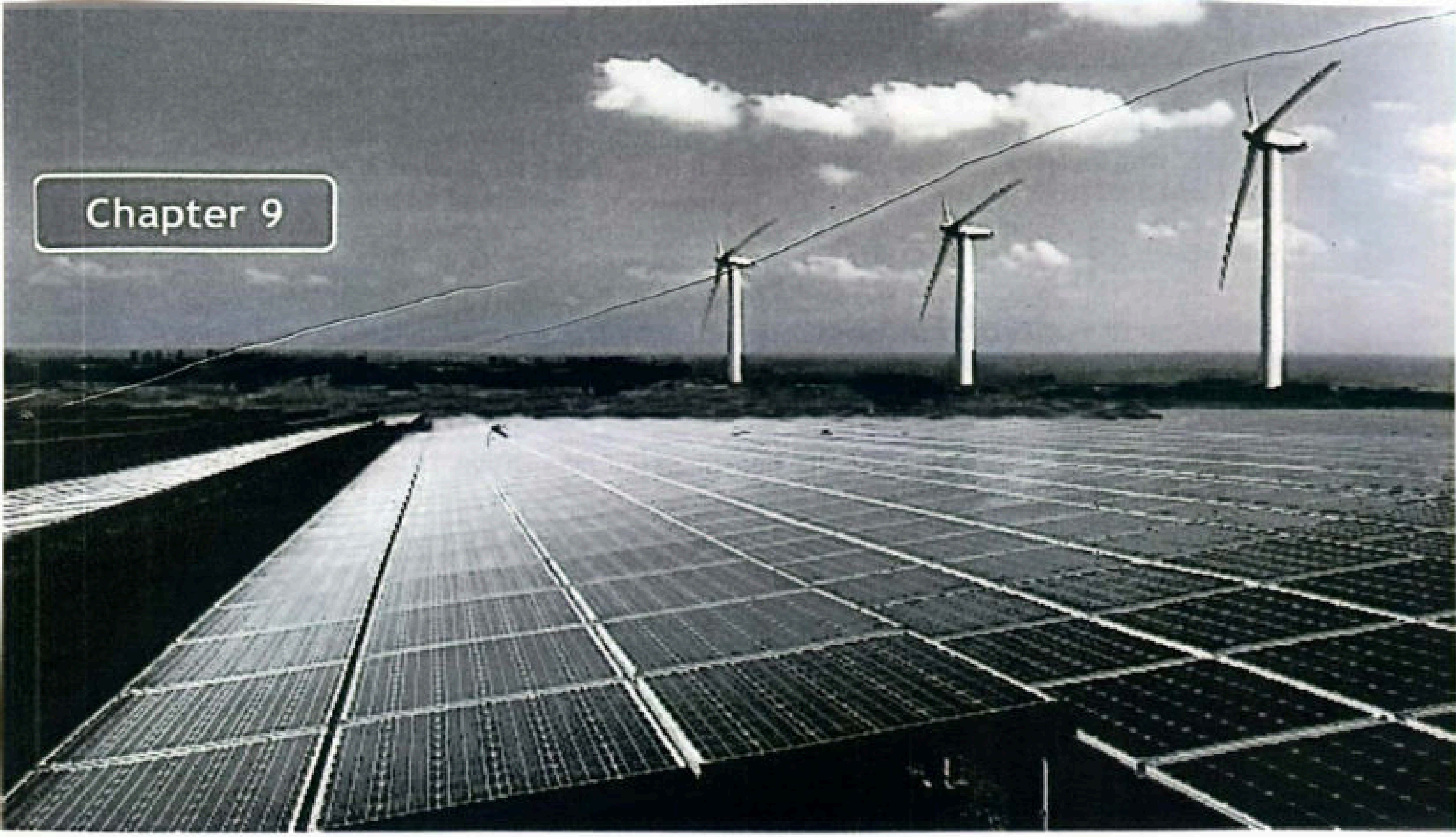


FORCES

SLOs: After completing this lesson, the student will be able to:

1. Explain the force of gravitation and compare gravitational field strength 'g' of Earth with other planets.
2. Justify that the gravitational force is a non-contact force.
3. Using formula to calculate the weight of an object.
4. State that there are four fundamental forces and describe them in terms of relative strength.
5. Analyze the dissipative effect of friction.
   [this include identifying where dissipation may occur and giving examples such as rubbing hands together produces heat, asteroids that enter the Earth atmosphere disintegrate due to high temperature generated from air resistance]
6. Justify methods to reduce friction.
7. Define efficiency and describe why machine cannot be 100% efficient.

Man has been searching for the reasons why we can live on Earth? Why we are not flying into the space? Why things fall downward? The quest for the search for answers of these questions started long ago. From the work of Newton and Galileo to the work of Einstein we found a lot about the reasons behind these and such type of observations. We found that the objects fall towards Earth due to the pull of Earth which is known as the force of gravity.

In this unit we will discuss about the force of gravity, the gravitational field strength, weight of bodies which is due to gravitational pull of Earth, the frictional force and the energy resources available in the nature and their types.

9.1 FORCE OF GRAVITATION

We observe that all the things which are not supported by anything fall towards the Earth; this is due to a force, called the force of gravity.

"The force with which the Earth attracts everybody towards its centre, is called the force of gravitation"

The region around a massive object, such as Earth or Sun etc. where gravitational force is operative is termed as gravitational field. It can be defined as:

"The region or space around any massive object where it can apply a force of attraction on a unit mass within this region, is called the gravitational field of that massive object"

The gravitational field of massive bodies can bend the path of that body if there is a large distance between the two bodies. For small distance and small velocities bodies usually falls on the massive object, but with increase in distance and large velocities bodies use to orbit around the massive objects. Such orbits are made , in fact due to falling of bodies towards the massive bodies but due to curved surfaces of naturally massive objects, hence the curvature of such bodies prevents small bodies to fall on them instead they move in orbital path. Just like our Moon is continuously falling towards the Earth but the curvature of its path is so aligned with the curvature of the Earth that it moves in a circular path around the Earth without falling. Hence the gravitational force (the pull of the Earth) bends the straight line path of the Moon into a circular one.

