Why Pole vaulters use sticks that bends?

Unit 6 WORK AND ENERGY

CHECK LIST

After studying this unit you should be able to:

- ✓ define work and its SI unit.
- ✓ calculate work done using equation: *work = force x distance moved in the direction of force*
- ✓ define energy, kinetic energy and potential energy. State unit of energy.
- ✓ prove that Kinetic Energy $E_k = \frac{1}{2} mv^2$ and potential energy E_{GPE} = mgh and solve problems using these equations.
- ✓ list the different forms of energy with examples.
- ✓ describe the processes by which energy is converted from one form to another with reference to - fossil fuel energy - hydroelectric generation - solar energy - nuclear energy - geothermal energy - wind energy and biomass energy
- ✓ state mass energy equation $E = mc^2$ and solve problems using it.
- ✓ describe the process of electricity generation by drawing a block diagram of the process from fossil fuel input to electricity output.
- ✓ list the environmental issues associated with power generation.
- ✓ differentiate energy sources as non renewable and renewable energy sources with examples of each.
- ✓ explain by drawing energy flow diagrams through steady state systems such as Filament lamp, a power station, a vehicle traveling at a constant speed on a level road.
- ✓ define efficiency of a working system and calculate the efficiency of an energy conversion using the formula: *efficiency = energy converted into the required form / total energy input*
- ✓ explain why a system cannot have an efficiency of 100%.
- ✓ define power and calculate power from the formula *Power = work done / time taken*
- ✓ define the unit of power "watt" in SI and its conversion with horse power.
- ✓ Solve problems using mathematical relations learnt in this unit.

Newton laws can be used to predict motion using forces and accelerations. While dealing with Newton laws we freeze the action in particular instant of time, and then we draw a free body diagram and set-out equations e.t.c. Work energy allow us to predict motion by different technique - we just look at starting conditions and final conditions to get all the required information ignoring what happens in between.

6.1 WORK

The scientific definition of work differs in some ways from its everyday meaning. Certain things we think of as hard work, such as writing an exam or carrying a heavy load on level ground, are not work as defined by a scientist. For work, in the scientific sense, to be done, a force must be exerted and there must be motion or displacement in the direction of the force.

Work is said to be done when a force displaces a body in its own direction. When an object moves distance 'S' in the direction of applied force F, then work done W is given mathematically as

$$W = F \times S \qquad (6.1)$$

Unit of Work:

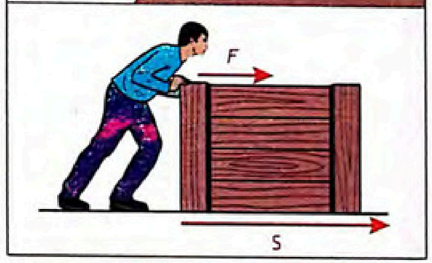
The SI unit of work is joule (abbreviateds J, and named in honor of the 19th-century English physicist James Prescott Joule). The unit of work is the unit of force (newton) multiplied by the unit of distance (metre).

1 joule = (1 newton)(1 meter)

or *1J = 1 Nm*

Work done is scalar quantity, however force is vector quantity, sometime force is not perfectly applied in the direction of motion. For example consider the figure in which a box is moving in horizontal

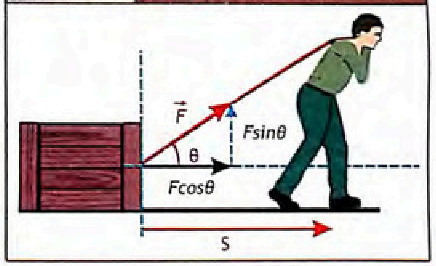
Figure 6.1 Work



TID BIT — PLAY IS WORK?

Who is doing more work? A boy playing and running in school ground or a teacher sitting on chair working on physics problems.

Figure 6.2 Work



direction and force F is applied making certain angle θ with the horizontal. In such situations the force is resolved into its rectangular components.

From the figure it is clear that the effective component of force, in the direction of motion is $F\cos\theta$, Mathematically work done can be written as

$$W = F\cos\theta \times S \qquad (6.2)$$

Example 6.1 SUITCASE

A person pulls a suitcase through the airport at 45° angle . The tension in the rope is 20 N. How much work does the tension do if the suitcase is pulled 100 m?

SOLUTION

GIVEN:

Tension = Force F = 20 N

Distance = S = 100 m

Angle = 45°

REQUIRED:

Work W = ?

By definition of workdone

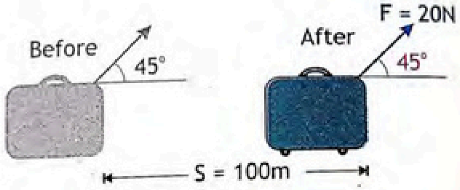
$$W = F\cos\theta \times S$$

putting values

$$W = 20N\cos 45^o \times 100m$$

or $$W = 2000\,Nm \times 0.707$$

$$W = 1400\,J \quad \text{Answer}$$



Because a person pulls the rope, we would say informally that the person does 1400 J of work on the suit case.

