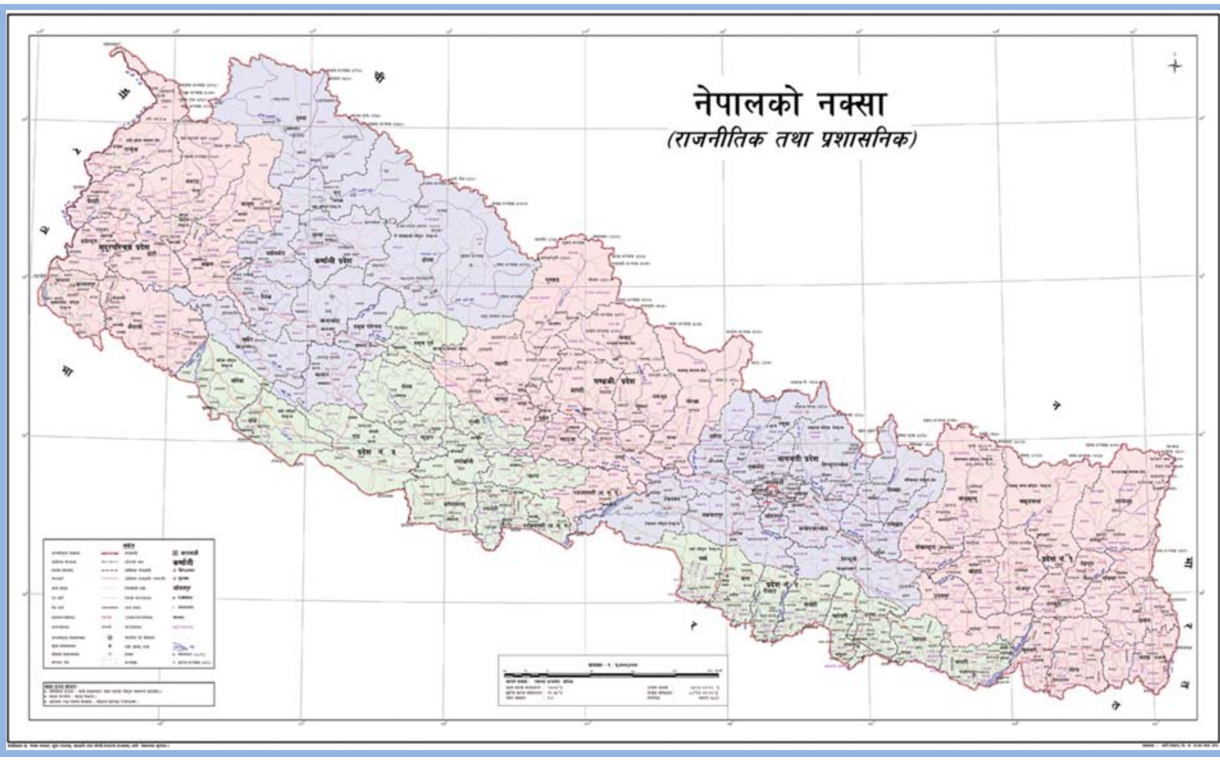
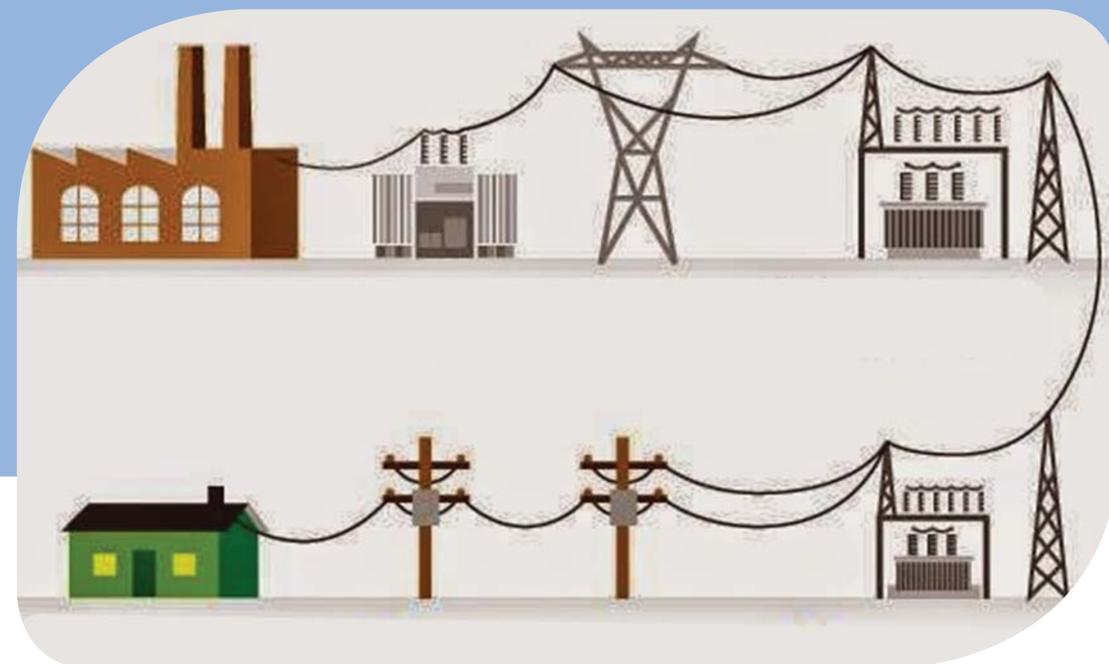
Electrical Engineering

Utilization of Electrical Energy





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Technical and Vocational Stream
Learning Resource Material

Utilization of Electrical Energy
(Grade 10)

Secondary Level
Electrical Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

Publisher : Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

Layout by Khados Sunuwar

Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. it is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This Learning Resource Material for Electrical Engineering has been developed in line with the Secondary Level Electrical Engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Pro.Dr. Indraman Tamrakar, Dipak Shrestha, Akhileshwar Mishra, Nabin Adhikari, Shivaram Shrestha, Harisharan Kafle, Abin Maharjan is highly acknowledged. The book is written by Rupesh Maharjan and the subject matter of the book was edited by Badrinath Timalsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

2076 BS

Ministry of Education, Science and Technology
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Table of Contents

UNIT - 1

Introduction to Electrical Energy

Objectives

This main objectives of this chapter are as follows:

- To understand the concept of generation, transmission and distribution of electrical energy.
- To know the applications of electrical energy and its advantages.

Course Content

Electrical Energy:

The energy due to the flow of charge or electrons through a conductor is known as electrical energy.

In present context, electrical energy is one of the most essential form of energy and can be used in various sectors or fields such as, medical sector, industrial sector, domestic purpose, agricultural purpose, educational purpose, IT purpose and so on.

Use of electrical energy for domestic purpose:

1. For lighting (Bulbs)
2. For operating various electrical equipments or appliances
3. For cooking (Rice cooker, Microoven, Heater)
4. For charging batteries (invertors)
5. For heating purpose (Heater, Iron)
6. For cleaning purpose (Vacuum cleaners)
7. For refrigeration (Fridge)
8. For washing purpose (washing machin, dish washers)
9. For operating various electric motors (fan, water pumps)
10. For operating musical instruments (entertainment)

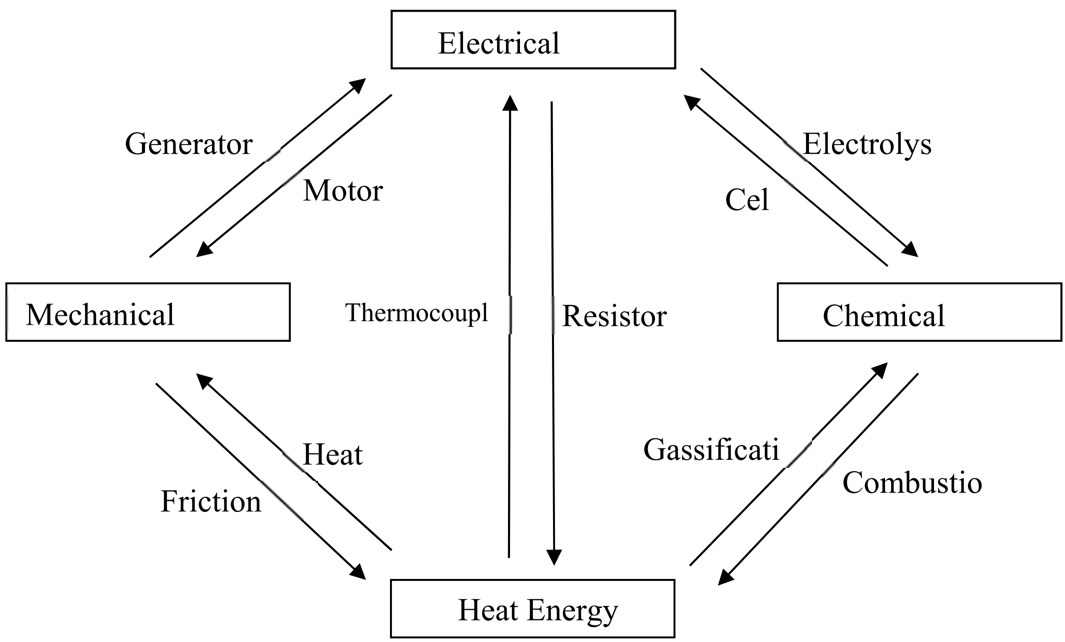
Use of electrical energy for Commercial purpose:

1. For communication
2. For transportation (Cable cars, electric trains)
3. For lighting
4. For operation of elevators or lifts

Advantages of Electrical Energy

1. It can be controlled efficiently.
2. It can be transmitted at the speed of light.
3. It can be easily converted into various other forms at greater efficiency.
4. Conversion into other forms of energy is direct and easier.
5. It is totally pollution free.
6. It can be stored efficiently.

Conversion of Electrical Energy:



Sources of Electrical Energy:

Usually electrical energy is generated by converting other forms of energy using a specific device known as generators. The sources of electricity can be broadly classified into two categories:

1. Thermal sources (Heat needed)
2. Non-thermal Sources (Heat not needed)

1. Thermal Sources:

a) Coal　　b) Nuclear fission

c) Natural gases / oil　　d) Geo thermal energy　　e) Solar energy

2. Non thermal energy:

a) Hydro power　　b) Tidal Energy

c) Steam Energy　　d) Wind Energy

Chemical energy. This is stored, or "potential," energy. Releasing chemical energy from in carbon-based fuels generally requires combustion – for example the burning of coal, oil, natural gas, or a biomass such as wood.

Thermal energy. Typical sources of thermal energy are heat from underground hot springs, combustion of fossil fuels and biomass (per above) or industrial processes.

Kinetic energy. Kinetic energy is movement, which occurs when water moves with tides or flows downstream, or when air moves wind turbines in the wind.

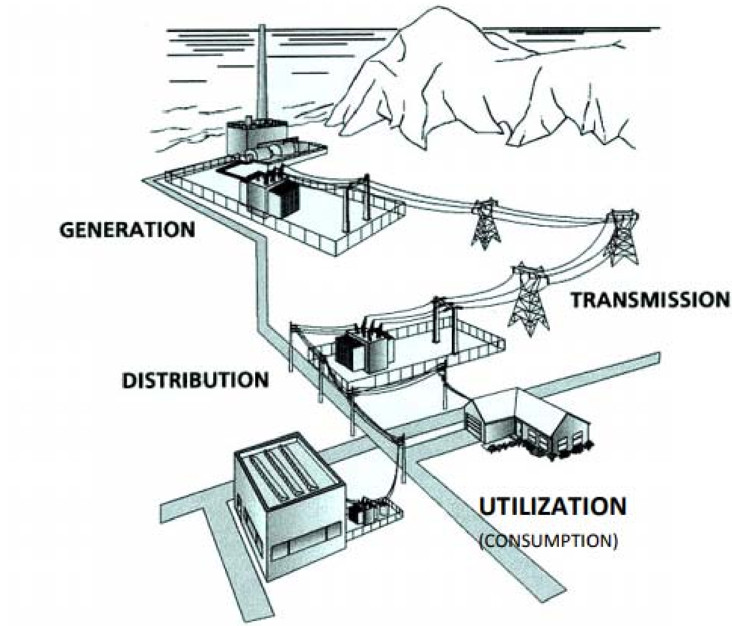
Nuclear energy. This is the energy stored in the bonds inside atoms and molecules. When nuclear energy is released, it can emit radioactivity and heat (thermal energy) as well.

Rotational energy. This is the energy of spinning, typically produced by mechanical devices such as flywheels.

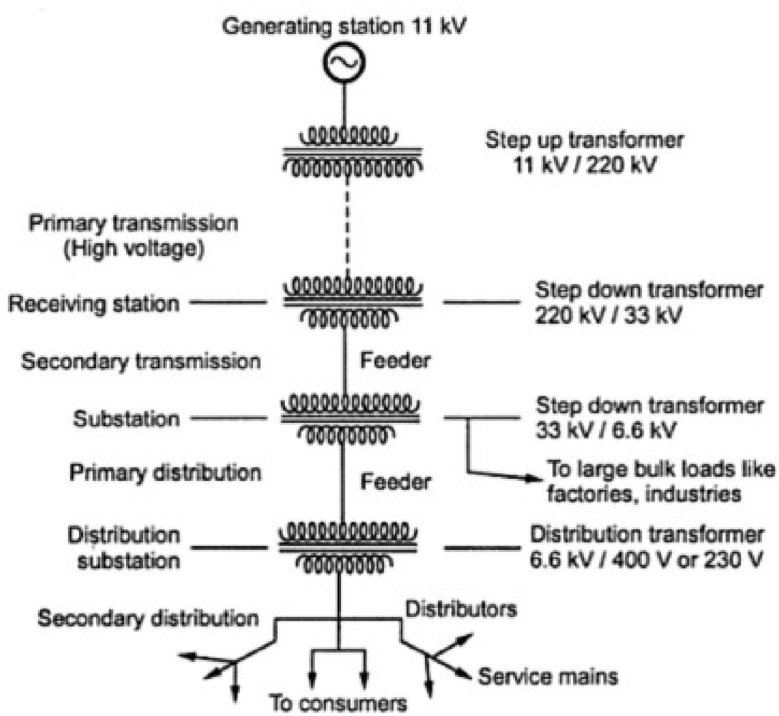
Solar energy. Energy radiates from the sun and the light rays can be captured with photovoltaic and semiconductors. Mirrors can be used to concentrate the power, and the sun's heat is also a thermal source.

