PHYSICAL WORLD

WHAT IS PHYSICS

Physics is the study of matter, basic principles and laws of nature along with their manifestations. The study of physics is mainly involved in the explanations of the diverse phenomena of its concepts.

Definition of Physical

The physical world is referred to as the complexity in nature and solving its own complexities will give us new insights into this physical world. It is referred to as the analysis of nature conducted in order to understand how the world around us performs.

The Fundamental Forces of nature

In this diverse world, the fundamental forces which govern the phenomena occurring in it are:

Gravitational Force

it is a universal force that exists which is of mutual attraction between any two objects by virtue of their masses.

Electromagnetic Force

Is the force between charged particles. If charges are in a state of rest, it is given by Coulomb's law whereas when they are in motion, they generate a magnetic field, hence the name electromagnetic forces as they are inseparable. They also act over a large distance as seen in the case of gravitational forces without the intervention of any medium

Strong Nuclear Force – in a nucleus it binds protons and neutrons. It is the strongest of all the fundamental forces and is charge-independent acting between proton-proton, proton-neutron, or neutron-neutron

Weak Nuclear Force

observed only in some nuclear processes. Example – β-decay of a nucleus. It is not as weak as the gravitational force but weaker than electromagnetic and strong nuclear force

What are the laws of conservation in nature?

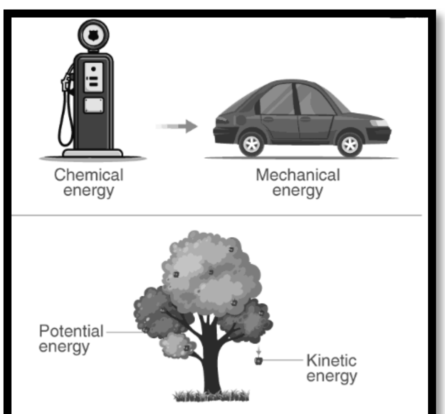
The conservation laws in physics are very important when it comes to understanding the subject. The laws are:

- **Laws of Conservation of Energy**
- **Laws of Conservation of Momentum**
- **Laws of Conservation of Mass.**
- **Laws of Conservation of Charge etc.**

Law of Conservation of Energy

The law of conservation of energy states that energy can neither be created nor be destroyed. Although, it may be transformed from one form to another. If you take all forms of energy into account, the total energy of an isolated system always remains constant. All the forms of energy follow the law of conservation of energy. In brief, the law of conservation of energy states that

In a closed system, i.e., a system that is isolated from its surroundings, the total energy of the system is conserved.



Example of Energy Transformation

So, in an isolated system such as the universe, if there is a loss of energy in some part of it, there must be a gain of an equal amount of energy in some other part of the universe.

Although this principle cannot be proved, there is no known example of a violation of the principle of conservation of energy.

The amount of energy in any system is determined by the following equation:

$$U_T = U_i + W + Q$$

- U_T is the total energy of a system
- U_i is the initial energy of a system
- Q is the heat added or removed from the system
- W is the work done by or on the system

The change in the internal energy of the system is determined using the equation

$$\Delta U = W + Q$$

Law of Conservation of Energy Derivation

Considering the potential energy at the surface of the earth to be zero. Let us see an example of a fruit falling from a tree.

Consider a point A, which is at height 'H' from the ground on the tree, the velocity of the fruit is zero hence potential energy is maximum there.

$$E = mgH \qquad \ldots (1)$$

When the fruit falls, its potential energy decreases, and kinetic energy increases.

At point B, which is near the bottom of the tree, the fruit is falling freely under gravity and is at a height X from the ground, and it has speed as it reaches point B. So, at this point, it will have both kinetic and potential energy.

$$E = K.E + P.E$$

$$P.E = mgX \qquad \ldots (2)$$

According to the third equation of motion,

$$v^2 = 2g(H - X)$$

$$\frac{1}{2}mv^2 = \frac{1}{2}m \cdot 2g(H - X)$$

$$K.E = \frac{1}{2}m.2g(H - X)$$

$$K.E = mg(H - X)$$

$$K.E=mg(H-X) \qquad \dots (3)$$

Using (1), (2) and (3)

$$E = mg\ (H - X) + mgX$$

$$E = mg\ (H - X + X)$$

$$E = mgH$$

Similarly, if we see the energy at point C, which is at the bottom of the tree, it will come out to be mgH. We can see as the fruit is falling to the bottom, here, potential energy is getting converted into kinetic energy. So there must be a point where kinetic energy becomes equal to potential energy. Suppose we need to find that height 'x' from the ground. We know at that point,

$$K.E = P.E$$

$$P \cdot E = K \cdot E = \frac{E}{2}$$

As the body is at height X from the ground,

$$P.E = mgX \qquad \dots (5)$$

Using (4) and (5) we get,

$$mgX = \frac{mgH}{2}$$

$$X = \frac{H}{2}$$

H/2 is referred to as the new height.

