LIFEPAC®

SCIENCE

STUDENT BOOK

12th Grade | Unit 10

Alpha Omega
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SCIENCE 1210
KINEMATICS – NUCLEAR ENERGY

LIFEPAC Test is located in the center of the booklet. Please remove before starting the unit.

Authors:
Mary Grace Ferreira, M.N.S.
Lee H. Dunning, M.S.T., M.S.Ed.

Editor:
Alan Christopherson, M.S.

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804 N. 2nd Ave. E.
Rock Rapids, IA 51246-1759

Kinematics – Nuclear Energy

Introduction

Physical phenomena may be grouped into four categories: mechanics, wave motion, electricity and magnetism, and atomic and nuclear physics.

Mechanics is the study of motion, force, momentum, work, power, and energy; *wave motion* is the study of wave behavior as it explains phenomena associated with light; *electricity* and *magnetism* deal with those two related phenomena; and *atomic* and *nuclear physics*, frequently referred to as *modern physics*, is the most imaginative of the four branches if only because imagination was copiously applied during its development. It is the most comprehensive of the four, applying principles from the other three, and introducing several unique insights.

Physics, like other true sciences, is a description and interpretation of natural phenomena. Advancing technology has made description more accurate; new interpretation has had to follow. Two cases in which interpretations have been adjusted to new descriptions are the models for light and for the atom. Three hundred years ago the wave model of light was postulated. That model still holds; but experiments of the twentieth century have revealed that light *also* behaves like a stream of particles. Somehow, light is both a wave and a particle.

In the second case, our perception of the atom has changed from an invisible solid sphere to an incredibly complex solar system, an analogy of which does not exist on the macroscopic level.

Objectives

Read these objectives. The objectives tell you what you will be able to do when you have successfully completed this LIFEPAC ®. When you have finished this LIFEPAC, you should be able to:

1. Define and apply *displacement*, *velocity*, and *acceleration*.
2. Explain and apply Newton's laws of motion.
3. Define and apply *momentum* and *impulse*.
4. Explain and apply Kepler's laws of planetary motion.
5. Define and apply *energy*, *work*, *power*, and *efficiency*.
6. Describe transverse and longitudinal waves.
7. Calculate velocity problems for sound and light.
8. Calculate index of refraction problems for light.
9. Draw lens and mirror diagrams.
10. Calculate lens and mirror problems.
11. Describe refraction, diffraction, interference, and polarization.
12. Identify the phenomena that support the particle model and the wave model of light.
13. Identify natural sources of electricity and magnetism.
14. Describe force fields that surround electric charges and magnetic poles.
15. Apply Ohm's law to series and parallel circuits.

16. Describe the development of the atomic model.
17. Associate major contributors to the atomic model with their contributions.
18. Describe emission and absorption spectra as they relate to the quantum atom.
19. Describe the matter-energy duality.
20. Define *isotope* and *half-life*.
21. Explain nuclear reactions.

Survey the LIFEPAC. Ask yourself some questions about this study and write your questions here.

1. MECHANICS

The study of mechanics covers a broad area that includes kinematics, dynamics, and energy. In this review of mechanics, the emphasis will be on the use of equations to solve problems and to understand the relationships of distance, time, velocity, acceleration, force, momentum, energy, and power.

Section Objectives

Review these objectives. When you have completed this section, you should be able to:

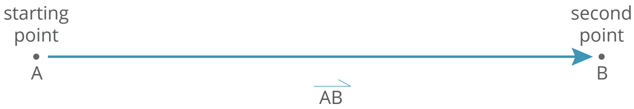
1. Define and apply *displacement*, *velocity*, and *acceleration*.
2. Explain and apply Newton's laws of motion.
3. Define and apply *momentum* and *impulse*.
4. Explain and apply Kepler's laws of planetary motion.
5. Define and apply *energy*, *work*, *power,* and *efficiency*.

KINEMATICS

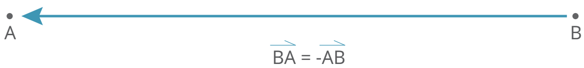
You may wish to review LIFEPAC 1201: the vocabulary words, the difference between fundamental and derived units, and scalars and vectors.