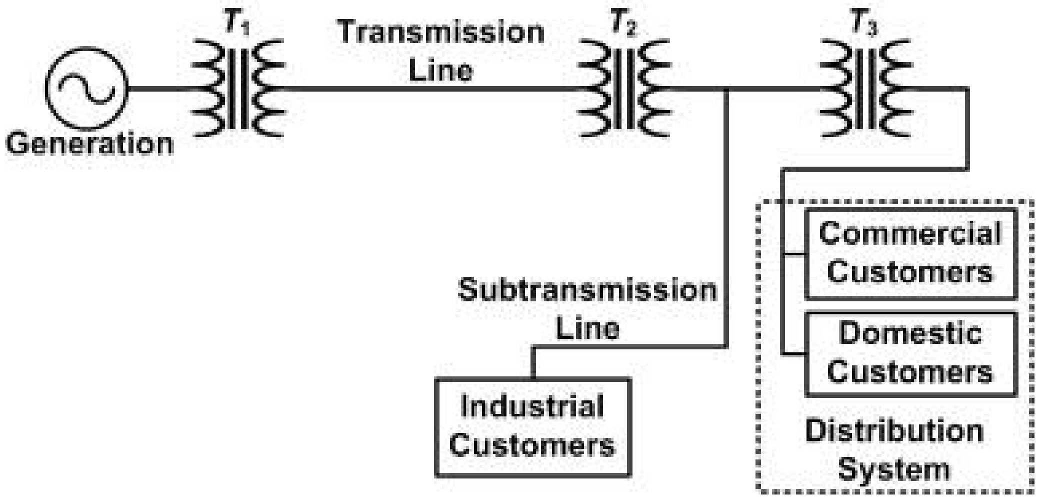
Generation, Transmission and Distribution of Electrical Energy:

The main three phases related with production of electrical energy are generation, transmission and distribution. Generation of electricity is done at hydropower. The generation stations and distribution systems are connected through transmission lines. It also connects one power station to another. A distribution system connects all the loads in a particular areas to the transmission lines.



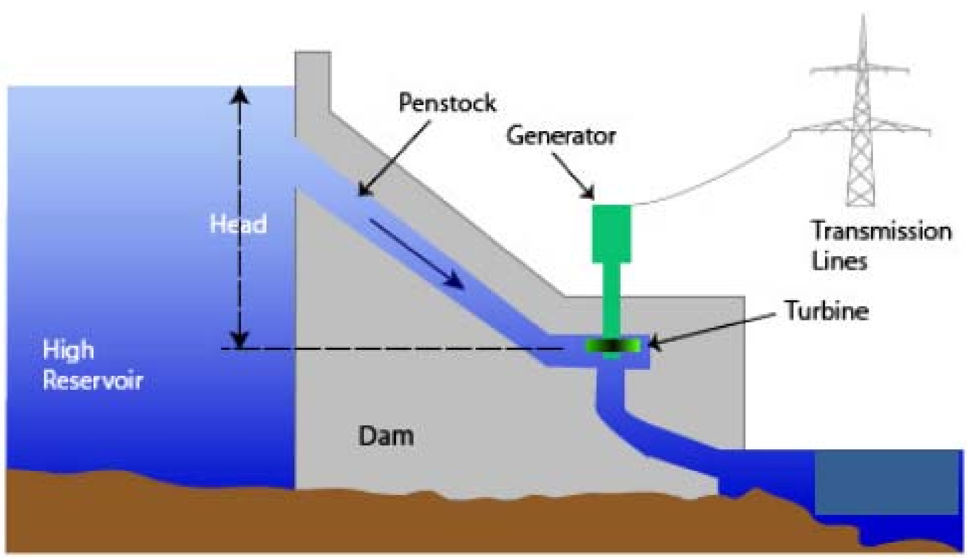
The structure of a power system can be described as:





Generation

Electricity is generated by different methods as stated in Source of electricity. In case of Hydropower:



Potential energy of water in reservoir is passed through Penstock to a water turbine. Potential Energy of water is transferred to mechanical rotation by means of water turbine. A shaft coupled with turbine rotates the Generator and electricity is produced.

Transmission:

Generally power station are very long distance from load centre or consumer so electricity generated is required to transferred from generation station to different load centers via Transmission line. To reduce the transmission line loss voltage of transmission line is kept very high which may be 132kV, 320kV or more. But the power is not generated at such high voltage. Therefore, generated voltage is raised up to transmission voltage level by using step-up transformer at generation substation. Then it is transmitted to different parts of the country via transmission towers and lines. There are also some substations which interconnects different transmission lines .Interconnected network of transmission line is also known as grid.

Distribution:

Near the load centre, at distribution substation the transmitted voltage is reduced to Primary Distribution voltages 11kV, 33kV or 66kV via step down transformer from which electricity for large industrial consumer can be supplied. A number branches of primary distribution supply starts from distribution substation and which is known as feeders. From feeders, voltage is further reduced to 220V-380V via pole mounted distribution transformer to supply small industrial, commercial as well as domestic Consumer. It is known as secondary distribution.

Utilization:

Electricity is supplied to different consumers via connection lines through an Energy meter which is used to determine monthly electricity consumption of that consumer.

Domestic: Electricity is used for mainly lighting, cooking, heating and cooling , cleaning, personal caring, computer and entertainment.

Commercial : Lights, office equipments, computer and entertainment, heating and cooling, cooking, personal caring, lift, elevator etc.

Industrial Load: Motors, lights, HVAC etc.

Note:

Why is the generated electric power transmitted at high power?

It is because the transmission efficiency is directly proportional to square of the transmitted voltage i.e. higher the transmission voltage more the transmission efficiency and vice-versa.

Why is the generated voltage around 11 kV isn't directly distributed to the consumers?

It is because if transmitted at that level, it produces lot of electric hazards and accidents. So for the personal safety, that voltages are stepped down to appropriate level before it is distributed over to the customers.

Why the distribution voltage in European countries is is 110V and that in other parts is 220V?

It is because they are more concerned of safety. So to minimize the risk of electric hazards, the distribution voltage is made lower.

Assesment:

Very Short Answer Questions

1. What is electrical energy?
2. At what value is the electrical energy been distributed in Nepal?
3. Define thermal energy.
4. What do you mean by renewable source of energy?
5. Define transmission of electrical energy.
6. What do you mean by distribution of electrical energy?
7. Name the device that coverts:
    a. Electrical energy into mechanical energy
    b. Chemical energy into electrical energy
    c. Heat energy into electrical energy

Short Answer Questions

1. What are the applications of electrical energy?
2. What are the advantages of electrical energy?

Long Answer Questions

1. Draw the schematic diagram showing the generation, transmission and distribution of electrical energy.
2. Hydro electricity is considered as better source of energy in context of Nepal. Justify the statement.

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http://www.electricaltechnology.org

UNIT – 2
Illumination

Objectives:

This main objectives of this chapter are:

1) To understand the concept of illumination and its parameters.
2) To know the different types of luminaries and its applications.
3) To perform the lighting calculations and its design.
4) To understand different lighting schemes and its parameters.

Learning materials

1) Filament lamp
2) Fluorescent lamp
3) High pressure sodium vapour lamp
4) High pressure mercury vapour lamp
5) Neon lamps
6) Compact filament lamp
7) LEDs
8) Lux meter

Course Content

Waves:

The oscillations or disturbances produced due to application of some external energy is called wave.

Terminologies:

i) Cycle:

When a wave completes one positive and one negative cycle, then the wave is said to have completed one cycle.

ii) Frequency:

The number of complete cycles made by a wave in one second is known as frequency. It is denoted by 'f' and its SI unit is Hertz (Hz).

iii) Wavelength:

The distance travelled by a wave in one complete cycle is known as wavelength. It is denoted by 'λ' and its SI unit is metre, m.

iv) Time period:

The time taken by a wave to complete one cycle is called time period. It is denoted by 'T' and its SI unit is second.

v) Amplitide:

The maximum positive or negative value attained by a wave from its mean position is called amplitude. It is denoted by 'A' and its SI unit is meter, m.

Types of waves:

According the propogation of wave, the waves can be classified into two different types.

1. Transverse wave:

It the particles vibrate perpendicularly with the direction of propagation of wave, then the wave is said to be transverse wave. For eg, light waves, waves in water, waves in string etc.

The maximum positive height attained by a wave is called crest and the maximum negative height attained by a wave is known as trough. And the distance between two successive crests or two successive troughs is known as wavelength.

2. Longitudinal wave:

If the particles of wave vibrate parallel to the direction of propagation, then the waves are said to be longitudinal waves. For eg, sound waves, waves in spring etc. The part in the wave where the vibration of the particles is maximum is known as rarefaction and the part of the wave where the vibration of particles is less is called compression.

If the wavelength of the wave is λ m and the frequency of it is f Hz, then the speed of the wave is given by,

Speed of wave (c) = frequency X wavelength

$= f \times \lambda$

Relation between wavelength and frequency

The wavelength and frequency of the wave are inversely proportional to each other. That means the wave with longer wavelength has less frequency which leads to lesser energy whereas the wave with shorter wavelength has more frequency which leads to more energy possessed for the wave.

Types of waves:

On the basis of medium required for the wave, the waves can be classified into two distinguished types.

1. **Electromagnetic waves:**

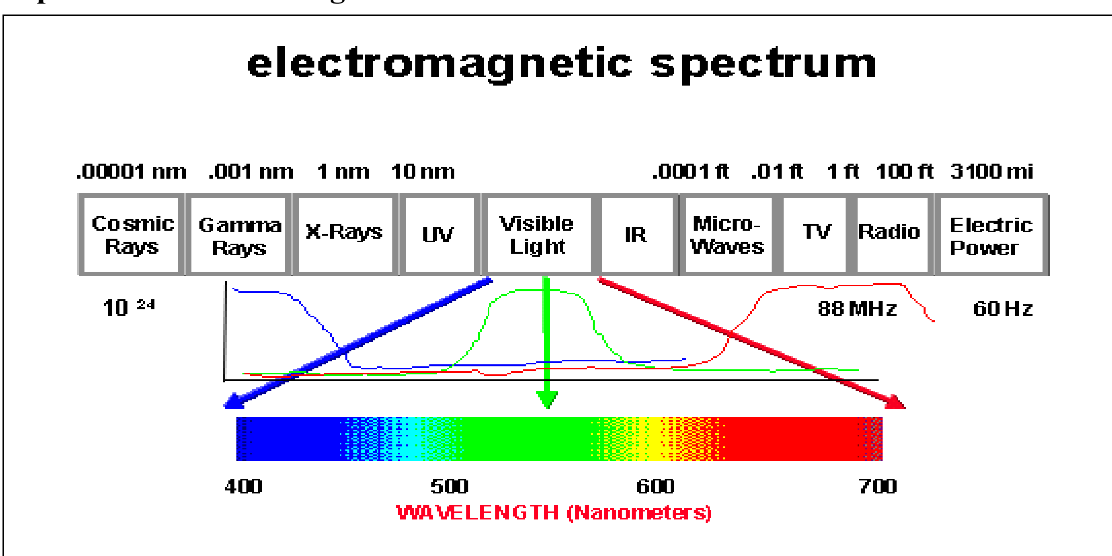
   The waves that don't require a particular medium for propagation is known as electromagnetic waves. For eg, light waves.

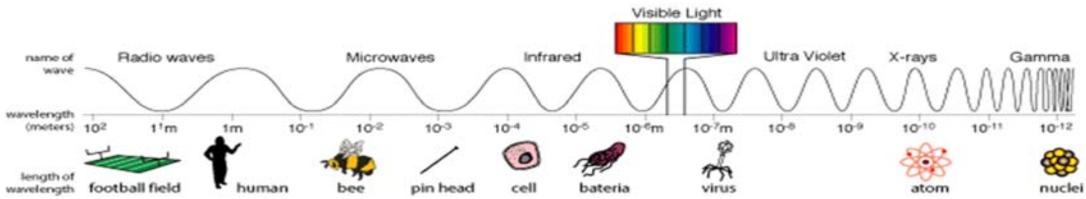
2. **Mechanical waves:**

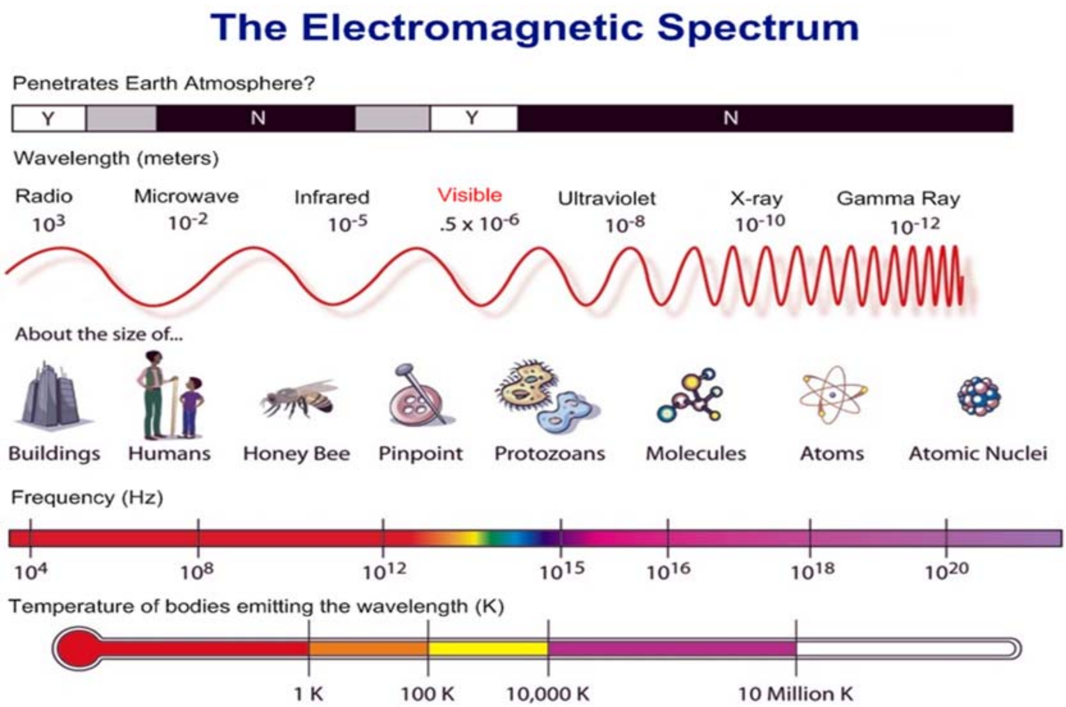
   The waves that require a particular medium for propagation is known as mechanical waves, For eg, sound waves.

