Unit - 8

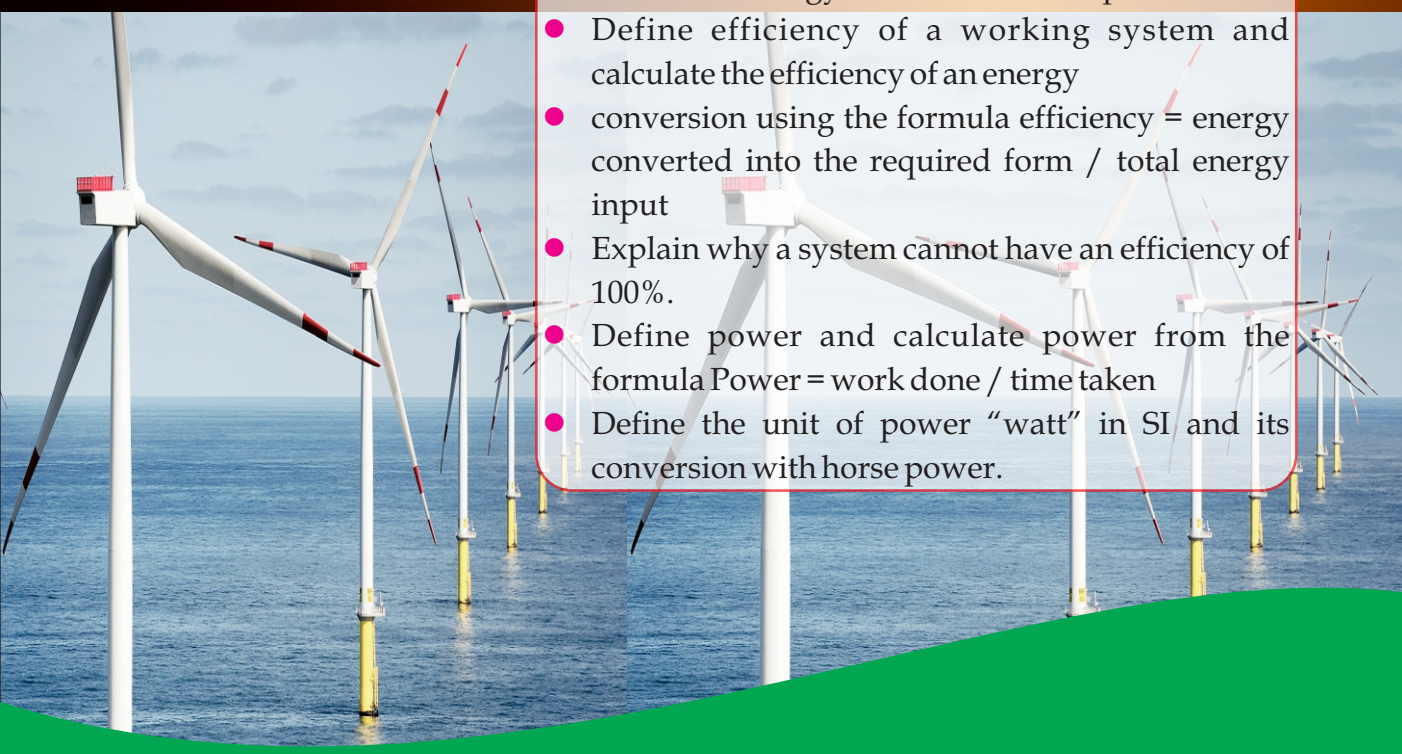
ENERGY SOURCES AND TRANSFER OF ENERGY

Energy is the most important physical concept which is studied in all sciences. work is closely related with energy which provides a link between force and energy. Work, energy and power have special meaning in physics.

Students Learning Outcomes (SLOs)

After learning this unit students should be able to:

- Define work and its SI unit.
- Calculate work done using equation Work = force × distance moved in the direction of force
- Define kinetic energy and potential energy
- Use Kinetic Energy $E_k = \frac{1}{2} mv^2$ and potential energy $E_p = mgh$; to solve problems.
- 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, biomass energy and tidal energy.
- Differentiate energy sources as non renewable and renewable energy sources with examples of each.
- 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.



Do You Know!

Force is an agent which tends to change the state of an object.

