LIFEPAC®

SCIENCE

STUDENT BOOK

12th Grade | Unit 2

Alpha Omega PUBLICATIONS

SCIENCE 1202

DYNAMICS

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

Author:
Mary Grace Ferriera, M.A.T., M.N.S.

Editor:
Alan Christopherson, M.S.

Media Credits:
Page 5: © Netta07, iStock, Thinkstock; **19:** © Ingram Publishing, Thinkstock; **35:** © ktsimage, iStock, Thinkstock.

Alpha Omega PUBLICATIONS

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

Dynamics

Introduction

Having a foundation of kinematics in physics, you will begin a study of dynamics (from the Greek word "*dynamis*," meaning *power*). In dynamics, we will observe and discuss the causes of motion, what is actually moving, and how the nature of the object affects the motion. You have already studied one very famous scientist, Galileo; now you will encounter two others, Sir Isaac Newton and Johannes Kepler.

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. Identify and explain Newton's first law of motion and second law of motion.
2. Identify and explain force, impulse, and momentum.
3. Solve problems involving Newton's second law of motion.
4. Explain why all objects exert a gravitational force.
5. Explain the difference between gravitational and inertial masses.
6. Calculate the acceleration due to the earth's gravitational field.
7. Solve problems using the equations of motion with acceleration due to the earth's gravity.
8. Explain how different objects' gravitational fields differ.
9. Explain the cause of centripetal acceleration.
10. Calculate problems involving centripetal acceleration and centripetal force.
11. Identify and explain Newton's third law of motion.
12. Apply the conservation of momentum concept in solving problems.
13. Solve problems using vector arithmetic.
14. Identify and explain Kepler's laws of planetary motion.
15. Solve problems using Kepler's laws of motion.

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

1. NEWTON'S FIRST AND SECOND LAWS OF MOTION

To begin a study of dynamics, you will become acquainted with Sir Isaac Newton and his laws of motion. Newton once stated that he had made strides in physics only because he had stood on the shoulders of a giant—Galileo Galilei. As we investigate the first two laws of motion, review the law of inertia from the previous LIFEPAC.

Section Objectives

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

1. Identify and explain Newton's first law of motion and second law of motion.
2. Identify and explain force, impulse, and momentum.
3. Solve problems involving Newton's second law of motion.

Vocabulary

Study these words to enhance your learning success in this section.

force	**impulse**	**momentum**
Newton's first law of motion	**Newton's second law of motion**	

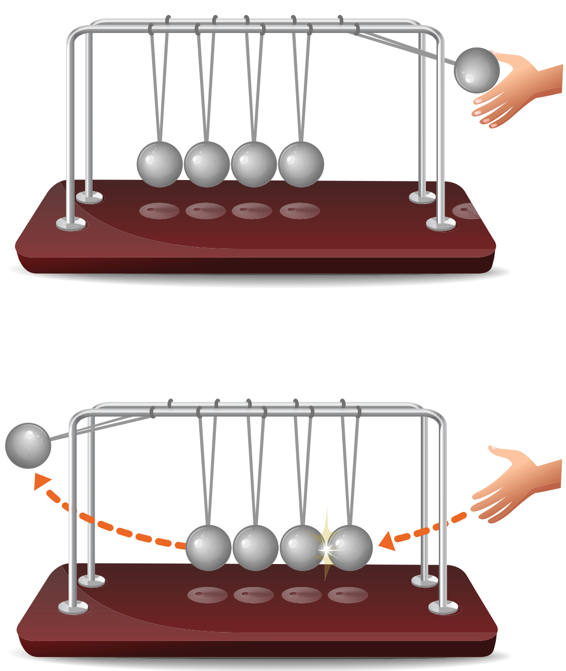
Note: *All vocabulary words in this LIFEPAC appear in* **boldface** *print the first time they are used. If you are not sure of the meaning when you are reading, study the definitions given.*

NEWTON'S FIRST LAW OF MOTION

Isaac Newton (1642–1727) was born the year that Galileo Galilei died, and at age twenty-three, formulated his laws of motion. Galileo's law of inertia is a special case of **Newton's first law of motion**, which, when translated from Newton's *Principia*, states:

> "Every object continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by **forces** acting on it."