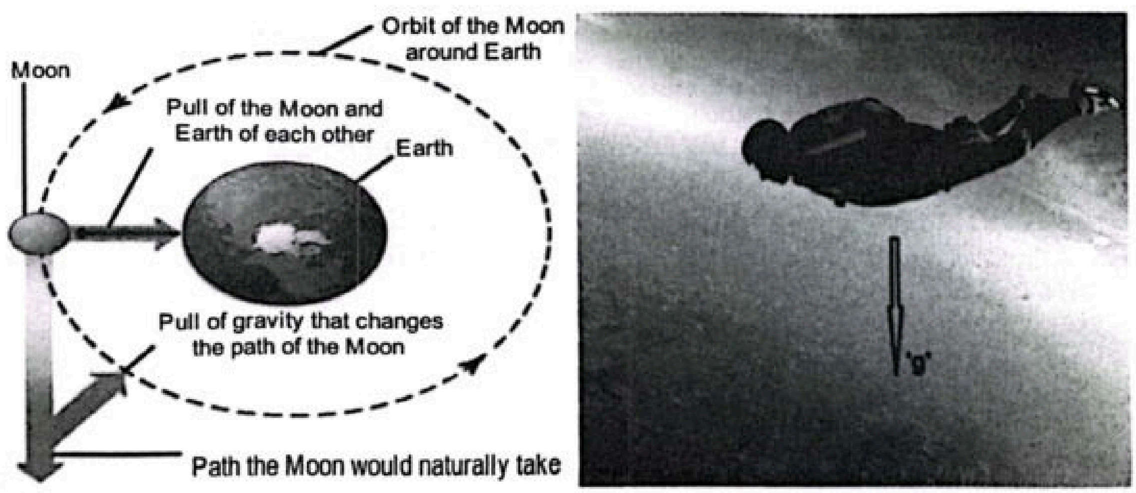


Fig. 9.1: Motion of Moon and a man due to gravitational pull of Earth

In gravitational field the massive body exerts a force of attraction on other bodies, which is called the gravitational force. The gravitational field strength is the amount of force per unit mass acting on objects in the gravitational field. The value of gravitational field strength 'g' is equal to the magnitude of the gravitational force exerted on a unit mass at that point. Mathematically it can be given as:

$$g = \frac{F_g}{m} \text{ ---------- } (9.1)$$

Here the 'F_g' is the gravitational force and 'm' is the unit mass.

"The gravitational field strength (g) is a vector with magnitude 'g' that points in the direction of gravitational force i.e. towards the centre of the body which is applying the gravitational force"

The gravitational field strength 'g' for the Earth is shown in figure 9.2.

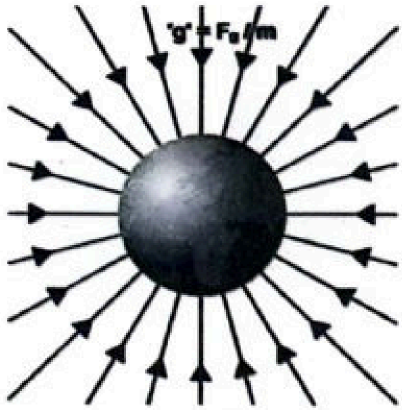


Fig. 9.2: Gravitational field strength

As we know that from Newton's second law of motion, the force applied (F) on an object is equal to the product of the mass (m) of that object and the acceleration (a) of that object, as:

$$F = m\ a \text{ ---------- } (9.2)$$

But in this case the acceleration is due to force of gravitation, hence we replace 'a' by 'g' in the above relation, as:

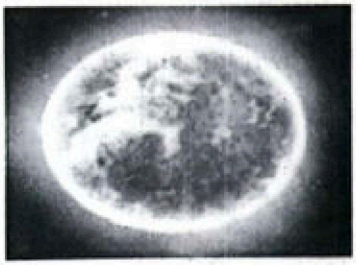
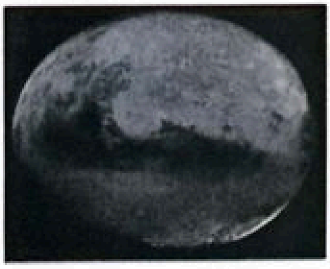
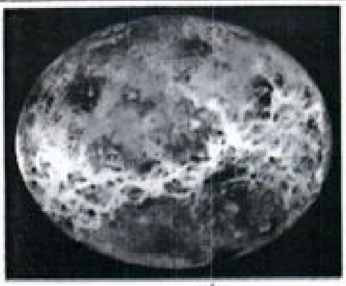
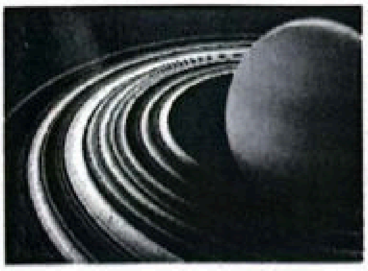
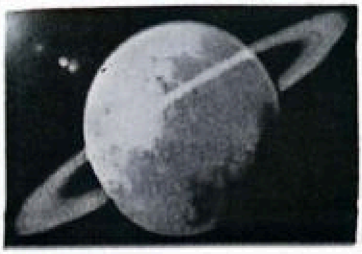
$$F_g = m\ g \text{ ---------- } (9.3)$$

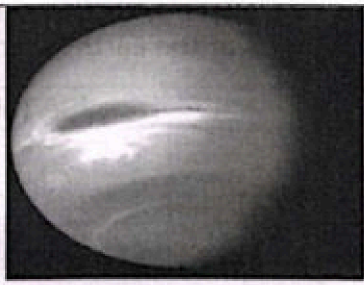
Hence the gravitational field strength 'g' can be given as:

$$g = \frac{F_g}{m}$$

The SI unit of the gravitational field strength is measured in newton per kilogram (N / kg). It is a vector quantity which has the direction towards the centre of the Earth. Since the gravitational field strength and the acceleration due to gravity are equal in magnitude, the same symbol 'g' is used for both. Therefore, on Earth's surface, g = 9.8 N/kg or g = 9.8 m/s^2. The gravitational field strength is not the same everywhere. Gravitational field strength decreases as we move away from the surface of Earth, therefore gravitational field strength also decreases. Even the gravitational field strength is different for different celestial objects, as it depends upon the mass of the object. Hence the Sun, the Earth and all other planets have different values of gravitational field strength.

Table 9.1 Gravitational field strengths of solar system

Name	**Value of 'g' (m s^{-2})**	**Picture**	**Name**	**Value of 'g' (m s^{-2})**	**Picture**
Sun	274		Mars	3.7	
Mercury	3.7		Jupiter	24.8	
Venus	8.9		Saturn	10.4	
Earth	9.8		Uranus	8.9	

Moon	1.6		Neptune	11.2	

Gravity a Non-contact Force

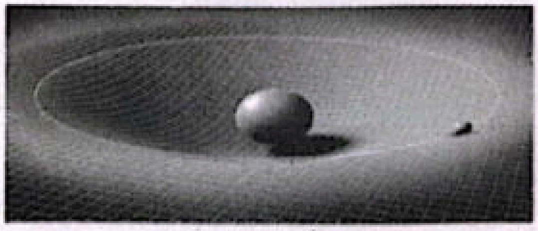
To push a book towards your friend you need a contact with that book. To lift your school bag you have to apply a force to lift it, but this force can only be transmitted to bag with some contact, without contact you cannot apply force on it. Is it necessary to make a physical contact for applying all the forces? The answer is 'No'. There are some forces which do not require any physical contact for their application.

"The force which does not require any physical contact between the objects for its application is called a non-contact force"

The force which acts at a distance, without any physical contact between bodies is termed as non-contact force. This force acts even if the objects involved are not touching, also known as action at a distance force.

