relations are explained to students mainly by using problems related to the races, car motions, throwing of balls to create an interest in physics.

Emphasis is given to the units in the metric system, using dimensional methods and to answering different problems with the desired number of significant digits and using scientific notation. This particular unit is helpful to my 9^{th} and 12^{th} grade physical science students. The difficulty level of problems is properly taken care of. Each lesson plan starts with easy problems and terminates in more complex and difficult problems with critical thinking. The subject area of my unit is open to different grades 9-12, because algebraic equations have a significant place in Algebra I, Algebra- II and Discrete Mathematics for seniors. This unit on equations of motion begins with certain vocabulary terms so that students have no difficulty in understanding the language of problems to solve.

Definitions

- **Kinematics** is the study of objects in motion; the terms used most frequently in kinematics are speed, velocity, acceleration, time, distance and displacement. As we define these physical quantities, emphasis will be given to scalar or vector quantities.

- **Scalar Quantities**: The physical quantities that are described by only a magnitude, and not a direction, are known as scalar quantities. Examples are distance, temperature, area, volume, speeds, etc. While specifying these quantities one does not need to specify direction. For example, the temperature on a cold windy day is 5 degree Celsius (only magnitude) or the distance traveled by Kim from school to home is 2 miles (only magnitude).

- **Vector Quantities:** These physical quantities need both a magnitude and a direction for their description. Examples include displacement, velocity, acceleration, force, and momentum. For example, an ant traveled a distance of 2.3 meters from east to west is a vector quantity and is termed as displacement, because it has a magnitude of 2.3 and direction east to west. Force is another vector quantity. For example, earth attracts an object with a force of 98 N towards the center of the earth. Similarly, the speed in a specified direction is a vector quantity and is termed as velocity.

- **Distance**: In the language of a nonprofessional, distance and displacement have the same meaning but in physics distance is defined as the length covered during the motion of an object. Its SI unit is METER and it is a SCALAR quantity. For example, a boy walks from school to his home and covers 800 meters so distance is 800 meters. The symbol used for distance throughout the unit is 's' i.e. s = 800 m.

- **Displacement**: Displacement is the shortest distance between the point of origin and the point of termination. Thus displacement concerns the direction and magnitude both. Thus it is a VECTOR quantity and its SI unit is "meter."

- **Speed:** The average speed of an object is the ratio of the total distance traveled to the time interval. Automobile speeds are measured in miles/hour (mph) or kilometers/hour (kmph). The metric unit of speed is meters/second or (m/s). Speed is a scalar quantity. The speed of an automobile is measured by using a device called speedometer. An automobile speedometer is related to the rotation of a gear in the transmission of the car.

- **Velocity*:*** The speed of an object in a specific direction is called the velocity. It is a vector quantity, In other words it is the displacement per unit time. Thus mathematically

$$\text{Average Velocity} = (d_2 - d_1) / (t_2 - t_1)$$

where, $(d_2 - d_1)$ is the displacement that took place in time $(t_2 - t_1)$. As the displacement is in meters and time is in seconds, the units for velocity are meters per second. Sometimes the velocity over the large period is also called average velocity. Usually speeds of automobiles are expressed as average speeds, i.e.

average speed = total distance traveled / total time taken.

Another type of velocity is instantaneous velocity i.e. defined as the velocity of an object at a particular instant of time. According to the definition of average velocity, if d_1 and d_2 are two positions of an object at time t_1 and t_2 respectively, then average velocity = $(d_2 - d_1) / \Delta t$ or $d_2 = d_1 + \text{average velocity} * \Delta t$ is the equation of motion. This equation allows us to find the position of an object after the lapse of time Δt when the original position is other than the origin.

- **Acceleration**: The acceleration of a moving object is the rate of change of velocity per unit time. For example, if an object is moving with a velocity of 5.0 m/s and it changes its velocity to 7.5 m/s in 5.0 seconds, then acceleration of object is

a = Change in Velocity/ Time Taken = 7.5 – 5.0 / 5 = 0.5 m/sec^2

Acceleration is a vector quantity and its S.I unit is m/sec^2

Sometimes the change in the velocity is due to decrease in velocity that leads to negative acceleration called deceleration or retardation.

The definition of acceleration gives the very first equation of motion in kinematics.

