UNIT 1

Electric Drive

1.1 INTRODUCTION

Motor control is required in large number of industrial and domestic applications such as transportation systems, rolling mills, paper machines, textile mills, machine tools, fans, pumps, robots, and washing machines. Systems employed for motion control are called *drives* and may employ any of the prime movers. Drives employing electric motors are known as electric drives.

Nowadays, in electric power stations generating large amounts of electric energy for agriculture, industry, domestic needs, and electrified traction facilities and in driving all kinds of working machines, electric motor is essential, which is the predominant type of drive so the term electric drive being applied to it.

Electric drive becomes more popular because of its simplicity, reliability, cleanliness, easiness, and smooth control. Both AC and DC motors are used as electric drives; however, the AC system is preferred because:

- It is cheaper.
- It can be easily transmitted with low-line losses.
- It can be easy to maintain the voltage at consumer premises within prescribed limits.
- It is possible to increase or decrease the voltage without appreciable loss of power.

In spite of the advantages of AC motor, sometimes DC motor is used because:

- In some processes, such as electrochemical and battery charging, DC is the only type of power that is suitable.
- The speed control of DC motors is easy rather than AC; thus, for variable speed applications such as lift and Ward Leonard system, the DC motors are preferred.
- DC series motor is suited for traction work because of high starting torque.

1.2 BLOCK DIAGRAM OF ELECTRIC DRIVE

Source

1-φ and 3-φ, 50-Hz AC supplies are readily available in most locations. Very low power drives are generally fed from 1-φ source; however, the high power drives are powered from 3-φsource; some of the drives are powered from a battery

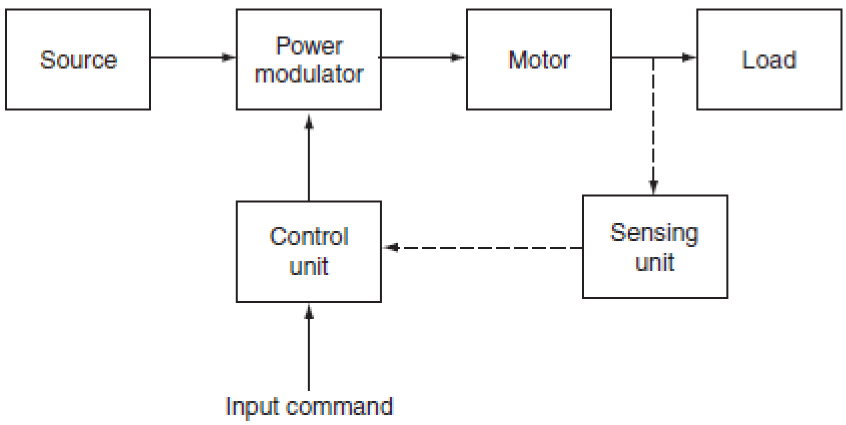

Fig. Block diagram of electric drive

Ex: Fork lifts trucks and milk vans.

Power modulator

Power modulator performs the following functions:

- It modulates flow of power from the source to the motor is impart speed–torque characteristics required by the load.
- It regulates source and motor currents within permissible values, such as starting, braking, and speed reversal conditions.
- Selects the mode of operation of motor, i.e., motoring or braking.
- Converts source energy in the form suitable to the motor.

Electrical motors

Motors commonly used in electric drives are DC motors, induction motors, synchronous motors, blushless DC motors, stepper motors, and switched reluctance motors, etc. In olden days, induction and synchronous motors were employed mainly for constant speed drives but not for variable speed drives, because of poor efficiency and are too expensive. But in nowadays, AC motors employed in variable speed drives due to the development of semiconductors employing SCRs, power transistors, IGBTs, and GTOs.

Load

It is usually a machinery, such as fans, pumps, robots, and washing machines, designed to perform a given task, usually load requirements, can be specified in terms of speed and torque demands.

Control unit

Control unit controls the function of power modulator. The nature of control unit for a particular drive depends on the type of power modulator used. When semiconductor converters are used, the control unit will consists of firing circuits. Microprocessors also used when sophisticated control is required.

Sensing unit

Sensing unit consists of speed sensor or current sensor. The sensing of speed is required for the implementation of closed loop speed control schemes. Speed is usually sensed using tachometers coupled to the motor shaft. Current sensing is required for the implementation of current limit control.