Kinematics is the study of motion apart from the cause of that motion. The aspects of motion are displacement, velocity, and acceleration.

Displacement. Displacement is the distance from a defined starting point to a second point along a straight line. Implicit in this definition is the specific direction *from* the starting point *to* the second point: displacement is a vector quantity.



The vector from the second point back to the starting point is a negative of the vector previously cited.



The magnitude of displacement is distance, the length of the straight line connecting the two points, without regard for the direction of travel.

The standard metric unit of distance and displacement is the meter. The meter has convenient subdivisions and multiples.

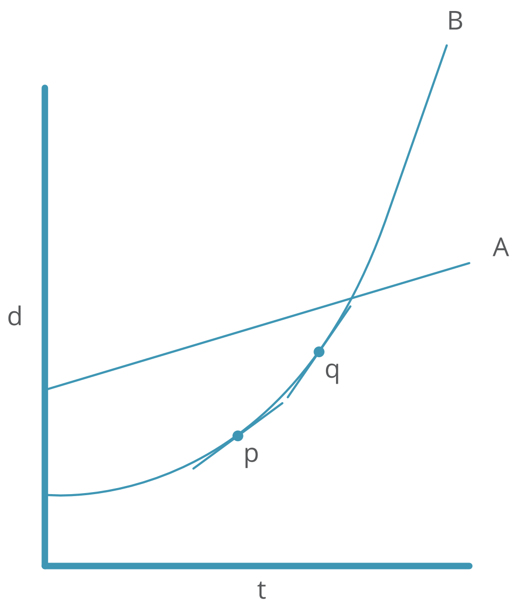
1,000 meters (m)	= 1 kilometer (km)
10^{-2} meters	= 1 centimeter (cm)
10^{-3} meters	= 1 millimeter (mm)
10^{-6} meters	= 1 micron (∝)
10^{-10} meters	= 1 angstrom (Å)

Velocity. Velocity is the rate at which displacement changes with respect to time. If a greater displacement occurs in a given period of time or if the same displacement occurs in a shorter period of time, the velocity increases. The reverse cases produce a decrease in velocity.

The symbol that conventionally represents change is the Greek letter Δ (delta). A change in displacement is Δd, and a change in displacement divided by the time interval required for that change is the definition of *velocity*:

$$v = \Delta d / \Delta t$$

Velocity is the slope of a displacement-time graph:

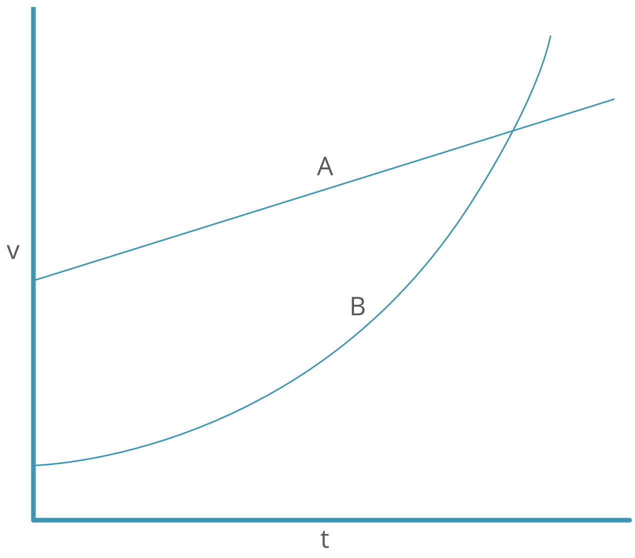


Curve A represents constant velocity because the slope $\Delta d/\Delta t$ is uniform. Curve B represents increasing velocity because the slope at Point q is greater than the slope at Point p.

Acceleration. The rate of change in velocity with respect to time is acceleration. A greater velocity change in a given period of time or the same velocity change in a shorter period of time produces an increase in acceleration. The reverse cases produce a decrease in acceleration.