Derivations (Analytical)

1. Derivation of first equation of motion, $v = u + at$ relating initial velocity (u), final velocity (v), acceleration (a), and time (t).

Let us consider an object moving with a velocity of 'u' and changes it velocity to 'v' over a time of 't' then by the definition of acceleration.

a = v – u / t, or v – u = at or v = u + at

Note1: All the symbols are in S.I units i.e. 'u', 'v' is in m/s,'t' is in seconds and 'a' is in m/sec^2.

Note2: Throughout the unit term acceleration used is considered as constant acceleration

Example: Tom is cycling at constant speed of 3m/s. Watching his friend Kim from a distance, Tom accelerates at 0.2 m/sec^2 for 20 seconds to catch up with him. Find the velocity of Tom just before he catches up with Kim.

Solution: u = 3.0 m/s, a = 0.2 m/sec^2

t = 20s, v =?

Using equation of motion, v = u + at = 3 + (0.2*20) = 3 + 4 = 7.0 m/s

2. Derivation of Equation of motion relating displacement (s), initial velocity (u), acceleration (a) and time (t).

$$\boldsymbol{s} = ut + \frac{1}{2}at^2$$

Let us consider an object moving with an initial velocity 'u' and uniform acceleration 'a'. If 's' is the displacement of object after 't' seconds, then

Displacement = average velocity * time

$$s = \frac{u+v}{2} * t$$

or, $s = \frac{u + u + at}{2} * t$ [v = u + at]

or, $$\boxed{\mathbf{s} = ut + \frac{1}{2}at^2}$$

Example: A racer car starts from rest and acquires an acceleration of $5 m/s^2$ after 10 seconds. Find the displacement covered by car in 10 seconds.

Solution: Initial velocity (u) = 0

Acceleration (a) = $5 m/s^2$

Time taken (t) = 10 s

Displacement (s) =?

Equation relating these four variables is:

$$s = ut + \frac{1}{2}at^2$$

$$\therefore s = 10 + \frac{1}{2} * 5 * 10^2$$

s = 250 meters

3. Derivation of equation of motion relating initial velocity (u), final velocity (v), acceleration (a) and displacement (s).

$2as = v^2 - u^2$

Let us consider an object moving with initial velocity ‘u’ and uniform acceleration ‘a’. If after ‘t’ seconds of traveling its velocity changes to ‘v’ and displacement covered is ‘s’, then, v = u + at or   t = v – u / a

and, $s = ut + \frac{1}{2}at^2$

Substituting the value of ‘t’ in second equation and simplifying, we get

$$s = \frac{u(v-u)}{a} + \frac{1}{2}a[\frac{(v-u)}{a}]^2$$

$$\boxed{\therefore\ 2as = v^2 - u^2}$$

4. Derivation of equation of motion for the distance traveled in a particular second.

$s_{nth} = u + \frac{a}{2}$ (2n-1)

Proof: Let us consider an object traveling with an initial velocity 'u' and uniform acceleration 'a'. Distance traveled in 'n' seconds is given by

$S_n = un + \frac{1}{2}an^2$. …………(I)

Distance traveled in (n-1) seconds is given by

$S_{n-1} = u\,(n-1) + \frac{1}{2}a\,(n - 1)^2$ …………. (II)