Advantages of electric drives

There are a number of inherent advantages that the electric drive possesses over the other forms of conventional drives are:

- They have comparatively long life than the mechanical drive.
- It is cleaner, as there are no flue gases, etc.
- It is more economical.
- They have flexible control characteristics.
- There is no need to store fuel or transportation.
- It requires less maintenance.
- Do not pollute environment.
- It is the reliable source of drive.
- The electrical energy can be easily transmitted by using transmission lines over long distances.
- Available in wide range of torque, speed, and power.
- High efficiency.
- Electric braking system is much superior and economical.
- Smooth speed control is easy.
- They can be started instantly and can immediately be fully loaded.
- They can operate in all the quadrants of speed torque plane.
- Being compactness, they require less space.
- They can be controlled remotely.

Disadvantages of electric drives

The two inherit disadvantages of the electric drive system are:

- The non-availability of drive on the failure of electrical power supply.
- It cannot be employed in distant places where electric power supply is not available.

TYPES OF ELECTRIC DRIVES

Depending on the type of equipment used to ran the electric motors in industrial purpose, they may be classified into three types. They are:

1. Group drives.
2. Individual drives.
3. Multi-motor drives.

Group drives

Electric drive that is used to drive one or more than two machines from line shaft through belts and pulleys is known as *group drive*. It is also sometimes called the *line shaft drive*.This drive is economical in the consideration of the cost of motor and control gear. A single motor of large capacity cost is less than the total cost of a number of small motors of the same total capacity. In switch over from non-electric drive to electric drive, the simplest way is to replace the engine by means of motor and retaining the rest of power transmission system.

Advantages

- The cost of installation is less. For example, if the power requirement of each machine is 10 HP and there are five machines in the group, then the cost of five motors will be more than one 50-HP motor.
- If it is operated at rated load, the efficiency and power factor of large group drive motor will be high.
- The maintenance cost of single large capacity motor is less than number of small capacity motors.
- It is used for the processes where the stoppage of one operation necessitates the stoppages of sequence of operations as incase of textile mills.
- It has overload capacity.

Disadvantage

Even though group drive has above advantages, it suffers from the following disadvantages.

- If there is any fault in the main motor, all the machines connected to the motor will fail to operate; thereby, paralyzing a part of industry until the fault is removed.
- It is not possible to install any machine at a distant place.
- The possibility of the installation of additional machines in an existing industry is limited.
- The level of noise produced at the work site is quite large.

- The speed control of different machines using belts and pulleys is difficult.
- The flexibility of layout is lost due to line shaft, belts, and pulleys.

Individual drive

In individual drive, a single electric motor is used to drive one individual machine. Such a drive is very common in most of the industries.

Advantages

- It is more clean and safety.
- Machines can be located at convenient places.
- If there is a fault in one motor, the output and operation of the other motors will not be effected.
- The continuity in the production of the industry is ensured to a higher degree.
- Individual drive is preferred for new factories, as it causes some saving in the cost.

Disadvantage

- Initial cost will be high.
- Power loss is high.

Multi-motor drive

In multi-motor drives, several separate motors are provided for operating different parts of the same machine.

Ex: In traveling cranes, three motors are used for hoisting, long travel, and cross-travel motions. Multi-motor drive is used in complicated metal cutting machine tools, rolling mills, paper making machines, etc.

CHOICE OF MOTORS

The selection of the driving motor for a given service depends upon the conditions under which it has to operate. Due to the universal adoption of electric drive, it has become necessary for the manufacturer to manufacture motors of various designs according to the suitability and the use in various designs according to the suitability and the use in various classes of industry. This has resulted into numerous types of motors. For this reason, the selection of motor itself has become an important and tedious process. The conditions under which an electric motor has to operate and the type of load it has to handle, determine its selection.

While selecting a motor, the following factors must be taken into consideration:

1. Cost:

1. initial cost and
2. running cost.

Electric characteristics:

1. starting characteristics,
2. running characteristics,
3. speed control characteristics, and
4. braking characteristics.

Mechanical characteristics:

1. type enclosure and bearings,
2. arrangement for the transmission of power,
3. noise, and
4. cooling.

Size and vetting of motors:

1. requirements for continuous, Intermittent, or variable load cycle and
2. overload capacity.

Type of drive:

1. the drive is for one or more machines and
2. the type of transmission through gears, belts, etc.

Nature of supply.

From the above, it is seen that a large number of factors are to be considered in making the choice of an electric motor for a given drive. The motor selected must fulfill all the necessary load requirements and at the same time, it should not be very costly if it has to be a commercial success. The factors motioned above will be individually discussed in the following sections to bring home to the reader the importance of each. While making the final choice of the motor, a satisfactory compromise may have to be made in some cases on account of the conflicting requirements.