Assignment 6.1 TUG OF WAR

During a tug-of-war, team A pulls on team B by applying a force of 1100 N to the rope between them. The rope remains parallel to the ground. How much work does team A do if they pull team B toward's them a distance of 2.0 m?

6.2 ENERGY AND ITS FORMS

If we look at the world around us we can identify things that are capable of doing work, that is, exerting a force to move an object.

- A boy is kicking a ball. The boy exerts a force on the ball and the ball moves.

The work done on the ball is transfer energy from boy to the ball.

- A stretched bow can shot an arrow due to energy store in it. The energy is the stretched sting is transferred to arrow.

So energy is defined as '**Energy is the capacity of a body to do work**'.

Unit of energy:

The unit of energy is the same as that of work i.e. joule (abbreviated J = Nm).

As you have learned, Grade 6, Chapter Energy and its forms, all forms of energy (Heat, electrical, light and sound) can be classified as one of two types, either as stored or potential energy or as moving or kinetic energy. The few energy types are given in table 6.1.

6.3 KINETIC ENERGY

The energy possessed by a body due to its motion is called Kinetic energy.

When a cricket ball is thrown it moves, similarly a car starts moving when pushed. Now Think that a cricket ball and a car are moving with same speed. Which possess greater ability to do work? Of course it is the car with larger mass, it is difficult to stop. Similarly now two cricket balls are approaching you with different speeds, which can do more work? Again it is easy to answer as the ball with greater speed is difficult to stop. Thus object mass and its speed are contributing to its kinetic energy.

Mathematically Kinetic energy is one half the product of an object's mass 'm' and the square of its velocity 'v'.

$$E_K = \frac{1}{2}mv^2$$

POINT TO PONDER DOES THE EARTH DO WORK ON THE MOON?

The Moon revolves around the Earth in a nearly circular orbit, kept there by the gravitational force exerted by the Earth. This gravitational force provides it centripetal acceleration, inward along the radius of the Moon's orbit. The Moon's displacement at any moment is tangent to the circle, perpendicular to the force of gravity F_g. Hence the angle between the force and the instantaneous displacement of the Moon is 90°, and the work done by gravity is therefore zero. (W= F S cos 90° = 0). This is why the Moon, as well as artificial satellites, can stay in orbit without expenditure of fuel: no work needs to be done against the force of gravity.

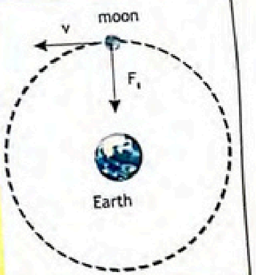


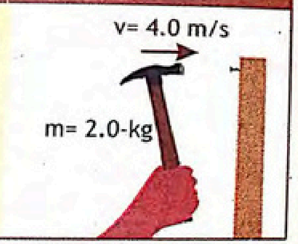
TABLE 6.1: TYPES OF ENERGY

Type	Description	Example
Chemical Energy	The energy contained within the bonds between atoms.	These bonds can take many different forms, including energy derived from carbohydrates in food to energy stored in gasoline.
Radiant Energy	Radiant energy travels as an electromagnetic (light) wave.	Radiant energy from the Sun supplies Earth with all of the energy required to sustain life.
Electrical Energy	The energy associated with charges.	Electrons moving from negatively to positively charged objects.
Heat Enrgy	Energy that travel from hot body to cold body.	Fire burning transfer the energy to keep room warm.
Sound Energy	Energy as wave, as a sound wave passes through, the atoms or molecules of the substance vibrate back and forth.	Sound vibrations cause a person's eardrums to vibrate.
Nuclear Energy	Energy in the Nucleus of an atom.	Nuclear power stations use nuclear energy to generate electric energy.

Like all energies kinetic energy is also a scalar quantity. For example, a 2.0-kg hammer head moving with a speed of 4.0 m/s has a kinetic energy of 16 J.

Figure 6.3

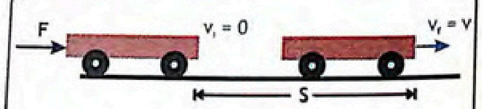
The moving hammer has kinetic energy and thus can do work on the nail, driving it into the wall.



Mathematical proof:

Consider a situation in which all of the work done on a cart transfers only kinetic energy to the cart. Consider a cart which is initially at rest. A horizontal force F is applied to it comes it to move through a displacement 's' and achieve a final volicty of $v_f = v$ as shown in figure 6.4. This work done W appears as the kinetic energy K_E. Such that

Figure 6.4 Work



$$W = E_K = F \times S \quad \text{——} (1)$$

By Newton's Second Law of motion

$$F = ma \quad \text{——} (2)$$

By third equation of motion

$$2as = v_f^2 - v_i^2$$

rearranging

$$S = \frac{v_f^2 - v_i^2}{2a} \quad \text{——} (3)$$

putting equation 2 and 3 in equation 1

$$E_K = m\cancel{a} \times \frac{v_f^2 - v_i^2}{2\cancel{a}}$$

or $$E_K = m \times \frac{v_f^2 - v_i^2}{2}$$

As the object started from rest

therefore $v_i = 0$ and $v_f = v$

$$E_K = \frac{1}{2} mv^2 \quad \text{——} (6.3)$$

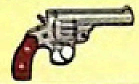
INFORMATION

Magnetar: On December 27, 2004, astronomers observed the greatest flash of light ever recorded from outside the solar system. It came from the highly magnetic neutron star SGR 1806-20 (a magnetar). During 0.20 s, this star released as much energy as our sun does in 250,000 years.