SCIENCE TIDBITS

According to modern view of gravitation (gravitational force), the force of attraction between the masses is due to the curvature of space and time. Infect the space and time around the heavy masses bends due to which other light objects orbit around them. You can make this analogy by assuming a rubber sheet, it bends when a heavy ball is put on it.

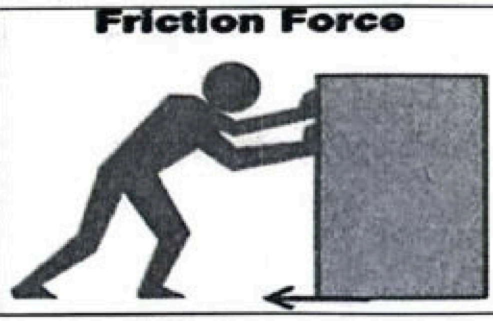
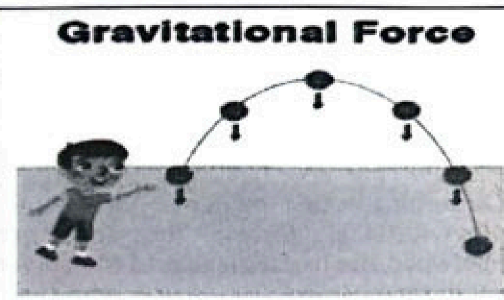


The attractive force between two objects with mass is called the gravitational force, as the force of attraction of Earth on moon. An attractive or repulsive force experienced between magnetic poles is called magnetic force. These two are examples of non-contact forces.

Fig. 9.3: Non- contact force (gravity)

As our Earth is moving around the Sun due to attractive force of gra vitation of the Sun, as our Earth and the Sun are not in contact but still the force of attraction is working, similarly the Moon is orbiting the Earth due to gravitational force of the Earth which is not in contact with the Moon, these above examples proved that the gravitational force is a non-contact force. Similarly dropping of a paratrooper from an airplane is an example, as when the paratrooper is in air he/she is not in contact with the Earth, as shown in figure 9.3, but feels the gravitational force of attraction of the Earth, which proves the gravitational force to be a non-contact force.

Table 9.2 Contact and non-contact forces

	Contact Forces	Non-contact Forces
How are they formed	Between two objects that are in physical contact	Between two objects that are not in physical contact
Field	Does not exist	Exist
Types	Friction, tension Normal force, air resistance and spring force	Gravitational force, Electric force Magnetic force
Example	The friction offered by a floor when a box slides on it	The force of attraction between the Earth and the Moon
Illustration		

Weight

In our daily life we use the term mass and weight in almost the same meaning. However, mass is the amount of matter an object contains which is also called as the measure of inertia of an object. Weight is the gravitational force acting on a mass or object.

"The force with which the Earth attracts an object towards its centre is called the weight of that object"

By using equation (9.2) we can relate these two quantities i.e. the mass and the weight. On the surface of the Earth, where the acceleration due to gravity is relatively constant ($g = 9.8$ ms^{-2}), the weight 'W' can be given as:

Weight = mass x acceleration due to force of gravity

$$W = m\ g \quad \text{----------} \ (9.4)$$

Note that this equation is the special case of equation (9.2), $F = m\ a$, where symbols are simply different, as in this case the force is that of gravity that is why force 'F' is replaced by weight 'W' and the acceleration is in vertical direction, hence acceleration 'a' is replaced by the vertical acceleration 'g', which is also known as the gravitational field strength. Weight can be measured with spring balance, as by adding the more weight it stretches the spring more due to the Earth's gravity, as shown in figure 9.4.

Spring balance is a device used for measuring the force acting on an object. It consists of a spring which gets stretched when a force is applied on it. Stretching of the spring is measured by a pointer moving on a graduated scale. The reading on the scale gives the magnitude of the force. For higher degree of accuracy the scale uses an electronic gauge. It gives a digital readout or a graph of the forces when interfaced with a computer. A spring balance is shown in figure 9.5. As weight depends upon the gravitational field strength at that point, hence weight is different at different points relative to field strength. For example if we were to move on the Moon, our weight would be reduced by 1/6, as the gravitation field of the Moon is smaller than that of the Earth, but our mass remains the same as it is "the quantity of matter in a substance".

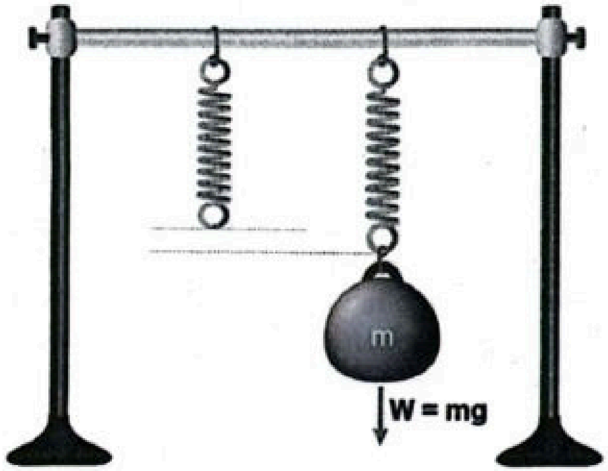


Fig. 9.4: Weight

Fig. 9.5: spring balance for weight measurement

By using equation (9.4) we can find our weight at any place easily.

Example 9.1 (Finding weight) Find the weight of your school bag having a mass of 2kg. Also find the weight of this bag if it were on the Sun and on the Moon.

GIVEN

Mass of the school bag: $m = 2\ kg$

REQUIRED

Weight on Earth 'W_E' = ?

Weight on Sun 'W_S' = ?

Weight on Moon 'W_M' = ?

SOLUTION: To find the weight we use equation 9.4, as: $W = m\ g$

On Earth: g = 9.8 ms^{-2},

$$W_E = 2kg \times 9.8ms^{-2}$$

$$W_E = 19.6\ kgms^{-2} = 19.6\ N$$

On Sun: g = 274 ms^{-2},

$$W_S = 2kg \times 274 ms^{-2}$$

$$W_S = 548\ kgms^{-2} = 548\ N$$

On Moon: g = 1.6 ms^{-2},

$$W_M = 2kg \times 1.6 ms^{-2}$$

$$W_M = 3.2\ kgms^{-2} = 3.2\ N$$

Assignment: 9.1: Find your weight. What would be your weight if you were on Jupiter, on Mars and on Uranus.

9.2 FUNDAMENTAL FORCES

When you move you exert a force on the path which in reaction exerts an equal force on you. When you rub your hands they become hot due to frictional force. Iron is attracted towards a magnet due to a magnetic force and you lift a book by applying force on it in gravitational field. We deal with a lot of forces in our daily life routine. There are many different types of forces around us, but in physics, we classify all these forces into only four types based on how objects interact with one another. All the forces we observe in nature in daily life belong to these four fundamental forces at atomic and sub atomic level. The four fundamental forces are the gravitational force, the electromagnetic force, the strong nuclear force and the weak nuclear force, as shown in figure 9.6.