The key word is *continues*: the object continues to do whatever it is doing unless a force acts on it. A force is a push or a pull: that which causes an object to be accelerated. If the object is stationary, it will remain stationary; and if it is moving, it will continue to move without changing direction or speed; that is, *it does not accelerate*. The tendency of a body to resist a change in motion is what Galileo termed *inertia*.



| Newton's cradle

Prepare a report.

1.1 Newton stated that, if he had made any strides in science, he had done so by standing on the shoulders of a giant named Galileo Galilei. This statement was modest coming from a man who made discoveries in so many different areas of physics. Prepare a report on the life of Sir Isaac Newton, his accomplishments, discoveries, books written, and honors received. This report should be approximately 500 words. Submit the report for evaluation.

CHECK ______________ ______________
Teacher Date

Complete these calculations.

1.2 In this activity, assume that the effect of friction can be discounted.

a

a. Referring to diagram *a*, how high will the ball rise on the right-hand incline? ________________

b

b. Referring to diagram *b*, if the incline on the right has a slope of 5 cm of rise for each 2 cm of run, how far will the ball travel horizontally? ________________

c. If, in *b*, the rise is only 0.5 cm for each 2 cm of run, how far will the ball travel horizontally?

____

d. If, in *b*, the rise is 0.01 cm for each 2 cm of run, how far will the ball travel horizontally?

____

e. If, in *b*, no gravitational force retarded the ball's movement (that is, if the right-hand side of the diagram were horizontal), how far would the ball travel? ____________________

1.3 If a ball is given an initial speed of 15 m/sec on a horizontal, frictionless surface, how fast will the ball be rolling in 5 seconds? ____________________

1.4 A car moves down the street at 45 kph. The driver takes his foot off the gas pedal but does not brake. Explain why the car slows down.

____

____

NEWTON'S SECOND LAW OF MOTION

Nearly everyone has had at least one experience of helping push a friend's car to a garage or gas station. If you have enough friends in this situation, you know that pushing a light car is easier than pushing a heavier one. If a detailed study is made, a relationship is discovered: The acceleration of an object is directly proportional to the net force acting on the object, and is inversely proportional to the mass of the object. This relationship is called **Newton's second law of motion**.

Force. To move an object from rest to a certain velocity requires an acceleration: $a = \Delta v/\Delta t$. If more than one force is exerted, the total, or net force is the vector sum of all the forces. The greater the net force, the greater the acceleration. This relationship is called a *direct proportion*. That is, when one quantity increases, the other increases by the same proportion.

If the mass of the object is increased, the same force produces a smaller acceleration. In fact, doubling the mass produces half the acceleration previously attained, and tripling the mass yields only one-third of the former acceleration. This relationship is called an *inverse proportion*. We can write Newton's second law as $a = F/m$. By cross multiplying, we obtain $F = ma$.

Impulse and momentum. If in the formula $F = ma$, a is replaced by $\Delta v/\Delta t$, then $F = m\,\Delta v/\Delta t$ and $F\Delta t = m\Delta v$.

This last equation, derived from Newton's second law, is rather important. The term on the left, $F\Delta t$, is called the **impulse**, which is the product of the force on an object and the time during which the force acts. When a bat hits a baseball, a tennis racket hits a tennis ball, an oar pushes against water, or a foot pushes against the ground, an impulse is imparted that equals force times the lapsed time. The smaller the force, the smaller the impulse; the shorter the time, the smaller the impulse. The metric unit of impulse is the newton-second (N•sec), or the kilogram-meter/second (kg•m/sec).