This equation shows the relation between the kinetic energy of a moving object with its mass and velocity. Equally important, it demonstrate the work kinetic energy theorem which states that the work done on an object s equal to change in energy.

Example 6.2 – BULLET SPEED

A 60.0-g bullet is fired from a gun with 3150 J of kinetic energy. Find its velocity.



SOLUTION

GIVEN:

mass m = 60 g = 0.06 kg

Kinetic energy E_k = 3150 J

REQUIRED:

velocity v = ?

The kinetic energy is given as

$$E_K = \frac{1}{2} mv^2$$

rearranging

$$v^2 = \frac{2E_K}{m}$$

EXTENSION EXERCISE 6.1

If a car of mass 800 kg is having same kinetic energy, what will be its speed?

taking square root on both sides

$$\sqrt{v^2} = \sqrt{\frac{2E_K}{m}}$$

or $$v = \sqrt{\frac{2E_K}{m}}$$

putting values

$$v = \sqrt{\frac{2 \times 3150\cancel{J}}{0.06\,kg} \times \frac{kg\,m^2/s^2}{\cancel{J}}} \qquad as\ 1\ J = kgm/s^2 m$$

therefore $v = 324\,m/s$ — Answer

The bullet is moving with speed 324 m/s.

Assignment 6.2 BULLET KINETIC ENERGY

A bullet of mass 30 g travels at a speed of 400 ms^{-1}. Calculate its kinetic energy.

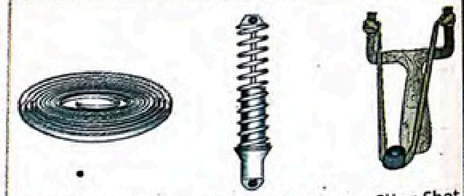
6.4 POTENTIAL ENERGY

The energy possessed by a body by virtue of its position or configuration in a force field is called potential energy.

Consider the work you do on your physics textbook when you lift it from the floor and place it on the top shelf. You have done work on the textbook and yet it is not speeding off (not gained E_K). The work you did on your textbook is now stored in the book by virtue of its position. By doing work against the force of gravity, you have given your book a special form of potential energy called gravitational potential energy. You will come to know about this if you release book from the top shelf it will accelerate, gaining kinetic energy, thus gravitational potential energy can be released and have the ability to do useful work. Gravitational potential energy is only one of several forms of potential energy.

For example, chemical potential energy is stored in the food you eat. Doing work on an elastic band by stretching it stores elastic potential energy in the elastic band

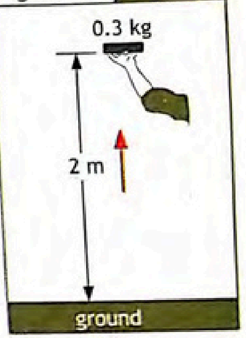
Figure 6.5 Potential Energy



Winding spring (toys, watches) | Spring (Shock absorber) | Sling Shot

(springs, slingshot in figure 6.5 are examples of elastic potential energy). A battery contains both chemical and electrical potential energy.

Figure 6.6



Mathematically Gravitational potential energy is the product of mass 'm', the acceleration due to gravity 'g', and the change in height 'h'.

$$E_{GPE} = mgh$$

Like all energies potential energy is also a scalar quantity. For example if we lift a brick of mass 0.3 kg from the ground to 2 m high the work is done against the force of gravity, this work appears as 5.88 J of energy.

Mathematical proof:

consider an object of mass 'm' being lifted vertically by a force 'F' to 'h' as shown in figure 6.7. The work done by the force F is given by equation.

$$W = E_{GPE} = F \times S \qquad (1)$$

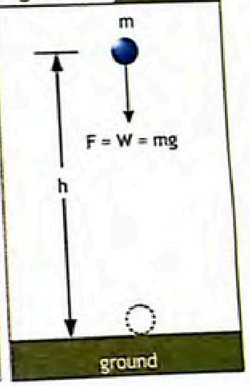
Since the force in this case is equal to its weight

$$F = W = mg \qquad (2)$$

TABLE 6.2: Energy of Various Objects and Phenomena

Object/phenomenon	Energy in joules
Big Bang	10^{68}
Annual world energy use	4×10^{20}
1 kg uranium	4×10^{13}
1 ton TNT	4.2×10^{9}
1000-kg car at 90 km/h	3.1×10^{5}
Tennis ball at 100 km/h	22
Single electron in TV Screen	4×10^{-15}
Energy to break one DNA strand	10^{-19}

Figure 6.7



Here the distance moved is the height 'h' $S = h \qquad (3)$

putting equation 2 and 3 in equation 1, we get

$$E_{GPE} = mg \times h \quad \text{——} \quad 6.4$$

Example 6.3 HUMAN JUMP

The maximum height a typical human can jump is about 60 cm. By how much does the gravitational potential energy increase for a 72-kg person in such a jump? Where does this energy come from?