CHARACTERISTICS OF DC MOTOR

The performance and, therefore, suitability of a DC motor are determined from its characteristics. The important characteristics of DC motor are

Torque vs. armature current characteristics (*T vs.* I_a):

This characteristic curve gives relation between torque developed in the armature (T) and armature current (I_a). This is also known as *electrical characteristic.*

1. *Speed vs. armature current characteristics (N vs.* I_a):

   This characteristic curve gives relation between speed (N) and armature current (I_a). This is also known as *speed characteristics.*

2. *Output (HP) vs. armature current characteristics (HP vs.* I_a):

   The horse power of the motor is dependent on the shaft torque, so its characteristics follows *shaft torque characteristic.*

3. *Speed vs. characteristics (N vs. T):*

   This characteristic gives relation between speed (N) and torque (T) developed in the armature. This curve may be derived from the two characteristics mentioned in characteristics (i) and (ii) above.

   Characteristics (i), (ii), and (iii) are called *starting characteristics,* and (iv) is known as*running characteristics.*

While discussing motor characteristics, the following relations should always be kept in mind.

$$T \propto \phi\, I_a \quad \text{and} \quad N \propto \frac{E_b}{\phi},$$

where T_a is the torque developed in the armature in N-m, I_a is the armature current in ampere, E_b is the back emf in volts, and φ is the flux in weber.

Characteristics of shunt motor

The field winding connected across the armature terminals called as *shunt motor* as shown in Fig.. Rated voltage is applied across the field and armature terminals.

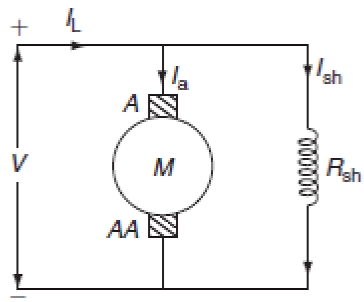

Fig. DC shunt motor

STARTINGCHARACTERISTICS

The study of starting characteristics of a motor is essential to know the starting torque necessary to accelerate the motor from standstill position is also to require to overcome the static friction and the standstill load or, to provide load torque.

TORQUE VS ARMATURE CHARECTERISTICS

In the expression for the torque of a DC motor, torque is directly proportional to the product of flux per pole (φ) and armature current (I_a):

$$\therefore T \propto \phi I_a$$

Since, in case of a DC shunt motor, the flux per pole (φ) is considered to be constant.

$\therefore T \propto I_a$.

So, the torque is proportional to armature current and is practically a straight line passing through the origin as shown if Fig. 1.3.

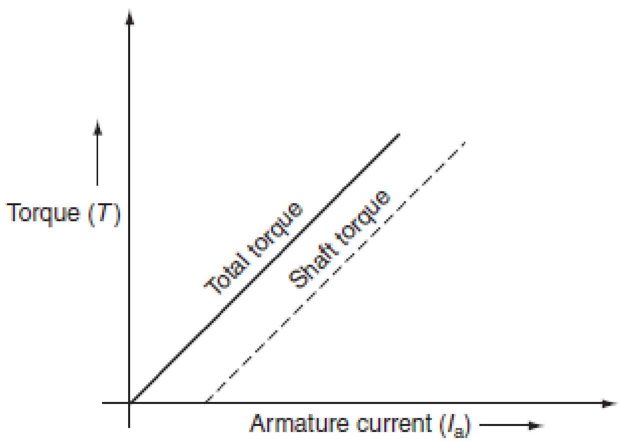

Fig. 1.3 Torque vs. armature current characteristics

To generate high starting torque, this type of motor requires a large value of armature current at starting. This may damage the motor, hence DC shunt motors can develop moderate starting torque and hence suitable for such applications where starting torque requirement is moderate.

Speed vs. armature current (N Vs I_a)

In shunt motor, the applied voltage ‘ *V*' is kept constant, the field current will remain constant, and hence the flux will have maximum value on no load due to the armature reaction; if load on the motor increases, the flux will be slightly decrease. By neglecting the armature reaction, the flux is almost constant.

From the speed equation of DC shunt motor:

$$N \propto \frac{E_b}{\phi},$$

where $E_b = V - I_a R_a$

$$\therefore N \propto \frac{V - I_a R_a}{\phi}.$$

Since, for DC shunt motor, the flux per pole is considered to be constant.

$$\therefore N \propto V - I_a R_a.$$

So, as the load on the motor increases, the armature current increases and hence $I_a R_a$ drop also increases. For constant supply, the voltage (V-$I_a R_a$) decreases and hence the speed reduces.

Hence, as armature current increases, the speed of the DC motor decreases. The variation of speed with armature current is shown in Fig. 1.4.

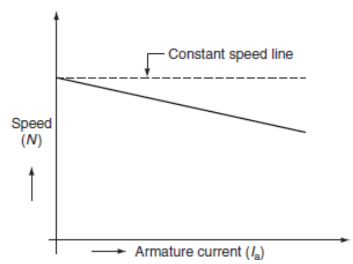

Fig. 1.4 Speed vs. armature current characteristics

Output vs. armature current

The output of the motor is dependent on the shaft torque. If the armature current increases, the output of the motor gradually increases. The variation of output with the armature current is shown in Fig. 1.5.