What source of energy is more beneficent ? Why we face the shortage of petroleum and gas in our country? Why the people are replacing electric energy by solar energy? Why government is focusing its attention on the use of tidal, solar and wind energy? Why the waste material should be buried in Earth?
After learning this unit you will be able to answer these questions and some other similar questions.

8.1 WORK

Generally, work refers to perform some task or job. But in physics work has different meaning.
For example: A tailor stitching a suit, a shopkeeper selling fruits at his shop, a women cooking in her kitchen are all considered as "doing work" in daily life but in physics work has a proper meaning i.e. "work is done only when a force makes something to move; Fig 8.1(a,b)". Thus work can be define as

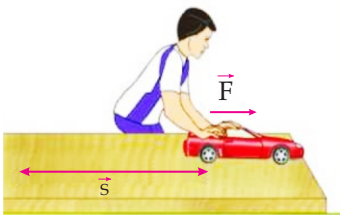


Fig 8.1 (a)
Demonstration of work done

The amount of work is the product of force and the distance moved in the direction of force.

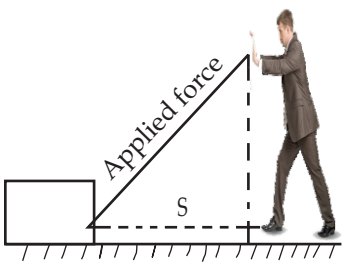


Fig 8.1 (b)
Demonstration of work done

Units of Work

The S.I unit of work is Joule other units of work can be Foot, Pound, Erg.

1 Joule = 1Nm

Suppose a constant force "F" acts on a body and motion takes place in a straight line in the direction of force then work done is equal to the product of magnitude of force "F" and the distance "d" through which the body moves.

$$W = Fd \cos\theta \quad \text{.....(8.2)}$$

The force "F" however may not act in the direction of motion of the body instead it makes some angle "θ" with it; Fig 8.2. In that case, we define the

work by the force as the product of the component of the force along the line of motion and the distance "d"; the body moves along that line, i.e.

Suppose a constant force "F" acts on a body

Work = (component of force) · (distance)

$W = (F\cos\theta)\, d$

or $W = (F\cos\theta)\, d$

If $\theta = 0 \Rightarrow \cos\theta = 1$

then Work = W = Fd

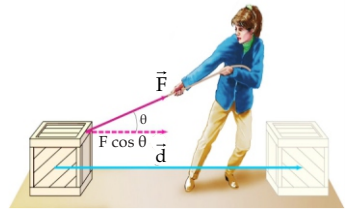


Fig 8.2 (a)
Force making some angle θ with the direction of motion

Worked Example 1

Find the work done when a force of 50N is applied to move a trolley at a shopping mall through a distance of 200m? Assume the angle to be of 0° between the force and the distance the trolley moved.

Solution

Step 1: Write down known quantities and quantities to be found.

F = 50N
d = 200m
θ = 0°
W = ??

Step 2: Write down formula and rearrange if necessary

$W = F \cdot d$
$W = Fd\cos\theta$

Step 3: Put the values in formula and calculate:

$W = 50N \times 200m \times \cos 0°$
$W = 10000J$

Hence, the work done is 10000 Joules.

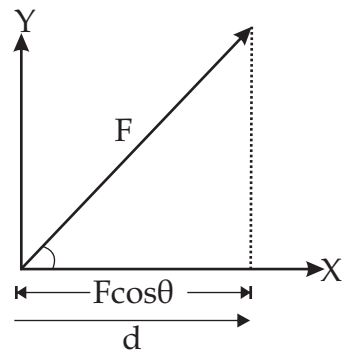


Fig 8.2 (b)
Force making some angle θ with the direction of motion

Self Assessment Questions:

Q1: Write down the names of any three units of work

Q2: According to the definition of work in physics, Urwa did not perform any work if she made and assignment on her laptop in three hours. Why?

Q3: At what angle between force and displacement the work done by a body will be maximum?

Energy

Energy is define as

The ability to do work.

the S.I unit of energy is joule (J). There are many forms of energy. Some of them are discussed below:

8.2 Energy Forms

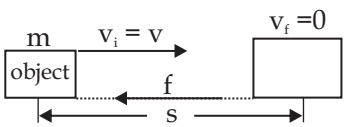
Kinetic Energy

Kinetic energy of a body defined as:

Energy possessed by an object due to its motion is called kinetic energy.

