CHAPTER 3

WORK, ENERGY AND POWER

1. What is work?

Work is defined as the product of force and displacement in the direction of force. If F is the applied force, S is the displacement in the direction of applied force and work done W is given by

Work done = Force x Displacement in the direction of force

$$W = F \times S$$

In SI system, the unit of work is Nm or joule (J).

2. Define energy. What is its SI unit?

The capacity (or ability) of a body to do work is called energy. Energy and work are equivalent concepts. The SI unit of energy is joule (J).

3. Explain the terms kinetic energy and potential energy.

The energy possessed by a body due its motion is called kinetic energy. If *m* is the mass of the body and *v* is its velocity, then kinetic energy is given by

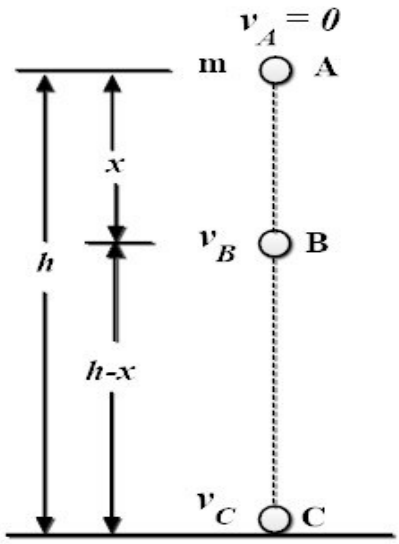
$$K = \frac{1}{2} mv^2$$

The energy possessed by a body by its position or configuration is called potential energy. Consider a mass m held at a height h above ground level in the gravitational field of Earth. If g is the acceleration due to gravity on the surface of the Earth, the potential energy of the body is given by

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

4. State and prove the law of conservation of energy.

Law of conservation of energy states that energy can neither be created nor be destroyed, but can be converted from one form to another. In other words, the total energy of an isolated system remains a constant.

Consider a body of mass m, initially placed at height h above the ground level as shown in the figure. Let the body is allowed to fall freely from its initial position A. In the case of a freely falling body, the total energy is the sum of its kinetic energy and potential energy. As the body moves under gravity, its velocity and hence, kinetic energy increases. But at the same time, the height of the body from the ground decreases and hence, potential energy decreases.	

At Point A

Velocity at point A, $v_A = 0$

Kinetic energy at point A, $K_A = \frac{1}{2}mv_A{}^2 = 0$

Potential energy at point A, $V_A = mgh$

Total energy at point A, $E_A = K_A + V_A$

$E_A = 0 + mgh = mgh$ ---------- (1)

At Point B

Let B be a point at a distance x from the point A. The velocity at point B, v_B can be calculated using the equation, $v^2 = u^2 + 2as$.

$v = v_B\,; \quad u = v_A = 0; \quad a = g; \quad s = x;$

$v_B{}^2 = 2gx$

Kinetic energy at point B, $K_B = \frac{1}{2}mv_B{}^2 = \frac{1}{2}m \times 2gx = mgx$

Potential energy at point A, $V_B = mg(h - x)$

Total energy at point A, $E_B = K_B + V_B$

$E_B = mgx + mg(h - x) = mgh$ ---------- (2)

At point C

Let C be a point on the ground. The velocity at point C, v_C can be calculated using the equation,

$v^2 = u^2 + 2as$.

$v = v_C\,; \quad u = v_A = 0; \quad a = g; \quad s = h;$

$v_C{}^2 = 2gh$

Kinetic energy at point C, $K_C = \frac{1}{2}mv_C{}^2 = \frac{1}{2}m \times 2gh = mgh$

Potential energy at point A, $V_C = 0$

Total energy at point A, $E_C = K_C + V_C$

$E_C = mgh + 0 = mgh$ ---------- (3)

It is clear from equations (1), (2) and (3) that $E_A = E_B = E_C$. Hence total energy of the freely falling body remains constant at every point on its path.

5. **Define power. What is its unit**.

Power is defined as the rate at which work is done. In other words, power is the work done in unit time. If W is the work done in a time t, the average power is given by

$$Power = \frac{work}{time}$$

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

The SI unit of power in is joule/second or watt (W).

6. **What is friction? What are different types of friction?**

The property by which an opposing force is generated between two surfaces in contact of bodies in relative motion is called friction. Friction is generally classified into two main categories namely static friction and kinetic friction.

Static friction

The frictional force comes into play when one body tends to move over the surface of another, but the actual motion has yet not started is called static friction.

Kinetic or dynamic friction

Kinetic or dynamic friction is the opposing force that comes into play, when one body is actually moving over the surface of another body.

7. **What are the methods to reduce friction?**

Lubrication

When the gap between two surfaces is filled with oil or grease, irregularities become filled with this and the friction reduces. This process is called lubrication and the substance used for this are called lubricants. When the surface becomes smooth, the contact pressure decreases and hence friction reduces.

Polishing of rough surfaces

A hard substance is used to grind and remove the irregularity on the soft surface. When the surface becomes smooth, the contact pressure decreases and hence friction reduces.

Use of ball bearings in moving parts

It is easier to role a body than to slide it along the ground. This is the principle which ball bearings work. Hard steel balls are placed between the moving parts. The balls rotate as the cylinders turn relative to each other. This considerably reduces friction.

8. **Explain different temperature scales**.

