LIFEPAC®

SCIENCE

STUDENT BOOK

12th Grade | Unit 3

Alpha Omega PUBLICATIONS

SCIENCE 1203
WORK AND ENERGY

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

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Work and Energy

Introduction

You have mastered the areas in physics known as kinematics and dynamics. Now you will add to that foundation another concept, energy. These three areas of physics form the backbone of all future studies of waves, sound, light, electricity and magnetism, and nuclear and atomic energy. Your success in this LIFEPAC® will affect your success in other areas of physics.

Energy is the ability to do work. In this LIFEPAC you will undertake a study of energy—its sources and forms, its basic laws, and its transformations.

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 energy.
2. Identify various forms and sources of energy.
3. Solve kinetic and potential energy problems.
4. Apply the law of conservation of energy in energy problems.
5. Solve problems involving power.
6. Solve problems concerning the efficiency of machines.
7. Apply thermodynamics to the solution of problems related to heat flow and machines.
8. Identify and classify phases of matter.
9. Distinguish between temperature and heat.
10. Calculate heat energy involving latent heats.

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

1. TYPE AND SOURCES OF ENERGY

Energy is the ability to do **work**. Energy has a variety of forms: **chemical**, **heat**, **electrical**, **nuclear**, **solar**, **geothermal**, **hydroelectric**, **tidal**, and **wind**. The gasoline your car burns contains energy in the bonds of the hydrogen and carbon atoms of which the fuel is comprised. Substances may contain energy but the substance should not be confused with the energy it contains.

This section will treat two forms of energy, **kinetic** and **potential**. A later section will deal with heat energy. Other LIFEPACs will introduce the study of electrical, light, and nuclear energy. Chemical energy is covered in the chemistry series of LIFEPACs; geothermal, tidal, and wind energy are covered in LIFEPACs on the earth sciences.

Section Objectives

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

1. Define energy.
2. Identify various forms and sources of energy.
3. Solve kinetic and potential energy problems.

Vocabulary

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

acceleration due to gravity
chemical energy
displacement
distance
electrical energy
energy
force
geothermal energy
heat energy
hydroelectric energy
kinetic energy
light energy
mass
nuclear energy
potential energy
solar energy
tidal energy
wind energy
work

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.*

MECHANICAL ENERGY

Energy is the ability to do work. **Work** occurs whenever a **force** (F) is exerted through a **distance** (d). The product of the net force and the **displacement** through which it is exerted is work.

work = F • d

Net force means that if more than one force is acting upon an object, the *vector sum* must be obtained.

The displacement through which the force acts is parallel to the direction of the force. (Trigonometry is used to solve problems involving forces not parallel to the displacement.) If the force were perpendicular to the displacement, the object would not move in a straight line but would rotate in a circular path.

Mechanical energy has two forms, kinetic and potential. These two forms are the subject of this section.

Kinetic energy. An object in motion can do work by virtue of its motion because it can exert a force through a distance. The energy it has due to its motion is called **kinetic energy**.

Kinetic energy = $\frac{1}{2}mv^2$

where *m* is the **mass** of the object and *v* is its velocity.

Since kinetic energy results from a force acting over a certain distance,

$F \cdot d = \frac{1}{2}mv^2$

This equation could have been derived from Newton's second law:

$F = ma$
$F \cdot d = mad$

| Baseball pitchers apply force on the ball to get the ball over home plate.

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

$F \cdot d = ma(\frac{1}{2}at^2) = \frac{1}{2}ma^2t^2$

Substituting $v = at$,

$F \cdot d = \frac{1}{2}mv^2$

Complete these activities.

1.1 A car traveling at 60 mph has how much more energy than a car going at 20 mph?

1.2 How much farther will a car skid if it locks its brakes at 60 mph as compared to a skid from 15 mph?

If the metric (SI) system is used, force is measured in newtons (N); displacement is in meters (m); velocity is in meters/second (m/s); mass is in kilograms (kg); and work and energy are both measured in joules (J). A newton or force is equal to mass × acceleration; therefore, a newton is actually a kg • m/s^2. Work is a force × distance the force is moved, so a joule is actually kg • m^2/s^2 and energy, although using a different formula also uses the measuring unit of joules.

Energy is a bit more complex as there are different forms of energy; thus, it may be derived in using a different formula. Kinetic energy is energy of an object in motion, and potential kinetic energy is energy due to an object's position or height above the earth. There are two types of potential energy: gravitational and elastic. In this text, we will only be using the formula concerned with gravitational energy. Mechanical energy is the sum of all the kinetic and potential energy of an object.

A joule of energy is defined as a force of 1 newton exerted over a distance of 1 meter.

Work = Force (F) × distance (d)
Kinetic Energy (KE) = ½ mass × velocity squared
= ½ mv^2
= kg • m^2/s^2

Potential energy (PE) = mgh, since mass x gravity (gravity is an acceleration) is a force and height is a distance, the formula for PE is just like that of work.