Energy Conservation:

Energy conservation is not about limiting the use of resources which will finally run out altogether. The ideal way of conservation would be reducing demand on a limited supply and enabling that supply to begin to rebuild itself. Many times the best way of doing this is to replace the energy used with an alternative.

Law of Conservation of Energy Examples:

In Physics, most of the inventions rely on the fact that energy is conserved when it is transferred from one form to another. A number of electrical and mechanical devices operate solely on the law of conservation of energy. We will discuss a few examples here.

In a torch, the chemical energy of the batteries is converted into electrical energy, which is converted into light and heat energy.

In hydroelectric power plants, waterfalls on the turbines from a height. This, in turn, rotates the turbines and generates electricity. Hence, the potential energy of water is converted into the kinetic energy of the turbine, which is further converted into electrical energy.

In a loudspeaker, electrical energy is converted into sound energy.

In a microphone, sound energy is converted into electrical energy.

In a generator, mechanical energy is converted into electrical energy.

When fuels are burnt, chemical energy is converted into heat and light energy.

Chemical energy from food is converted to thermal energy when it is broken down in the body and is used to keep it warm.

Momentum Conservation Principle

Law of conservation of momentum states that

For two or more bodies in an isolated system acting upon each other, their total momentum remains constant unless an external force is applied. Therefore, momentum can neither be created nor destroyed.

The principle of conservation of momentum is a direct consequence of Newton's third law of motion.

Derivation of Conservation of Momentum

Newton's third law states that for a force applied by an object A on object B, object B exerts back an equal force in magnitude, but opposite in direction. This idea was used by Newton to derive the law of conservation of momentum.

Consider two colliding particles A and B whose masses are m1 and m2 with initial and final velocities as u1 and v1 of A and u2 and v2 of B. The time of contact between two particles is given as t.

$$A = m_1(v_1 - u_1)$$

(Change in momentum of particle A)

$$B = m_2(v_2 - u_2)$$

(Change in momentum of particle B)

$$F_{BA} = -F_{AB}$$

(From third law of motion)

$$F_{BAA} = m_2^* a_2 = \frac{m_2(v_2 - u_2)}{t}$$

$$F_{AB} = m_1^* a_1 = \frac{m_1(v_1 - u_1)}{t}$$

$$\frac{m_2(v_2 - u_2)}{t} = \frac{-m_1(v_1 - u_1)}{t}$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Therefore, above is the equation of law of conservation of momentum where

$$m_1u_1 + m_2u_2$$

is the representation of total momentum of particles A and B before the collision and

$$m_1v_1 + m_2v_2$$

is the representation of total momentum of particles A and B after the collision.

Law of Conservation of Energy

Law Of Conservation of Angular Momentum

Examples of Law of Conservation of Momentum

Following are the examples of law of conservation of momentum:

Air-filled balloons

System of gun and bullet

Motion of rockets

Solved Problems on Law of Conservation of Momentum

Q. There are cars with masses 4 kg and 10 kg respectively that are at rest. The car having the mass 10 kg moves towards the east with a velocity of 5 m.s-1. Find the velocity of the car with mass 4 kg with respect to ground.

Ans: Given,

$m_1 = 4$ kg

$m_2 = 10$ kg

$v_1 = ?$

$v_2 = 5$ m.s-1

$P_{initial =}$ 0, as the cars are at rest

$P_{final} = p_1 + p$

$P_{final} = m_1.v_1 + m_2.v_2$

$= (4\text{ kg}).(v_1) + (10\text{ kg}).(5\text{ m.s}^{-1})$

We know from the law of conservation of momentum that,

$P_{initial} = P_{final}$

$0 = 4\text{ kg}.v_1 + 50\text{ kg.m.s}^{-1}$

$v_1 = 12.5\ m.s^{-1}$

Q. Find the velocity of a bullet of mass 5 grams which is fired from a pistol of mass 1.5 kg. The recoil velocity of the pistol is 1.5 m. s-1.

Ans: Given,

Mass of bullet, $m_1 = 5$ gram $= 0.005$ kg

Mass of pistol, $m_2 = 1.5$ kg

The velocity of a bullet, $v_1 = ?$

Recoil velocity of pistol, $v_2 = 1.5\ m.\ s^{-1}$

Using law of conservation of momentum,

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Here, Initial velocity of the bullet, $u_1 = 0$

Initial recoil velocity of a pistol, $u_2 = 0$

$(0.005\ kg)\ (0) + (1.5\ kg)\ (0) = (0.005\ kg)\ (v_1) + (1.5\ kg)\ (1.5 m.s^{-1})$

$0 = (0.005\ kg)\ (v_1) + (2.25\ kg.m.\ s^{-1})$

$v_1 = -450\ m.s^{-1}$

Hence, the recoil velocity of the pistol is $450\ m.s^{-1.}$

Law of Conservation of Mass

The law of conservation of mass states that

"The mass in an isolated system can neither be created nor be destroyed but can be transformed from one form to another".