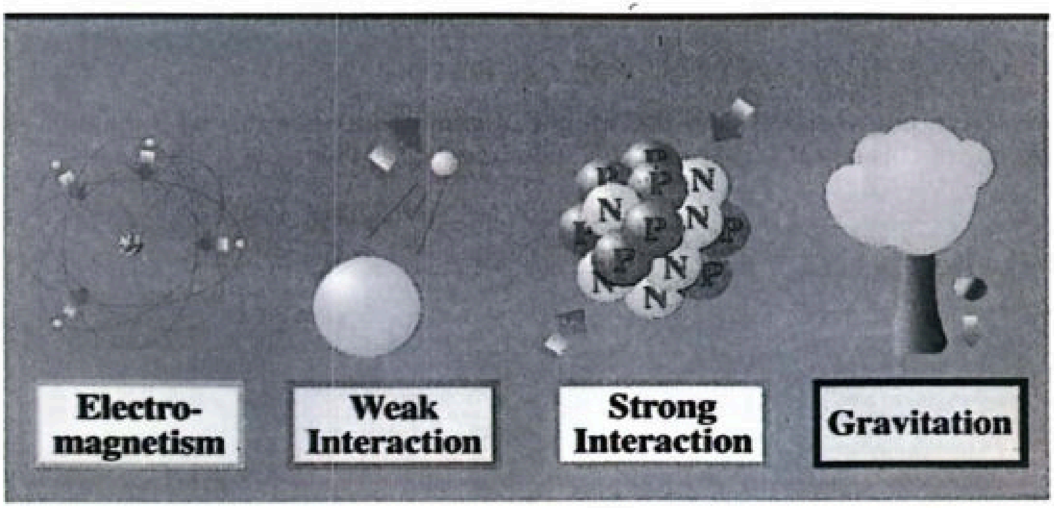


Fig. 9.6: Four fundamental forces of nature

These four fundamental forces in nature are explained through exchange particles. Elementary particles which are lighter than a proton travel from one object to another "carrying" the force. Each force of the nature is carried or mediated by the exchange of a particle.

Electromagnetic Force

The electromagnetic force acts between the electric charges. It includes both the electric force and the magnetic force. The electromagnetic force can either be attractive or repulsive in nature. The electromagnetic force is mediated by a massless particle known as photon. The massless nature of the photon makes the effective range of this force to be infinite, even though the strength of the force decreases rapidly as the distance between the two objects increases. The electric and the magnetic forces fields are separately shown in figure 9.7.

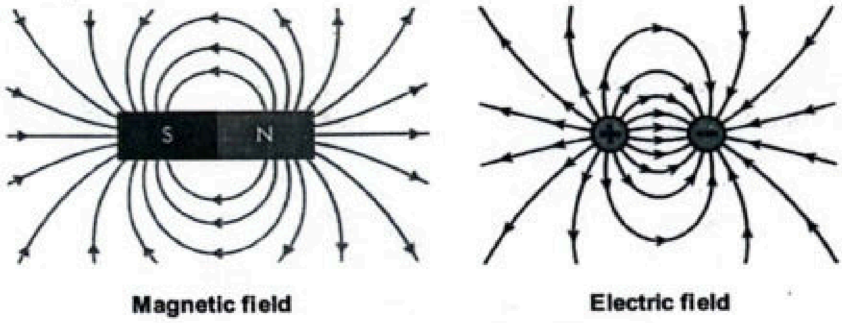


Fig. 9.7: Electric and magnetic field forces

The normal force, frictional force, cohesion, adhesion and tension are caused by the interaction of particles on the contact surfaces and are thus a result of the electromagnetic force. Electromagnetic force cause all chemical reactions, it binds together atoms, molecules and all substances at micro level.

Strong Nuclear Force

The strong nuclear force is the strongest among all the fundamental forces. Despite its different effective strength, the strong nuclear force is very short ranged force it is effective only within sub-nuclear distances of the order of 10^{-14} to 10^{-15} m and therefore confines protons and neutrons inside the nucleus. It keeps the positively charged protons tightly packed in the nucleus of an atom, by overcoming the repulsion between them due to electromagnetic force. Hence we can say that it is responsible for the formation of nucleus. As shown in figure 9.8.

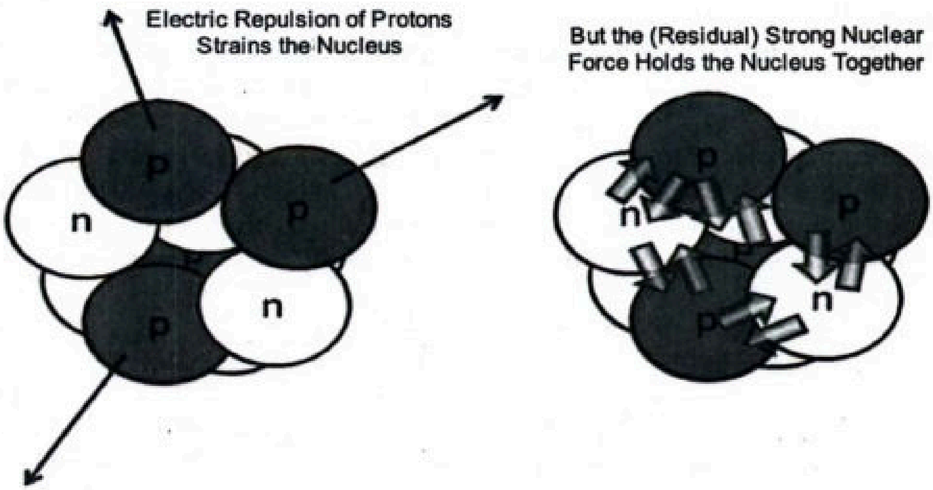


Fig. 9.8: Strong nuclear force

The exchange particles of strong force are called 'gluon'. This force is blind for electric charge. The most amazing property of the strong force is that, it does not follow inverse square law unlike electromagnetic and gravitational forces. It behaves like two masses attached by an elastic spring in which by increasing the stretching force, elastic force also increases so by increasing the distance between particles its strength increases, but for very short range beyond which this force vanishes.