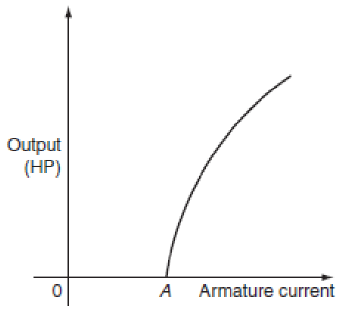

Fig. 1.5 Armature current and HP characteristics

Assignment questions:

Short question:

Long questions:

UNIT 2

Electric Heating

INTRODUCTION

Heat plays a major role in everyday life. All heating requirements in domestic purposes such as cooking, room heater, immersion water heaters, and electric toasters and also in industrial purposes such as welding, melting of metals, tempering, hardening, and drying can be met easily by electric heating, over the other forms of conventional heating. Heat and electricity are interchangeable. Heat also can be produced by passing the current through material to be heated. This is called electric heating; there are various methods of heating a material but electric heating is considered far superior compared to the heat produced by coal, oil, and natural gas.

ADVANTAGES OF ELECTRIC HEATING

The various advantages of electric heating over other the types of heating are:

Economical
Electric heating equipment is cheaper; they do not require much skilled persons; therefore, maintenance cost is less.

Cleanliness
Since dust and ash are completely eliminated in the electric heating, it keeps surroundings cleanly.

Pollution free
As there are no flue gases in the electric heating, atmosphere around is pollution free; no need of providing space for their exit.

Ease of control
In this heating, temperature can be controlled and regulated accurately either manually or automatically.

UNIFORM HEATING

With electric heating, the substance can be heated uniformly, throughout whether it may be conducting or non-conducting material.

High efficiency

In non-electric heating, only 40–60% of heat is utilized but in electric heating 75–

100% of heat can be successfully utilized. So, overall efficiency of electric heating is very high.

Automatic protection

Protection against over current and over heating can be provided by using fast control devices.

Heating of non-conducting materials

The heat developed in the non-conducting materials such as wood and porcelain is possible only through the electric heating.

Better working conditions

No irritating noise is produced with electric heating and also radiating losses are low.

Less floor area

Due to the compactness of electric furnace, floor area required is less.

High temperature

High temperature can be obtained by the electric heating except the ability of the material to withstand the heat.

Safety
The electric heating is quite safe.

MODES OF TRANSFER OF HEAT

The transmission of the heat energy from one body to another because of the temperature gradient takes place by any of the following methods:

conduction,
convection, or
radiation.
Conduction

In this mode, the heat transfers from one part of substance to another part without the movement in the molecules of substance. The rate of the conduction of heat along the substance depends upon the temperature gradient.

The amount of heat passed through a cubic body with two parallel faces with thickness 't' meters, having the cross-sectional area of 'A' square meters and the temperature of its two faces T_1°C and T_2°C, during 'T' hours is given by:

$$Q = \frac{k\,A}{t}(T_1 - T_2)\ T\ \text{MJ},$$

where k is the coefficient of the thermal conductivity for the material and it is measured in MJ/m^3/°C/hr.

Ex: Refractory heating, the heating of insulating materials, etc.

Convection

In this mode, the heat transfer takes place from one part to another part of substance or fluid due to the actual motion of the molecules. The rate of conduction of heat depends mainly on the difference in the fluid density at different temperatures.

Ex: Immersion water heater.

The mount of heat absorbed by the water from heater through convection depends mainly upon the temperature of heating element and also depends partly on the position of the heater.

Heat dissipation is given by the following expression.

$H = \mathrm{a}\,(T_1 - T_2)^{\mathrm{b}}$ W/m^2,

where 'a' and 'b' are the constants whose values are depend upon the heating surface and $T_1$and T_2 are the temperatures of heating element and fluid in °C, respectively.

Radiation

In this mode, the heat transfers from source to the substance to be heated without heating the medium in between. It is dependent on surface.

UNIT 3

Fundamentals of Illumination

INTRODUCTION

Study of illumination engineering is necessary not only to understand the principles of light control as applied to interior lighting design such as domestic and factory lighting but also to understand outdoor applications such as highway lighting and flood lighting. Nowaday, the electrically produced light is preferred to the other source of illumination because of an account of its cleanliness, ease of control, steady light output, low cost, and reliability. The best illumination is that it produces no strain on the eyes. Apart from its esthetic and decorative aspects, good lighting has a strictly utilitarian value in reducing the fatigue of the workers, protecting their health, increasing production, etc. The science of illumination engineering is therefore becoming of major importance.