SOLUTION

GIVEN:
mass m = 72 kg
height h = 60 cm = 0.06 m
acceleration due to gravity g = 9.8 m/s^2

REQUIRED:
Gravitational Potential energy E_p = ?

The gravitational potential energy is given as

$$E_{GPE} = mg \times h$$

putting values $E_{GPE} = 72\text{kg} \times 9.8\text{m/s}^2 \times 0.6\text{m}$

$$E_{GPE} = 423.36J$$

rounding off $E_{GPE} = 420J$ —— Answer

This gravitational potential energy comes from elastic potential energy stored in the jumper's tensed muscles.

Assignment 6.3 GAIN IN GRAVITATIONAL POTENTIAL ENERGY

An object of mass 10 kg is lifted vertically through a height of 5 m at a constant speed. What is the gravitational potential energy gained by the object?

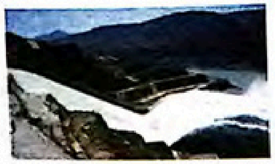
6.5 ENERGY CONVERSION AND CONSERVATION

The law of conservation of energy states that **'energy can neither be created nor destroyed in any process. It can be converted from one form to another, but the total amount remains constant'**. The following examples explain the law of conservation of energy.

1. **A diver on a spring board:**

Stored chemical energy in the body of the diver allows him to bend the diving board. This causes the bent diving board to store elastic

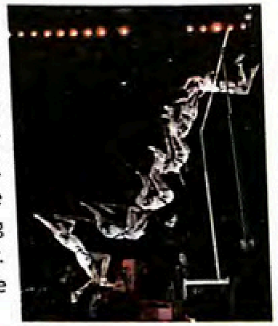
potential energy which is then converted into kinetic energy as an upward push.



2. **Generation of Electricity:**

Potential energy of water which is stored at a certain height is converted into kinetic energy by making it fall on turbine to produce electricity.

3. **Pole vault:**



Pole vaulters undergo several energy conversions. The initial run gives the vaulter kinetic energy. The vaulter plants the pole, transforming kinetic energy into potential energy of the deformed pole. Then the pole straightens and lifts the vaulter over the bar, transforming its elastic potential energy into gravitational potential energy. The athlete then falls toward's the pit, exchanging gravitational potential energy for kinetic energy. Finally, kinetic energy is dissipated in deforming the landing cushion.

POINT TO PONDER

What type of energy weightlifter used to lift weight?

The stored chemical energy in food enables a weightlifter to lift the barbell over her head.

6.5.1 MASS ENERGY EQUIVALENCE:

Einstein's mass energy equation is given by $E = mc^2$, *In other words:*

Energy = mass × the speed of light squared

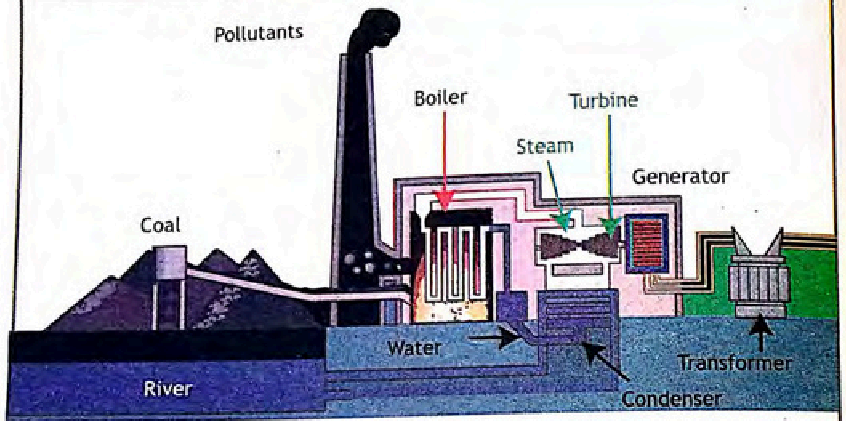
E = energy (measured in joules, J)

m = mass (measured in kilograms, kg)

c = the speed of light (measured in metres per second, ms^{-1}).

Speed of light is constant having value 3×10^8 ms^{-1}, however this value needs to be squared. This equation shows that mass and energy are the same physical entities and can be changed into each other.

Figure 6.8 PRODUCING ELECTRICAL ENERGY



In a power station, energy from a fuel (like burning coal) is used to boil water. The light-pressure steam is used to turn a turbine, which turns a generator to produce electricity

INFORMATION

Some insects jump using a catapult technique. The knee joint of a flea contains an elastic material called resilin (a rubber-like protein). The flea slowly bends its knee, stretching out the resilin and storing elastic energy, and then locks its knee in place . When the flea is ready to jump, the knee is unlocked and the resilin quickly contracts with a sudden conversion of the stored elastic energy into kinetic energy. Some of this kinetic energy is then converted into gravitational potential energy as the flea moves higher and higher.