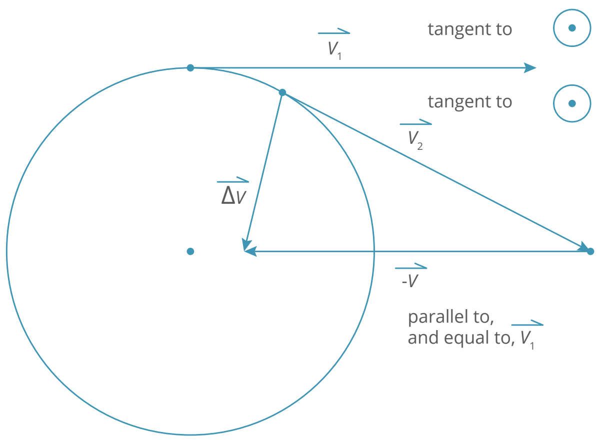
$$a = \Delta v/\Delta t$$

Acceleration is the slope of a velocity-time graph:



Curve A represents constant acceleration because the slope $\Delta v/\Delta t$ is uniform. Curve B represents increasing acceleration.

Velocity is a vector quantity. If the *magnitude* of the velocity (the speed) remains constant but its direction changes, this change in velocity, by definition, constitutes acceleration. Motion of an object in a circular path is *centripetal* acceleration.



When velocity vectors on a circular path are taken infinitely close together, the centripetal ("center-seeking") acceleration vector points to the center of the circle.

The magnitude of centripetal acceleration is proportional not to velocity but to velocity squared,

$$a \propto v^2$$

and is inversely proportional to the radius of the curve,

$$a \propto {}^1\!/_R$$

Combining these two formulas, the result is

$$a \propto {}^{v^2}\!/_R$$

When a car turns a corner, the car is harder to control; and the centripetal acceleration is increased if the speed is increased or if speed is maintained on a curve with a smaller radius. Rollovers occur at high speeds on sharp turns.

As the velocity changes, the acceleration changes in ratios of 2:4, 3:9, 4:16, 5:25, and so on. Notice that the change in acceleration is as the square of the velocity. The radius of the curve, however, affects the centripetal acceleration in this manner ⅓:3, ½:2, 2:½, 4:¼. Therefore, if the car turns in a larger arc (double the radius) and doubles the speed, the acceleration is decreased by half because of the greater arc; but the acceleration is increased by a factor of four because of the greater speed.

Therefore, the centripetal acceleration has increased by a factor of two (½ • 4 = 2).

The last item in this section is the acceleration due to gravity. To simplify the study, assume that the initial velocity of an object in free fall is zero, that frictional effects are negligible, and that the acceleration is constant. A general statement of displacement produced by acceleration is

$$d = \frac{1}{2}at^2$$

When the acceleration is a result of gravity, the equation is conventionally rewritten

$$d = \frac{1}{2}gt^2$$

The former equation is valid for any object undergoing acceleration. Acceleration resulting from gravitational attraction is called *acceleration due to gravity*. In either case the displacement is proportional to acceleration and to the square of time. Therefore, in a given time, tripling the acceleration triples the distance covered. However, if the time factor is tripled, the displacement is nine times greater.

Complete these sentences.

1.1 If displacement per unit time is tripled, the velocity is a. ____________________ (increased, decreased) by a factor of b. ____________________ .

1.2 If the velocity decreases, the acceleration has a ____________________(positive, negative) value.

1.3 If the velocity is halved, the acceleration is a. ____________________ (halved, quartered, doubled, quadrupled) and has a b. ______________ (negative, positive) value.

1.4 An object is traveling in a circular motion at constant speed. If the speed is doubled, the centripetal acceleration is changed by a factor of ____________________ (one-half, one-fourth, two, four).

1.5 A car turns a corner at 15 kph. If the car were to turn in a shorter radius, the centripetal acceleration will a. ____________________ (increase, decrease). If the radius of the arc is decreased to one-half, the centripetal acceleration is changed to b. ____________________ (one-half, one-fourth, two times, four times) its original value.

1.6 An object falls toward the surface of the earth, traveling 120 feet in a given period of time. The gravitational acceleration of the moon is one-sixth that of the earth; therefore, the object would fall a a. ____________________ (greater, shorter) distance in the same period of time as it falls toward the surface of the moon. Specifically, it would fall b. ____________________ feet.

Solve these problems.