Distance traveled in n^{th} second is

$S_{nth} = S_n - S_{n-1}$

$$= un + \frac{1}{2}an^2 - [u(n-1) + \frac{1}{2}a(n-1)^2]$$

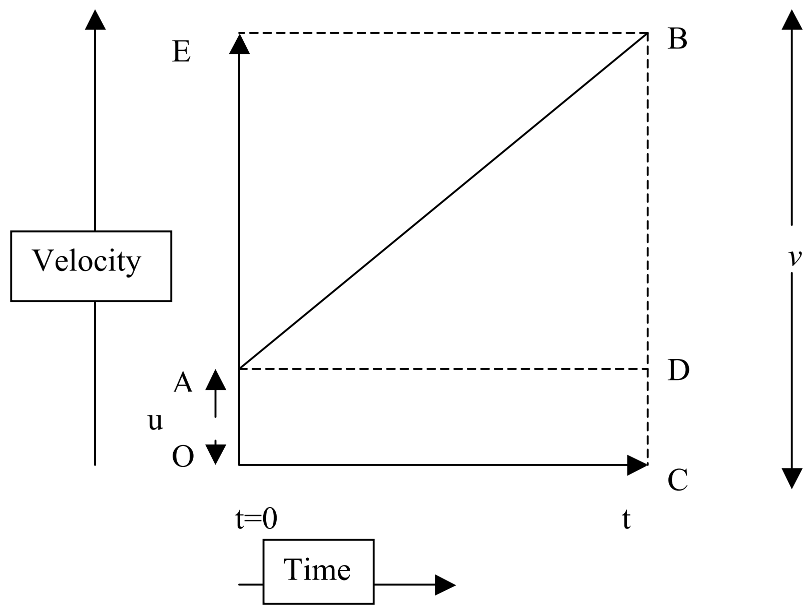
$$= un + \frac{1}{2}an^2 - [un - u + \frac{1}{2}an^2 - an + \frac{1}{2}a]$$

$$\mathbf{S_{nth} = u + \frac{a}{2}(2n-1)}$$

Note: The above equation seems to be dimensionally incorrect but it is a good tool to find the distance traveled in a particular second. However, if the unit for distance traveled in a particular second is taken as m/s, then this equation becomes dimensionally correct.

GRAPHICAL METHODS:

1. For the derivation of $v = u + at$, let us consider the velocity time graph of an object moving with constant acceleration "a."



Graph AB shows that the initial velocity at t=0 is *u* and the final velocity is *v*. By the definition of acceleration

a = Change In Velocity/Change in Time = Velocity at B – Velocity at A/Time at B – Time at A

$a = v - u / t$ or $v = u + at$

2. Derivation of s = $ut + \frac{1}{2}at^2$

Let us consider the same velocity – time graph of an object moving with constant acceleration 'a'. The area under the graph depicts distance or displacement traveled. i.e.
s = Area of region OABC
or, s = Area (trapezoid OABC)
or, s = $\frac{1}{2}(u + v)t$

or, s = $\frac{1}{2}(u + u + at)t$

$$s = ut + \frac{1}{2}at^2$$

3. Derivation of $v^2 - u^2 = 2as$

For the same velocity–time graph, displacement or distance S = area of region OABC
or, S = area of rectangle OCBE – area of triangle ABE

$$= vt - \frac{1}{2}(v-u)\,t$$

$$= \frac{v+u}{2} * t$$

$$= \frac{v+u}{2}\,\frac{v-u}{a} \qquad [\because t = \frac{v-u}{a}]$$

$$\boldsymbol{v^2 - u^2 = 2as}$$

Objectives

The main objective of this unit is to enable the students to master the concepts of kinematics and the equations used in solving numerical problems analytically and graphically. We may use basic algebra, geometry and graphing to solve problems associated with this unit. Equations and graphs both are means of expressing relationships among variables. Algebraic equations are manipulated by performing the same operation on each side of the equation. Unit provides a useful way of checking the correctness of an equation.

Students will gain knowledge and understanding of the fundamental quantities of motion i.e. distance, time, velocity, and acceleration. From the uses of position time graph and velocity-time graph, students will predict beforehand certain shapes and curves like: when velocity is constant, displacement varies directly with time. The slope of a curve of a displacement time graph will be velocity and steepness will measure the greatness of velocity, however the zero slope will depict the object at rest.

- Student will be able to represent real world relationships between the terms such as distance, speed, displacement, velocity and acceleration (speedometers/odometers in automobiles).
- Students will also make connections of speed in Earth Science. Meteorologists to indicate wind speeds use the Beauport scale.
- Students will be able to identify the equation of motion to be used for a particular problem on motion

This unit will further develop academic skills and enhance student's academic knowledge by relating algebra and geometry to study equations of motion analytically and graphically.

Strategies

To achieve my objectives narrated in the curriculum, I will start my lesson by teaching the basic concepts that are used in kinematics. These concepts will be taught to my students by connecting them with real life situations: such as sports field and race track etc. In order to solve kinematics problems, students will be given the examples of plugging in values in linear and quadratic equations. Once they are familiar with substituting values of different variables, they will be given assignments on equation of motion. To further strengthen students' skills, classroom activities on collecting data, graphing data and analyzing data will be done in groups and students will be assessed on the basis of cooperative learning. At the end of the derivation of each equation of motion, students will be provided with a worksheet based on that equation and will be assessed individually.