   This is the reason that sound is not heard in vacuum or in space.

Spectrum of electromagnetic waves:







Visible Spectrum

Violet/Indigo	Blue	Green	Yellow	Orange	Red
400nm	475nm	530nm	580nm	629nm	700nm

- **Cosmic / Gamma rays**

Shorter wavelength

Much higher frequency and energy

Can be used for treating cancer but excess use may itself lead to cancer.

Produced during atomic explosions, nuclear reactions etc

- **X-ray**

  Used for filming the internal parts of the body

  May lead to cancer on long use

  Used in airport for checking the luggage.
- UV rays

  Contained in the rays coming from sun

  May cause skin cancer and skin burn
- Visible light

  Can be seen by human beings
- Infrared

  Produced from heating sources

  Used in remote controls

  Also used in night vision spectacles and binoculars
- Microwaves

  Particularly used for cooking purposes such as micro oven

  Used for communication purposes such as mobile communication
- Radio waves

  Used for broadcasting purposes and used in radio stations.

Difference between heat and light

Both of them are the form of energy. But heat gives the sensation of warmth to us whereas light gives the sensation of vision to us.

Light is an electromagnetic wave that carry energy from one place to another in the form of photons whereas heat is the energy that moves from one place to another due to temperature difference between two objects.

The difference can also be described in terms of frequency. Energy contained in a wave is $E = hf$ and "f" for heat is less than that for light.

Luminous Flux:

The total quantity of light energy emitted or radiated by a luminous object per second in the form of light waves is known as luminous flux. It is denoted by 'ϕ' or 'F' and it is measured in terms of lumens.

It can also be defined as the rate of luminous energy produced by a source. If "Q" lumens hour is the luminous output of a source of light and energy is radiated for "t" hours, then the flux is given by ,

Flux (F) = $\frac{Q}{t} lumens$

Luminous Intensity:

Luminous intensity in any given direction is the luminous flux emitted by the source per unit solid angle measured in the direction in which the intensity is required.

It is denoted by the symbol 'I' and it is measured in Candela (cd) or lumen per steradian.

Luminous Intensity (I) = $\frac{Flux}{Solidangle} = \frac{'F' or '\phi'}{w} = \frac{lemens(lu)}{steradians}$

Illumination:

The total amount of light emitted from a lighting source or luminous objects per unit surface area is known as illumination. It is denoted by E and its Si unit is lumens /m^2 or Lux.

Illumination (E) = $\frac{Lu\min ous\ \text{Flux}}{Area} = \frac{F}{A}$ Lux or lumens/m^2

Light Energy:

It is defined as the energy obtained in visual radiations in a specific time. It is denoted by "Q".

Phase angle:

It is the angle formed by two converging lines in a same plane. It is measured in radians. The maximum plane angle can be 2π radians.

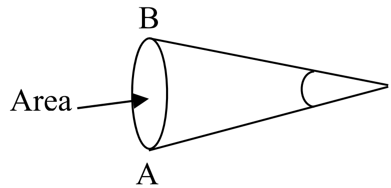
Phase Angle (ϕ) = $\frac{lengthofarc(l)}{radius(r)}$

1 radian:

It is the angle formed at the centre of a circle by an arc whose length is equal to the radius of the circle.

Solid Angle:

The angle formed by the surface passing through a point space and its surrounding area is known as solid angle. It is denoted by 'w' and its SI unit is steradians



Brightness or Luminous:

The brightness of the surface is defined as the luminous intensity per unit projected area of either a surface source of light or reflecting surface. It is denoted by 'L' and its SI unit is stilb or lambert.

1 Lambert = 1 lumen/cm^2

1 stilb = 1 candle/cm^2

Brightness or Luminance (L) = $\frac{I}{A\cos\theta}$ candela/m^2

Candle power:

It is the light radiating capacity of a source in a given direction and it is defined as the number of lumens given out by the source in a unit solid angle in a given direction. It is denoted by symbol C.P.

i.e. C.P. = lumens/ ω

Glare:

Eye is the organ that enables to see the object in the surrounding. For the formation of image in the retina, appropriate amount of light rays must enter through the eye. If a bright object comes into view of an eye, large amount of light produces sharp image on retina. In that case, the iris will automatically contract pupil to limit the light. And when the eye need to view the object at less light compared to bright object already in view, the iris will contract reducing amount of light. So it becomes difficult to see the object. This phenomena is called glare.

Simply, glare can be defined as the discomfort felt by an observer doe to presence of a very bright light source in the visual field. It is generally caused die to excessive and uncontrolled brightness.

For a good lighting system, the glare should be taken in consideration, as it plays an important role in good illumination. To remove the glare, the more bright lights should not be used.

Effect of Glare:

- Annoyance
- Discomfort
- Interference
- Fatigue of the eye

Reduction technique

- Use of reflected light instead of direct light.
- Use of diffusers (Translucent material for softening of light)

Laws of illumination:

There are two laws of illumination, namely

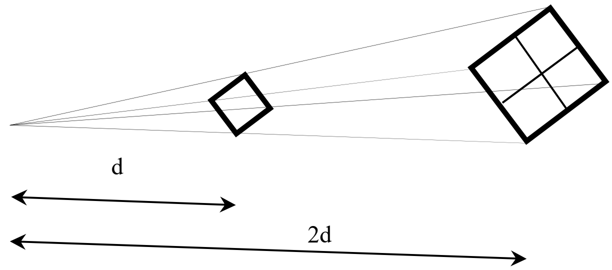
i. First law(Inverse square law)
ii. Second law (Lanbert Cosine law)

First law or inverse square law states that " The illumination produced by a lighting source is inversely proportional to square of distance between the source and the surface given that the distance between the source and the surface should be infinitely high so that the source can be assumed as a point source.

$$E \propto \frac{1}{d^2} \ldots\ldots\ldots\ldots\ldots\ldots (i)$$

where E = illumination required

d= distance between source and object



Let E_1 and E_2 be the illuminations produced on a surface at a distance "d" and "2d" from source respectively. Then it is found that, at a distance of "2d" from source, the surface is 4 times bigger than the surface formed at a distance of "d" from source.

So the illumination produced at a distance of "2d" will be 4 times lesser than the illumination produced at a distance "d".

i.e. $E_2 = \frac{1}{4} E_1$

Applications:

- Radioactive protection
- Patent dose calculations
- Radioactive density

Second law or Lambert's cosine law states that "Illumination varies directly to the cosine of angle between the direction of incident light and the normal to a particular point.

$$E \propto \cos\theta \text{ ……………… } (ii)$$

where θ is the angle between direction of incident light and the normal to a particular point

Combining (i) and (ii)

$$E \propto \frac{\cos\theta}{d^2}$$

$$E = \frac{I}{d^2}\cos\theta \text{ …………… } (iii)$$

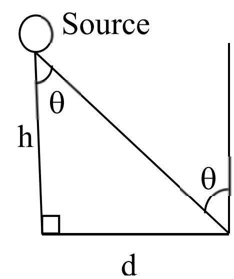
where I = proportionality constant known as luminous intensity expressed in candle power(CP).

From figure.

$\cos\theta = \frac{h}{d}$ where h=height of source from working plane

$d = \frac{h}{\cos\theta}$

Substituting the value of d in (iii)



$$E = \frac{I}{\frac{h^2}{(cos\theta)^2}} \times \cos\theta$$

$$E = \frac{I}{h^2}\cos^3\theta$$

Solved Numericals

1) 1.A 100 CP lamp is hung 2m above the centre of a circular area of 3m diameter. Determine the illumination at the center of the circle.

Sol^n.

Luminous intensity(I)=100CP

Illumination(E)=?

Angle between incident ray and the normal to the point (θ) = 0^o

we have,

Illumination at the centre (E) $= \frac{I}{h^2}\cos^3\theta$

$$= \frac{100}{2^2}(\cos 0^o)^3$$

$$=25 \text{ lumens/m}^2$$

∴ The illumination at the center of the circle is 25 Lux (lumens/m^2)

2. The lamp of 500 watt gives 1250 CP uniformly below the horizontal plane.If the lamp is suspended at the height of 2.7m above the working plane, find the illumination vertically below the lamp. Also find the illumination at a point on the horizontal 3 meters away from vertically below the lamp.

Sol^n.

Luminous intensity(I)=1250CP

Height (h) = 2.7m

(i) At point A

(Vertically below the lamp)

Illumination(E)=?

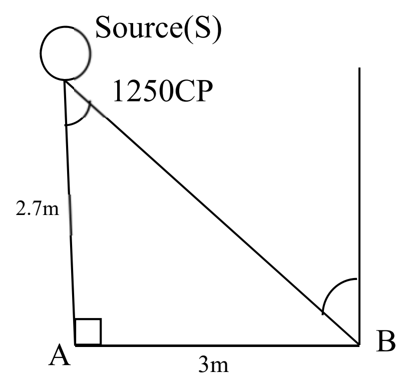
Angle between incident ray and the normal to the point (θ) = 0^o

we have,

$$E = \frac{I}{h^2}\cos^3\theta$$

$$= \frac{1250}{(2.7)^2}(\cos 0^o)^3$$

$$= 171.47 \text{ Lux}$$



(i) At point B (3m away from the vertical axis of lamp)

In $rt.\Delta SAB$

$$SB = \sqrt{SA^2 + AB^2}$$

$$= \sqrt{2.7^2 + 3^2}$$

$$= \sqrt{16.29}$$

$$= 4.04 \text{ m}$$

$$\therefore \cos\theta = \frac{SA}{SB} = \frac{2.7}{4.04} = 0.668$$

And,

$E_B = \frac{I}{h^2}\cos^3\theta$

$= \dfrac{1250}{2.7^2}(0.668)^3$

$= 51.11$ Lux

∴ The illumination at point 3m away from the vertical axis of lamp is 51.11 Lux.

3.The illumination at a point on a working plane directly below the lamp is to be 100 lumens/m^2. The lamp gives 250 CP uniformly below the lamp. Determine the height at which the lamp is suspended. Also find the illumination at a point on the working table 1.2 meters away from the vertical axis of the lamp.

Sol^n.

Luminous intensity(I)=25-0CP

(i) At point A

(Vertically below the lamp)

Illumination(E)=100 lumens/m^2

Angle between incident ray and the normal to the point (θ) = 0^o

we have,

$E = \frac{I}{h^2}\cos^3\theta$

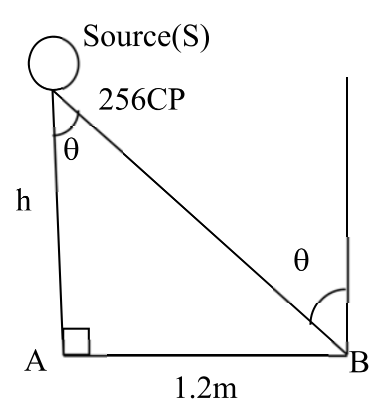
or, $100 = \frac{250}{h^2}(\cos 0^o)^3$

or, $100 = \frac{250}{h^2} \times 1^3$

or, $h^2 = \frac{250}{100}$

or, $h = \sqrt{2.5}$

$\therefore h = 1.6m$



(i) At point B (1.2m away from the vertical axis of lamp)

In *rt.ΔSAB*

$SB = \sqrt{SA^2 + AB^2}$

$= \sqrt{1.6^2 + 1.2^2}$

$= \sqrt{4}$

$= 2$ m

$\therefore \cos\theta = \frac{SA}{SB} = \frac{1.6}{2} = 0.8$

And,

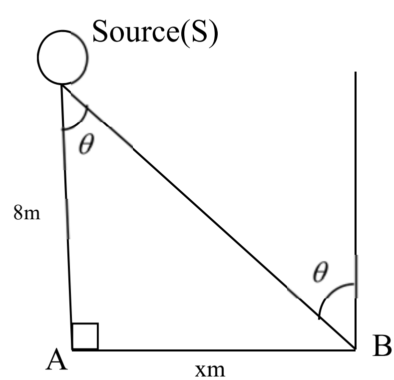
$E_B = \frac{I}{h^2}\cos^3\theta$

$= \frac{250}{1.6^2}(0.8)^3$

$= 51.2$ Lux

∴ The illumination at point 1.2m away from the vertical axis of lamp is 51.2 Lux.

4. A light source with intensity uniform in all direction is mounted at a height of 8 m above the horizontal surface. Two points A and B both lie on the surface with point A directly below the source. How far is B from A so that the illumination at B is only $\frac{1}{20}$ as great as A?



Sol^n,

Height (h) = 8m

Let luminous intensity given out by the lamp to be I CP

Now,

In *rt.ΔSAB*

$SB = \sqrt{SA^2 + AB^2}$

$= \sqrt{8^2 + x^2}$

$= \sqrt{64 + x^2}$

$\therefore \cos\theta = \frac{SA}{SB} = \frac{8}{\sqrt{64+x^2}}$

According to question,

$E_B = \frac{1}{20} E_A$

or, $\frac{I}{h^2}(\cos\theta)^3 = \frac{1}{20} \times \frac{I}{h^2}(\cos 0^o)^3$

or, $\left(\frac{8}{\sqrt{64 + x^2}}\right)^3 = \frac{1}{20}$

or, $\left(\frac{8}{\sqrt{64 + x^2}}\right) = \sqrt[3]{\frac{1}{20}}$

or, $\left(\frac{8}{\sqrt{64 + x^2}}\right) = 0.3685$

or, $21.71 = \sqrt{64 + x^2}$

or, $471.3241 = 64 + x^2$

or, $407.3241 = x^2$

or, $20.18 = x$

$\therefore$ B is 20.18m far from point A.