Example 6.4 ENERGY WITHIN US

What is the energy released, when 50 kg person is converted completely into energy?

SOLUTION

GIVEN:
mass m = 50 kg
speed of light c = 3×10^8 ms^{-1}

REQUIRED:
Energy E = ?

By Einstein Famous equation

$$E = mc^2$$

putting values $E = 50\,kg \times (3 \times 10^8\ ms^{-1})^2$

therefore $E = 4.5 \times 10^{18}\ J$ — Answer

This is 450,000,000,000,000,0000 J, which is an incredibly large amount of energy. Equivalent to billion tons of TNT.

EXTENSION EXERCISE 6.2

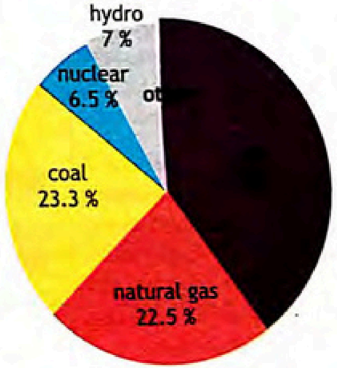
Find your mass and convert it into energy.

Assignment 6.4 ONLY 1g OF ENERGY

How much energy is generated when mass of 1g is completely converted into energy?

6.6 MAJOR SOURCES OF ENERGY

Energy transformation technologies convert energy from some source into a useful form of energy. The original source of the energy, called an energy resource, is a raw material obtained from nature that can be used to do work. A resource is considered renewable if it renews itself in the normal human life-span. All other resources are considered non-renewable.



Energy usage of the world

Scientific and technological advances have led society from a world that required only food energy to be transformed into muscle power, to one that makes use of every imaginable form of energy. In every energy-transformation process, some useful energy is lost. Clearly, society cannot continue to demand more and more energy without consideration for the future generations.

The challenge is to develop energy sources and processes that are sustainable. A sustainable resource is one that will not deplete over time and will not damage Earth's sensitive biosphere, while still being able to provide for the energy demands of society. Some of the important energy resources are:

A. Fossil Fuels:

Fossil fuels are the remains of millionyear- old plant life – now coal – or aquatic animal life – now gasoline and natural gas.

1. Coal:

Coal is the most abundant fossil fuel in the world, with an estimated reserve of one million metric tons. but burning coal results in significant atmospheric pollution.

2. Oil:

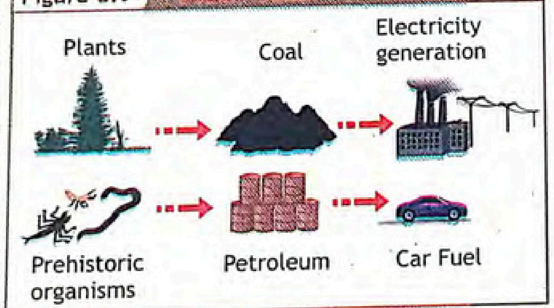
Crude oil is refined into many different energy products such as gasoline, jet fuel and heating oil. Despite the limited reserves of oil in the world it is a preferred source over coal because oil produces more energy than same amount of coal.

3. Natural gas:

Natural gas is often a by product of oil, it is mixture of gases the most common of which is methane. The advantage that natural gas has is that, it is easy to transport.

Fossil fuels are consumed in more than 80% of the world demand for energy. However the waste gases produced in the consumption is polluting the atmosphere.

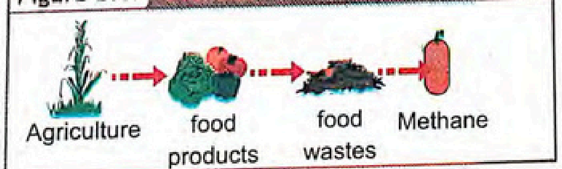
Figure 6.9 FOSSIL FUELS



B. Bio-mass:

"Bio" means life, so bio-energy is energy from living things. The term "biomass" refers to the

Figure 6.10 BIOMASS



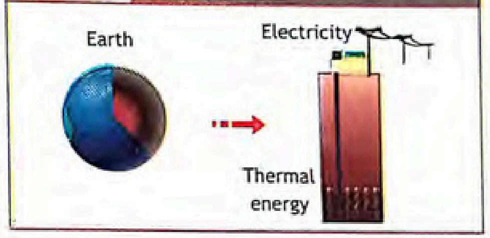
material from which we get bio-energy. Biomass is produced when the Sun's solar energy is converted into plant matter (carbohydrates) by the process of photosynthesis. Only green plants and photo synthetic algae, containing chlorophyll, are able to use solar energy.

The simplest process employed to make use of this energy is eating. Every time you eat a fruit, a vegetable, or a processed version of either, you are taking advantage of the energy stored as biomass.