Weak Nuclear Force

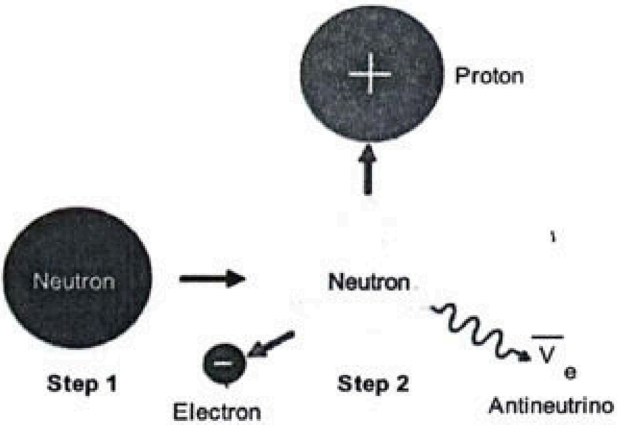


Fig. 9.9: Weak nuclear force (decay of neutron)

The weak nuclear force is the short range force, like the strong nuclear force and is responsible for spontaneous breaking of the nucleus. It is a sort of repulsive force of very short range of the order of 10^{-15} to 10^{-17} m. like strong nuclear force it does not obey inverse square law. The weak nuclear force is mediated by the exchange of a particle called 'W' and 'Z' bosons. There is a close similarity between the electromagnetic force mediated by a photon and the weak nuclear force mediated by the W^+, W^- and Z^0 particles. Pakistani Nobel laureate scientist Dr. Abdus Salam along with two other scientists showed that the neutral photon (electromagnetic force carrier) and the Z^0 (weak force carrier) particles belong to the same family and are genetically related, hence they called it electroweak force by the unification of electromagnetic and the weak nuclear forces. This force plays the major role within the nucleus when a proton changes into a neutron or a neutron changes into a proton.

Gravitational Force

The gravitational force is the force of attraction between all objects in the universe. Gravity is the weakest force among all the fundamental forces of nature. It can be noticed only when one of the masses has a very large mass like planets and stars etc. it holds the planets and large heavenly bodies and controls their motions. Objects fall towards the Earth is due to this force, we have weight due to this force. Its exchange particle is 'graviton' a massless particle which shows the range of gravitational force to be infinite, graviton is only theorized but not found yet experimentally. This force keeps the atmosphere and seas fixed to the surface of Earth. Like electromagnetic force it also obeys inverse square law like $1/r^2$. Unlike electromagnetic force which can either be attractive or repulsive, gravitational force is only attractive force. About gravity there are two prominent theories. The magnitude of gravitational force between two point masses can be given by a formula as:

$$F = G\frac{m_1 m_2}{r^2} \quad \text{----------} \quad (9.5)$$

Here 'F' is the gravitational force between the masses 'm_1' and 'm_2', 'r' is the distance between them and 'G' is the universal gravitational constant having value $G = 6.67 \times 10^{-11} N\ m^2 kg^{-2}$. This relation for the Earth (with mass 'M') and the Moon (with mass 'm') is shown in figure 9.10.

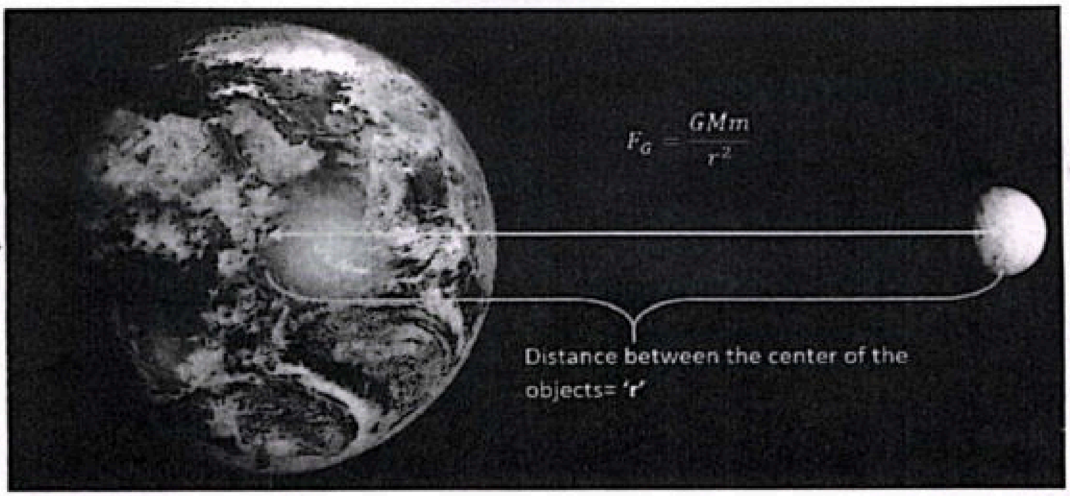


Fig. 9.10: Force of gravitation between Earth and Moon

Example 9.2 (Finding gravitational force) Find the gravitational force between the Earth and the Sun, if the masses of the Earth and the Sun are 6×10^{24} kg and 2×10^{30} kg respectively. The average distance between the Sun and the Earth is 1.5×10^{8} km.

GIVEN

Mass of the Earth: $m_E = 6\times10^{24} kg$

Mass of the Sun: $m_S = 2\times10^{30} kg$

Distance between the earth and the Sun: $r = 1.5\times10^{8} km = 1.5\times10^{11} m$

REQUIRED

Force of gravitation 'F_g' = ?

SOLUTION: To find the gravitational force we use equation 9.5,

as: $$F_g = G\frac{m_E m_S}{r^2}$$

Using values,

$$F_g = (6.67\times10^{-11} N\ m^2 kg^{-2})\frac{(6\times10^{24} kg)\ (2\times10^{30} kg)}{(1.5\times10^{11} m)^2}$$

$$F_g = 3.55\times10^{22} N$$

Assignment: 9.2: Find the gravitational force between the Earth and the Moon, if the masses of the Earth and the Moon are 6×10^{24} kg and 7.3×10^{22} kg respectively. The average distance between the Earth and the Moon is 384,400 km.

Answer: $F_g = 2\times10^{20} N$

Newton called the gravity an intrinsic property of masses but Einstein gave the concept of curvature of space and time locally near heavy bodies.

Table 9.3: Comparison of fundamental forces

Force	Illustration	Strength	Range (m)	Particle
Strong	Force which holds nucleus together	1	10^{-15} (diameter of a medium sized nucleus)	gluons, π(nucleons)
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	neutrino interaction induces beta decay	10^{-6}	10^{-18} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity		6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2

9.3 FRICTION

Friction '*f*' is the resistance to relative motion that occurs whenever two materials are in contact with each other, whether they are solids, liquids or gasses. Since it is a force therefore it is a vector quantity i.e. has some direction and has unit as newton 'N'. It can be defined as:

"The force that resists motion when the surface of one object comes in contact with the surface of the other, is called the frictional force or simply friction"

The mechanical advantage or the efficiency (which is the ratio of the output to the input) of every machine is reduced due to friction. Every surface is rough, even the surface that appears to be highly polished can actually look quite rough when examine under a microscope. As shown in figure 9.11. There is no such thing which is a perfectly flat surface, the ups and downs are there on every surface even small they may be.