1.7 If a car previously traveled at 15 mph but now covers the same distance in half the time, calculate its velocity.

1.8 If an object moved at 30 m/sec and at a later time covers half the distance in the same time, calculate its new speed.

1.9 A car turns a corner that has a radius of 5 m and experiences a centripetal acceleration of 20 m/sec^2. If the radius of turn were increased to 10 m, calculate the centripetal acceleration.

1.10 A stone whirled on a string experiences a centripetal acceleration of 10 m/sec^2. If the string were shortened to half its length (one-half the radius) and the speed were doubled, calculate the centripetal acceleration.

1.11 A car undergoing uniform acceleration travels 100 meters from a standing start in a given period of time. If the time were increased by a factor of four, calculate the displacement.

DYNAMICS

You may wish to review LIFEPAC 1202: the vocabulary words and the concepts of force, conservation of momentum, gravitational force fields, Newton's laws of motion, and Kepler's laws of planetary motion.

Dynamics is the study of forces and of their effects on objects. Through brilliant intuition and with no experimental confirmation, Newton declared that force tends to produce proportional acceleration: no force, no acceleration; small force, small acceleration; and so on. The ubiquitous force is gravity. It is, conveniently, a uniform acceleration. Springs and rubber bands do not exert uniform forces and are, therefore, not as useful for study on this elementary level.

Force. An object in the state of rest or in the state of uniform linear motion continues in that state unless a net (unbalanced) external force acts on it. A car moving in a straight line at constant speed does so only because the friction in the drive train, the tires, and the wind resistance are balanced by the action of the engine. Removing your foot from the gas pedal produces a reduction in the velocity; therefore, external forces must be present. Except for the pull of gravity, the planets would move in straight lines; instead, they orbit in elliptical paths around the sun.

Force is simply a push or a pull. Force is proportional to mass and to acceleration,

$$F = ma$$

Mass and acceleration are inversely proportional to each other. As mass increases, the acceleration produced by a force decreases.

Momentum. Momentum is the product of mass and velocity and is, therefore, proportional to both mass and velocity. Mass and velocity are inversely proportional to each other.

$$\text{momentum} \propto m$$
$$\text{momentum} \propto v$$

$$v \propto {}^{1}\!/_{m}$$

A more massive car has more momentum than a smaller car traveling at the same speed. If several objects have the same mass, the object with the greatest speed has the most momentum.

Momentum is a property of all moving objects. A change in momentum (Δmv), either from zero or from a finite value, is produced when the object undergoes acceleration:

$$F = ma$$

$$F = m(\Delta v/\Delta t)$$

$$F\Delta t = m\Delta v$$

The left side of the equation, simplified to $F \cdot t$, is called *impulse*. An impulse—a force acting during some time interval—causes a change in momentum. Both momentum and impulse are vector quantities.

Gravity. When the force under consideration is the gravitational attraction close to the surface of the earth, the symbol a is changed to g:

$$F = mg;$$

g is 9.8 m/sec^2 or 32 ft/sec^2. The force of gravity obeys the inverse square law:

$$F = G\,\frac{m_1 \cdot m_2}{d^2}$$

G is the universal gravitational constant: ($6.67 \cdot 10^{-11}\ {}^{\mathrm{N \cdot m^2}}\!/_{\mathrm{kg^2}}$), m_1 and m_2 are the masses of the two objects, and d is the separation of the two objects measured from the centers of mass. At 4,000 miles from the center of the earth (the surface), a man experiences a force:

$$F = G\,\frac{m_{earth}m_{man}}{(radius\ of\ earth)^2}$$

$$F = (G\ {}^{m_e}\!/_{R^2})\,m_{man}$$

The value of the factors in parentheses is g, 9.8 m/sec^2 or 32 ft/sec^2.

$$F = (m_{man})(g)$$

The weight of a man 8,000 miles above the surface of the earth (12,000 miles from its center, equal to three earth radii) is one-ninth his weight on the surface. If an object weighs 10 pounds at 5 radii, then on the surface of the earth (⅕ of 5 radii), the object will weigh more by a factor of the inverse of $(⅕)^2$: the object will weigh 25 times more, or 250 lbs. The weight of an object is a measure of gravitational force.

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800-622-3070
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