Nature of light

Light is a form of electromagnetic energy radiated from a body and human eye is capable of receiving it. Light is a prime factor in the human life as all activities of human being ultimately depend upon the light.

Various forms of incandescent bodies are the sources of light and the light emitted by such bodies depends upon their temperature. A hot body about 500–800°C becomes a red hot and about 2,500–3,000°C the body becomes white hot. While the body is red- hot, the wavelength of the radiated energy will be sufficiently large and the energy available in the form of heat. Further, the temperature increases, the body changes from red-hot to white-hot state, the wavelength of the radiated energy becomes smaller and enters into the range of the wavelength of light. The wavelength of the light waves varying from 0.0004 to 0.00075 mm, i.e. 4,000-7,500 Å (1 Angstrom unit = 10^{-10} mm).

The eye discriminates between different wavelengths in this range by the sensation of color. The whole of the energy radiated out is not useful for illumination purpose. Radiations of very short wavelength varying from 0.0000156×10^{-6} m to 0.001×10^{-6} m are not in the visible range are called as rontgen or x-rays, which are having the property of penetrating through opaque bodies.

TERMS USED IN ILLUMINATION

The following terms are generally used in illumination.

Color: The energy radiation of the heated body is monochromatic, i.e. the radiation of only one wavelength emits specific color. The wavelength of visible light lies between

4,000 and 7,500 Å. The color of the radiation corresponding to the wavelength is shown in Fig. 6.1.

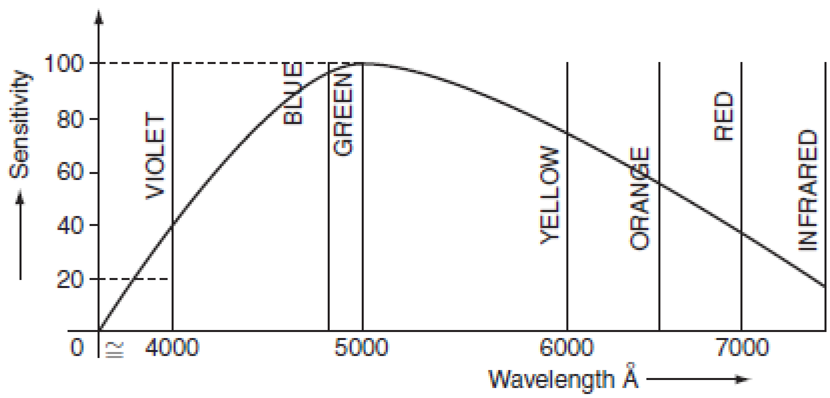

Fig. Wavelength

Relative sensitivity: The reacting power of the human eye to the light waves of different wavelengths varies from person to person, and also varies with age. The average relative sensitivity is shown in Fig. 6.2.

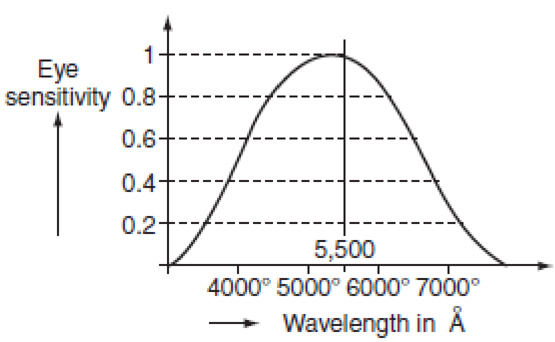

Fig. 6.2 The average relative sensitivity

The eye is most sensitive for a wavelength of 5,500 Å. So that, the relative sensitivity according to this wavelength is taken as unity.

Referred from Fig. 6.1, blue and violet corresponding to the short wavelengths and red to the long wavelengths, orange, yellow, and green being in the middle of the visible region of wavelength. The color corresponding to 5,500 Å is not suitable for most of the applications since yellowish green. The relative sensitivity at any particular wavelength (λ) is known as relative luminous factor (K_{λ}).

Light: It is defined as the radiant energy from a hot body that produces the visual sensation upon the human eye. It is expressed in lumen-hours and it analogous to watt- hours, which denoted by the symbol '*Q*'.

Luminous flux: It is defined as the energy in the form of light waves radiated per second from a luminous body. It is represented by the symbol 'φ' and measured in lumens.

Ex: Suppose the luminous body is an incandescent lamp.

The total electrical power input to the lamp is not converted to luminous flux, some of the power lost through conduction, convection, and radiation, etc. Afraction of the remaining radiant flux is in the form of light waves lies in between the visual range of wavelength, i.e. between 4,000 and 7,000 Å, as shown in Fig. 6.3.