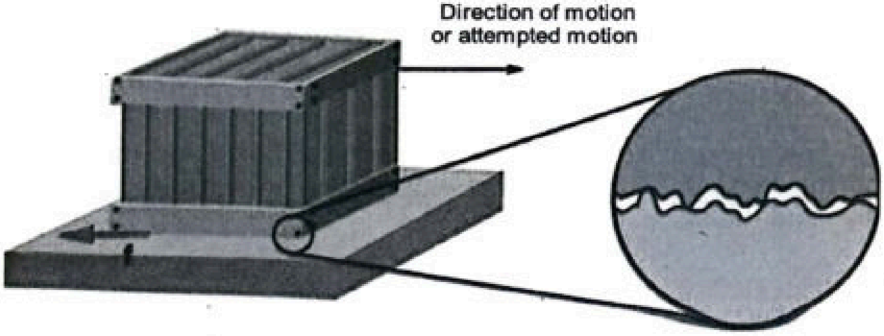


Fig. 9.11: Microscopic view of contact surfaces

As a result the two surfaces that are touching are not really touching across the entire area that appears to be touching. Thus the roughness's of both surfaces interlock which makes friction. Friction always acts in a direction to oppose motion of the body. If you push a solid box on a floor to the left, the force of friction on the box will be to the right, as shown in figure 9.12. When an object falls downward through the air, the force of friction (which is the air resistance) acts upward.

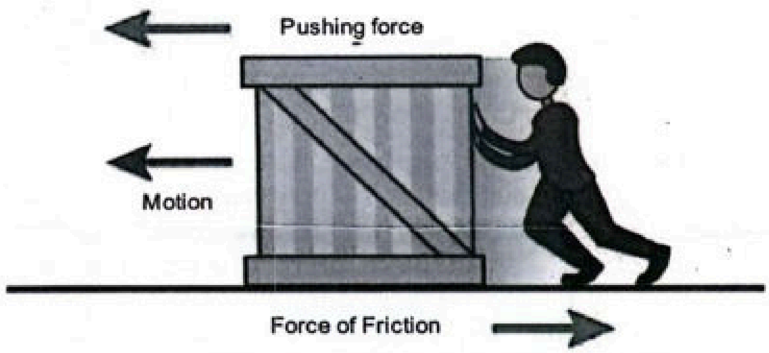


Fig. 9.12: Direction of applied force and friction

Sliding friction is the resistance created by any two objects when sliding against each other. It is the sliding friction between the brake pads and our bike rims, which slows the rolling wheels so we can stop our bike in time.

Advantages of Friction

Friction is not a bad thing at all it can be used for our daily life routine. Many of our daily life works cannot be done without friction. Some of the daily life uses of friction are given below.

- Driving a vehicle on a road is due to friction between the tyres of the vehicle and the road.
- Applying brake to stop a moving vehicle, as when we apply brakes we push brake pedal to the rim, due to friction between them they stop the motion of vehicle.
- Skating is a process of gliding on ice. Skating is possible only due to friction.
- Walking on road is an application of friction. Without friction one cannot walk.
- Writing on notebook is also an application of friction as the ink stuck on rough paper due to friction between paper and pen.
- Drilling a nail into a wall is due to friction.
- Lighting a matchstick is an application of friction.

Dis-advantages of Friction

Friction on other hand is not desirable in same cases. Some of the examples in which friction plays a negative effect on our daily routine are given here.

- Energy is wasted to overcome friction between moving parts of machinery.
- Friction produces wear and tear on the contacting surfaces. This reduces the life of machine parts.
- Friction produces heat which damages the moving parts.


Fig. 9.13: Rubbing hands to produce friction in winter

The work done used against friction is converted into heat. Dissipative forces like force of friction decreases the mechanical energy in a system. Dissipative forces acting on an object always oppose the motion of the object. In winter when we rub hands together we feel the sensation *of warmth*, as shown in figure 9.13.

It is because friction causes the increase in the temperature of our hands, which makes our hands warm. Similarly you would have noticed shooting stars (a small piece of rock which is called meteor that enters into the Earth's atmosphere from outer space) as shown in figure 9.14.

Fig. 9.14: Meteor entering into the Earth's atmosphere

When they enter into the Earth's atmosphere, meteors compress the air in front of them and are heated due to the friction of air molecules, dust particles and water vapours present in the atmosphere. Due to heat produced they glow and the intense heat vaporizes most of the meteors, creating what we call shooting stars.

Methods to Reduce Friction

Where there is no use of friction we need to decrease the friction. For this purpose we use different techniques to reduce the unwanted friction. Some of the methods are discussed here.

- By polishing: if we polish the rough surface, they become smooth and friction is reduced as shown in figure 9.15.

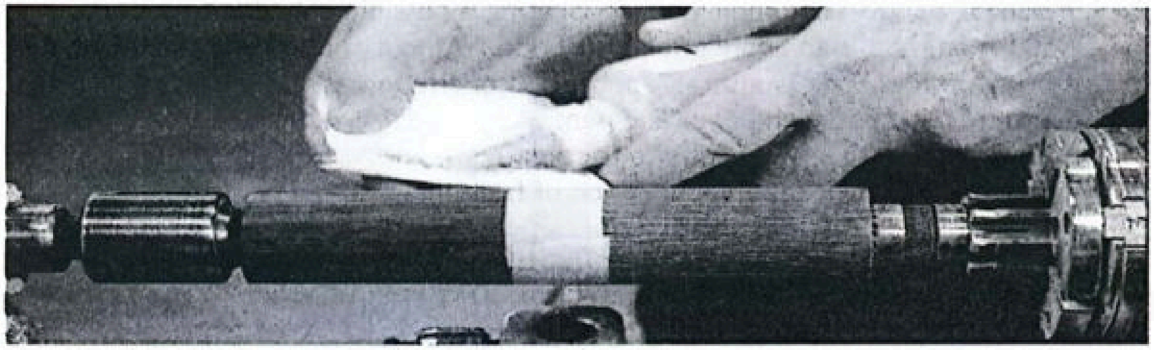


Fig. 9.15: Polishing a surface to reduce friction

- By using ball bearing: this method converts the sliding friction into rolling friction, which reduces the total friction between the contact surfaces as shown in figure 9.16.

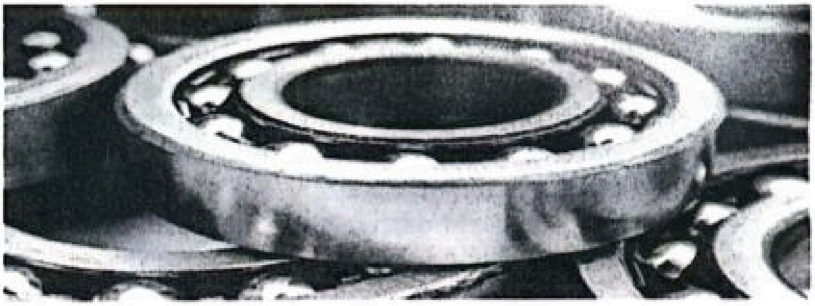


Fig. 9.16: Ball bearings to reduce friction

- By applying lubricants (oil or grease) to surfaces: friction of certain liquids is less than that of solid surfaces, therefore, oiling or greasing the surface between the parts of machinery reduces the friction as shown in figure 9.17.