The S.I unit of kinetic energy is joule.

It is also defined as "The work required to accelerate a body of a given mass from rest to its stated velocity". A moving body maintains its kinetic energy unless its speed changes.



Mathematically kinetic energy is given as:

$$\mathbf{K.E} = \frac{1}{2}\mathbf{mv}^2 \quad \text{.....(8.3)}$$

As we know that kinetic energy is due to the motion of object. Therefore for an object of mass m moving with speed v kinetic energy depends upon:

- the mass m of the object- the greater the mass, the greater its K.E
- the speed v of the object- the greater the speed, the greater the K.E

Do You Know!

Sailing boat, moving air, driving car, running and walking are example of kinetic Energy.

Worked Example 2

A ball of mass 400 gram, strikes the wall of velocity 4m/sec. How much is the kinetic energy of the ball at the time it strikes the wall?

Solution

Step 1: Write down known quantities and quantities to be found.

$$m = 400\,\text{gram} = \frac{400}{1000}\,\text{kg} = 0.4\,\text{kg}$$

$$v = 4\text{ms}^{-1}$$

$$K.E = ?$$

Step 2: Write down formula and rearrange if necessary

$$K.E = \frac{1}{2}\,mv^2$$

Step 3: Put the values in formula and calculate

$$K.E = \frac{1}{2} \times 0.4\text{kg} \times (4\text{ms}^{-1})^2$$

$$K.E = 3.2\text{J}$$

Hence, Kinetic Energy is possessed by the ball 3.2 joules.

Potential Energy

Potential energy of a body is defined as:

The energy that a body possesses by virtue of its position, shape or state of a system.

There are different types of potential energy. Like gravitational potential energy, elastic potential energy and chemical potential energy; Fig 8.4 (a, b, c).

For Example:

- A body raised to a height "h" above the ground has gravitational potential energy.
- A stretched spring has elastic potential energy due to its stretched position (condition).

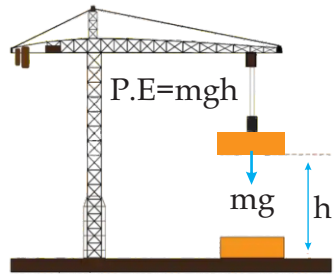


Fig 8.4 (a)
Gravitational Potential Energy

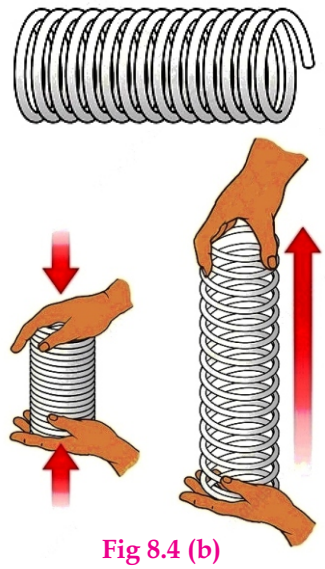


Fig 8.4 (b)
Elastic Potential Energy

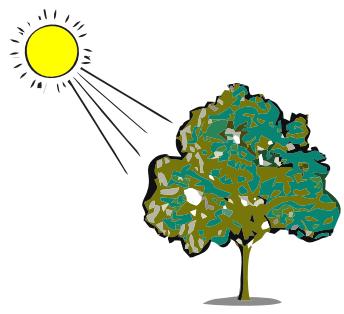


Fig 8.4 (c)
Chemical Potential Energy

- The energy stored in the plants that we eat is chemical potential energy.

S.I. unit of potential energy is Joule (**J**).

It is also defined as the work done stored in a body in lifting it to a height "h". The potential energy changes only when its position relative to ground changes; otherwise it remains same.

Mathematically potential energy is given as

P·E = mgh ..... (8.4)

Do You Know!

A book lying on the table and the water stored in a dam have potential energies.

Derivation of Gravitational Potential Energy P.E=mgh

To derive the expression for gravitational potential energy, let us consider an object of mass "m" which is raised up through height "h" from the ground; Fig 8.5. The work done in lifting it to height "h" is stored in it as its gravitational potential energy "P·E", i.e.