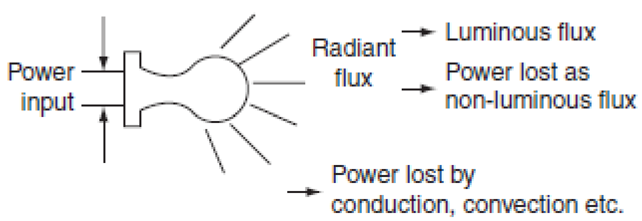

Fig. Flux diagram

Radiant efficiency

When an electric current is passed through a conductor, some heat is produced to I^2R loss, which increases its temperature of the conductor. At low temperature,
conductor radiates energy in the form of heat waves, but at very high temperatures, radiated energy will be in the form of light as well as heat waves.

'Radiant efficiency is defined as the ratio of energy radiated in the form of light, produces sensation of vision to the total energy radiated out by the luminous body'.

$$\text{Radiant efficiency} = \frac{\text{energy radiated in the form of light}}{\text{total energy radiated by the body}}.$$

Plane angle

A plane angle is the angle subtended at a point in a plane by two converging lines (Fig. 6.4). It is denoted by the Greek letter 'θ' (theta) and is usually measured in degrees or radians.

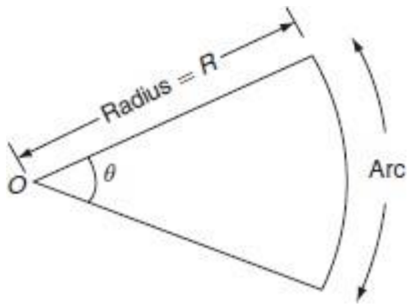

Fig. 6.4 Plane angle

$$\therefore \text{Plane angle } (\theta) = \frac{\text{arc}}{\text{radius}}. \qquad \textbf{(6.1)}$$

One radian is defined as the angle subtended by an arc of a circle whose length by an arc of a circle whose length is equals to the radius of the circle.

Solid angle

Solid angle is the angle subtended at a point in space by an area, i.e., the angle enclosed in the volume formed by numerous lines lying on the surface and meeting at the point (Fig. 6.5). It is usually denoted by symbol 'ω' and is measured in steradian.

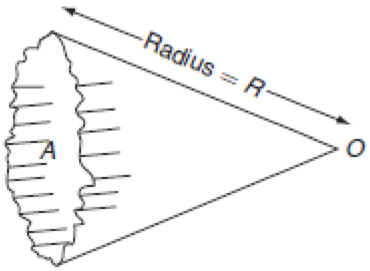

Fig. Solid angle

$$\therefore \text{Solid angle } (\omega) = \frac{\text{area}}{\text{radius}^2}. \qquad \textbf{(6.2)}$$

The largest solid angle subtended at the center of a sphere:

$$\omega = \frac{\text{area of sphere}}{\text{radius}^2} = \frac{4\pi r^2}{R^2} = 4\pi \ \text{steradians.}$$

Relationship between plane angle and solid angle

Let us consider a curved surface of a spherical segment ABC of height '*h*' and radius of the sphere '*r*' as shown in Fig. 6.6. The surface area of the curved surface of the spherical segment $ABC = 2\pi rh$. From the Fig. 6.6:

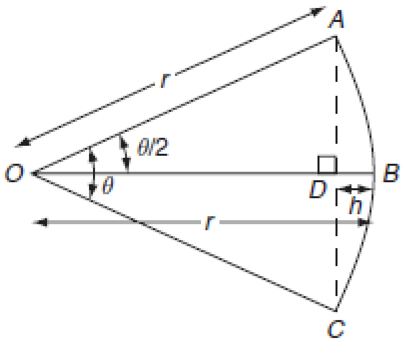

Fig. Sectional view for solid angle

$BD = OB - OD$

$$h = r - r\cos\left(\frac{\theta}{2}\right) \quad [\therefore \text{From } \Delta ODA, OD = r\cos\theta/2]$$

$$= r\left(1 - \cos\frac{\theta}{2}\right).$$

$$\therefore \text{The surface area of the segment} = 2\pi rh$$

$$= 2\pi r^2\left[r - \cos\frac{\theta}{2}\right].$$

$$\text{We know solid angle } (\omega) = \frac{\text{area}}{(\text{radius})^2}$$

$$= \frac{2\pi r^2\left(1 - \cos\frac{\theta}{2}\right)}{r^2}$$

$$= 2\pi\left(1 - \cos\frac{\theta}{2}\right). \qquad \textbf{(6.3)}$$

From the Equation (6.3), the curve shows the variation of solid angle with plane angle is shown in Fig. 6.7.