The curriculum unit will be taught to students through classroom interaction. The definitions of different vocabulary terms will be explained after connecting them with real world situations. Class work assignments and homework assignment will be correlated. To strengthen skills in reading technical terms, students will read numerical problems in class. After reading problems, students will recognize the different terms or data in the problems. Students will then select the equation of motion according to the data he/she has collected. For example, a racer who starts running from rest position completes 100m race in 12.5 seconds. What is his acceleration?

After reading the problem students will select the appropriate data such as: the racer started from the rest, so initial velocity (u = 0); completes the race in 12.5 seconds (t =12.5 seconds); and distance traveled or displacement (s = 100 m) and the requirement is a = ? So given a mathematical model, to the problem, u = 0; t =12.5 seconds; s =100m; a=? . Check all the physical quantities are in proper units. Select the equations of motion, which fits in the data collected.

However, if the units in the data are not correct, students will be encouraged to change them in proper units, for example, if the time given in the problem is in minutes: change it to seconds and for distance, if it is in kilometer: change it to meters etc.

After solving the problem, practical concepts will be discussed. For example, after solving a problem, if the acceleration comes out with negative sign, students should be convinced that the significance of the negative sign is that the velocity is increasing rather than decreasing. (Such a negative acceleration is sometimes referred to as deceleration or retardation [Critical Thinking]).

Suppose that in some mathematical calculations, the speed of a car or object is of the order of 350m/sec. Students will be told that this is a high speed and that sound travels with this speed in air (Critical Thinking)

To sum up, I will advise my students to follow the strategies below while they work on problems related to kinematics:

1. First, read the question carefully and after reading the question, make a list of variables that are given or known in the problem.
2. Write the appropriate symbol for known quantities with their values and units.
3. Write the symbol for unknown quantity with question mark. It emphasizes your concentration to find out that variable

4. Go through the list of equations of motion and select which one contains all the variables (known and unknown)
5. Substitute the value of known variables and solve the linear or quadratic equation for the unknown variable.
6. Estimate the value of unknown variable and justify with the value you calculated. Sometimes the value of variable you calculated is far away from the estimated one. For example, if you estimate the speed of a racer to be 4m/s but your calculated value is 100 m/s due to some error, check back all the steps and try to rectify the error.

However, the teachers can use following strategies to achieve his/her objectives:

Alternative Teaching Strategy: If the student is having any difficulty in using the analytical method, he/she can use the graphical method and vice versa.

Inclusive Strategies: All educators share the responsibility for accommodating the learning and behavior needs of all; learners to the maximum extent possible. It focuses on the mandate for providing quality education to all students' inclusive diverse learners.

Enrichment Strategy: It provides richer and varied content through strategies that supplement usual grade level work. Enrichment options include independent study and independent project, field trips, Saturday programs, summer programs and small group investigations.

Co-operative Learning Strategy: This strategy place students in teams and encourage them to work toward common goals. Strategy used effectively at all grade levels and in all content areas. They increase achievement, improve attitudes towards minorities and those with disabilities and increase inclusion in mainstream classroom activities.

Classroom Activities and Lesson Plans

Lesson Plan 1

I will start my lesson by defining vocabulary terms such as distance, displacement, speed, velocity, scalar, vector and acceleration to my students. All these terms will be explained using examples from everyday life. Proper attention will be given to SI units in expressing these terms.

Completing a worksheet with different illustrations will assess students. The main objective of the worksheet is to explain the difference in physical quantities such as distance and displacement. Before starting the worksheet, students will be asked a question stating; how to measure the length of a curved path? After getting the response from the students, they will be directed to use a thread to coincide with the curved path and measure the length of thread on the meter scale or ruler.

On the worksheet, printed illustrations will use materials such as strong thread, meter ruler and scissors to find distance and displacement. After completing the worksheet, students will conclude that in most cases distance is always greater than the displacement.

Lesson Plan 2

Classroom Activity

The main objective of my lesson plan is to calculate the average velocity for a series of time intervals, classify the displacement-time ratio as uniform or non-uniform motion, and analyze the relationship between total displacement and time, velocity and time, interpret data to establish trends. Materials Needed: , a constant velocity vehicle, a meter stick, a C-clamp, a CBL unit, graphing calculator, link cable, and ultrasonic motion detector.