P·E = Work done

P·E = W — As W = F·d

P·E = F·d — where d = h (height)

P·E = (mg) · h — F = mg (weight)

Therefore equation becomes:

P·E = mgh ..... (8.4)

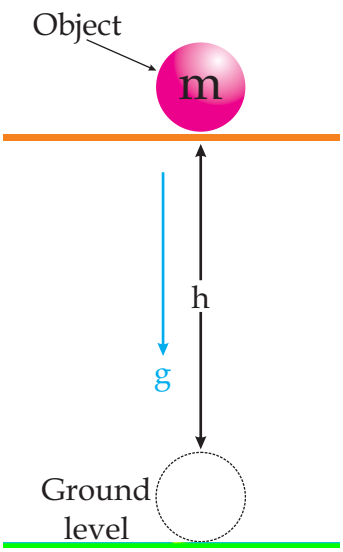


Fig 8.5
An object of mass 'm' raised to height 'h'.

Worked Example 3

A ball of mass 50 gram is raised to a height of 7m from the ground. Calculate its gravitational potential energy?

Solution

Step 1: Write down known quantities and quantities to be found.

$$m = 50gm = \frac{50}{1000} kg = 0.05kg$$

$h = 7m$

$g = 10ms^{-2}$

$P{\cdot}E = ??$

Step 2: Write down formula and rearrange if necessary

$P{\cdot}E = mgh$

Step 3: Put values in formula and calculate

$P{\cdot}E = 0.05kg \times 10ms^{-2} \times 7m$

$P{\cdot}E = 3.5\,Joule$

Hence, gravitational potential energy of the ball is 3.5 Joules.

Self Assessment Questions:

Q4: A car of mass 50kg moving with velocity $10ms^{-1}$ in the direction of force. Calculate its Kinetic energy.

Q5: A body of mass 10kg is dropped from a height of 20m on the ground. What will be its potential energy, if $g=9.8\,m/sec^2$?

Q6: Give the energy changes when a ball is dropped from a height of 7m to the ground.

8.3 CONVERSION OF ENERGY

Energy neither be created nor it can be destroyed but it can be converted from one form to other form. This is called law of conservation of energy.

Conversion of Energy from one form to another

i. Fossil Fuel Energy

Fossil fuel energy is formed from decayed plants and animals that have been converted to crud oil, coal, natural gases or heavy oils by exposure to heat and pressure in the Earth's crust over hundreds of millions of years; Fig 8.6.

Fig 8.6
Fossil fuel energy

Fig 8.7
Burning charcoal

Fossils fuels have stored chemical energy. This energy is converted by oxidation through burning. Thus on burning a fossil fuel like charcoal, produce heat energy and light energy; Fig 8.7.

ii. Hydroelectric Energy

Fig 8.8
Hydroelectric energy

Hydro electricity is the term referring to electricity generated by hydro power by using gravitational force of falling or flowing water; Fig 8.8.

Most common type of hydro electric power plants uses a dam on a river to store water in a reservoir. Water releases from the reservoir flows through a turbine, spinning it, which in turn runs a generator to produce electricity.

iii. Solar Energy

Fig 8.9 (a)
Solar energy (Solar Panel)

Fig 8.9 (b)
Solar energy (Solar heater)

The energy radiated from the sun is known as solar energy. This is the most available source of energy throughout Pakistan. There are many devices which are capable of absorbing solar energy, which is then converted into electrical energy or heat energy. These devices may be photovoltaic solar panels and solar cells. Which convert the sun rays into electricity for different uses; Fig 8.9(a). Also solar heaters are used to convert solar energy "sun rays" into heat energy to heat water tanks and indoor spaces; Fig 8.9(b).

iv. Nuclear Energy

The energy released during a nuclear reaction such as fission or fusion reaction. All radioactive materials store nuclear energy. For example Uranium,

Radium etc. It is released from the nucleus in the form of radiation in addition to heat and light. A nuclear power plant utilize nuclear energy to produce steam to turn a turbine and generate electricity; Fig 8.10.

Fig 8.10
Nuclear energy

v. Geothermal Energy

Geothermal energy is stored in the Earth as its natural heat. Deep in the Earth, there is hot molten part called magma. Water close to magma changes to steam due to high temperature. This thermal energy is conducted to the surface of Earth. This energy is called geothermal energy; Fig 8.11(a).

