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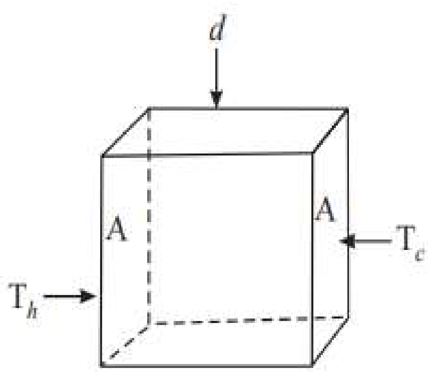
HEAT TRANSFER AND SOLAR ENERGY

There are three processes by which transfer of heat takes place.

These are : conduction, convection and radiation

Heat is transferred from atom to atom by conduction. In this process, the atoms do not bodily move but simply vibrate about their mean equilibrium positions and pass energy from one to another.

Conduction



Thermal conductivity of a material is defined as the amount of heat transferred in one second across a piece of the material having area of cross-section $1m^2$ and edge 1m when its opposite faces are maintained at a temperature difference of 1 K. The SI unit of thermal conductivity is W $m^{-1}k^{-1}$

$$Q \ \alpha \ \frac{A(T_h - T_c).t}{d}$$

$$Q = \frac{KA(T_h - T_c)t}{d}$$

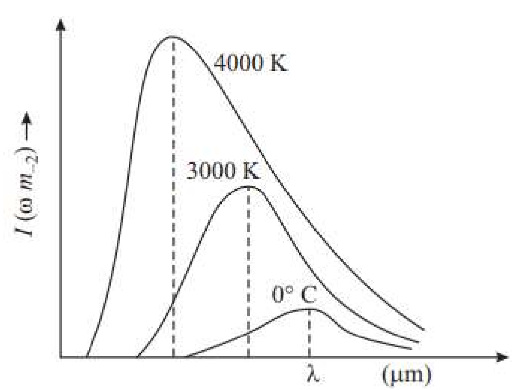
Convection

Rate of heat transfer by convection depends on the temperature difference between the surfaces and also on their areas

Radiation

Radiation refers to continuous emission of energy from the surface of a body. This energy is called radiant energy and is in the form of electromagnetic waves. These waves travel with the velocity of light (3 × l08 ms–1) and can travel through vacuum as well as through air. They can easily be reflected from polished surfaces and focussed using a lens.

RADIATION LAWS



The rate of radiation at a particular temperature (represented by the area between each curve and the horizontal axis) increases rapidly with temperature.

2) Each curve has a definite energy maximum and a corresponding wavelength λm (i.e. wavelength of the most intense wave).

The λm shifts towards shorter wavelengths with increasing temperature.

w. It states that λm shifts towards shorter wavelengths as the temperature of a body is increased

The product λm T is constant for a body emitting radiation at temperature T:

λm T = constant

Kirchhoff's Law

1 = rλ + aλ + tλ

Emissive and Absorptive Power

Emissive power

The ability of a hot body to emit radiation is known as its emissive power.

The total emissive power of a radiating body at a particular temperature is defined as

The total amount of energy radiated per second per unit area of its surface.

It also depends upon the temperature of the body above the surroundings.

Its unit is $Jm^{-2}s^{-1}$

Absorptive power

- When the radiant energy falls on a body, a part of the energy is absorbed.
- The ability of the body to absorb radiant energy falling on it is known as its absorptive power

The total absorptive power of a body is defined as

- The ratio of the energy absorbed to the energy falling. The absorptive power (a) is the fraction of the incident energy which is absorbed.

Stefan-Boltzmann Law

The radiant energy emitted per second from a surface of area A is proportional to fourth power of temperature

$$E = A\, e\, \sigma T^4$$

Where σ is Stefan-Boltzmann constant and has the value 5.672 × 10-8 $Jm^{-2}\ s^{-1}\ K^{-4}$

e is emissivity or relative emittance. It depends on the nature of the surface and temperature. The value of e lies between 0 and 1, being small for polished metals and 1 for perfectly black materials.

SOLAR ENERGY

The sun is radiating tremendous amount of energy in the form of light and heat and even the small fraction of that radiation received by earth is more than enough to meet the needs of living beings on its surface.

Solar Constant

The amount of energy received per unit area in one second is called solar constant. Solar constant for earth is found to be 1.36 × 103 W m^{-2}.

Solar constant multiplied by the surface area of earth gives us the total energy received by earth per second.

$Q = 2\pi R_e^2 C$

Where R_e is radius of earth and C is solar constant

Greenhouse Effect

The atmosphere, which contains a trace of carbon dioxide, is transparent to visible light. Thus, the sun's light passes through the atmosphere and reaches the earth's surface. The earth absorbs this light and subsequently emits it as infrared radiation. But carbon dioxidein air is opaque to infra-red radiations.CO2 reflects these radiations back rather than allowing them to escape into the atmosphere. As a result, the temperature of earth increases. This effect is referred to as the greenhouse effect.

NEWTON'S LAW OF COOLING

the rate of cooling of a hot body is directly proportional to the mean excess temperature of the hot body over that of its surroundings provided the difference of temperature is small. The law can be deduced from stefan-Boltzmann law.

$E = e\sigma (T - T0)\ 4\ \ T_0^3\ A$

$= k (T - T0)$ where $k = 4e\sigma\ 3\ T0\ A$. Hence,

$E\ \alpha\ (T - T0)$ This is Newton's law of cooling.

Check Yourself

1. **Heat is transferred in solid by ....**
   A. Conduction
   B. Convection
   C. Radiation
   D. None of these
2. **Bad conductor is also known as ....**
   A. Conduction
   B. Insulator
   C. Radiant
   D. Termaids
3. **The Stefan-Boltzmann constant depends on the_________________?**
   a) Medium
   b) Temperature
   c) Surface
   d) None of these
4. **Which of the following property of air does not increase with rise in temperature**
   (A) thermal conductivity
   (B) thermal diffusivity
   (C) density
   (D) dynamic viscosity
5. **According to Wien's law, the wavelength corresponding to maximum emission is proportional to**
   (A) absolute temperature (T)
   (B) f
   (C) t
   (D) inverse of absolute temperature (T)
6. **The amount of radiation mainly depends on**
   (A) nature of body
   (B) temperature of body
   (C) type of surface of body
   (D) All of these

Stretch Yourself

1. Why are the woollen clothes warmer than cotton clothes
2. Why is it more difficult to sip hot tea from a metal cup than from a china cup

3. Determine the surface area of the filament of a low incandescent lamp at 300 K . Given σ =5.7 * 10^{-8} wm-2k^{-4} and emissivity e of the filament 0.3