Mechanical Energy (ME) = KE + ∑ PE

Notice, however, that in all of these formulas, the measuring unit of a joule is correct.

1 J = 1 N • m, thus 1 kg • m^2/s^2

In the English system, force is measured in pounds; mass is in slugs; distance is in feet; and velocity is in ft/s. So the English unit for work or **energy** is a foot-pound.

Work = Force (F) × distance (d)
= pound (slug • ft/s^2) • ft,
so the unit is slug • ft^2/s^2

SI Units		
Name	**Symbol**	**Measure**
meter	m	length
kilogram	kg	mass
second	s	time
ampere	A	electric current
kelvin	K	thermo-dynamic temperature
mole	mol	amount of substance
candela	cd	luminous intensity
newton	N	force

KE = ½ mv^2, so the unit is slug • ft^2/s^2

PE = mgh, so the unit is slug • ft/s^2 • ft
= slug • ft^2/s^2

Regardless of whether energy is measured in metric or English, the unit for measurement is equal to mass (m) times distance (d) squared divided by time (t) squared.

Energy = Work = m • d^2/t^2

In the metric system,

$$36 \text{ km/hr} = 36{,}000 \text{ m/hr} = \frac{36{,}000 \text{ meters}}{3{,}600 \text{ sec}}$$

36 km/hr = 10 m/sec

Unfortunately, since hours are not in a base-ten form, a conversion factor is needed to convert from km/hr to m/sec. In the English system, miles must be changed to feet and hours to seconds to yield a ratio of 15 mph = 22 $^{ft}/_{sec}$; so 45 mph = 66 $^{ft}/_{sec}$.

Complete these activities.

1.3 A car weighing 3,200 lbs. is traveling at 30 mph. How much kinetic energy does it possess? (Hint: calculate the mass of the car.)

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1.4 In the preceding problem, how much less energy would the car have if it were traveling at 15 mph?

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1.5 A force of 80 N is exerted on an object on a frictionless surface for a distance of 4 meters. If the object has a mass of 10 kg, calculate its velocity.

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1.6 Why are the chances of death occurring in an accident of a car traveling 60 to 70 mph fourteen times greater than in a car traveling at 30 to 40 mph?

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Potential energy. Kinetic energy is the energy a body contains by virtue of its motion. The energy stored in a body by virtue of its position is called **potential energy**. A spring has potential energy when it is compressed or stretched because it can do work on any object attached to it. A stretched rubber band or a stretched bowstring also stores potential energy. A rock resting on the ground has no stored energy. The potential energy depends also on the gravitational field.

$$P \cdot E = mgh$$

where *m* is the mass, *g* is the **acceleration due to gravity**, and *h* is the height above ground. Where ground level is 4,000 feet elevation, an object at 4,100 feet has potential energy proportional to 100 feet. The *h* is vertical height (displacement) and does not depend on the path. Since the object was lifted to that height, work was done on it.

$$Fd = mgh$$

Notice that this equation could have been derived by using the definition that weight is a force:

$$\text{weight} = F = mg$$

and multiply both sides by distance, d:

$$F \cdot d = mg \cdot d$$

If that distance is height, d = h

$$F \cdot d = mg \cdot h$$

Complete these activities.

1.7 A rock with mass of 5 kg is carried up a small hill 10 meters high. What is the potential energy of the rock at the hilltop?

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1.8 How much work had to be done in carrying that rock up hill?

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1.9 A 20 kg barrel is rolled up a 20 m ramp to the back of a truck whose floor is 5 m above the ground. What work is done in loading one barrel into the truck?

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1.10 How much potential energy does that one barrel (from Problem 1.9) have when it is in the truck?

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FORMS OF ENERGY

In the late eighteenth century, a depleted supply of whales whose blubber was used for lamp oil accelerated the infant petroleum industry. In the early 1970s, the Arab oil embargo initiated searches for replacement sources of energy. Technological advances have been made that will allow oil to continue as an important source of energy as research is done to look for alternatives.

Chemical energy. The energy that coal possesses is chemical bonding between hydrogen and carbon atoms. This energy is **chemical energy**. From the molecular point of view, chemical energy is potential energy because the electron positions are changed when a chemical reaction takes place. Work is obtained by breaking the chemical bonds. When either coal, oil, gas, or wood is burned, a chemical reaction takes place and chemical energy is released.

Heat energy. When a temperature change occurs, **heat energy** is involved. At the microscope level, atoms and molecules all possess energy of motion and position. Addition of heat energy increases the random motion of the atoms and molecules.

| Solar panels collect solar energy.

Solar energy. Most energy is ultimately derived from the sun. Various forms of energy occur under the title **solar energy**. Visible light would properly be called **light energy**. The infrared portion of the spectrum could also be called *infrared* or *heat energy*. However, energy that is directly from the sun is termed *solar energy*. The future trend is to harness solar energy to do work economically. Solar ovens and energy collectors to cook food, to generate electricity, and to heat water, swimming pools, and houses are already in use.

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