A geothermal power plant utilizes geothermal energy to drive an electrical generator; Fig 8.11 (b). Geothermal well can be built by drilling deep near hot rocks at different places, where hot molten or magma is very close, water is then pushed down into the well. The rocks quickly heat the water and change it into steam. The steam is used for heating purpose or to generate electricity.

Fig 8.11(a)
Geothermal energy

Fig 8.11(b)
Geothermal power plant

vi. Wind Energy

The energy obtained by the wind is called wind energy. It is generated by wind mills (Fig 8.12). A wind mill consists of a turbine which rotates due to wind. Kinetic energy is produced due to the motion of turbine. Wind turbines convert this kinetic energy into the mechanical power. A generator converts that mechanical power into electricity.

Fig 8.12
Wind energy

Application

- It is being used as source of energy for sailing ships in oceans.
- It is being used by wind mills to pump water.

Fig 8.13(a)
Biomass energy (Wood)

Fig 8.13(b)
Biomass energy
(Organic materials)

Fig 8.13(c)
Biomass energy (Garbage)

Fig 8.14
Tidal energy

- It is being used by wind mills to grind grain.
- It is used to turn wind turbines to produce electricity.

ii. Biomass Energy

Biomass is the organic material that comes from plants and animals. Biomass consists of stored energy from Sun, garbage, wastes, sugarcane etc. Solid biomass, such as wood, organic material and garbage, can be burned directly to produce heat; Fig 8.13 (a, b, c).
Biomass can also converted into gas called biogas and into liquid biofuels such as ethanol and biodiesel.

viii. Tidal Energy

It is a form of hydro power that converts the energy obtained from tides into useful form of power; mainly electricity as the Earth uses the gravitational forces of both the moon and the sun every day to move vast quantities of water around the oceans and seas producing tides and in this way energy is produced called tidal energy; Fig 8.14.

Self Assessment Questions:

Q7: What is biomass?

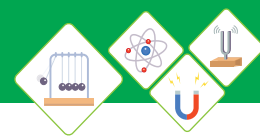
Q8: Write down the name of fossil fuel?

Q9: Which type of energy is stored deep in the Earth?

8.4 RENEWABLE AND NON-RENEWABLE ENERGY SOURCE

Renewable Energy Source

The renewable sources can be consumed and used again and again. Solar energy, wind energy, tidal energy and geothermal energy are renewable sources.



Since very earlier age, people have tried to consume renewable sources of energy for their survival. Such as wind and water for milling grain and solar for lighting.

Non-Renewable Sources

Non-renewable resources are limited and will finish once used. Coal, petroleum and natural gases are nonrenewable sources. About 150 years ago scientists invented new technology to extract energy from the ancient fossilized remains of plants and animals. These super-rich but limited sources of energy (coal, oil and natural gas) replaced wood, wind and water as the main sources of fuel. They are being used at a faster rate than they can be restored again and, therefore cannot be renewed.

Self Assessment Questions:

Q10: Write down the names of any three renewable energy sources?

Q11: Write down the names of any three non-renewable energy sources.

Q12: What is the difference between renewable and non-renewable energy sources?

8.5 EFFICIENCY

Every machine needs some energy to perform work. Whatever energy given to a machine is called input and the work done by the machine is called output.

For example: We give electric energy as input to the electric motor in washing machines and in drilling machines.

Do You Know!

- Wind energy is clean fuel source.
- It does not pollute the air.
- Wind turbines does not produce atmospheric emission that causes greenhouse gasses.

Do You Know!

The costal belt of Pakistan is about 1045 km long with best resources for utilizing and producing tidal energy.

A system in which some energy 'E_1' is supplied to it as 'input' and the system returns back some energy 'E_2' as output has some efficiency. This efficiency is defined as

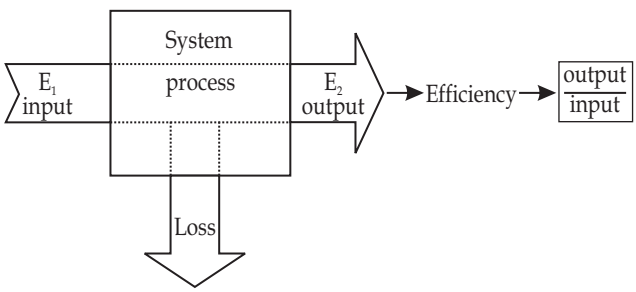
The ratio of output to the input is called Efficiency.