The major temperature scales used are the Celsius, Fahrenheit and Kelvin scales. Most temperature scales have two fixed points: lower fixed point and upper fixed point.

Celsius Scale

Celsius or centigrade scale is a temperature scale based on the freezing point of water and the boiling point of water. The temperature corresponding to the freezing point of water is taken as the lower fixed point and it is taken as 0 ^{0}C. The boiling point of water is taken as upper fixed point and is given a value 100 ^{0}C. The interval between these two temperatures is divided into 100 equal parts and one division is called one degree Celsius.

Fahrenheit scale

In Fahrenheit scale, the freezing point of water is taken as 32 ^{0}F and boiling point of water is 212 ^{0}F. The interval is divided into 180 equal parts. Each division is called one degree Fahrenheit (1^0 F).

Kelvin scale

Absolute zero, or 0 K, is the lowest possible temperature for any substance and it corresponds to a temperature of −273.15° on the Celsius temperature scale. The Kelvin degree is the same size as the Celsius degree; hence the two reference temperatures for Celsius, the freezing point of water (0°C), and the boiling point of water (100°C), correspond to 273.15°K and 373.15°K, respectively.

9. Write the formula for the conversion between temperature scales.

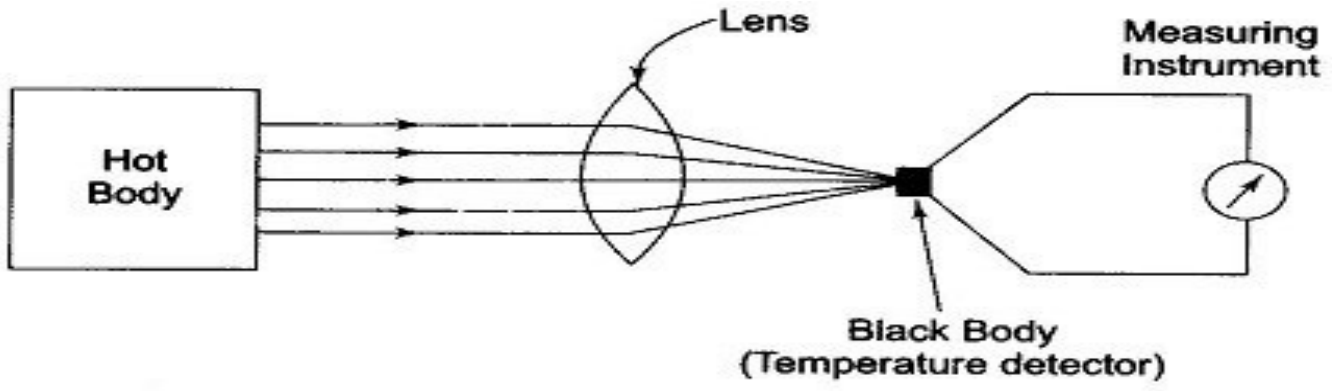
The relation connecting Celsius, Fahrenheit and Kelvin scales is given by the following formula where C stands for temperature in Celsius, F stands for temperature in Fahrenheit and K stands for temperature in Kelvin scale.

$$\frac{C-0}{100} = \frac{F-32}{180} = \frac{K-273}{100}$$

$$\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5}$$

10. Briefly explain the working of pyrometer.

The name pyrometer is given to those thermometers which are used for measuring temperatures above 500 ^{0}C. Pyrometer is used to detect the temperature of an object's surface temperature, which depends on the radiation emitted from the object. A pyrometer is useful for measuring moving, extremely hot or hard-to-reach objects. The basic principle of the pyrometer is that it measures the object's temperature by sensing the heat radiation emitted from the object without making contact with the object. It records the temperature level depending upon the intensity of radiation emitted. The pyrometer has two basic components like optical system and detectors that are used to measure the surface temperature of the object. Infrared pyrometers are made up of pyroelectric materials like polyvinylidene fluoride (PVDF), triglycine sulfate (TGS), and lithium tantalate (LiTaO3). This radiation can be directed to a thermocouple to convert into electrical signals.



11. **Differentiate the process Conduction, Convection and radiation.**

Transfer of heat from one place to another or one end to the other end of the substance, without the actual movement of particle is called conduction. Conduction is the slowest mode of heat transfer. Conduction is most significant in solids and less in liquids and gases, due to the space between molecules.

Convection is the phenomena in which heat is transferred from one place to another by the actual movement of the particles of heated substance. Convection process is faster than conduction. Transfer of heat by convection mode takes place in liquids and gases.

Radiation is the fastest mode of heat transfer which does not required a material medium. All bodies radiate energy in the form of electromagnetic waves. The energy transferred in this mode is often called thermal radiation. The type of radiation associated with the transfer of heat energy from one location to another location is often known as infrared radiation. In radiation process, a hot body emits thermal radiation in all directions. Emitted radiation travels through space and falls on another body. The body absorbs thermal radiation and gets heated up.

12. What do you mean by specific heat capacity?

The specific heat capacity of a substance is defined as the quantity of heat required to raise the temperature of unit mass of the substance through one kelvin.

The amount of hear (Q) absorbed by a body depends on the mass of the body (m), change in temperature (ΔT) and nature of the material. Hence, $Q \propto m\Delta T$

$$Q = Cm\Delta T$$

where the constant C is called the specific heat capacity of substance.