The term on the right is called the **momentum**, which is the product of the mass and its change in velocity. Momentum is not speed, velocity, force, nor energy. Let us look at some examples that convey the concept of momentum. A turtle moving at a meter per minute is not a formidable object. But imagine an ocean liner moving toward you at a meter per minute. Its momentum is not due to its velocity, but to its mass. Air molecules move at rifle-bullet speeds, and we think nothing of them. They collide, bounce off each other, and off other objects including ourselves. Let an object of ten grams (the approximate mass of a bullet) move at rifle-bullet speeds and this momentum can be lethal. Momentum is the product of mass *and* velocity. *Change* in momentum is the product of mass and change in velocity.

Try these activities.

1.5 If a cart of 2 kg mass has a force of 8 newtons exerted on it, what is its acceleration?

____

1.6 If, in the preceding example, the cart's mass were increased to 4 kg, what would the new acceleration be?

____

1.7 The impulse given to a ball with mass of 2 kg is 16 N•sec. If the ball starts from the rest, what is its final velocity?

____

1.8 If, in the previous example, the ball were already moving at 3 m/sec, what would the final velocity be? (Remember that $\Delta v = v_{final} - v_{initial}$.)

____

1.9 If a boy (m_1 = 50 kg) at rest on skates is pushed by another boy who exerts a force of 200 N on him and if the first boy's final velocity is 8 m/sec, what was the contact time?

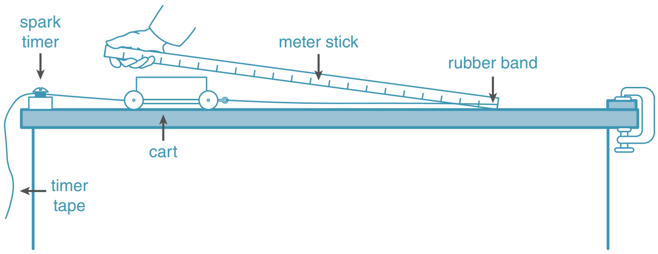
____

Try this investigation of Newton's second law of motion. You will investigate the quantitative relationship between force, mass, and acceleration.

These supplies are needed:

- spark timer
- balance
- 2 C-clamps
- several masses
- timer tape
- several heavy rubber bands
- cart
- several plastic bags
- metric ruler
- masking tape
- wood bumper

Follow these directions and complete the activities. Put a check in the box when each step is completed.



☐ 1. Find the mass of the cart and record it here: ______________ g

☐ 2. From the assorted masses, make four groups of masses each equal to the mass of the cart, and place these in plastic bags so that they will stay together. If your cart has a mass of 876 g, rounding to 880 g will introduce a small error that can be ignored. The mass of the cart is 1 C, the cart plus one packet is 2 C, and so on.

☐ 3. Hook a heavy rubber band to the front of the cart. Control the amount of force exerted on the cart by placing the metric ruler at the free end of the rubber band and stretching it a constant length. Determine a given stretch that produces a small acceleration of your cart. This stretch of rubber band is 1 F of force. When two identical rubber bands are hooked to the cart and stretched the predetermined amount, the force is 2 F (see illustration).

☐ 4. Clamp the spark timer to the table. Let five ticks equal one tock, then two tocks will equal ten ticks, and so on. At the other end of the table have either a bumper to stop your cart or a person to catch it.

☐ 5. The cart should move at a constant speed when no force is exerted on it, so run several tapes of 1 C, 2 C, and 3 C. Start the timer and give the cart a gentle push with your hand. Compare distances between tocks at several locations on the tape.

1.10 Is velocity constant when the rubber band is not pulling the cart? ______________________________

____

____

1.11 Is the velocity more uniform when the cart moves slowly or rapidly? ______________________________

____

____

____

Newton's Second Law of Motion Experiment (Continued on next page)

Alpha Omega
PUBLICATIONS

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

800-622-3070
www.aop.com

SCI1202 – Apr '18 Printing

ISBN 978-1-58095-592-8

9 781580 955928