C. Geothermal Energy:

Geothermal energy is the energy recovered from Earth's core. The thermal energy contained within Earth's core results from energy trapped almost five (5) billion years ago during the formation of the planet. In many countries geothermal energy is used to generate electricity.

Figure 6.11 GEOTHERMAL



D. Wind Energy:

The kinetic energy of the wind is currently used in many parts of the world to generate electricity. It is eco friendly source of energy but require very large open space.

E. Nuclear Energy:

Nuclear fission is the process of splitting extremely large atoms (Like Uranium or Polonium) into two or more pieces, which releases an enormous amount of energy in the form of radiation or heat. The heat is used to boil water that eventually is used to produce electricity. In nuclear reactor small quantities of fuel produce large amounts of energy ($E = mc^2$). However there is the potential for catastrophic damage to human life and the environment that an accident – however unlikely – could cause.

Figure 6.12 WIND

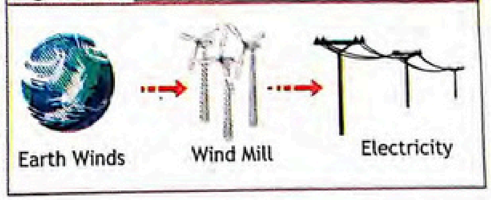
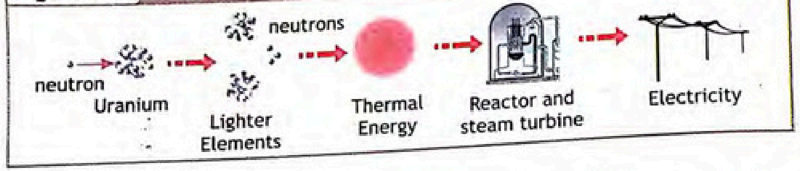


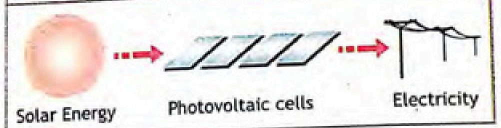
Figure 6.13 NUCLEAR



F. **Solar Energy:**

The energy from direct sun light can be used to produce electricity. Today, solar cells are used to power everything from calculators and watches to small cities. Sunlight, the fuel required by solar cells, is 100% free and is very eco friendly. However just like wind energy significant land area is required to produce large amounts of electricity.

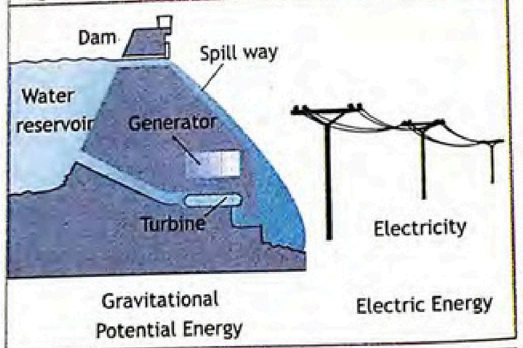
Figure 6.14 SOLAR



G. **Hydroelectric generation:**

Electric energy generation using the gravitational potential energy of water is known as hydroelectric generation. The force of gravity does work on the water, pulling it down and providing it with a tremendous amount of kinetic energy. This kinetic energy is transformed into electric energy by very large turbines. Such large reservoirs sometimes flood thousands of hectares of farmland drastically altering the ecosystem. For many years, engineers did not have the technology to economically use smaller reservoirs for generating electricity. With improvements in technology, smaller generation facilities are becoming much more popular.

Figure 6.15 HYDRO



6.7 EFFICIENCY

A light bulb is designed to convert electric energy into light energy. A car engine is designed to convert chemical potential energy stored in the fuel into kinetic energy for the car. While the light bulb and the car engine are transforming some of the potential energy into the desired form of energy, part of its energy is 'lost'.

As you know, energy can neither be created nor destroyed. The lost energy is converted into forms that do not serve the intended purpose. Often the lost energy is transformed into heat. The efficiency of a machine or device describes the extent to which it converts input energy or work into the intended type of output energy or work.

Efficiency is the ratio of useful energy or work output to the total energy or work input.

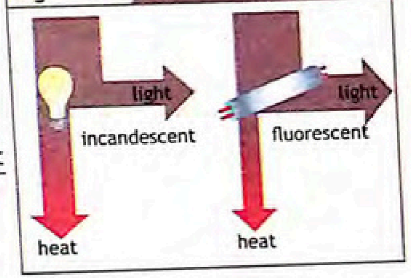
$$\text{efficiency} = \frac{\text{useful output work}}{\text{input work}}$$

$$\text{or efficiency} = \frac{W_o}{W_i} \qquad (6.5)$$

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}}$$

$$\text{or efficiency} = \frac{E_o}{E_i} \qquad (6.6)$$

Figure 6.16 EFFICIENCY



Efficiency is the ratio of same quantities and therefore units cancel, therefore efficiency has no units. An incandescent light bulb is designed to provide light energy. Unfortunately, it also produces a lot of thermal energy while in use. In fact, only about 5% of the electrical energy delivered to the bulb transforms to light energy; the rest becomes waste thermal energy. We say that the incandescent light bulb is only 5% efficient.