Formula Used:

Average Velocity $v = (d_2 – d_1) / (t_2- t_1)$

Instructions for Students:

1. With your lab partner, set up the ultrasonic motion detector and vehicle on a long smooth table.
2. Connect the CBL unit to the calculator. Connect the ultrasonic motion detector to the sonic port of the CBL unit.
3. Turn on the CBL unit and graphing calculator. If not already loaded into your calculator, load the program PHYSICS. Start the program physics on graphing calculator.
4. Select the option SET UP PROBES from main MENU. Enter 1 for the number of probes. Then from the select probe menu Choose MOTION from the list.
5. After setting the experiment, press ENTER, the READY EQUIPMENT command should appear. One student should press ENTER on the Graphing calculator and another should turn on the vehicle.
6. Record the displacement (y-value) and time (x-value) into your data table.

Data and Observations:

Time (s)	Displacement (m)	Total Displacement (m)	Average Velocity (m/s)

** The data should be tabulated in the above-mentioned manner.*

Lesson Plan 3

Class Room Activity

The main objective of my lesson plan is, to measure the displacement of a moving object, to calculate the velocity of a moving object, to analyze motion, using graphs of the relationships between: displacement - time, velocity – time, acceleration – time.

Materials Needed: Laboratory cart, CBL unit, Ultrasonic motion, Link cable detector, Graphing calculator, 500-g mass, Masking tape, Pulley and string, Graph-paper.

Formula Used:

$v = (d_2-d_1) / (t_2-t_1)$

$a = (v_2-v_1) / (t_2-t_1)$

Instructions for Students:

1. First we will set up the apparatus so that detector, cart and pulley are in a straight line.
2. Connect the CBL unit to the detector calculator
3. Connect the ultrasonic motion detector to the SONIC port of the CBL unit.

4. Turn on the CBL unit and graphing calculator. Load the program PHYSICS and its subprograms into your calculator from another calculator or download from a computer
5. Select the option SET UP PROBES from the MAIN MENU.
6. Select the MONITOR INPUT option from the COLLECT DATA menu.
7. Select the COLLECT DATA option. In Data Collection, select Time-graph. On the time-graph menu, select NON-LIVE Display.
8. Press ENTER, The READY EQUIPMENT command should appear.
9. When the detector has stopped clicking and the CBL unit displays DONE. Press enter on the graphing calculator.
10. Select VELOCITY/ACCELRATION to plot a graph.

DATA and OBSERVATIONS

TABLE 1		TABLE 2	
Time (s)	Displacement (m)	Time (s)	Velocity (m/s)

Annotated Bibliography/ Resources

Books:

Murphy, Hollon, Zitzewitz, Smoot, *Physics: Principles and Problems*, Charles E. Merryl, Columbus, Ohio. A study of physics and its applications appeals to students with a wide range of interests.

Paul Zitzewitz, Glencoe, *Physics: Principles and Problems*, McGraw-Hill Publication 2005. An understanding of physics to make informed decisions as a citizen in an increasing complex world. The book offers integrated support, abundant opportunities for problem solving and varities of realistic applications. It actively involves students through Launch Labs – inquiry based labs at the beginning of each chapter.

Cutnell & Johnson, *Physics (6th edition), Wiley, Fundamentals of Physics II, 2001*. The sixth edition helps readers understand the interrelationships among basic Physics concepts.

Holt, Rinehart and Watson, *Holt Physics, 2002*. A comprehensive physics course that takes a step-by step approach to problem solving, Holt Physics, provides just the right balance between theoretical, mathematical models and concrete, real – world examples.

Robert. M. Oman, Daniel M. Oman, *How to solve Physics Problems*- Pg 30, Net Library, Inc-1997 – 407 pg. Kinematics equations of motion are derived under the assumption of constant acceleration.

Paul G. Hewitt, Conceptual Physics, 3rd Edition – 2005 with expanded technology. Scott Foresman Addison Wesley. Conceptual Physics does not merely describe Physics – it explores it. Physics is the most basic of the living and non living senses. We can understand science in general much better if we understand physics first. All other sciences are built on knowledge of Physics. Physics equations are systems of connections, following the rules of logic.