According to the law of conservation of mass, the mass of the reactants must be equal to the mass of the products for a low energy thermodynamic process.

It is believed that there are a few assumptions from classical mechanics which define mass conservation. Later the law of conservation of mass was modified with the help of quantum mechanics and special relativity that energy and mass are one conserved quantity. In 1789, Antoine Laurent Lavoisier discovered the law of conservation of mass.

Formula of Law of Conservation of Mass

Law of conservation of mass can be expressed in the differential form using the continuity equation in fluid mechanics and continuum mechanics as:

$$\frac{\partial p}{\partial t} + \nabla(\rho v) = 0$$

Where,

- ρ is the density
- t is the time
- v is the velocity
- ▽ is the divergence

Law of Conservation of Mass Examples

Combustion process: Burning of wood is a conservation of mass as the burning of wood involves Oxygen, Carbon dioxide, water vapor and ashes.

Chemical reactions: To get one molecule of H2O (water) with the molecular weight of 10, Hydrogen with molecular weight 2 is added with Oxygen whose molecular weight is 8, thereby conserving the mass.

Law of Conservation of Mass Problems

Q. 10 grams of calcium carbonate ($CaCO_3$) produces 3.8 grams of carbon dioxide (CO_2) and 6.2 grams of calcium oxide (CaO). Represent this reaction in terms of law of conservation of mass.

Ans: According to law of conservation of mass:

Mass of reactants = Mass of products

10 gram of $CaCO_3$ = 3.8 grams of CO_2 + 6.2 grams of CaO

10 grams of reactant = 10 grams of products

Hence, it is proved that the law of conservation of mass is followed by the above reaction.

Conservation of Charge

A charge is a property associated with the matter due to which it produces and experiences electrical and magnetic effects. The basic idea behind the conservation of charge is that the total charge of the system is conserved. We can define it as:

Conservation of charge is the principle that the total electric charge in an isolated system never changes. The net quantity of electric charge, the amount of positive charge minus the amount of negative charge in the universe, is always conserved.

As we know, the system is the group of objects, and its interaction with charges is similar to the conservation of energy and momentum, But this conservation law is more intuitive because the net charge of an object depends on the number of electrons and protons. The protons and electrons cannot just appear or disappear out of nowhere, and the total charge has to be the same. That's the reason there is always the same number of electrons and protons in a body.

It is known that every atom is electrically neutral, containing as many electrons as the number of protons in the nucleus. Bodies can also have any whole multiples of the elementary charge:

Electrical charge resides in electrons and protons, and the smallest charge that a body can have is the charge of one electron or proton. [ie. -1.6×10^{-19} C or $+1.6 \times 10^{-19}$ C]

Explanation:

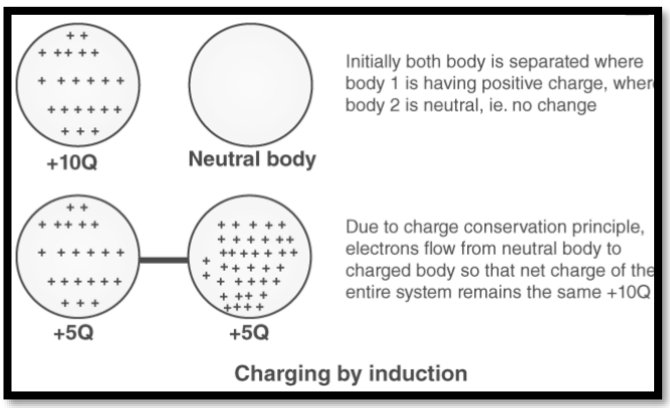
The law of conservation of charge says that the net charge of an isolated system will always remain constant. Let's try to understand it in more depth. There is a possibility of two ideal states for a system for multiple objects.

The first one is that all the object has a net neutral charge. So in the whole system, there is the same number of protons and electrons. So for each proton, there is an electron to balance it.

Another ideal state would be the net charge of the system being distributed uniformly in the objects. So rather than concentrating negative charge in a few bodies, the charge on the body is evenly distributed throughout by the transfer of the electron, and this can be achieved by the transfer of electrons from higher to lower polarity. Only electrons can be involved in the transfer charges, not protons.

Conservation of Charge Examples

Conservation of charge means one can't produce a net charge.



Some of its examples are provided below.

Charges due to induction.

During radioactive decay, a proton decays into a positron and a neutron, but no net charge production.

From the above image, we can say that if our system is not in the influence of any other charges, the net internal distribution among charge will go on in such a way that the entire net charge of the system will remain the same.

In other words, we can say that: Charge can neither be created nor be destroyed and there is total conservation of charge.