A florescent lamp is about 20 % efficient of converting electrical energy into light as shown in the figure 6.16. Efficiency, expressed as a percentage, is the ratio of the useful energy provided by a device to the energy required to operate the device. The efficiency of an energy transformation as percentage is calculated as follows:

$$\text{efficiency} = \frac{E_o}{E_i} \times 100\% \qquad (6.7)$$

It is not possible to have a machine with 100% efficiency, because friction lowers the efficiency of a machine. Work output is always less than work input, so an actual machine wasting input energy as heat(which is not required) cannot be 100% efficient. Typical Efficiencies of Energy Transformation Technologies are shown in the table 6.3.

TABLE 6.3 : Typical Efficiencies of Energy Transformation Technologies

Device	Efficiency (%)
electric generator	98
hydroelectric power plant	95
large electric motor	95
home gas furnace	85
wind generator	55
fossil fuel power plant	40
automobile engine	25
fluorescent light	20
incandescent light	5

6.8 POWER:

The definition of work makes no reference to the passage of time. For example, if you lift a barbell weighing 100 N through a vertical distance of 1.0 m at constant velocity, you do (100 N) (1.0 m) = 100 J of work whether it takes you 1 second or 1 hour to do it. But often we need to know how quickly work is done. We describe this in terms of power.

INFORMATION

Solar energy can be used to power road signs. Photo voltaic cells convert the energy of light into electric energy.

Power is the time rate at which work is done. Mathematically

$$P = \frac{W}{t} \quad (6.8)$$

Like work, power is a scalar quantity. The SI unit of power is watt (W), in honour of James Watt, a Scottish physicist who invented the first practical steam engine. From equation (6.8), the unit of power is given by 1 watt = 1 joule / 1 second or in symbols $1\ W = 1\ Js^{-1}$

INFORMATION

Shuttle puts out a few GW (giga-watts, or 10^9 W) of power!

In the British system, the unit of power is the foot-pound per second (ft.lb/s).

For practical purposes, a larger unit is often used, the **horse power** (hp). One horsepower (hp) is defined as 550 ft.lb/s which equals 746 W.

1 hp = 746 W

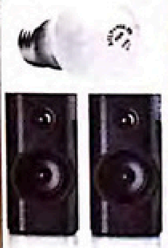
A unit of energy (or work) can now be defined in terms of the unit of power. One **kilowatt hour (kWh)** is the energy converted or consumed in 1h at the constant rate of 1kW = 1000 J/s. The numerical value of 1 kWh is, **1 kWh = $(10^3\ W)(3600\ s)$ or 1 kWh = 3.6×10^6 J**

The electricity bills that we pay are measured in terms of this unit.

TABLE 6.4: Power Output or Consumption

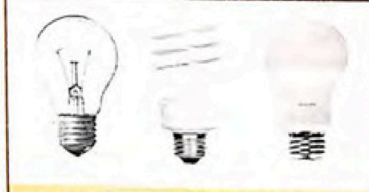
Object/phenomenon	Power in Watts
Milky Way galaxy	10^{37}
Sun	4×10^{26}
Lightning bolt	2×10^{12}
Nuclear power plant (total)	3×10^{9}
Car (total)	8×10^{4}
Person at rest (all heat transfer)	100
Electric clock	3
Pocket calculator	10^{-3}

INFORMATION



Light bulbs are rated with a certain number of watts. Many light fixtures have limits on the power of light bulb that can be used. Stereo speakers are rated according to their power output in watts

POINT TO PONDER — ENERGY



The light Generated by 16 W LED is same as light emitted by 23 W CFL and 100 W bulb. What are the energy used per day (24hrs) for these three types in kWh.

TID-BIT — RUNNING 100 W

The energy does a 100-watt light bulb use is $W = P\Delta t = (100W)(3600s)$ $W = 3.6 \times 10^5$ J. How fast would a 70-kg person have to run to have that amount of kinetic energy?

Example 6.5 — CRANE POWER

A crane is capable of doing 1.50×10^5 J of work in 10.0 s. What is the power of the crane in watts and hp?

SOLUTION

GIVEN:
Work $W = 1.50 \times 10^5$ J
time t = 10 s

REQUIRED:
Power P = ?

By definition of power $P = \frac{W}{t}$

putting values $P = \frac{1.50 \times 10^5 J}{10 s}$

or $P = 1.50 \times 10^4 J/s$

therefore $P = 1.50 \times 10^4 W$ — Answer

the conversion factor for hp to W is $1 hp = 746$ W

or $1 W = \frac{1}{746} hp$

or $1.50 \times 10^4 W = \frac{1.50 \times 10^4}{746} hp$

Hence $1.50 \times 10^4 W = 20 hp$

therefore $P = 20 hp$ — Answer

Assignment 6.5 ELECTRIC HEATER

An electric heater is heated at 250 W. Calculate the quantity of heat generated in 10 minutes.