Tutorials:

1. A source of 5000 lumens is suspended 6.1m above the ground. Find the illumination:

   a. At a point vertically below the lamp.

   b. At a point 12.2 m away from vertically below the lamp.

(Hint: Luminous Intensity (I) = $\frac{Flux}{4\pi}$)

[Ans: 10.69 Lux, 0.96 Lux]

2. A lamp giving out 95.5 CP luminous intensity in all directions is suspended 8m above the working plane. Calculate the illumination at a point on working plane 6m away frpm vertically below the lamp.

   [Ans: 0.764 Lux]

3. A lamp of 750 watt with luminous intensity of 1500 CP is suspended 3m above the horizontal plane. Calculate:

   a) Illumination directly below the lamp.

   b) Illumination at a point 5m away from vertically below the lamp.

   [Ans: 166.67 lux, 22.7 Lux]

4. The illumination at a point on working plane directly below the lamp is to be 50 lumens/m^2(Lux). The lamp gives 162 CP uniformly below the horizontal plane. Find the height at which the lamp is suspended. Also find the illumination at a point on working plane 5.4m away from vertically below the lamp.

   [Ans: 1.8m, 1.557 Lux]

5. A small light with intensity uniform in all direction is mounted at a height of 10m above horizontal surface. Two points A and B both lie in the surface with point A vertically below the source. How far is B from A if illumination at B is $\frac{1}{10}$ as that at point A?

6. Two lamp posts are 16m apart and are fitted with a 100 CP lamp each at a height of 6m above the working plane. Calculate the illumination on the working plane (a) under each lamp (b) midway between the lamps.

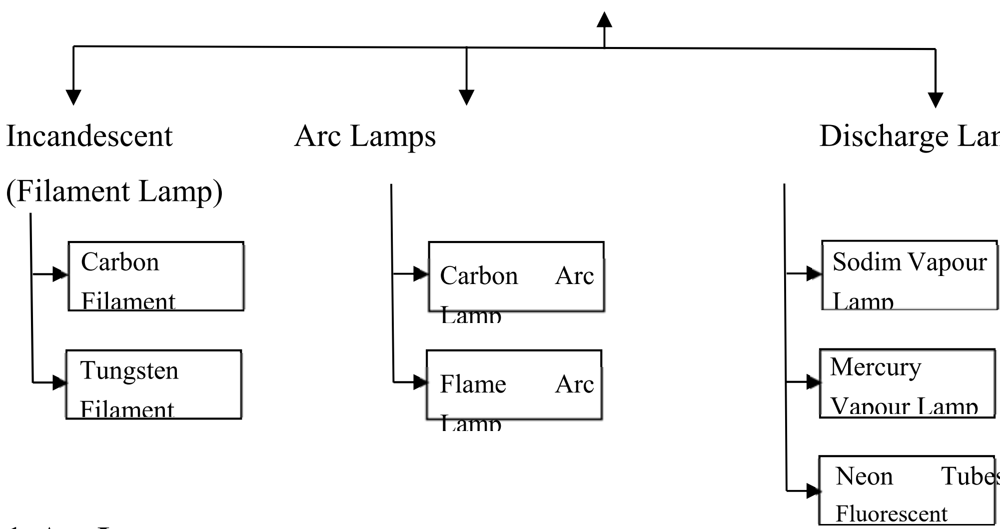
Source of light:

The light energy can be generated in following ways.

- By passing electricity over a filament by raising its temperature to emit light. (Incandescent lamp)
- By maintaining electric discharge through gas or vapour as in fluorescent lamps, vapour lamps etc.
- By establishing arc between two electrodes producing light. Eg, arc lamps

The various electric lamps are classified as follows:

Electric Lamps

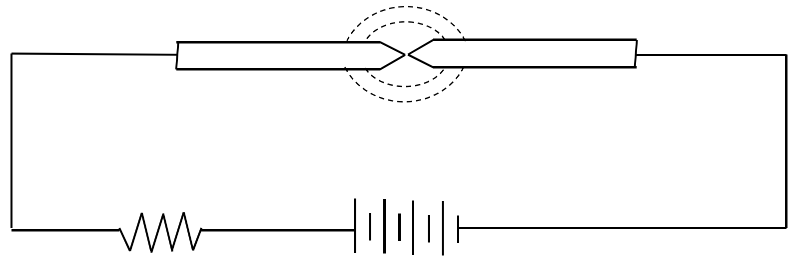


1. Arc Lamps

It consists of two electrodes through which an electric current is passed. When the electrodes come in contact with each other, it produces arc due to heat which in turn produces light. The light is produced due to vaporization of the electrode(carbon). Generally there are two types of arc lamps namely,

i) Carbon arc lamp
ii) Flame arc lamp

i) Carbon Arc Lamp



The positive electrode (anode) will vaporize twice times than that of cathode.

It is used in cinema projectors, search light and flash cameras. When electric current is passed through carbon electrodes, an arc will be produced between them and a white light is produced.

The rate of burning of positive rod is twice as that of negative rod. A resistance 'R' is used for maintaining the arc.

The whole assembly is kept in a sealed glass tube with addition of some inert gases. The gases are used for colouration of the light.

For eg, Neon give reddish colour

Argon gives bluish white colour

Helium gives pinkish colour

The efficiency of this lamp is 12 lumens/watt.

Note: When AC is passed in this lamp then flickering may take place but in case of DC, there is no flickering.

INCANDESCENT LAMP

When any conductor is heated to a very high temperature, it produces electromagnetic radiations containing both heat and light energy. This process is called incandescence and the bulb that works in this principle is known as incandescent lamp. It is also known as filament lamp.

Advantages:

- Its initial cost is low. (Cheaper)
- The brightness can be controlled.
- The quality of colour of light is high.

Carbon Filament Lamp

It consists of a fine carbon filament placed inside an evacuated bulb in order to increase the life of filament.

The carbon filament lamp has a melting point of around 3600°C but it starts vapourizing at arounf 1700°C at excessive rate. So the efficiency of this bulb is less.

And this efficiency can be increased by filling the bulb with some inert gases.

Disadvantages:

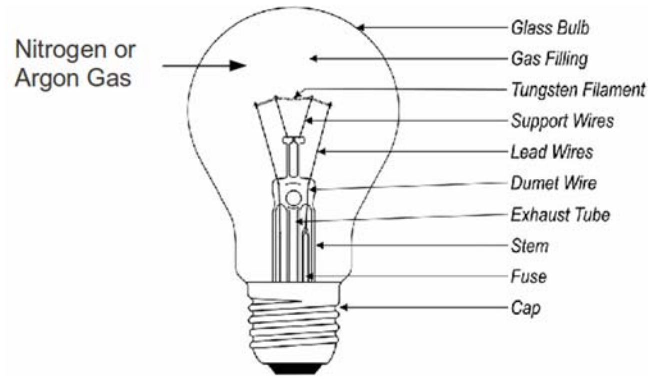
Because of having a lot of disadvantages, carbon filament lamps are not in use these days. Some of the disadvantages are as follow:

1) The carbon filament vaporizes at around 1700°C. So its efficiency is less.
2) The vaporized carbon remains inside the bulb as black particles. So it reduces the brightness of the bulb.
3) The carbon is brittle. So it is very difficult to stretch it for making a filament.
4) Making a coil from carbon is not easy.
5) The energy consumption is 4 watts/CP against 12 watt/CP (candle power) of tungsten filament lamp.

Tungsten Filament Lamp

In this lamp, the tungsten is used as filament which has melting point of around 3400°C. The filament lamps are classified into two types, namely vacuum filament lamp and gas filled lamp. The vacuum lamp prevents the oxidation of filament and also prevents decrement in temperature due to radiation.

A filament temperature of around 2000ºC can be obtained in vacuum lamp whereas a temperature of around 2500ºC can be obtained in gas filled lamp. So the efficiency is increased.



Likewise, the filament can be used I n two different forms, namely zig-zag and coiled filament. A zig-zag filament is used in vacuum lamp and a coiled filament is used in gas filled lamps.

Different colours are obtained by using different coloured glass and its average life is around 1000 hrs.

Properties of filament to be used

- It should have very high melting point.
- It should have high resistance and low temperature coefficient.
- It should be ductile
- It should be mechanically strong so that it won't break during normal vibrations.

Disadvantages:

1. It has very less efficiency (i.e. 12 lumens per watt)
2. It produces yellowish white light which is not taken as of high quality.

Discharge Lamps:

To remove the drawbacks of filament lamps, a discharge lamp is been introduced.

It works on the phenomenon of electric discharge through a gas or vapour and the colour of light depends on the nature of gas or vapour filled.

In the fluorescent lamp, phosphors are used to absorb the light energy.

Discharge Phenomenon:

When an electric potential is applied across two electrodes sealed inside the glass tube containing gas or vapour, the electrons start to flow from cathode to anode. During the movement of electrons, it comes in contact with the molecules of gas or vapour producing ultra violet rays.

Discharge lamps are of two types,

1. The lamp that produces the same colour of light as produced by discharge through gas or vapour.

   Eg, sodium vapour lamps, mercury vapour lamps, neon gas lamps

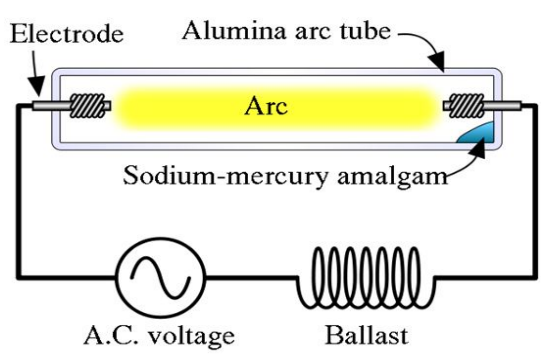
2. The lamps that work on the process of fluorescence and are known as fluorescent lamps. It absorbs the UV rays produced during discharge and emits visible light.

Note:

Fluorescence:
When colliding takes place, UV rays are produced and they are absorbed by phosphors and turn the invisible light into visible light. This phenomena is known as fluorescence.

1. Sodium Vapour Lamp

Amonge the various discharge lamps, sodium vapour is most efficient one having an efficiency of around 60 to 70 lumens per watt. But if compared in terms of input and output power, its efficiency is just 20%. Mostly, it is used in streets and highways.



Construction:

It consists of a U-shape discharge tube containing neon gas and sodium vapour. The neon gas is used for starting discharge.

The tube is enclosed in a double walled evacuated glass known as outer tube for preventing the heat loss. It also consists of a high reactance transformer for supplying high voltage for starting discharge. It also stabilizes the amount of current. And a capacitor is used for improving the power factor.

Working:

When electric current is passed through the lamp, the electrons move from cathode to anode. This ionizes the gas and the electric discharge starts. Due to this, the sodium vapourizes and the lamp starts at normal operation.

It produces a yellowish colour. So it is called monochromatic lamp. The lamp should be placed horizontally so that the sodium can spread uniformly.

Once the lamp goes out, it again needs certain time to come to normal operation. Its average life is around 3000 hrs and isn't affected by voltage variations.

2. Mercury Vapour Lamp:

The construction of this lamp is similar to sodium vapour lamp. But in this lamp, either mercury or high gas pressure is used to increase the efficiency.

It consists of two main electrodes of tungsten coated with barium oxide for the easiness of electrodes to flow, which are enclosed in a hard glass tube containing argon gas and mercury. An auxiliary electrode (starting electrode) is placed near main electrode. The tube us enclosed in another ordinary glass coated with fluorescent powder. The space in between is evacuated to prevent the loss of heat.

Working:

The choke used in bulb supplies high voltage required for discharge and it also stabilizes the amount of current. The power factor of the bulb is increased by connecting a capacitor in parallel.

Initially, the current doesn’t flow through main electrodes. It starts to flow between auxiliary and main electrodes through argon gas. The heat produced vapourizes mercury which decreases the resistance between electrodes and then the discharge starts.

This lamp is about 2.5 times more efficient than the incandescent lamp with an efficiency of around 35 to 40 lumens per watt. It is generally used as street lamps and park lights.

Disadvantage of Gaseous Discharge Lamps:

1. The starting time is high. i.e. Take more time to come to normal operation.
2. It must be placed in particular position.
3. It has very high initial cost.
4. The starting process is complicated.
5. Its power factor is very low.

Fluorescent Lamp:

Standard length – 2 ft - 20 watts

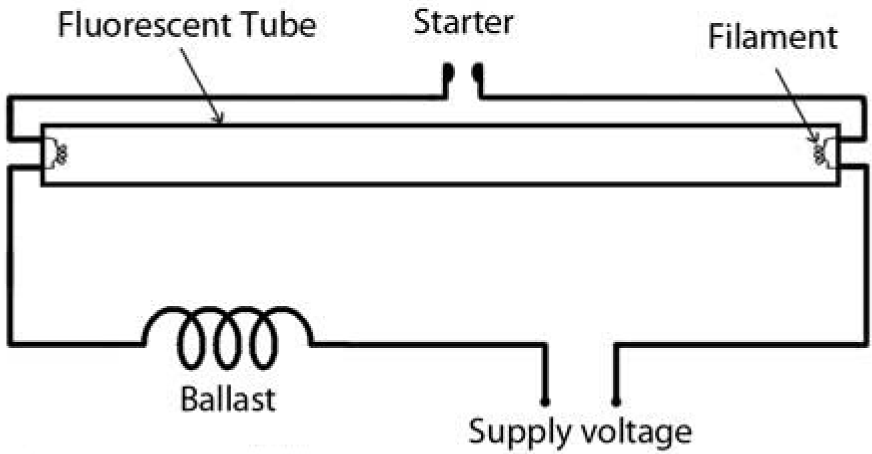
- 4 ft – 40 watts

It is low pressure vapour mercury lamp that works on the process of fluorescence.

Construction:

It consists of a starter and choke connected in series with mains. A starter is a small cathode glow lamp having bimetal strip at the electrodes. A choke provides around 1000V when starter is open and about 110V during normal operation. The tube is filled with small quantity of mercury and argon gas along with electrodes at both ends.