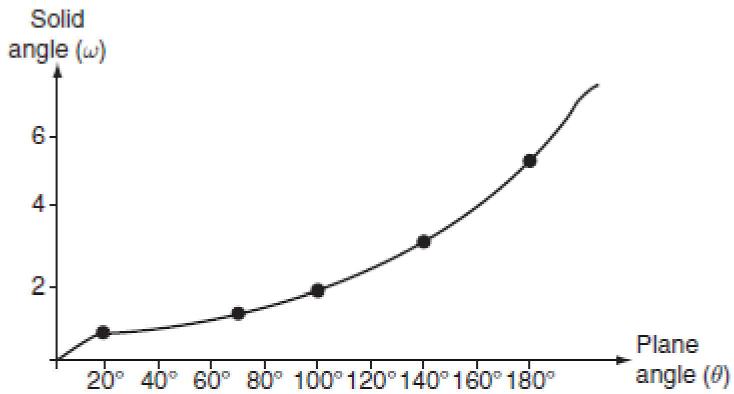

Fig. 6.7 Relation between solid angle and plane angle

Luminous intensity

Luminous intensity in a given direction is defined as the luminous flux emitted by the source per unit solid angle (Fig. 6.8).

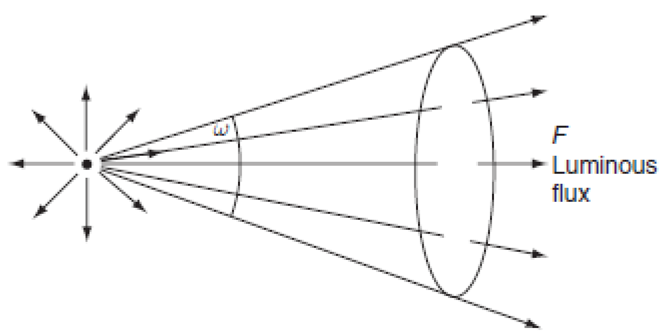

Fig. 6.8 Luminous flux emitting from the source

It is denoted by the symbol '*I*' and is usually measured in 'candela'.

Let '*F*' be the luminous flux crossing a spherical segment of solid angle 'ω'. Then luminous intensity $(I) = \dfrac{\phi}{\omega}$ lumen/steradian or candela.

Lumen: It is the unit of luminous flux.

It is defined as the luminous flux emitted by a source of one candle power per unit solid angle in all directions.

Lumen = candle power of source × solid angle. Lumen = CP × ω
Total flux emitted by a source of one candle power is 4π lumens.

Candle power (CP)

The CP of a source is defined as the total luminous flux lines emitted by that source in a unit solid angle.

$$\text{CP} = \frac{\text{lumen}}{\omega} \text{ lumen/steradian or candela.}$$

Illumination

Illumination is defined as the luminous flux received by the surface per unit area.

It is usually denoted by the symbol 'E' and is measured in lux or lumen/m^2 or meter candle or foot candle.

$$\text{Illumination, } E = \frac{\text{luminous flux}}{\text{area}}$$
$$= \frac{\phi}{A} = \frac{CP \times \omega}{A} \text{ lux.}$$

Lux or meter candle

It is defined as the illumination of the inside of a sphere of radius 1 m and a source of 1 CP is fitted at the center of sphere.

Foot candle

It is the unit of illumination and is defined as the illumination of the inside of a sphere of radius 1 foot, and a source of 1 CP is fitted at the center of it.

We know that 1 lux = 1 foot candle = 1 lumen/$(ft)^2$

$$1 \text{ foot candle } = \frac{\text{lumen}}{\left(\frac{1}{3.28}\right)^2 \text{m}^2} = 10.76 \text{ lux or m-candle}$$

$$\therefore 1 \text{ foot candle} = 10.76 \text{ lux.}$$

Brightness

Brightness of any surface is defined as the luminous intensity pen unit surface area of the projected surface in the given direction. It is usually denoted by symbol '*L*'.

If the luminous intensity of source be '*I*' candela on an *area A,* then the projected area is *A*cos *θ.*

$$\therefore \text{Brightness}, L = \frac{I}{A\cos\theta}$$

The unit of brightness is candela/m^2 or candela/cm^2 or candela/$(ft)^2$.

Relation between I, E, and L

Let us consider a uniform diffuse sphere with radius *r* meters, at the center a source of 1 CP, and luminous intensity *I* candela.

$$\therefore \text{ Brightness } (L) = \frac{I}{\pi r^2}$$

$$\text{and Illumination } (E) = \frac{\phi}{A} = \frac{CP \times \omega}{A}$$

$$= \frac{I}{4\pi r^2} \times 4\pi = \frac{I}{r^2}$$

$$\therefore E = \frac{I}{r^2} = \frac{I}{\pi r^2} \times \pi = \pi L$$

$$\therefore E = \pi L = \frac{I}{r^2}. \qquad \textbf{(6.4)}$$

Mean horizontal candle power (MHCP)

MHCP is defined as the mean of the candle power of source in all directions in horizontal plane.