KEY POINTS

Work: Work is force multiplied by distance moved in the direction of the force $W = FS \cos \theta$

Energy: Energy is the capacity of a body to do work.

Kinetic Energy: It is the energy of an object due to its motion and is given by $E_k = ½ m v^2$

Potential Energy: It is the energy of an object due to its position. Gravitational potential energy is given by $E_{P,grav} = mgh$

Law of conservation of energy: Energy can neither be created nor destroyed in any process. It can be converted from one form to another or transferred from one body to another, but the total amount remains constant.

Power: It is the rate of doing work or rate of conversion of energy. P = W/t

PROJECTS

GROUP - A

RESEARCH ARTICLE ON LIGHT TYPES EFFICIENCIES: Search library or internet and compare the efficiencies of lighting technology available in Pakistan (incandescent bulbs, fluorescent lamps, LED lights). Compare their advantages and disadvantages. Write a research article for school library.

GROUP - B

ENERGY GENERATION MODELS: Create your own homemade models of structures, such as wind turbines and geothermal plants, and put them to work with wind and water power donate the model for school laboratory.

GROUP - C

ARTICLE ON ENERGY **FOR SCHOOL MAGAZINE:** Pakistan is hit by worst energy crisis in the recent years. Analyze the economic , social and environmental impact of various energy sources. e.g. fossil fuel, wind, falling water, solar, biomass, nuclear, thermal energy. Research different types of power generation facilities developed in Pakistan to overcome this problem and articulate which energy resource must be used in Pakistan for energy production. Write your research article to be published in school magazine.

GROUP - D

SPORTS AND ENERGY CONSERVATION: Make a presentation of energy to explain improvements in sports performance using principles and concepts related to work and law of conservation of energy.

GROUP - E

YOUR POWER: Design experiments for measuring your power output when doing push-ups, riding on swings running up a flight of stairs, loading boxes onto a truck, throwing a cricket ball, or performing other energy transferring activities. What data do you need to measure or calculate? Form groups to present and discuss your plans. If your teacher approves your plans, perform the experiments.

EXERCISE

MULTIPLE CHOICE QUESTIONS

Choose the best possible answer:

1. Work done will be zero when the angle between force and displacement is
   A. 30° B. 45° C. 60° D. 90°
2. 30 N force is exerted and the trolley moves a distance of 5 m in the direction of the force, the work done is
   A. 6 J B. 25 J C. 150 J D. 0.17 N
3. If the speed of a car decreases by half, The kinetic energy change by factor
   A. 4 B. 2 C. 1/2 D. 1/4
4. An object of mass 10 kg is lifted vertically through a height of 5 m. The gravitational potential energy gained by the object is
   A. 0.5 J B. 2 J C. 50 J D. 490 J
5. If a petrol engine does 20 J of useful work for every 100 J of energy supplied to it, then its efficiency is
   A. 80 % B. 60 % C. 40 % D. 20 %
6. kWh is unit for
   A. Energy B. Power C. Efficiency D. None
7. 1 hp =
   A. 476 W B. 550 W C. 746 W D. 1 ft.lb/s
8. Hira weighing 500 N takes 90 s to reach the top of a hill 18 m high. Her average muscle power is
   A. 2500 W B. 100 W C. 32.8 W D. 3.24 W
9. A machine is able to lift 200 N of concrete slab vertically up to a height of 30 m above the ground in 50 s. The average power of the machine is
   A. 1.33 W B. 60 W C. 120 W D. 6000 W

CONCEPTUAL QUESTIONS

Give a brief response to the following questions.

1. Can a centripetal force ever do work on an object? Explain.
2. What happens to the kinetic energy of a bullet when it penetrates into a sand bag?
3. A meteor enters into earth's atmosphere and burns. What happens to its kinetic energy?
4. Two bullets are fired at the same time with the same kinetic energy. If one bullet has twice the mass of the other, which has the greater speed and by what factor? Which can do the most work?
5. Can an object have different amounts of gravitational potential energy if it remains at the same elevation?
6. Why do roads leading to the top of a mountain wind back and forth?
7. Which would have a greater effect on the kinetic energy of an object, doubling the mass or doubling the velocity?
8. If the speed of a particle triples, by what factor does its kinetic energy increase?
9. The motor of a crane uses power P to lift a steel beam. By what factor must the motor's power increase to lift the beam twice as high in half the time?

COMPREHENSIVE QUESTIONS

Give an extended response to the following questions.

1. Define work and explain how work is calculated if force is applied at an angle.
2. Define kinetic energy. Derive the expression used for kinetic energy.
3. What is potential energy? Prove that the gravitational potential energy of a body of mass m at a height h above the surface of earth is given by mgh.
4. State the law of conservation of energy and mass energy conversion relation.
5. Explain briefly major sources of energy. Such fossil fuel, wind, solar, biomass, nuclear and thermal energy.
6. Define and explain efficiency.
7. Define and explain power.