It is available in different sizes as 4 ft(40 watt) and 2 ft(20 watt)



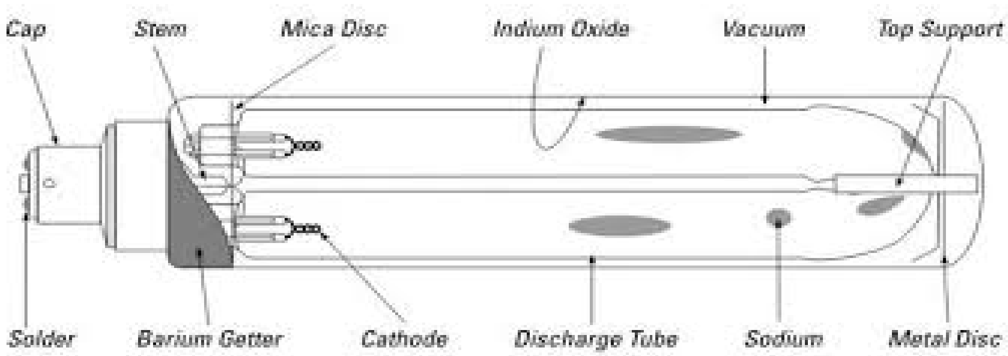
Working:

When the starter is not connected, there is no flow of current. As the mains are on, the current flows through the starter and the electrodes. This heats the electrode and there is flow of electrons between them. Also the close circuit 'CC' of the starter will be heated so that it breaks down. Due to this, the choke supplies the high voltage of around 1000V which helps to start the discharge and the lamp lights on.

In general, the UV radiations produced due to discharge between the electrodes is absorbed by absorbing materials 'phosphors' coated at the walls, which in turn produces visible light.

It is mainly used for lighting purposes and has an efficiency of 30 to 40 lumens per watt. It has an average life of about 3000 hrs.

Neon Lamps:



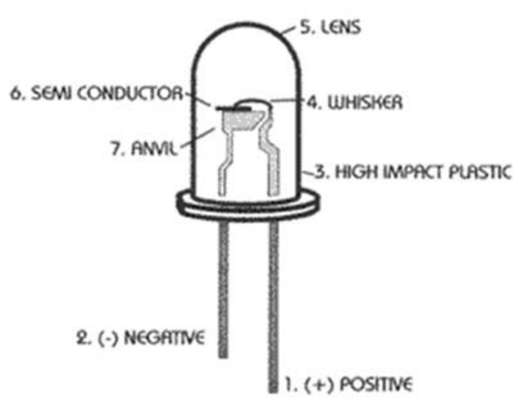
Neon lamps consist of glass tube containing neon gas mixed with some helium. Two pure iron electrodes (for good discharge) are placed close to each other so that it can be used in low voltages as 110V AC or 150V DC.

If it is used in AC supply, the electrode should be of equal length and if used in DC supply, the negative electrodes should be slightly longer.

The resistance connected in it reduces fluctuate current due to voltage variations. It gives orange pink coloured light and has an efficiency of 15 to 40 lumens per watt. It is used generally in indicators and night lamps. It can be also used for the determination of polarity of DC supply.

LED

LED (light emitting diode) is basically a small light producing device. It is a solid state lamp that uses LEDs as the main source of light. It produces different colours of light. It is a P-N junction diode that emits light when activated. The two terminals (anode and cathode) of LED when connected to the voltage source in correct polarity produces lights of different colours as pre the semiconductor substance used inside it. LED doesn't need a filament to produce light. Rather its effectively done through the passage of electrons and due to bandgap effect of the semiconductor material. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device releasing the energy in the form of photons. This effect is called electroluminescence. The colour of the light is determined by the energy bandgap of semiconductor.



Advantages:

- Low energy consumption.
- Long life
- Smaller size (Portable)
- Faster switching
- Physical strength is more.
- Can be easily replaced in normal fittings.

Applications:

Used in head lamps, advertising, general lighting , camera flashes, traffic lights etc.

Halogen Lamps:

It is also known as tungsten halogen lamo or quartz halogen lamp. It works on the same principle as that of incandescent lamp.

It consists of a tungsten filament sealed inside a glass tube containing inert gas mixed with halogens like iodine or bromine. The use of halogen reduces the vaporization of tungsten filament so the chance of blackening will be prevented. Beside this, the halogen allows the filament to operate at higher temperature without reducing its life.

This lamp produces a bright yellow light and has an efficiency of around 10 to 20 % more than filament lamp.

Generally, this lamps are used in sport stadiums, parks, factories, airports and so on. The quartz halogen lamps are specially used in scientific and medical instruments.

Note:

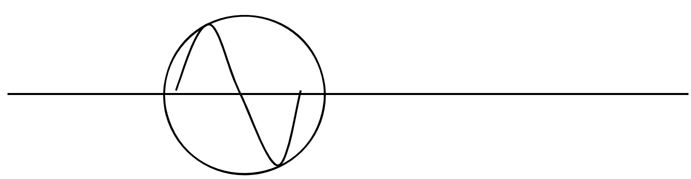
1. If a filament lamp has an efficiency of 10% then it means that the lamp converts 10% of the supplied electrical energy into light energy and remaining 90% is converted into heat energy and other radiations.

2. if a bulb is rated with 60 watt, it means that the bulb can convert 60 Joule of supplied electrical energy into heat and light energy in one second.

Comparison of filament and fluorescent lamp

Incandescent Lamp	Fluorescent Lamp
It is almost spherical in structure.	It is tubular in structure
It is cheap and simple	The initial cost is high.
Its average life is 1000 hrs	Its average life is 3000hrs
Its efficiency is 10%	Its efficiency is 30%
It produces yellowish color of light	The color of light depends on the fluorescent powder coated on tube.
It works on the principle of heating effect of current.	It works on the principle of electric discharge and phenomena of fluorescence.

Stroboscopic Effect:



When an AC supply is passed through the discharge lamps, the lamp extinguishes for about 100 times in 1 second as the supply voltage is of range 220V, 50Hz. This cannot be detected under normal situation. But when a rotating object is observed under such lamps, the objects are seen rotating at different speed than its actual speed.

And this effect seen in variation of speed of rotating objects when seen under the discharge lamps is known as stroboscopic effects.

Requirement for good lighting scheme

For a good lighting system, the brightness of the lighting source should be properly maintained so that the objects can be seen clearly. For that, the following factors are to be considered.

i) Illumination level
ii) Absence of glare
iii) Color of lighting (Source)
iv) Absence of dark shadows

And the illumination level for various places should be maintained as follows:

1.	Entrances		100 lumens/m^2 (Lux)
2.	Living Room	-	300 Lux
3.	Bed Room	-	30 – 100 Lux
4.	Dining Room	-	150 Lux
5.	Kitchen		-80 Lux
6.	Study Room	-	150 Lux
7.	Stairs		-80 Lux
8.	Bath Room	-	80 Lux

Terms of Illumination:

1. **Space Height Ratio:**
   It is defined as the ratio of horizontal distance between two adjacent bulbs to height of the bulbs from working plane.

i.e. $$\text{Space height ratio} = \frac{\text{Horizontal distance between two adjacent bulbs}}{\text{Height of bulb from working plane}}$$

Its value should vary from 0.8 to 1.2 but shouldn't exceed 1.5.

2. **Depreciation Factor:**
   It is the ratio of illumination produced under brand new condition to illumination produced under working condition.

i.e Depreciation factor =

$$\frac{\text{Illumination produce by brand new source}}{\text{Illumination produced by a source under working condition}}$$

The value of depreciation factor is always greater than 1.

3. Maintenance Factor:

It is the ratio of illumination produced under working condition to illumination produced under brand new condition. Simply it can be defined as the reciprocal of depreciation factor.

i.e Maintenance factor = $\dfrac{\text{Illumination produced under working condtion}}{\text{Illumination produced during brand new condition}}$

The value of depreciation factor is always less than 1.

4. Coefficient of Utilization:

It is defined as the ratio of light falling on the working plane to light emitted by a lighting source.

i.e Coefficent of Utilization = $\dfrac{\text{Light falling on the working plane (surface)}}{\text{Light emitted by the source}}$

Its value ranges from 0.4 to 0.6.

And the coefficient of utilization depends on following factors:

1. Nature of lighting source (Direct or Indirect)
2. Nature of the fittings like reflectors, diffusers and their height.
3. Colour of walls

Methods of Lighting (Design) Calculations:

The methods that can be used for the lighting calculations are as follows:

i) Watt per square meter method

ii) Lumen or Light Flux method

iii) Point to point or Inverse Square law method

i) Watt per square meter method:

This method is particularly used for rough calculations and checking. It is based on making an allowance of watt per square meter to be illuminated according to illumination needed.

ii) Lumen or light flux method:

This method is used where the source of light has to produce almost uniform illumination throughout the working plane.

The total output lumens is calculated as:

Total output lumens = No. of bulbs X Watt of each bulb X Efficiency of bulbs in terms of lumens per watt X Coefficient of Utilization

If depreciation factor is given,

Total output lumens = (No. of bulbs X Watt of each bulb X Efficiency of bulbs in terms of lumens per watt X Coefficient of Utilization) / Depreciation Factor

iii) Point to point or Inverse Square law method:

This method is used if one or more lighting source has to produce illumination at a point, given that the candle power of each source in a particular direction is known.

Calculation of light points required for interior illumination:

Let,

A = Area of working plane

E = Illumination required

Then,

Total output lumens = E X A

It is affected by coefficient of utilization,

Total output lumens = $\dfrac{E \times A}{U.F.}$

Likewise, it is also affected by depreciation factor,

$$\therefore \text{Total output lumens} = \frac{E \times A \times D.F}{U.F.}$$

If maintenance factor is given,

$$\therefore \text{Total output lumens} = \frac{E \times A}{U.F. \times M.F.}$$

Solved Numericals

1. It is required to provide an illumination of 100 lumens/m^2 in a workshop hall of 40m X 10m and efficiency of lamp is 14 lumens/watt. Calculate the watts required if coefficient of utilization is 0.4 and depreciation factor is 1.4.

Sol^n.

Length of the hall(l) =40m

Breadth of the hall(b) =10m

Area of the room =40X10 = 400m^2

Illumination(E) =100 Lux

Coefficient of utilization(U.F) =0.4

Depreciation factor(D.F) =1.4

Efficiency of bulb = 40 lumens/watt

Now,

Total output lumens $= \frac{E \times A \times D.F.}{U.F.}$

$$= \frac{100 \times 400 \times 1.4}{0.4}$$

=140000 lumens

Total watt required $= \frac{140000}{14}$

=10000 watts

Hence, the required total amount of power for the bulbs is 10000 watts.

2. A drawing hall of length 30m and breadth 15m is to be illuminated with 120 lux. The lamps are required to be hung 5m above the working plane. Assume the space height ratio of unity, a coefficient of utilization 0.5, depreciation factor of 1.4 and efficiency of bulb to be 40 lumens/ watt, find the number of 80 watt tubes to be used in that room.

Sol^n.

Length of the hall(l) =30m

Breadth of the hall(b) =15m

Area of the room =30X15 = 450m^2

Illumination(E) =120 Lux

Coefficient of utilization(U.F) =0.5

Depreciation factor(D.F) =1.4

Efficiency of bulb = 40 lumens/watt

Now,

Total output lumens $= \frac{E \times A \times D.F.}{U.F.}$

$= \frac{120 \times 450 \times 1.4}{0.5}$

=151200 lumens

Total watt required $= \frac{151200}{40}$

=3780 watts

No of tubes required $= \frac{3780}{80}$

= 47.25

$\approx$ 48 bulbs

Hence, the required number of tubelights is 48.

3. It is required to provide an illumination of 100 Lux in a factory hall 30m by 15m. Assume that depreciation factor is 1.25, coefficient of utilization is 0.4 and

efficiency of lamp is 14 lumens/watt. Find the number of bulbs required for (i) 100 watt ii) 250 watt iii) 400 watt iv) 500 watts ?

Sol^n.

Length of the factory hall(l) = 30m

Breadth of the factory hall(b) = 15m

Area of the room = 30X15 = 450m^2

Illumination(E) = 100 Lux

Coefficient of utilization(U.F) = 0.4

Depreciation factor(D.F) = 1.25

Efficiency of bulb = 14 lumens/watt

Now,

Total output lumens $= \frac{E \times A \times D.F.}{U.F.}$

$= \frac{100 \times 450 \times 1.25}{0.4}$

=140625 lumens

Total watt required $= \frac{140625}{14}$

=10044.64 watts

Now,

i)No of 100 watts required $= \frac{10044.64}{100}$

= 100.4464

≈ 105bulbs

i)No of 250 watts required $= \frac{10044.64}{250}$

= 40.18

≈ 41 bulbs

i)No of 400 watts required $= \frac{10044.64}{400}$

$= 25.11$

≈ 26 bulbs

i)No of 500 watts required $= \frac{10044.64}{100}$

$= 20.09$

≈ 21bulbs

4. A small assembly shop 16m long, 10m wide and 3m up to trusses is to be illuminated to a level of 200 Lux. The coefficient of utilization and maintenance factor are 0.74 and 0.8 respectively. Calculate the number of lamps required, if the lumens output of each lamp is 3000 lumens.

Sol^n.

Length of the assembly shop(l) =16m

Breadth of the assemble shop(b) =10m

Area of the room =16X10 = 160m^2

Illumination(E) =200 Lux

Coefficient of

utilization(U.F) =0.74

Maintenance factor(M.F) =0.8

Output of each bulb = 3000 lumens

Now,

Total output lumens $= \dfrac{E \times A}{U.F. \times M.F.}$

$= \dfrac{200 \times 160}{0.74 \times 0.8}$

=54054.05 lumens

No of bulbs required $= \dfrac{54054.05}{3000}$

= 18.01

$\approx$ 18 bulbs

Hence, the required number of bulbs is 18.