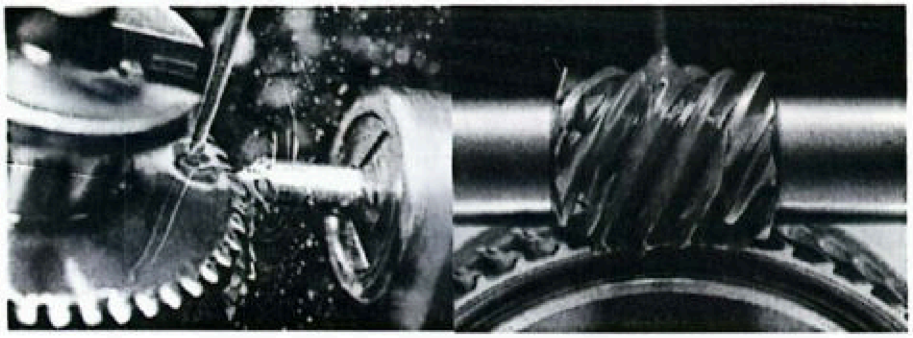


Fig. 9.17: Lubrication to reduce friction

- If we set a heavy spherical ball, ring or cylinder rolling, it experiences an opposing force called rolling friction as shown in figure 9.18.

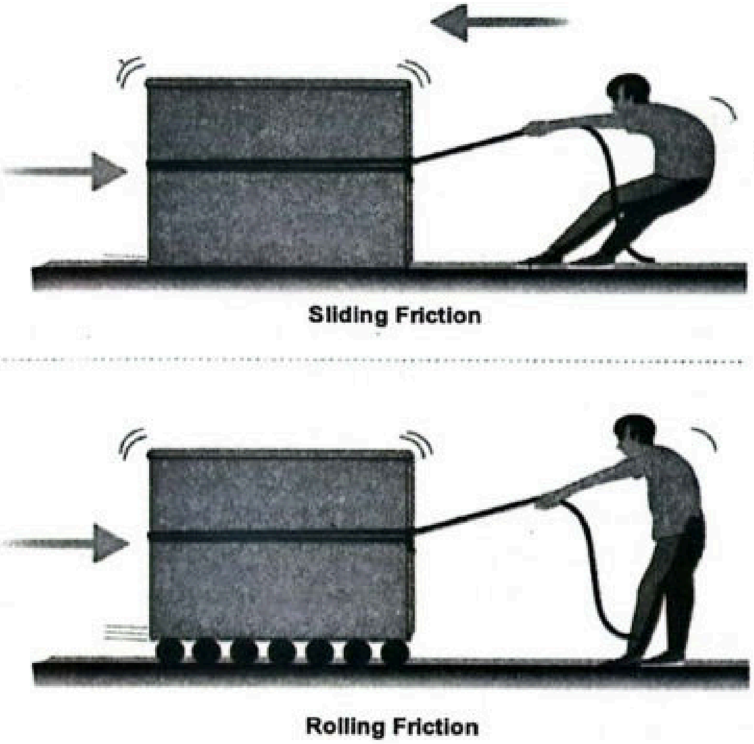


Fig. 9.18: Rolling and sliding friction

When a body rolls over a surface, the force of friction is called rolling friction. For the same weight the rolling friction is much smaller than the static or sliding friction. As the friction between two contacting surfaces depend upon the area of contact. In rolling friction the area of contact is smaller hence it reduces the friction, as shown in figure 9.18.

9.4 EFFICIENCY

Energy in this universe is transferring from one type to the other, but the total energy of the universe remains the same. Hence energy can neither be created nor be destroyed. The total energy at the output of any machine must be equal to the total energy at the input. However it is found that the energy output is always less than the energy input. This is mainly due to the work done against the frictional forces. Different machines and devices are used to convert one type of energy into the other type, like motor converts electric energy into mechanical energy, bulb converts electric energy into light energy and solar penal converts light energy into electric energy etc. in all transformations a part of energy is lost in form of heat. When the energy is converted into heat it is now not available for any work that is why we called it as energy loss or heat loss, because the lost energy transformed into heat. The efficiency 'η' of a machine or any other device describes the extent to which it converts input energy or work into useful type of output energy or work.

Efficiency 'η' is the ratio of useful work output 'W_o' to the total work input 'W_i', as:

$$Efficiency = \frac{useful\ work\ output}{input\ work}$$

Or

$$\eta = \frac{W_o}{W_i} \text{ ---------- } (9.6)$$

Efficiency has no unit as it is the ratio of the same quantities and therefore the same units get cancelled The efficiency of work/energy transfer is sometimes given in percentage as:

$$\%\ \eta = \frac{W_o}{W_i} \times 100 \text{ ---------- } (9.7)$$

The efficiency in terms of the power is normally used for the machines, if 'P_o' is the output power and 'P_i' is the input power, then efficiency can be written as:

$$\%\ \eta = \frac{P_o}{P_i} \times 100 \text{ ---------- } (9.8)$$

This equation shows that the output power is a fraction of the input power. In the event that the system operates at 100% efficiency (η=1), the output power will be equivalent to the input power. But in practical applications, energy is dissipated as waste heat or in other form, resulting the efficiencies lower than 100%.

Efficiency maximization plays a pivotal role in energy systems, as it allows for optimal utilization of resources while minimizing energy wastage. A car engine running on petrol transforms only 25% of its input energy obtaining from the fuel into the output work hence its efficiency is only 25%. Similarly an incandescent bulb transforms only 5% of its input electric energy into the output light and rest of 95% energy is lost in the form of heat. Hence incandescent bulb has only 5% efficiency. The incandescent bulb and moving parts of automobile are shown in figure 9.19.

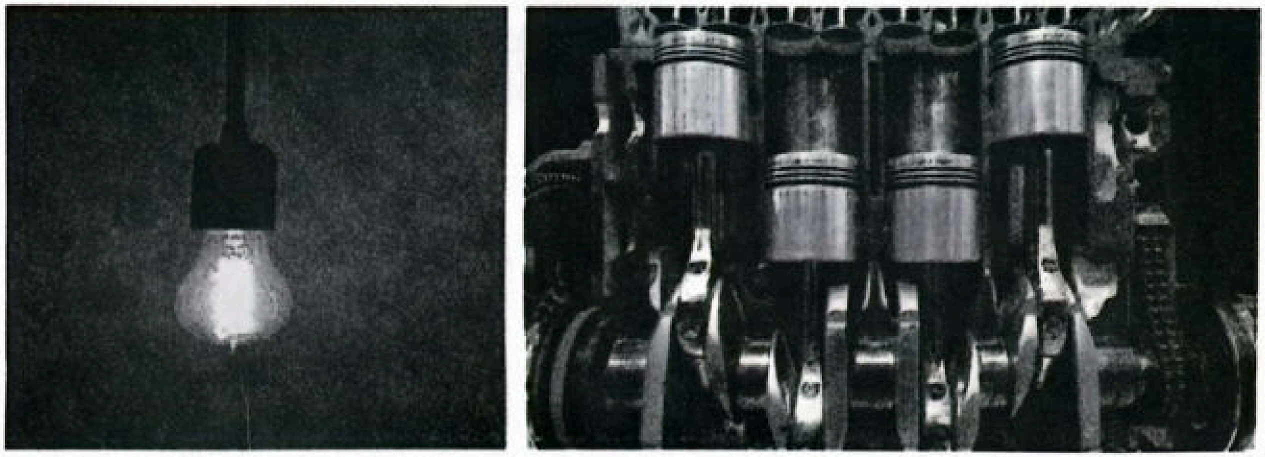


Fig. 9.19: Incandescent bulb and auto engine

It is not possible to have a machine with 100% efficiency, because frictional effects lower the efficiency of machines. Work output is always smaller than the work input. Efficiencies of some common devices/machines is given in table 9.3.

