LIFEPAC® Science

Alpha Omega Publications®

PHYSICS 1203
WORK AND ENERGY

CONTENTS

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WORK AND ENERGY

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. Write your questions here.

I. 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 unsure 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.

$$\text{work} = F \bullet d$$

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**.

$$\text{Kinetic energy} = \tfrac{1}{2}\, mv^2$$

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,

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

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

$$F = ma$$

$$F \cdot d = mad$$

Since $d = \tfrac{1}{2} at^2$.

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

Substituting $v = at$, $\quad F \cdot d = \tfrac{1}{2} mv^2$

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 system is used, force is measured in newtons; displacement, in meters; velocity, in $^{\text{meters}}/_{\text{second}}$; mass, in kilograms; and energy, in joules (J). A joule of energy is defined as a force of 1 newton exerted over a distance of 1 meter. Therefore,

$$\text{joule} = \text{newton} \cdot \text{meter}$$

$$1\ \text{J} = 1\ \text{N} \cdot \text{m}$$

$$F \cdot d = m \cdot a \cdot d$$

$$\text{joule} = \text{kilogram} \cdot {}^{\text{meter}}/_{\text{sec}^2} \cdot \text{meter}$$

$$\text{J} = {}^{\text{kg}\cdot\text{m}^2}/_{\text{sec}^2} = \text{N} \cdot \text{m}$$

In the English system, force is in pounds; mass, in slugs; distance, in feet; and velocity, in $^{\text{feet}}/_{\text{second}}$. An English unit of energy is a foot-pound.

$$\begin{aligned} \text{Work} &= F \cdot d \\ &= \text{pound} \cdot \text{feet} \end{aligned}$$

$$\begin{aligned} F \cdot d &= \tfrac{1}{2} mv^2 \\ \text{ft} \cdot \text{lb} &= \text{pound} \cdot \text{feet} = \text{slug} \cdot {}^{\text{feet}^2}/_{\text{second}} \\ \text{ft} \cdot \text{lb} &= {}^{\text{slug}\cdot\text{ft}^2}/_{\text{sec}^2} \end{aligned}$$

Regardless of whether energy is measured in metric or English, it is *dimensionally* equal to mass (m) times distance (d) squared divided by time (t) squared:

$$\text{energy} = \text{work} = m \cdot \frac{d^2}{t^2}$$

In the metric system,

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

$$36\ {}^{\text{km}}/_{\text{hr}} = 10\,{}^{\text{m}}/_{\text{sec.}}$$

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

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.) ______________________________

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. ________________________

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.

$$P \bullet E = mgh,$$

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:

$$F \bullet d = mg \bullet d$$

If that distance is height, d = h

$$F \bullet d = mg \bullet h$$