SUPPLEMENTARY MATERIAL

CHAPTER 9

9.6.5 POISSON'S RATIO

Careful observations with the Young's modulus experiment (explained in section 9.6.2), show that there is also a slight reduction in the cross-section (or in the diameter) of the wire. The strain perpendicular to the applied force is called **lateral strain**. Simon Poisson pointed out that within the elastic limit, lateral strain is directly proportional to the longitudinal strain. The ratio of the lateral strain to the longitudinal strain in a stretched wire is called **Poisson's ratio.** If the original diameter of the wire is d and the contraction of the diameter under stress is Δd, the lateral strain is $\Delta d/d$. If the original length of the wire is L and the elongation under stress is ΔL, the longitudinal strain is $\Delta L/L$. Poisson's ratio is then $(\Delta d/d)/(\Delta L/L)$ or $(\Delta d/\Delta L)\ \ (L/d)$. Poisson's ratio is a ratio of two strains; it is a pure number and has no dimensions or units. Its value depends only on the nature of material. For steels the value is between 0.28 and 0.30, and for aluminium alloys it is about 0.33.

9.6.6 Elastic Potential Energy in a Stretched Wire

When a wire is put under a tensile stress, work is done against the inter-atomic forces. This work is stored in the wire in the form of elastic potential energy. When a wire of original length L and area of cross-section A is subjected to a deforming force F along the length of the wire, let the length of the wire be elongated by l. Then from Eq. (9.8), we have $F = YA\ (l/L)$. Here Y is the Young's modulus of the material of the wire. Now for a further elongation of infinitesimal small length dl, work done dW is $F\ dl$ or $YAl dl/L$. Therefore, the amount of work done (W) in increasing the length of the wire from L to $L + l$, that is from $l = 0$ to $l = l$ is

$$W = \int_0^l \frac{YAl}{L} dl = \frac{YA}{2} \times \frac{l^2}{L}$$

$$W = \frac{1}{2} \times Y \times \left(\frac{l}{L}\right)^2 \times AL$$

$$= \frac{1}{2} \times \text{ Young's modulus } \ \text{strain}^2 \ \text{ volume of the wire}$$

$$= \frac{1}{2} \times \text{ stress } \ \text{strain } \ \text{volume of the wire}$$

This work is stored in the wire in the form of elastic potential energy (U). Therefore the elastic potential energy per unit volume of the wire (u) is

$$u = \frac{1}{2}\sigma\varepsilon \qquad \text{(A1)}$$

CHAPTER 10

CRITICAL VELOCITY

(*To be inserted on Page 260, Chapter 10, Physics, Class XI, Vol. 2 textbook before last paragraph of second column.*)

The maximum velocity of a fluid in a tube for which the flow remains streamlined is called its **critical velocity**. From Eq. 10.21, it is

$$v_c = R_e \ \eta \ /(\rho \ \ d).$$

CHAPTER 11

11.9.4 Blackbody Radiation

We have so far not mentioned the wavelength content of thermal radiation. The important thing about thermal radiation at any temperature is that it is not of one (or a few) wavelength(s) but has a continuous spectrum from the small to the long wavelengths. The energy content of radiation, however, varies for different wavelengths. Figure A1 gives the experimental curves for radiation energy per unit area per unit wavelength emitted by a blackbody versus wavelength for different temperatures.

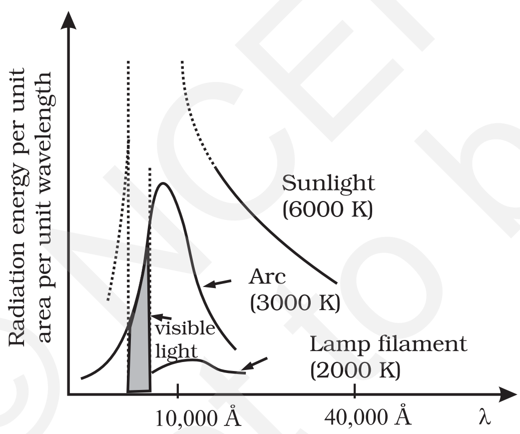

Fig. A1: *Energy emitted versus wavelength for a blackbody at different temperatures*

Notice that the wavelength λ_m for which energy is maximum decreases with increasing temperature. The relation between λ_m and T is given by what is known as **Wien's Displacement Law**:

$$\lambda_m T = \text{constant} \qquad \text{(A1)}$$

The value of the constant (Wien's constant) is 2.9×10^{-3} m K. This law explains why the colour of a piece of iron heated in a hot flame first becomes dull red, then reddish yellow and finally white hot. Wien's law is useful for estimating the surface temperatures of celestial bodies like the moon, sun and other stars. Light from the moon is found to have a maximum intensity near the wavelength 14 μm. By Wien's law, the surface of the moon is estimated to have a temperature of 200 K. Solar radiation has a maximum at λ_m = 4753 Å. This corresponds to T = 6060 K. Remember, this is the temperature of the surface of the sun, not its interior.