Frederick J. Bueche, Eugene Hecht, The Mcgraw Hill Companies. *Schaum's Outline's College Physics* Tenth Edition. This marvelous subject has heard the universal student lament, "I understand everything; I just cannot do the problems." Nonetheless most teaches believe that the "doing" of problems is the crucial culmination of the entire experience, it is the ultimate proof of understanding.

Appendix/ Standards

Pennsylvania Department of Education Standards

3.1.4 Unifying Themes (B)
3.2.2 Inquiry and Design (C)
3.4.4 Physical Science, Chemistry and Physics (C)
3.6 Technology Education (B)
3.7 Technological Devices (C, D, E)
3.8 Science, Technology and Human Endeavors (A, C)

National Science Content Standards

UCP.1, UCP.2, UCP.3; A.1, A.2, B.4, B.1

Academic standards in physical science, mathematics and physics support Pennsylvania's public schools to teach, challenge and support every student to realize his or her maximum potential and to acquire the knowledge and skills needed to observe and describe types of motion. The contents of this course relates to the standards such as " the teacher understands the central concepts, tools of inquiry and structures of discipline(s) he/ she teaches and can create learning experience which makes these aspects of subject matter meaningful to students."

Laboratory instructions and experimental techniques include design of experiments, data analysis and presentation, preparation of lab reports, operation of physics lab equipments, for example; motion detector device, simple electronic equipment and optics equipment. The program prepares students to structure and interpret the concepts, ideas and relationships in science that are needed to advance student learning in the area of licensure as defined by state and national standards developed by the science education community.

Assignments

Assignment 1

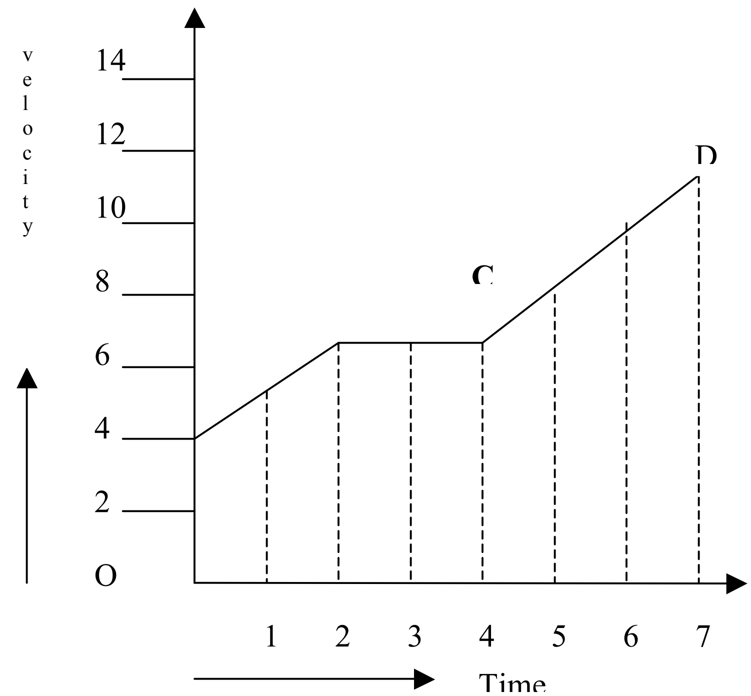
1. A train moving toward north is uniformly accelerated from a velocity of 10m/s to 18m/s over a time of 6.0 seconds. What is the acceleration of the train?
2. A car starting from rest covers a displacement of 200m over a time interval of 10 seconds. Find the acceleration of the car.
3. A bullet penetrates through a wooden block at a close range when fired with a rifle at a speed of 25 m/s and acceleration of 500 m/sec^{2}. Find the distance traveled through which the bullet penetrates?
4. Find the distance traveled by a car in the 7th second if it has an initial velocity of 10m/s and accelerating at the rate of 3 m/sec^{2}
5. A U.S airlines plane accelerates uniformly from a speed of 2.0 m/s at the rate of 4.5 m/sec^{2} on a runway of 300 meters. Find its speed at the end of runway.