Table 9.4 Efficiencies of some common devices

Device	Efficiency
Electric motor	90%
Gas Furnace	95%
Oil Furnace	80%
Coal Stove	75%
Automobile Engine	25%
Fluorescent Bulb	60%
LED	90%

Example 9.3 (Finding Efficiency) An electric motor consumes 100 watts of electric power to obtain 90 watts of mechanical power. Determine its % efficiency. Also find power loss.

GIVEN

Input power: $P_i = 100\ W$

Output power: $P_o = 90\ W$

REQUIRED

Efficiency: $\eta = ?$

Power loss: $\Delta P = ?$

SOLUTION: To find the efficiency we use equation 9.8,

as: $$\eta = \frac{P_o}{P_i} \times 100$$

Using values,

$$\eta = \frac{90}{100} \times 100$$

$$\eta = 90\ \%$$

Power loss = power input - power output

$$\Delta P = P_i - P_o$$

$$\Delta P = 100\ W - 90\ W$$

$$\Delta P = 10\ W$$

Assignment: 9.3: An automobile engine consumes 600 J energy of fuel and does 150 J of useful work. How efficient is the engine? Also find the energy loss.

Answer: 25%, 450 J

SUMMARY

1. The force with which the Earth attracts everybody towards its centre is called the force of gravitation.
2. The region of space around any massive object where it can apply a force of attraction on a unit mass within this region is called the gravitational field of that massive object.
3. The gravitational field strength is a vector with magnitude 'g' pointing in the direction of gravitational force i.e. towards the centre of the Earth.
4. The force which does not require any physical contact between the objects for its application is called a non-contact force.
5. The force with which the Earth attracts an object towards its centre is called the weight of that object.
6. The weight of an object is the product of its mass and the value of gravitational field strength.
7. In nature there are only four fundamental forces, all other macroscopic forces are due to these four forces.
8. The force which binds the atoms and molecules is called the electromagnetic force, which is due to attraction and repulsion between electric charges.
9. The force which binds the nucleus is called strong nuclear force.
10. The force which is responsible for decay of nuclei and conversion of neutron and protons into each other is called weak nuclear force.
11. The force which holds us on the Earth, planets, stars and galaxies is called the gravitational force it is due to point masses or due to curvature of space and time.
12. The force that resists the motion when the surface of one object comes in contact with the surface of the other is called the friction.
13. Frictional force has many advantages like we can walk on Earth due to friction.
14. Frictional force has many disadvantages like the wear and tear of machinery parts.
15. There are many methods to reduce unwanted friction like polishing the surfaces, using ball bearings and by applying lubricants.
16. Rolling friction has very small value than the sliding friction.
17. The ratio of output power to the input power is called the efficiency of the machine.
18. Efficiency of any real machine can never be 100% due to losses.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. The earth's atmosphere is held by:
   A) strong force B) weak force
   C) electromagnetic force D) gravitational force
2. The weight of an object at the Moon's surface is __________ of the weight on Earth.
   A) 1/6 B) 1/5
   C) 1/3 D) 1/2
3. The weight of a 5 kg box on the surface of Mars will be:
   A) 5 N B) 9.8 N
   C) 18.5 N D) 49 N
4. _____________ Force is blind to charge.
   A) strong force B) weak force
   C) electromagnetic force D) gravitational force
5. The gravitational force between the two point masses relates to the distance between them as:
   A) $1/r^3$ B) $1/r^2$
   C) $1/r$ D) r
6. Which of the following produces least friction?
   A) Sliding friction B) rolling friction
   C) static friction D) kinetic friction
7. As a fielder you roll a ball in the cricket ground, it stops before reaching the bowler due to:
   A) energy B) temperature
   C) pressure D) friction
8. What is the efficiency of a machine when the input is 263 J and the output is 142 J?
   A) 1.85 % B) 5.39 %
   C) 18.5 % D) 53.9 %
9. Efficiency of a machine can never be 100% in real cases due to __________ force:
   A) gravitational B) friction
   B) electric D) nuclear
10. Which of the following method can reduce the friction?
    A) Increasing surface roughness B) applying lubricant
    C) Increasing pressure D) using sticky materials
11. Which material property affects the friction?
    A) Density B) hardness
    C) surface roughness D) melting point

Section II: Short Response Questions

1. Does a person weigh less on the equator than the North Pole?
2. What is the magnitude of the gravitational force at the Earth's centre? Justify your answer.
3. Weight of a body on Earth is 90 N, what would be the weight of the same body on Mars, Moon and Jupiter?
4. How gravitational force is different from the electromagnetic force?
5. A diesel engine has efficiency 35%. What does it mean?
6. Why the ups and down are engraved on the tyres of your car? Explain.
7. It is difficult to walk on slippery floor, why?
8. Why a machine cannot be 100% efficient?
9. Why a person can move faster using roller skaters as compared to using flat shoes?
10. Without friction the life on Earth would not be the same. Justify the statement.

Section III: Extensive Response Questions

1. What is the force of gravitation also describe its significance in daily life.
2. Compare the gravitational field strength of the Sun and planets in solar system.
3. Differentiate between contact and non-contact forces, also show that gravitational force is a non-contact force with the help of daily life examples.
4. Prove that the gravitational force is a non-contact force by using daily life observations.
5. Is the weight of an object different on different planets? Justify.
6. Short range forces are called nuclear forces i.e. the strong nuclear force and the weak nuclear force, describe them with their application.
7. Explain the gravitational force and its applications on everyday life.
8. What is the electromagnetic force? How it is useful for us?
9. Discuss the term friction also explain the methods to reduce friction.
10. Define and explain efficiency. Also show that efficiency of any real machine can never be 100%.

Section IV: Numerical Response Questions

1. Pakistan's first satellite (iCube Qamar) was sent to the Moon on3rd May 2024, its mass was 6.5 kg. Find its weight on Earth and on Moon. **(Answer: 63.7 N, 10.4 N)**
2. Find the gravitational force between the Sun and the Moon, if mass of the Sun is 2×10^{30} kg, Moon's mass is 7.3×10^{22} kg and average distance between the Sun and the Moon is 150×10^{6} km. **(Answer: 4.3×10^{20} N)**
3. A motor consumes 1000 W of power and gives output power of 780 W. Find the efficiency of the motor. **(Answer: 78%)**