The most significant feature of the blackbody radiation curves in Fig. A1 is that they are *universal***.** They depend only on the temperature and not on the size, shape or material of the blackbody. Attempts to explain blackbody radiation theoretically, at the beginning of the twentieth century, spurred the quantum revolution in physics, as you will learn in later courses.

Energy can be transferred by radiation over large distances, without a medium (i.e., in vacuum). The total electromagnetic energy radiated by a body at absolute temperature T is proportional to its size, its ability to radiate (called emissivity) and most importantly to its temperature. For a body which is a perfect radiator, the energy emitted per unit time (H) is given by

$$H = A\sigma T^4 \qquad \text{(A2)}$$

where A is the area and T is the absolute temperature of the body. This relation obtained experimentally by Stefan and later proved theoretically by Boltzmann is known as **Stefan-Boltzmann law** and the constant σ is called Stefan-Boltzmann constant. Its value in SI units is 5.67×10^{-8} W m^{-2} K^{-4}. Most bodies emit only a fraction of the rate given by Eq. (A2). A substance like lamp black comes close to the limit. One, therefore, defines a dimensionless fraction e called *emissivity* and writes,

$$H = Ae\sigma T^4 \qquad \text{(A3)}$$

Here $e = 1$ for a perfect radiator. For a tungsten lamp, for example, e is about 0.4. Thus, a tungsten lamp at a temperature of 3000 K and a surface area of 0.3 cm^2 radiates at the rate $H = 0.3 \times 10^{-4} \times 0.4 \times 5.67 \times 10^{-8} \times (3000)^4 = 60$ W.

A body at temperature T, with surroundings at temperatures T_s, emits as well as receives energy. For a perfect radiator, the net rate of loss of radiant energy is

$$H = \sigma A\,(T^4 - T_s^4)$$

For a body with emissivity e, the relation modifies to

$$H = e\sigma A\,(T^4 - T_s^4) \qquad \text{(A4)}$$

As an example, let us estimate the heat radiated by our bodies. Suppose the surface area of a person's body is about 1.9 m^2 and the room temperature is 22°C. The internal body temperature, as we know, is about 37°C. The skin temperature may be 28°C (say). The emissivity of the skin is about 0.97 for the relevant region of electromagnetic radiation. The rate of heat loss is:

$$H = 5.67 \times 10^{-8} \times 1.9 \times 0.97 \times \{(301)^4 - (295)^4\}$$

$$= 66.4 \text{ W}$$

which is more than half the rate of energy production by the body at rest (120 W). To prevent this heat loss effectively (better than ordinary clothing), modern arctic clothing has an additional thin shiny metallic layer next to the skin, which reflects the body's radiation.

11.9.5 Greenhouse Effect

The earth's surface is a source of thermal radiation as it absorbs energy received from sun. The wavelength of this radiation lies in the long wavelength (infrared) region. But a large portion of this radiation is absorbed by greenhouse gases, namely, carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); chlorofluorocarbon (CF_xCl_x); and tropospheric ozone (O_3). This heats up the atmosphere which, in turn, gives more energy to earth resulting in warmer surface. This increases the intensity of radiation from the surface. The cycle of processes described above is repeated until no radiation is available for absorption. The net result is heating up of earth's surface and atmosphere. This is known as **Greenhouse effect**. Without the Greenhouse effect, the temperature of the earth would have been –18°C.

Concentration of greenhouse gases has enhanced due to human activities, making the earth warmer. According to an estimate, average temperature of earth has increased by 0.3 to 0.6°C, since the beginning of this century, because of this enhancement. By the middle of the next century, the earth's global temperature may be 1 to 3°C higher than today. This global warming may cause problem for human life, plants and animals. Because of global warming, ice caps are melting faster, sea level is rising, and weather pattern is changing. Many coastal cities are at the risk of getting submerged. The enhanced Greenhouse effect may also result in expansion of deserts. All over the world, efforts are being made to minimise the effect of global warming.

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