5. A motorcycle workshop of length 24m and breadth 16m is to be illuminated with 120 lux. The lamps are required to be hung 5m above the working plane. Assume the space height ratio of 1.0, a coefficient of utilization 0.5, maintenance factor of 0.8 and efficiency of bulb to be 40 lumens/ watt, find the number of 150 watt bulbs to be used in that room. Also show the spacing layout for required room.

Sol^n.

Length of the room(l) =24m

Breadth of the room(b) =16m

Area of the room =24X16 = 384m^2

Illumination(E) =120 Lux

Coefficient of utilization(U.F) =0.5

Maintenance factor(M.F) =0.8

Efficiency of bulb = 40 lumens/watt

Now,

Total output lumens $= \dfrac{E \times A}{U.F. \times M.F.}$

$$=\frac{120\times384}{0.5\times0.8}$$

=115200 lumens

Total watt required $= \frac{115200}{40}$

=2880 watts

No of bulbs required $= \frac{2880}{150}$

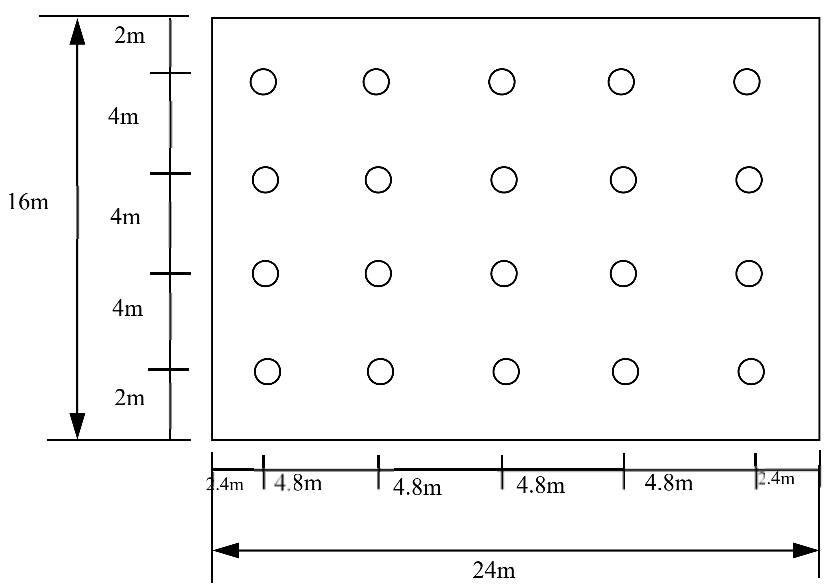
= 19.2

$\approx$ 20 bulbs

Therefore 5 lamps can be mounted along length of the room giving a space height ratio of $\left(\frac{4.8}{5}=0.96\right)$ and 4 lamps can be mounted along breadth of the room giving a space height ratio of $\left(\frac{4}{5}=0.8\right)$

……………………..1

The location of the lamps can be shown as below.



6. A classroom of size 30m by 12m is to be illuminated with 50 Lux. The lamps are required to be hung 5m above the workbench. Assume the space height ratio of around 1.2, coefficient of utilization factor of 0.5, lamp efficiency of 15 lumens/watt, depreciation factor of 0.77, estimate the number, rating and positon of lamps.(Rating of bulbs = 300 watt)

Sol^n.

Length of the room(l) =30m

Breadth of the room(b) =12m

Area of the room =30X12 = 360m^2

Illumination(E) =50 Lux

Coefficient of utilization(U.F) =0.5

Maintenance factor(M.F) =0.77

Efficiency of bulb = 15 lumens/watt

Now,

Total output lumens $= \dfrac{E \times A}{U.F. \times M.F.}$

$= \dfrac{50 \times 360}{0.5 \times 0.77}$

$= \dfrac{18000}{0.385}$

=46753.24 lumens

Total watt required $= \dfrac{46753.24}{15}$

=3116.88 watts

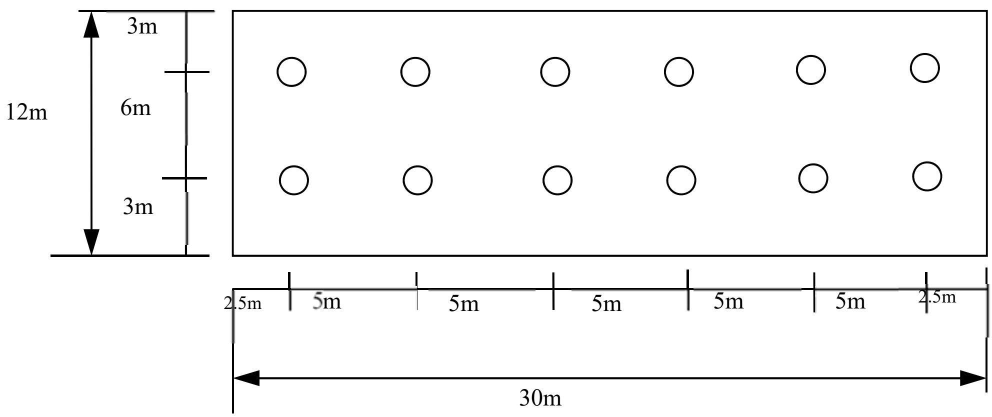
No of bulbs required $= \dfrac{3116.88}{300}$

= 10.38

≈ 12 bulbs

Therefore 6 bulbs can be mounted along length of the room giving a space height ratio of $\left(\dfrac{5}{5} = 1\right)$ and 2 bulbs can be mounted along breadth of the room giving a space height ratio of $\left(\dfrac{6}{5} = 1.2\right)$ ……………………..1

The location of the lamps can be shown as below.



7. A school canteen 40m in length and 25 m in breadth is to be illuminated with metal glass filled filament lamps to 90 lumens/m^2 on the working plane. If the coefficient of utilization is 0.5 and the source of 500 watt having a luminous efficiency of 20 lumens/watt is to be hung 5m above the working plane, calculate the number of bulbs required. Also show the suitable positions of the fittings. Take depreciation factor as 1.2.

Sol^n.

Length of the canteen(l) = 40m

Breadth of the canteen(b) =25m

Area of the room = 40X25 = 1000m^2

Illumination(E) = 90 Lux

Coefficient of utilization(U.F) =0.5

Depreciation factor(D.F) =1.2

Efficiency of bulb = 20 lumens/watt

Now,

Total output lumens $= \frac{E \times A \times D.F.}{U.F}$

$= \frac{90 \times 1000 \times 1.2}{0.5}$ =216000 lumens

Total watt required $= \dfrac{216000}{20} = 10800$ watts

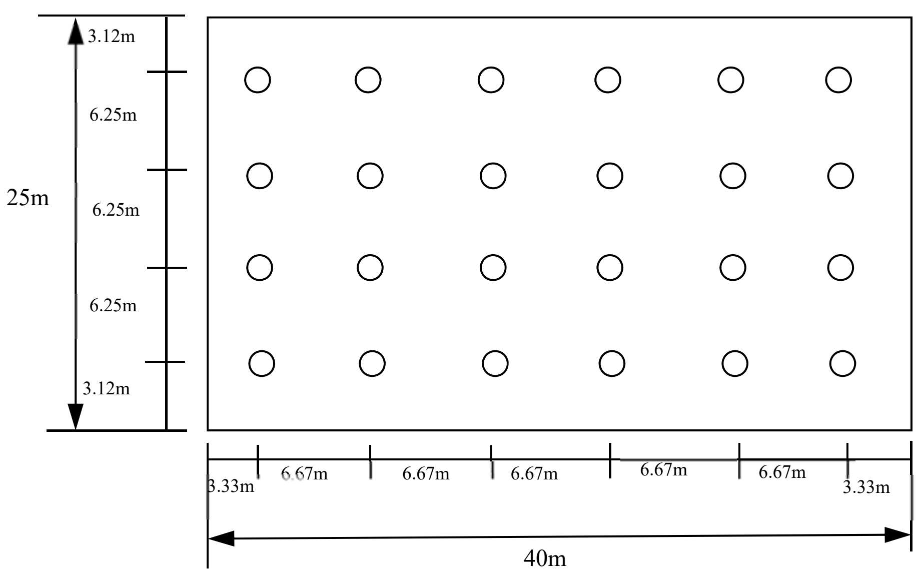
No of bulbs required $= \dfrac{10800}{500}$

$= 21.6 \approx 24$bulbs

Therefore 6 lamps can be mounted along length of the room giving a space height ratio of $\left(\dfrac{6.67}{5} = 1.334\right)$ and 4 lamps can be mounted along breadth of the room giving a space height ratio of $\left(\dfrac{6.25}{5} = 1.25\right)$

……………………..1

The location of the lamps can be shown as below.



Tutorials:

1. A hall measuring 15m X 45m is to be illuminated by a bulbs of 200 watt to give an illumination of 45 Lux. Assuming utilization factor to be 0.65 and depreciation factor is 1.3, find the number of bulbs required if efficiency of each bulb is 2880 lumens.

2. A minimum illumination of 80 lumens /m^2 is required in a factory shed of 100m by 10m. Calculate the number, location and wattage of the bulbs to be used. Assume depreciation factor is 0.8, coefficient of utilization is 0.4 and efficiency of lamp is 40 lumens/watt.
3. A classroom of size 30m by 30m is to be illuminated with 75 Lux. The lamps are required to be hung 5m above the workbench. Assume the space height ratio of 0.9 – 1.0, coefficient of utilization factor of 0.5, lamp efficiency of 15 lumens/watt, depreciation factor of 0.8, estimate the number, rating and positon of lamps.(Rating of lamp is 2000 watts).
4. It is required to illuminate the living room 16m X 30m with 80 Lux. If the lamps of 60 watts are to be hung 5m above the working plane, design the layout scheme for it. Take depreciation factor as 1.25, utilization factor as 0.5 and efficiency of bulb as 60 lumens/watt so that it meets the space height ratio in range of 0.8 to 0.9.
5. A workshop 30m X 15m is to have illumination of 150 Lux on its working plane. The lamps are hung 5m above it. Give the layout of a suitable installation using 80 watt fluorescent lamp. Take utilization factor as 0.5, depreciation factor as 1.4 and efficiency of lamp is 40 lumens/watt.
6. It is required to provide illumination of 100 Lux in a factory hall 30m by 15m. Assume that depreciation factor of 0.8, coefficient of utilization is 0.4 and efficiency of lamp is 14 lumens/watt. Find the number of lamps to be used, if the available rating of lamp is 250 watt. Also draw a schematic diagram of the layout, given that the lamps are suspended at a height of 2.5m above.
7. A hall measuring 15m X 45m is to be illuminated by suitable lamps to give an average illumination of 45 Lux. Assuming the mounting height of lamp to be 3m above the working plane, utilization factor of 0.65 and depreciation factor of 1.3, estimate the number and installation position of lamps, if a lamp of 150 watt is selected with an efficiency of 14 lumens per watt.

Reflectors and Diffusers:

The reflectors are the substances that reflect light onto the working plane (subject). They can be solid or flexible, round, oval, rectangular, square or an umbrella. They also come in cloth, metal, cardboard or foamcore mediums. Reflectors commonly come in a few colors: white, silver and gold. Since reflectors have two sides, we can often get a single reflector in two colors. The size and color of the reflector depends on the size of your shot and its mood or style.

White (an excellent choice for weddings) reflects a soft diffused light without changing its color. Silver reflects a brighter, crisper light that adds a bit of sparkle to the image (excellent for product shots) and gold adds warmth and a soft glow to the image (great outdoors). For example, if we shoot models or warm interviews, we will want medium to large diffused reflector that is either gold or a combination of gold and silver such as Lastolite's 48-inch Sunfire/Silver collapsible reflector ($64).

Diffusers

A diffuser is a large piece of translucent material that is placed between the light and the subject to spread the light and make it softer. The size of the diffuser depends on your subject. Chimera makes a large selection of light box diffusers that range in size from the XX-Small 1 light diffuser with a 12 X 16 inch face ($147) to huge 15 X 40 foot monsters. Of course diffusers include softboxes and scrims as well.

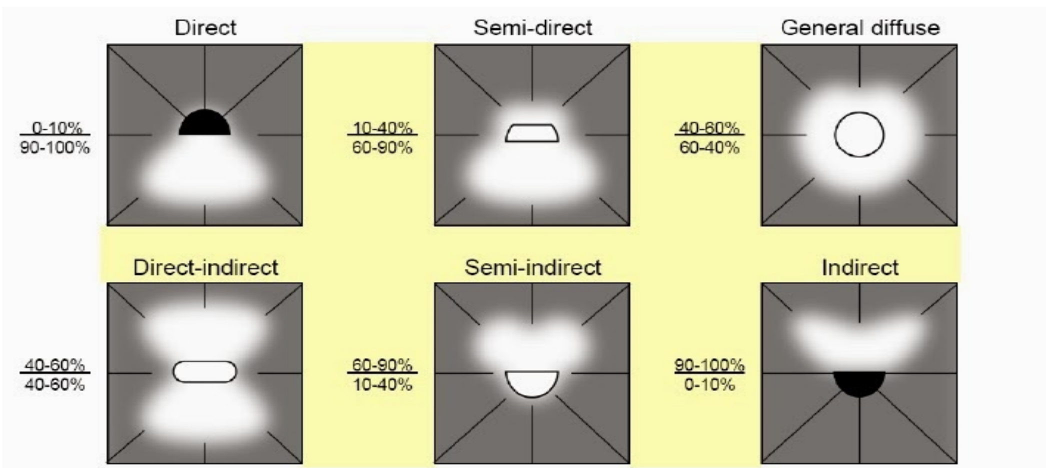
Factors to be considered for designing lighting schemes:

- Provide proper illumination
- Absence of glare
- Absence of dark shadows
- Uniform illumination throughout the working plane
- Colour of light and colour of the walls
- Mounting height
- Spacing of the bulbs

Types of lighting schemes:

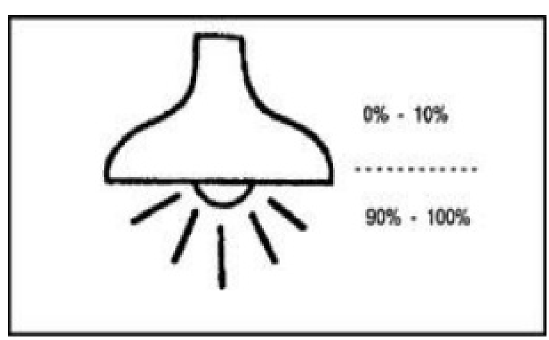
The distribution of light emitted by a lighting source (lamps) is usually controlled to some extent by means of reflectors and diffusers or even lenses. The interior lighting schemes can be classified as,

1. Direct Lighting Scheme
2. Semi-Direct Lighting Scheme
3. Semi-indirect Lighting Scheme
4. Indirect Lighting Scheme
5. General Lighting Scheme



1. **Direct Lighting Scheme:**

   It is the most commonly used type of lighting scheme. In this type of scheme, about 90% of the light falls on the working plane or surface from the lighting source with the help of deep reflectors. It is mostly used for uniform illumination. In this scheme , there is chances of presence of dark shadows and glare. It is mainly used for industrial and general outdoor lighting.