Efficiency is denoted by "η". As it is the ratio of two energies therefore it has no unit. No machine is 100% efficient because some energy is always wasted in the form of heat, sound or light etc.

$$\text{Efficiency} = \frac{\text{Energy as output } (E_2)}{\text{Energy as input } (E_1)}$$

$$\therefore \quad \eta = \frac{E_2}{E_1} \times 100$$

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} \times 100 \quad \text{.....(8.5)}$$



Do You Know!

We get

- Chemical energy from fuel, gas and battery
- Thermal energy from heat
- Nuclear energy from nuclear Fission and fusion
- Electrical energy from movement of electrons in atom
- Mechanical energy from walking, running
- Sound energy from sound waves

8.6 POWER

When you run up and cover distance in 5 seconds or take slow walk up the same distance in 20 seconds. You are doing the same amount of work, However, you are doing it at different rate. When you run up, you are working much faster and you have a higher power then when you walk up.

This quantity that tells us the rate of doing work. Thus, power is defined as:

The rate of doing work. or
The amount of energy transferred per unit time.

Mathematically,

$$\text{Power} = P = \frac{\text{work done}}{\text{time taken}}$$

$$\therefore \quad P = \frac{w}{t} \quad \text{.....(8.6)}$$

Since work and time are scalar quantities. Therefore, power is also a scalar quantity.

Unit of Power

In SI system unit of power is $\frac{\text{Joule}}{\text{sec}}$ = Watt

Thus SI unit of power is watt which is defined as:

The power of a body is said to be one watt if it does work at the rate of one Joule per second.

Worked Example 5

Calculate the power of a machine. If the machine performs 900 joules of work in 30 minutes.

Solution

Step 1: Write down known quantities and quantities to be found.

$W = 900J$

$t = 30min = 30 \times 60s = 1800\,s$

$P = ??$

Step 2: Write down formula and rearrange if necessary

$$P = \frac{W}{t}$$

Step 3: Put values in formula and calculate

$$P = \frac{900J}{1800s}$$

$$P = 0.5\,W$$

Hence, power of the machine is 0.5 Watt.

Do You Know!

1kg of 4% enriched fuel grade uranium releases energy equivalent to the combustion of nearly 100 tons of high grade coal or 60 tons of oil.

Do You Know!

Larger units of power are
Kilo watt (kW),
Mega watt (MW),
Horse Power (hp) etc.
$1kW = 1000W = 10^3$ watt
$1MW = 1000000W = 10^6$ Watt
1 hp = 746 Watt

Self Assessment Questions:

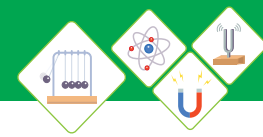
Q13: A man pushes a car 18m with a force of 2N in 4 second. Calculate the power of the man.

Q14: Why power is a scalar quantity?