Mean spherical candle power (MSCP)

MSCP is defined as the mean of the candle power of source in all directions in all planes.

Mean hemispherical candle power (MHSCP)

MHSCP is defined as the mean of the candle power of source in all directions above or below the horizontal plane.

Reduction factor

Reduction factor of the source of light is defined as the ratio of its mean spherical candle power to its mean horizontal candle power.

$$\text{i.e., reduction factor} = \frac{MSCP}{MHCP}.$$

Lamp efficiency

It is defined as the ratio of the total luminous flux emitting from the source to its electrical power input in watts.

$$\therefore \text{Lamp efficiency} = \frac{\text{luminous flux}}{\text{power input}}.$$

It is expressed in lumen/W.

Specific consumption

It is defined as the ratio of electric power input to its average candle power.

Space to height ratio

It is defined as ratio of horizontal distance between adjacent lamps to the height of their mountings.

$$\text{Space to height ratio} = \frac{\text{horizontal distance between two adjacent lamps}}{\text{mounting height of lamps above the working plane}}.$$

Coefficient of utilization or utilization factor

It is defined as the ratio of total number of lumens reaching the working plane to the total number of lumens emitting from source.

$$\text{Utilization factor} = \frac{\text{total lumens reaching the working plane}}{\text{total lumens emitting from source}}.$$

Maintenance factor

It is defined as the ratio of illumination under normal working conditions to the illumination when everything is clean.

$$\text{Maintanance factor} = \frac{\text{illumination under normal working condition}}{\text{illumination under every thing is clean}}.$$

Its value is always less than 1, and it will be around 0.8. This is due to the accumulation of dust, dirt, and smoke on the lamps that emit less light than that they emit when they are so clean. Frequent cleaning of lamp will improve the maintenance factor.

Depreciation factor

It is defined as the ratio of initial illumination to the ultimate maintained illumination on the working plane.

$$\therefore \text{Depreciation factor} = \frac{1}{\text{maintenance factor}}.$$

Its values is always more than 1.

Waste light factor

When a surface is illuminated by several numbers of the sources of light, there is certain amount of wastage due to overlapping of light waves; the wastage of light is taken into account depending upon the type of area to be illuminated. Its value for rectangular area is 1.2 and for irregular area is 1.5 and objects such as statues, monuments, etc.

Absorption factor

Normally, when the atmosphere is full of smoke and fumes, there is a possibility of absorption of light. Hence, the total lumens available after absorption to the total lumens emitted by the lamp are known as absorption factor.

$$\text{Absorption factor} = \frac{\text{the total lumens available after absorption}}{\text{the total lumens given out by the lamp}}.$$

Reflection factor or coefficient of reflection

When light rays impinge on a surface, it is reflected from the surface at an angle of incidence shown in Fig. 6.9. A portion of incident light is absorbed by the surface.

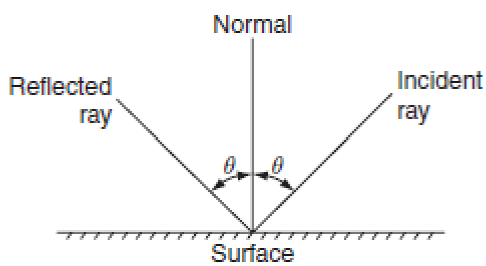

Fig. Reflected ray

The ratio of luminous flux leaving the surface to the luminous flux incident on it is known as reflection factor.

$$\text{Reflection factor} = \frac{\text{reflected light}}{\text{incident light}}.$$

Its value will be always less than 1.

Beam factor

It is defined as the ratio of ‘lumens in the beam of a projector to the lumens given out by lamps’. Its value is usually varies from 0.3 to 0.6. This factor is taken into account for the absorption of light by reflector and front glass of the projector lamp.

Example 6.1: A 200-V lamp takes a current of 1.2 A, it produces a total flux of 2,860 lumens. Calculate:

the MSCPofthe lamp and
the efficiency of the lamp.

Solution:

Given V = 200 V

I = 1.2 A, flux = 2,860 lumens.

(i) $\text{MSCP} = \frac{\text{total flux}}{4\pi} = \frac{2860}{4\pi} = 227.59.$

Example 6.2: A room with an area of 6 × 9 m is illustrated by ten 80-W lamps. The luminous efficiency of the lamp is 80 lumens/W and the coefficient of utilization is 0.65. Find the average illumination.