Answers:

1. 1.3 m/s ^{2}
2. 4 m/s^{2}
3. 0.625 m
4. 29.5 m
5. 52 m/s

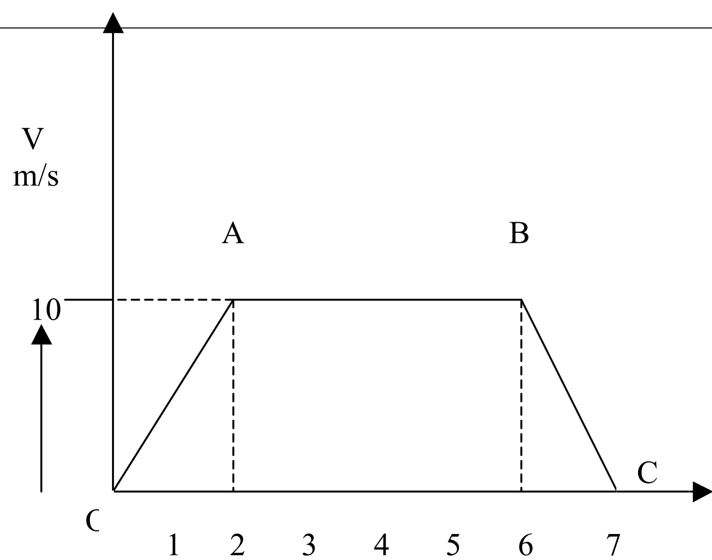
Assignment 2

1. The given velocity time graph motion shows the motion of a particle for 7 seconds. Find the acceleration of the particle for portions AB, BC and CD



B

2.



The velocity-time graph of a moving particle is shown in the above diagram. Find the acceleration of each portion OA, AB, BC. Also find the distance traveled during first two seconds and in the last one second.

3) Draw the velocity time graph of a moving object with the data collected in the following table

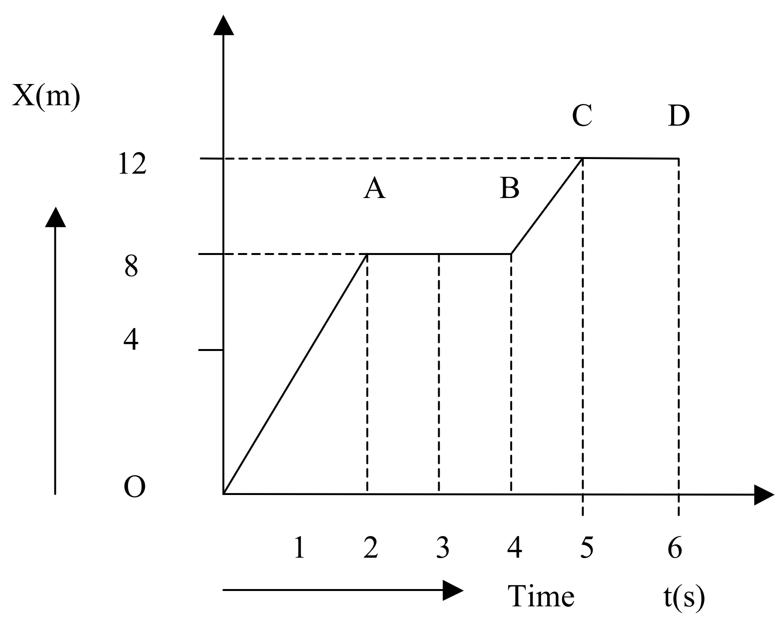
T(s)	0	4	5	6	7	8	10	12
V (m)	0	24	24	24	24	24	20	0

Also, find the acceleration of the object for four portions of the graph.

4) Using the graph in question three, find distance traveled by object during intervals

1) 0-4 seconds
2) 4- 8 sec
3) 8- 10 sec
4) 10-12 sec

5.



The displacement time graph of a particle is shown above.
Find the velocity of the particle for the time intervals

- 0-2 sec
- 2-4 sec
- 4-5 sec
- 5-6 sec

Answers:

1. 1.5 $m/s^{2,}$ 0 $m/s^{2,}$ 1.7 m/s^2
2. 5$m/s^{2,}$ 0 $m/s^{2,}$ - 10 m/s^2 , 10 m, 5 m
3. 6 m/s^{2} , 0 $m/s^{2,}$ -2 m/s^{2} , - 10 m/s^2
4. 48 m, 96 m, 44m, 20 m
5. 4 m/s, 0 m/s, 4 m/s, 0 m/s

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