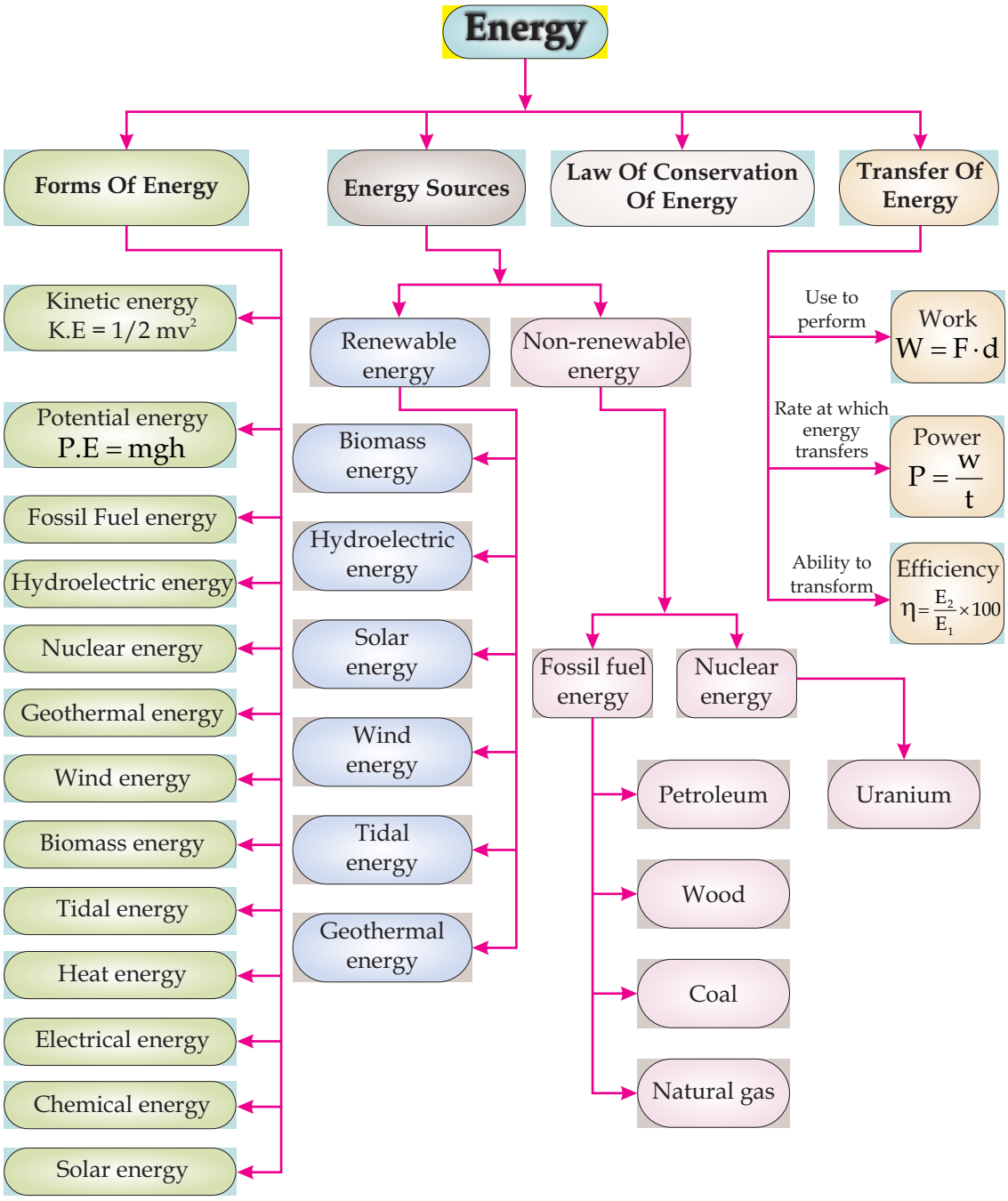
Q15: Name the physical quantity which gives the rate of doing work.

SUMMARY

- Work is the product of force and the distance W= F·S
- The ability to do work is called energy. SI unit of energy is Joule (**J**).
- Energy possessed by an object due to its motion is called as Kinetic Energy K·E = $1/2\,mv^2$
- Energy due to position of an object is called Potential Energy P·E=mgh.
- Energy exists in many different forms such as nuclear energy, heat energy, electrical energy, chemical energy, light energy, etc.
- Solar energy, wind energy, tidal energy, geothermal energy, biomass energy and hydroelectric energy are the examples of renewable sources of energy.
- Wood, coal, petroleum, natural gas and Uranium are examples of nonrenewable sources of energy.
- The ratio of output to the input is called efficiency.
- The work done in unit time is called power. SI unit of work is Watt.



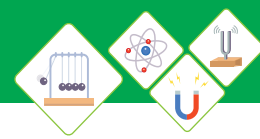
CONCEPT MAP


Energy
Forms Of Energy
Energy Sources
Law Of Conservation Of Energy
Transfer Of Energy
Kinetic energy K.E = 1/2 mv²
Potential energy P.E = mgh
Fossil Fuel energy
Hydroelectric energy
Nuclear energy
Geothermal energy
Wind energy
Biomass energy
Tidal energy
Heat energy
Electrical energy
Chemical energy
Solar energy
Renewable energy
Non-renewable energy
Biomass energy
Hydroelectric energy
Solar energy
Wind energy
Tidal energy
Geothermal energy
Fossil fuel energy
Nuclear energy
Petroleum
Wood
Coal
Natural gas
Uranium
Use to perform
Work W = F · d
Rate at which energy transfers
Power P = W/t
Ability to transform
Efficiency η = E₂/E₁ × 100

End of Unit Questions

Section (A) Multiple Choice Questions (MCQs)

