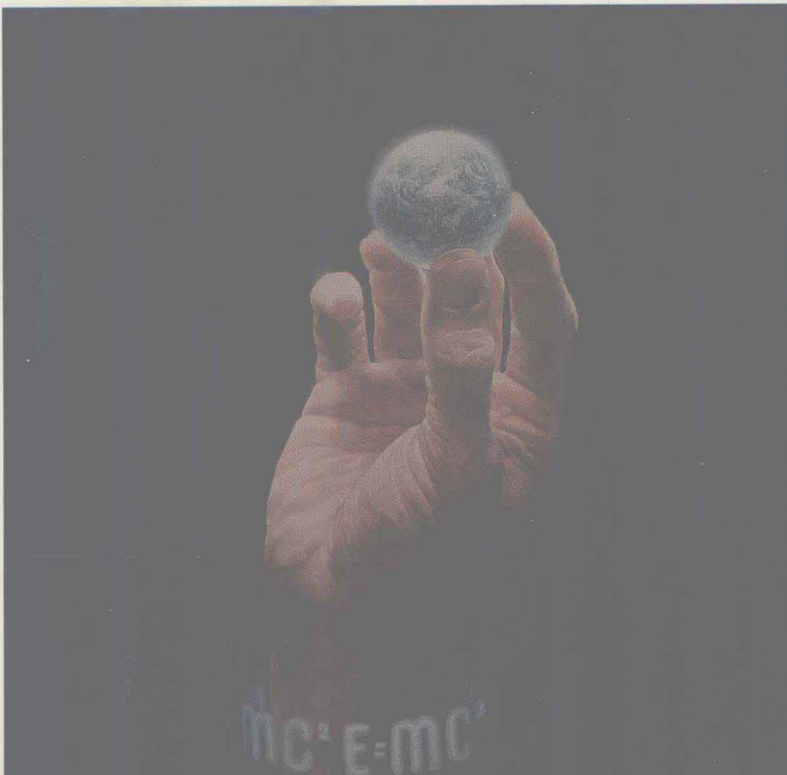
CLIFFS QUICK REVIEW™

PHYSICS



Cliffs Quick Review

Physics

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INTRODUCTION

Physics is a branch of physical science that deals with physical changes of objects. The mental, idealized models on which it is based are most frequently expressed in mathematical equations that simplify the conditions of the real world for ease of analysis. Even though the equations are derived from ideal conditions, they approximate real situations closely enough to allow accurate prediction of the behaviors of complex systems.

The primary task in studying physics is to understand its basic principles. Understanding these formal principles enables better understanding of the phenomena observed in the universe.

The system of units used throughout this book is called the International System of Units (SI). The fundamental quantities in this system are length, time, mass, electric current, temperature, amount of a substance, and luminous intensity.

Mechanics is the study of the motion of material objects. Classical or Newtonian mechanics deals with objects and motions familiar in our everyday world.

Kinematics in One Dimension

Kinematics analyzes the positions and motions of objects as a function of time, without regard to the causes of motion. It involves the relationships between the quantities **displacement** (*d*), **velocity** (*v*), **acceleration** (*a*), and **time** (*t*). The first three of these quantities are vectors.

Definition of a vector. A **vector** is a physical quantity with direction as well as magnitude, for example, velocity or force. In contrast, a quantity that has only magnitude and no direction, such as temperature or time, is called a **scalar**. A vector is commonly denoted by an arrow drawn with a length proportional to the given magnitude of the physical quantity and with direction shown by the orientation of the head of the arrow.

Displacement and velocity. Imagine that a car begins traveling along a road after starting from a specific sign post. To know the exact position of the car after it has traveled a given distance, it is necessary to know not only the miles it traveled but also its heading. The **displacement**, defined as the change in position of the object, is a vector with the magnitude as a distance, such as 10 miles, and a direction, such as east. **Velocity** is a vector expression with a magnitude equal to the speed traveled and with an indicated direction of motion. For motion defined on a number line, the direction is specified by a positive or negative sign. **Average velocity** is mathematically defined as

$$\text{average velocity} = \frac{\text{total displacement}}{\text{time elapsed}}$$

Note that displacement (distance from starting position) is *not* the same as distance traveled. If a car travels one mile east and then returns one mile west, to the same position, the total displacement is zero and so is the average velocity over this time period. Displacement is measured in units of length, such as meters or kilometers, and velocity is measured in units of length per time, such as meters/second (meters per second).

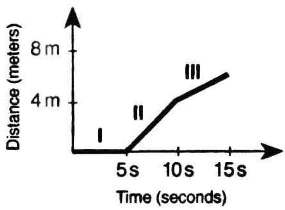
Average acceleration. Acceleration, defined as the rate of change of velocity, is given by the equation:

$$\text{average acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time elapsed}}$$

Acceleration units are expressed as length per time divided by time such as meters/second/second or in abbreviated form as m/s^2.