2. Semi-Direct Lighting:

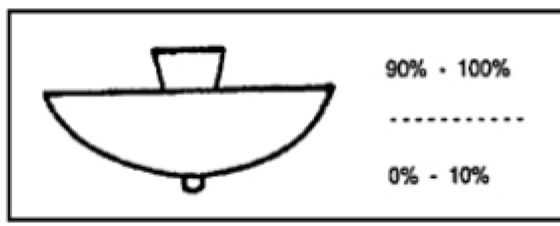
In this scheme, about 60 to 90% of total light flux is allowed to fall on the working plane and remaining light is used to illuminate the walls and ceilings. This scheme is best suited for rooms with high ceilings where high level of uniform distribution is required.

3. Semi-Indirect Lighting:

In this lighting about 60 to 90 percent of the total light is thrown upwards to the ceiling for diffused reflection and remaining reaches the working plane. It doesn't create glare and produces soft shadows. It is mostly applicable for indoor lighting decoration purposes.

4. Indirect Lighting:

In this lighting, 90 percent of total light is thrown uwards to the ceilings for diffused reflection using bowl or inverted reflectors. In this ceiling acts as a source and glare is removed. Thus the resulting illumination is much softer and diffused. It is used for decoration purpose in cinemas, seminar halls, theatres, hotels etc.



5. General Lighting:

In this scheme lamps made up of diffusing glass are used which gives nearly equal illumination in all directions.

Assessment

Very Short Answer Questions

1. Define electromagnetic wave.
2. Define frequency.
3. The frequency of a wave is 50 Hz. What does it mean?
4. Define the following terms

a. Wavelength
b. Luminous flux
c. Time period
d. Illumination
e. Space height ratio
f. Maintenance factor
g. Utilization factor
h. Luminous intensity

5. What is the full form of CFL and LED.
6. Define glare. How can it be removed?
7. Why is sodium vapour lamp called monochromatic lamp?

Short Answer Questions

1. What type of conductors can be used as a filament in incandescent lamp?
2. Write short notes on:
   a. Stroboscopic effect
   b. Reflectors
   c. Diffusers
3. What are the applications of inverse square law?
4. What are the factors to be considered for better illumination?
5. Why can't the high pressure lamps be used for interior lighting purpose?
6. What are the defects seen when carbon is used as filament in incandescent lamp?
7. Write short notes on LED.
8. Write short notes on CFL.

Long Answer Questions

1. Explain in detail about the construction and working principle of filament lamp.
2. Explain in detail about construction and working principle of fluorescent lamp.
3. Explain in detail about the different types of lighting calculation methods.
4. Differentiate between filament and fluorescent lamp.

5. State laws of illumination and derive the relation $E = \frac{I}{h^2}\cos^3\theta$ where the symbols have usual meaning.
6. List out the different types of lighting schemes. Explain them in detail.

References:

A text book of electrical engineering, B.L Thereja, A.K. Thereja

A handbook of electrical engineering, S.L.Bhatia

A textbook of electrical engineering, J.B.Gupta

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UNIT – 3

Industrial Utilization of Electric Energy

Objectives:

The main objective of this chapter are:

- To be familiar with the concept and parts of electric drive.
- To know the different types of drive and its selection criteria.
- To be familiar with the applications of different types.

Course Content

Electric Drives:

It is defined as the form of machine equipment used to convert electrical energy into mechanical energy. It also provides electric control over the whole process.

A well equipped machine can be classified into three different parts.

- Prime mover (engine)
- Transmission System (Shaft / Pulley / Belt / Gears)
- The working machine

Both the prime mover and the transmission system are functioned to operate the working machine. And to operate with better performance, the electric drive may also have frequency changer, rectification unit and so on.

Advantages of electric drive:

- Simple
- Cleanliness
- Smooth and easy control
- Facility of remote control
- Easy starting
- Long life
- Low maintenance cost

Role of electricity in modern industry / society

Electricity is one of those discoveries that have changed the daily life of everybody on the planet. Electricity is the key component to modern technology and without it most of the things that we use everyday simply could not work, and would never have been created. Our mobile phones, our computers, the Internet, our heating systems, our televisions, and our light bulbs - nearly everything in the home would be completely different. There would be completely different systems put in place in the home to ensure that we can remain warm, and to ensure that we can live properly every day.

Indeed, modern society would be incredibly different. Imagine how different things would be today without the Internet. The World Wide Web has had a huge effect on our lives. It has made everybody more aware of the world they live in, and it's allowed them to learn about our surroundings and know more about how near enough everything within modern society works. It is our gateway for knowledge, and allows us to find out nearly anything within a matter of seconds, hence, electricity has made us an incredibly intelligent and aware society.

It's also allowed us to become healthier. Without electricity, hospitals would have significantly less medical equipment available to help people with medical problems. Electricity, hence, saves lives and allows people to live longer. So not only are we are more aware and intelligent society but we have become much healthier. Our lives are improved no end by electricity, and it's certainly true that most people's living quality would be significantly reduced and affected if electricity were to somehow disappear. Electricity is the basis of most modern inventions and naturally without it, the 21st century would be comparable to the 19th.

In today's culture, electricity is a vital part of functioning as a society. Simple tasks, such as waking up at a designated time or enjoying a piece of music, are accomplished currently via electronic means. One only needs to consider the consequences of a relatively short power outage factories close down, phones and computers go dead, traffic slows to a crawl, food spoils in refrigerators to accurately observe how power-dependent our society has become. However, electricity is a constantly developing technology, and the aspects one currently associates with electricity and electricity generation are nowhere close to the original features. In the past century and a half, electricity has steadily evolved from a scientific curiosity, to a luxury of the affluent, to a modern need. Along the way, it has been shaped by a variety of non-technological factors: economic, political, social, and environmental, to name a few.

Advantages:

Time saving (Faster Operation)

Safety

Less labour

Higher production (Higher efficiency / output)

Easy control

Pollution free

Uniformity in production

Reliable / Durable

Production at less cost and less effort

Disadvantages:

Limited to electrified areas only

Chances of dangerous accicents

In case of power failure, whole equipment wont operate

Schematic Diagram of electric drive

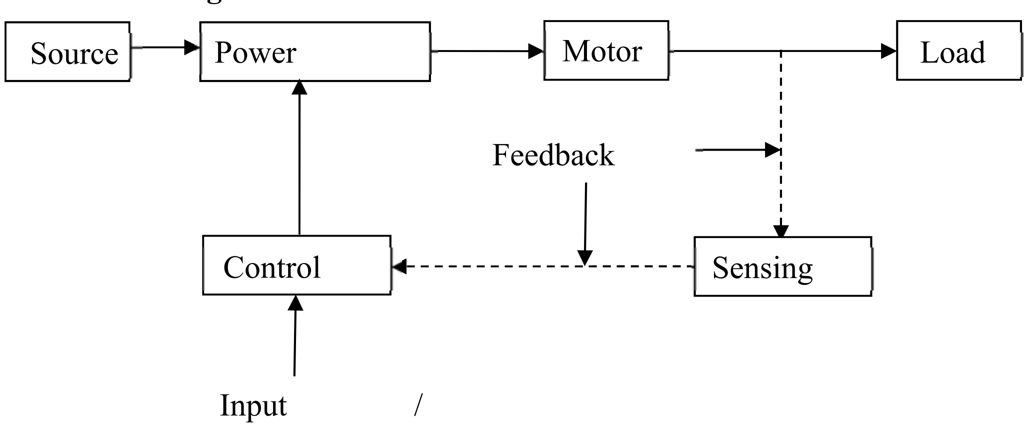


Fig: Schematic Diagram of electric drive

Source: It may be either AC or DC source.

Power Modulator:

i) In case of DC source and the motor to be used is induction motor, it converts DC into AC Source

ii) Selects mode of operation either braking or motoring

iii) Controls the speed

Load: Working equipment

Motor : Generally DC motors are used

Induction Motor (Squirrel cage / phase wound motor)

Synchronous motor (Wound field and permanent magnet)

Sensing Unit: For sensing drive parameters like speed, motor current etc.

Sends information to control unit.

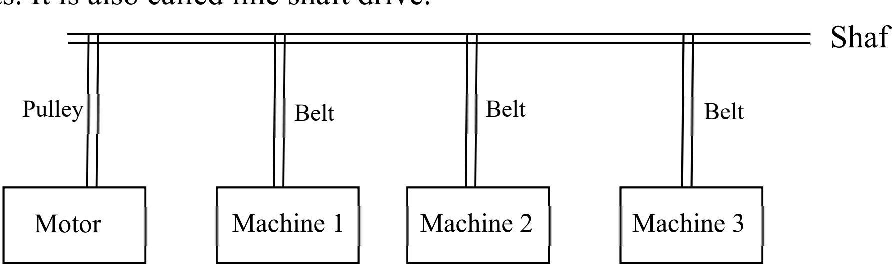
Control Unit: Control power modulator

Types of Drive:

1. Group Drive
2. Individual Drive
3. Combination Drive

1. Group Drive:

A single motor is used to operate two or more equipment connected via shaft, pulleys or belts. It is also called line shaft drive.



Advantages:

As single motor is used , it is more economical then using individual motors.

Disadvantages:

i) If there is any failure in motor, then none of the machine will operate.

ii) If all the machine aren't operating, then the motor will be operating at lesser efficiency.

iii) It is not possible to install machines far from the motor.

iv) Speed control of all the machines using belt and gears is difficult.

2. Individual Drive

In this type of electric drive, a single motor is used for each of the equipment or machine. For eg, spindle drilling machine, electric tools, simple metal working tools etc.

As separate motors are used for separate equipments, It is more expensive than group drive. But it gives complete control for operation over each machine or equipment.

In individual drive, the motor works at full load, so it's efficiency is more and power factor is also good. The machines can be installed at any desired locations and is more applicable for driving heavy equipments or machines like lifts, cranes etc.

3. Combination Drive:

In this method, more separate motors are used and in each of the motors, more working equipments or machines will be connected. In general, it can be said as the mix – up of individual and group drive.

Comparison between group and individual drive:

Factor	Group Drive	Individual Drive
Efficiency and Power factor	If all the connected equipments aren't operating, then the motor works at lesser efficiency and thus have less power factor	The motor works at full load. So it has more efficiency and hence better power factor.
Reliability	A fault in motor leads to failure in all connected machines. So it is less reliable.	A fault in motor will stop only connected motor. So more reliable.
Flexibility	A machines need to be installed over a particular positions (nearer to the motor)	A machine can be installed at any desired positions.
Speed	Constant speed cannot be obtained	Constant speed can be obtained.
Initial Cost	Less initial cost	As more motors are needed, very high initial cost
Space Required	Requires less space	Requires large space
Types of machines	Heavy equipments cannot be operated	Heavy equipments can be operated like lift, cranes etc.

Factors to be considered for selecting motor: (Criteria)

1. Nature of source
    - Either AC or DC or single phase or three phase
2. Types of drives:
    - Depending upon type of drive to be installed, either group, individual or combination
3. Types of load
    - Active load or passive load

4. Electrical Characteristics
    - Running characteristics
    - Starting Characteristics
    - Speed Control
    - Braking Characteristics
5. Mechanical Considerations
    - Type of enclosures
    - Type of bearings
    - Type of transmission for drive
    - Noise level
    - Heating and cooling time constants
6. Appearance
    - Physical structures and sizes
7. Cost
    - Initial Cost
    - Running Cost   -Maintenance Cost
    - Depreciation Cost
    - Power factor
    - Losses
8. Rating and size of motor
    - Requirement for continuous, intermittent or variable load cycle
    - Pull out torque and overload capacity

Motors for various purposes:

1. Synchronous Motor:

- It provides constant speed, So the control of speed is not possible. It has a power factor of 0.9 – 1.0 .

  Applications: teleprinters, timing devices, clocks recording instruments

2. Single phase series motor:

- It has high starting torque and has a power factor of 0.8 to 0.9 (lag)

  Applications: vacuum cleaner, refrigerators, electric traction

3. Repulsion Motor:

- It has high starting torque and has a power factor of 0.8 to 0.9 (lag). It has constant speed.

  Applications: Coil winding machines

4. Capacitor Start Induction Motor

- It has moderately high starting torque and has fairly constant speed. It has a power factor of 0.7 to 0.9 (lag).

  Applications: Compressors, refrigerator(compressor) etc.

5. Capacitor Start Capacitor Run Induction Motor

- Properties same like that of capacitor start induction motor but it has comparatively higher power factor than other motors.

  Applications: Drives requiring quite operations.

6. Repulsion Start Induction Motor:

- High starting torque. Has constant speed. It requires less maintenance with a power factor of 0.8 to 0.9 (lag)

  Applications: Drives requiring high starting torque, compressors, refrigerators

7. Shaded Pole Induction Motor:

- Simple and self start mechanism. It has low starting torque.

  Applications: Small fan, blowers, movie projectors etc.

8. Hysterisis Motor:

- Runs at synchronous speed.

  Applications: Electric clock

9. Universal Motor:

- Series motor that can be operated on both DC and AC supply. Also called fractional horse power motor.

  Applications: Mixers, Sewing machine etc

10. DC Series Motor:

- Used for heavy duty operations.

  Applications: electrical locomotives, rolling mills, cranes, lifts etc.

11. DC Shunt Motor

- Used for constant speed operations.