1. If force of 6N displaces an object 2m in the direction of force, then work done will be_____.
   a) 0 b) 12 Joule
   c) 3 Joule d) Both b and c
2. If a body of mass 1 kg is moving with velocity of 1m/sec then K.E of the body will be _____.
   a) Joules b) Joules
   c) Joules d) 1 Joule
3. If a machine performs 20J of work in 10sec then its power is _____.
   a) 200 watt b) 20 watt
   c. 2watt d) 0.2 watt
4. A body of mass 1kg is lifted through a height of 1m . The energy possessed in the body will be_____. (consider $g = 10ms^{-2}$)
   a) 1J b) 10 Joule
   c) 100 Joule d) 1000 Joule
5. The energy released during fission or fusion reaction is called _____.
   a) Solar energy b) Geothermal energy
   c) Tidal energy d) Nuclear energy
6. Which is the renewable source of energy
   a) Solar and wind b) Coal
   c) Natural gas d) Petrolium
7. The ratio of output to input is called
   a) Energy b) Work
   c) Power d) Efficiency



8. Work done per unit time is called _____.
   a) Efficiency b) Energy
   c) Power d) Force
9. Coal, gas and oil are all examples of_____.
   a) Tidal energy b) Nuclear energy
   c) Fossil fuel energy d) Biomass energy
10. _____ is not a renewable source of energy.
   a) Solar energy b) Coal
   c) Wind energy d) Geothermal energy

Section (B) Structured Questions

Work

1. a) Define work?
   b) Derive the equation; work = Fd cosθ.
2. How much work is needed to move horizontally a body 20m by a force of 30N, the angle between the body and the horizontal surface is 60°?
3. How much work is done, if a crate is moved at a distance of 50m, when a force of 30N is applied along the surface.
4. What is the work done by Usman? If a bar of weight 100 N is brought by him from A to B, then brought back to A.

Energy Forms

5. a) Define Kinetic energy
   b) Derive the equation.
6. What will be the Kinetic energy of a boy of mass 50kg driving a bike with velocity of $2ms^{-1}$.
7. a) Define Potential Energy
   b) Derive the equation. PE = mgh

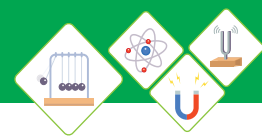
8. a) If LED screen of mass 10kg is lifted up and kept it on a cupboard of height 2m. Calculate the potential energy stored in the LED screen.
   b) Calculate the potential energy of 3kg water raised to the tank at the roof of a home 4m high. (assume $g=10ms^{-2}$)

Conversion of Energy

9. a) Why fossil fuel energy is called non-renewable source?
   b) Define solar energy and its importance in Pakistan?
10. Write notes on Tidal energy and Geothermal energy.
11. a) What is wing energy?
    b) Write any three applications of wind energy ?
12. a) Write the name of any one radioactive element which is used as source of nuclear energy.
    b) Write the names of any one device that can convert solar energy into heat energy.
    c) Write the names of any two devices that can convert solar energy into electrical energy.

Renewable and Non-renewable Energy Sources

13. Write a note on renewable energy sources?
14. Write a note on non-renewable energy sources?
15. What is the difference between renewable of non-renewable energy sources?
16. Make a table of renewable and non-renewable energy sources from the following:
    Uranium, Solar, Coal, Wind, Natural gas, Tidal, Biomass, Hydroelectricity.



Efficiency

17. Calculate the efficiency of a machine which consumes 200 J of energy and performs 50J of work.
18. Write a note on efficiency.
19. If the efficiency of a machine is 70% and its output is 100 J then calculate its input.
20. Which machine is more efficient, machine "A" which has an output of 200J after consuming 400J of energy or machine "B" which has an output of 300J after consuming 450J of energy?

Power

21. a) Define power.
    b) The energy of 600J dissipated by a bulb in 50 minutes. Find the power of the bulb.
22. a) Convert 20watt into horse power.
    b) Calculate the power of a machine, if it does 40 Joules of work in 10 sec.
23. a) Define Watt.
    b) A student of weight 400N takes 5 sec to climb up an obstacle of height 2m. Calculate the power consumed ?
24. a) Write down the names of any two larger units of power.
    b) If a machine consumes 250J of energy per hour then what will be its power?