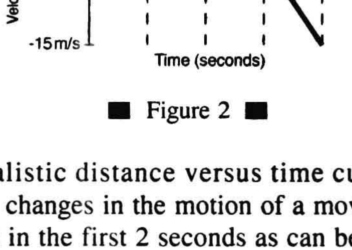
Graphical interpretations of displacement, velocity, and acceleration. The distance versus time graph in Figure 1 shows the progress of a person: (I) standing still, (II) walking with a constant velocity, and (III) walking with a slower constant velocity. The slope of the line yields the speed. For example, the speed in segment II is

$$\frac{(4 - 0)\ \text{m}}{(10 - 5)\ \text{s}} = \frac{4\ \text{m}}{5\ \text{s}} = .8\ \text{m/s}$$



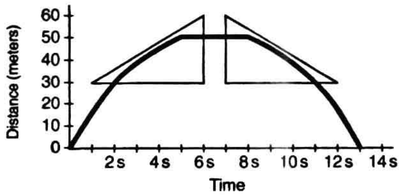
■ Figure 1 ■

Each segment in the velocity versus time graph of Figure 2 depicts a different motion of a bicycle: (I) increasing velocity, (II) constant velocity, (III) decreasing velocity, and (IV) velocity in a direction opposite the initial direction (negative). **The area between the curve and the time axis represents the distance traveled.** For example, the distance traveled during segment I is equal to the area of the triangle with height 15 and base 10. Because the area of a triangle is (1/2)(base)(height), then (1/2)(15 m/s)(10 s) = 75 m. **The magnitude of acceleration equals the calculated slope.** The acceleration calculation for segment III is (−15 m/s)/(10 s) = −1.5 m/s/s or −1.5 m/s^2.

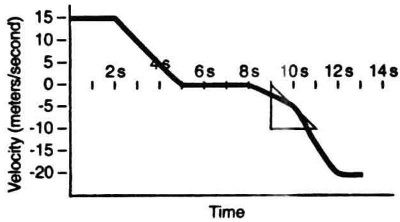


■ Figure 2 ■

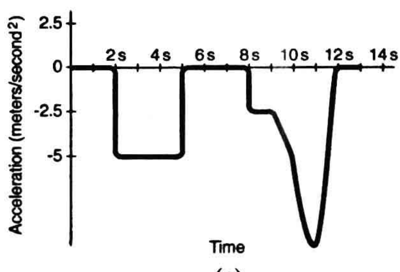
The more realistic distance versus time curve in Figure 3(a) illustrates gradual changes in the motion of a moving car. The speed is nearly constant in the first 2 seconds as can be seen by the nearly constant slope of the line; however, between 2 and 4 seconds, the speed



(a)



(b)



(c)

■ Figure 3 ■

is steadily decreasing and the **instantaneous velocity** describes how fast the object is moving at a given instant.

Instantaneous velocity can be read on an odometer in the car. It is calculated from a graph as the slope of a tangent to the curve at the specified time. The slope of the line sketched at 4 seconds is 6 m/s. Figure 3(b) is a sketch of the velocity versus time graph constructed from the slopes of the distance versus time curve. In like fashion, the

instantaneous acceleration is found from the slope of a tangent to the velocity versus time curve at a given time. The instantaneous acceleration versus time graph in Figure 3(c) is the sketch of the slopes of the velocity versus time graph of Figure 3(b). With the vertical arrangement shown, it is easy to compare the displacement, velocity, and acceleration of a moving object at the same time.

For example, at time $t = 10$ s, the displacement is 47 m, the velocity is −5 m/s, and the acceleration is −5 m/s^2.

Definitions of instantaneous velocity and instantaneous acceleration. The instantaneous velocity by definition is the limit of the average velocity as the measured time interval is made smaller and smaller. In formal terms, $v = \lim_{\Delta t \to 0} \Delta d/\Delta t$. The notation $\lim_{\Delta t \to 0}$ means the ratio $\Delta d/\Delta t$ is evaluated as the time interval approaches zero. Similarly, instantaneous acceleration is defined as the limit of the average acceleration as the time interval becomes infinitesimally short. That is, $a = \lim_{\Delta t \to 0} \Delta v/\Delta t$.

Motion with constant acceleration. When an object moves with **constant acceleration,** the velocity increases or decreases at the same rate throughout the motion. The average acceleration equals the instantaneous acceleration when the acceleration is constant. A negative acceleration can indicate either of two conditions: case (1) the object has a decreasing velocity in the positive direction, or case (2) the object has an increasing velocity in the negative direction. For example, a ball tossed up will be under the influence of a negative (downward) acceleration due to gravity. Its velocity will decrease while it travels upward (case 1); then, after reaching its highest point, the velocity will increase downward as the object returns to earth (case 2).

Using v_o (velocity at the beginning of time elapsed), v_f (velocity at the end of the time elapsed), and t for time, the constant acceleration is

$$a = \frac{v_f - v_o}{t} \quad \text{or} \quad v_f = v_o + at \qquad \text{[Equation 1]}$$

Substituting the average velocity as the arithmetic average of the original and final velocities $v_{avg} = (v_o + v_f)/2$ into the relationship between distance and average velocity $d = (v_{avg})(t)$ yields

$$d = \frac{1}{2}(v_o + v_f)t \qquad \text{[Equation 2]}$$

Substitute v_f from Equation 1 into Equation 2 to obtain

$$d = v_o t + \frac{1}{2}at^2 \qquad \text{[Equation 3]}$$

Finally, substitute the value of t from Equation 1 into Equation 2 for

$$v_f^2 = v_o^2 + 2ad \qquad \text{[Equation 4]}$$

These four equations relate v_o, v_f, t, a, and d. Note that each equation has a different set of four of these five quantities. The table below summarizes the equations for motion in a straight line under constant acceleration.

A special case of constant acceleration occurs for an object under the influence of gravity. If an object is thrown vertically upward or dropped, the acceleration due to gravity of -9.8 m/s^2 is substituted in the above equations to find the relationships among velocity, distance, and time.