  Applications: Lathes, Vacuum cleaners, wood working machines, laundry washing machines, milling machines, grinders, metal cutting machines, small printing press etc.

12. Commulative Compound motor:

- Applications: Compressors, stamping machines, pressure blower, centrifugal pumps, rotary press, circular saws, shearing machines, hydro – extractors etc

Asssesment

Very Short Answer Questions

1. Define electric drive.
2. Name the motor to be used for following purpose:

a. vacuum cleaner	b. Traction
c. Hair dryer	d. Mixers
e. Cranes	f. Sewing machine
g. Drilling machine	h. Lifts

Short Answer Questions

1. What are the different parts of an electric drive? Write their main functions
2. What type of drive would you prefer? Give reason.
3. What are the advantages of electric drive?
4. What are the disadvantages of electric drive?
5. Compare electric drive with mechanical drive.

Long Answer Questions

1. What are the different types of drive? Explain them in detail.
2. Compare individual drive with mechanical drive.
3. What are the factors to be considered for selecting an electric drive? Explain them in detail.

References:

A text book of electrical engineering, B.L Thereja, A.K. Thereja

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UNIT – 4

Electric Traction

Objectives:

The objectives of this chapter are:

- To explain the concept of traction along with its applications.
- To be familiar with the types of traction.

Course Contents:

Electric Traction:

It means a locomotion in which the driving energy is obtained from electric motors. One of the best application of electric traction in our daily life can be taken in the field of transportation. For eg, electric trains, trolley bus, trams, cable cars and so on.

It has many advantages over other forms of locomotion. If the initial cost and generation cost can be reduced, it would replace all other forms of locomotion.

Advantages:

- Cheapness
- Cleanliness
- Acceleration and braking are smooth and rapid
- Less maintenance cost
- High starting torque
- Can be started immediately
- Capacity of carrying more passengers at very high speed
- No need of extra power supply for lights and fans to be used in locomotive.

Disadvantages:

- High initial cost
- Limited to fixed tracks as in trolley bus, cable cars and electric trains.
- Failure in power supply will stop the operation of whole system,
- Limited to electrified areas only
- Requirement of additional equipment for braking and control.
- Precautions should be made to control interference with telegraph and telephone lines.

Types of electric Tarction (System of track electrification)

1. AC electric traction
2. DC electric traction

1. AC electric Traction

It is used for overhead distribution system and consists of DC series motors as drives. The locomotive carries transformers and mercury arcs or metal rectifiers. The transformer steps down the high voltage of around 25kV at 50 Hz to required level and the rectifier converts AC into DC.

It is used for main lines in the areas of high traffic density.

Advantages:

1) 1. As the distribution voltage is high, the sub-stations are placed at higher distances. So the substations are required in lesser number.
2) 2. As the higher distribution voltage is used, smaller sections of conductor are used, hence reduces the cost.
3) 3. Less maintenance and running or operation cost.

2. DC Traction System:

It is mostly used in sub-urban areas for the operation of trolley bus, electric trams and so on. The distribution voltage in this system is less compared to AC traction system. So the transmission efficiency is lesser. And more number of sub-stations are required at lesser distances, so the operation cost in DC traction system becomes higher.

Comparison of AC Traction & DC Traction System

AC Traction	DC Traction
It is mostly used in main line railway services. Eg, electric trains	It is mostly used in sub-urban line railway services. Eg, electric trams, trolley bus, local trains etc
Distribution voltage is very high.	Distribution voltage is comparatively lesser.
Energy consumption is high.	Energy consumption is lesser.
Efficiency is higher.	Efficiency is comparatively lesser.

The spacing of sub-stations is more. i.e. at around 50 – 60 kms	The spacing of sub-stations is lesser. i.e. at around 5 – 7 kms
Running cost, maintenance cost and operation cost of sub-stations are lesser.	Running cost, maintenance cost and operation cost of sub-stations are higher.
The size of overhead conductor is reduced.	The size of overhead conductor is more
It causes interference in communication lines.	It doesn't cause any sort of interferences.

Types of railway services:

On the basis of distance between two stops, it can be classified into following types.

1. Urban System
2. Sub-urban System
3. Main line (Railway) system

1. Urban System:

- Less gaping between the stops (around 1 km)
- High acceleration and retardation needed to control the speed.
- No chances of free run

2. Sub-Urban System:

- Gaping between the stops longer than the urban(around 8 km)
- Acceleration and retardation similar to that of urban system.
- Free run is not possible.

3. Main Line System:

- Gaping between the stops much higher
- Less importance for acceleration and retardation
- Possibility of free run.

Types of railway Electrification

1. DC System

    Ranges - 600V, 750V, 1500V, 3000V

2. Single phase AC

- 15-25kV, at $16\frac{2}{3}Hz$, 25Hz and 50Hz

3. Three phase AC

- 3000-5000V, at $16\frac{2}{3}Hz$

4. Composite (Kando System)

- Conversion of single phase to three phase ac or dc
- Three phase are supplied to 3-phase induction motor

Electric Traction

1. Tramways

It is one of the most economical means of transportation for very dense areas and in congested areas and streets of large cities. It receives power from a bow collector or a grooved wheel from an overhead conductor at about 600 V DC and the running rail acts as a return conductor.

It consists of at least two driving axles in order to:

- Start from either side
- Secure necessary adhesion
- Uses two motors with series parallel control.

Along with this, two drum type collators are used at each end to control the tramcars.

Disadvantages:

1. The track is always danger for other road users.
2. Lack flexibility of operation in congested areas.

Due to this tramways are been replaced by trolley buses and other fuel vehicles(internal combustion engined omnibuses)

2. Trolley bus:

It is an electrically operated pneumatic tyred vehicle which doesn't need a fixed track on roadways. It receives power at 600V DC from two overhead conductors.

It consists of single driving axle and a single motor. In trolley bus, there is high adhesion between wheel and ground. The trolley bus can move through traffic a meter or two on each side of centre line of trolley bus.

Usually dc compound motor of output of 50 to 100 kw is employed in it.

Braking in Traction System

The term braking comes from the term brake. Brake is an equipment to reduce the speed of any moving or rotating equipment, like vehicles, locomotives. The process of applying brakes can be termed as braking.

In mechanical braking the speed of the machine is reduced solely by mechanical process but in electrical braking the whole process is depended on the flux and torque directions. The main idea behind different types of electrical barking is the reversal of the direction of the flux. So it is the process of reducing speed of any rotating machine. The application of braking is seen at almost every possible area such as inside the motor used in factories, industrial areas or in locomotives or vehicles. Everywhere the use of mechanical and electrical brakes is very important.

Types of Braking

Brakes are used to reduce or cease the speed of motors. There are various types of motors available (like DC motors, induction motors, synchronous motors, single phase motors etc.) and the specialty and properties of these motors are different from each other, hence the braking methods also differs from each other. Braking can be divided into three parts mainly, which are applicable for almost every type of motors.

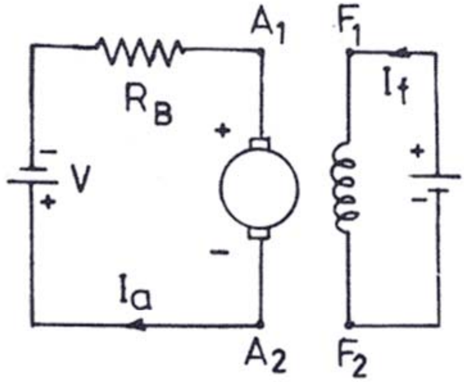
1. Regenerative Braking.
2. Plugging type braking.
3. Dynamic braking

Regenerative Braking

Regenerative braking takes place whenever the speed of the motor exceeds the synchronous speed. This baking method is called regenerative braking because the motor works as generator and supply itself is given power from the load, i.e. motors. The main criteria for regenerative braking is that the rotor has to rotate at a speed higher than synchronous speed, only then the motor will act as a generator and the direction of current flow through the circuit and direction of the torque reverses and braking takes place. The only disadvantage of this type of braking is that the motor has to run at super synchronous speed which may damage the motor mechanically and electrically, but regenerative braking can be done at sub synchronous speed if the variable frequency source is available.

Plugging Type Braking

In this method the terminals of supply are reversed, as a result the generator torque also reverses which resists the normal rotation of the motor and as a result the speed decreases. During plugging external resistance is also introduced into the circuit to limit the flowing current. The main disadvantage of this method is that here power is wasted.



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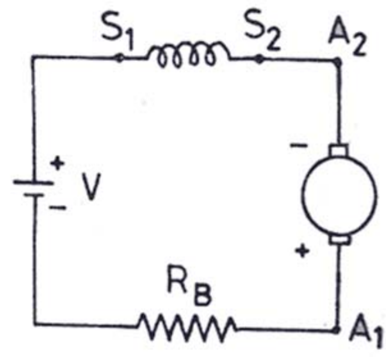

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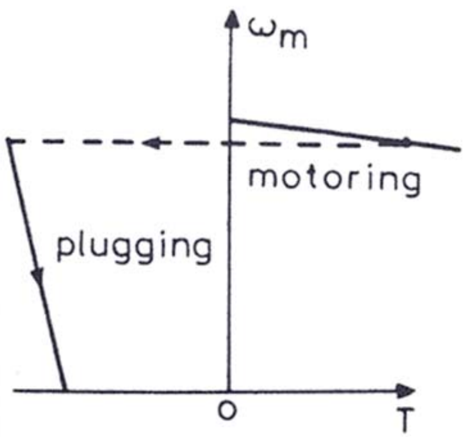

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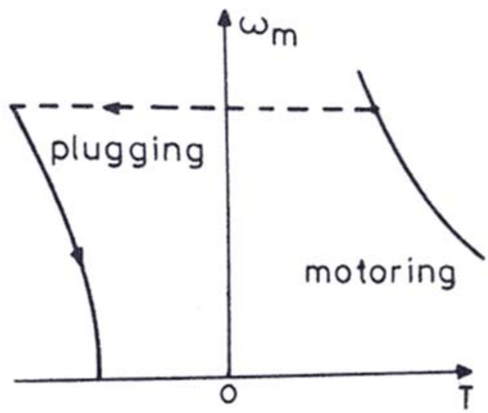
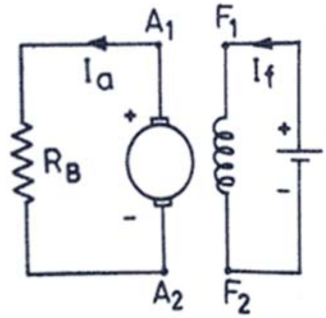


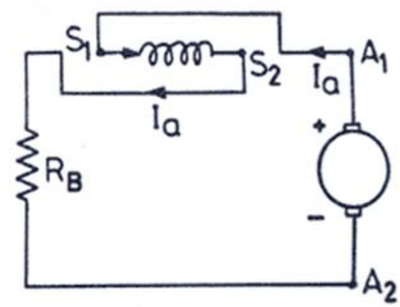
Series

Dynamic Braking

Another method of reversing the direction of torque and braking the motor is dynamic braking. In this method of braking the motor which is at a running condition is disconnected from the source and connected across a resistance. When the motor is disconnected from the source, the rotor keeps rotating due to inertia and it works as a self-excited generator. When the motor works as a generator, the flow of current and torque reverses. During braking to maintain the steady torque sectional resistances are cut out one by one.



Separately excited motor



Series motor

Asssesment

Very Short Answer Questions

1. Define traction and electric traction.
2. List out the different types of railway services.

Short Answer Questions

6. Compare electric traction and mechanical traction.
7. What type of traction would you prefer? Give reason.
8. What are the advantages of electric traction?
9. What are the disadvantages of electric traction?
10. Write short notes of electric trams.
11. Write short notes on trolley bus.
12. Compare AC traction system with DC traction system.

References:

A textbook of electrical engineering, J.B.Gupta

Utilization of electrical power and electrical traction- J.B.Gupta

A course in utilization of electrical energy-G. Garg

http://www.electrical4u.com

http://www.electricalbasicprojects.com

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UNIT – 5

Power Factor

Objectives:

The main objectives of this chapter are:

i) To explain the concept of power factor.
ii) To be familiar with the causes and effects of low power factor.
iii) To explain the methods of correcting low power factor and its advantages.

Course Contents:

Power factor

It is defined as the cosine of angle of lead or lag between the current and the voltage.

$$\text{i.e. p.f.} = \cos\phi$$

The value of p.f. will be leading in a capacitive circuit and it will lagging in a inductive circuit.

Note: It can also be defined as the ratio of resistance to impedance of the circuit or ratio of true power to apparent power.

i.e $p.f. = \frac{resistance}{impedance} = \frac{R}{Z}$

$$p.f. = \frac{truepower}{apparentpower} = \frac{w}{VA} = \frac{kw}{kVA}$$

(S) = Apparent power = I_{rms} X V_{rms}

(P) = Active power = Power dissipated in the circuit (resistor)

$$i.e. P = IV\cos\phi$$

(Q) = Reactive power (VAR) = power dissipated in inductive circuit

$$i.e. pf = \sin\phi$$

$$i.e. S^2 = P^2 + Q^2$$

Quality Factor

It is the reciprocal of power factor.

$$i.e. Q-factor = \frac{1}{p.f.} = \frac{1}{\cos\phi}$$

Causes of low power factor

1. Transformers and ac motors (expect overexcited synchronous motor and some commutative motor) operate at lagging power factor.The p.f. falls due to decrease in load.

   e.g. For induction motor, in full load, p.f.=0.8

   in 50% full load, p.f.=0.7

   in 25% full load, p.f.=0.5

   in no load, p.f.=0.1

2. Due to increase in supply voltage during low-load periods(lunch time, night hours), the magnetizing current of inductive reactance increases and p.f. of whole plant (system) decreases.

3. Due to improper repair and maintenance, the power factor of motor falls. Due to less winding, leakage of flux increases and pf decreases.

   Due to heavily worn out bearings, the rotor may catch at stator.

4. Arc lamp and discharge lamps operate at low power factor.

5. Industrial furnaces such as arc and induction furnaces operate at very lagging p.f.

   Note: If the power factor is less, then the amount of current should be more. $i.e. P = IV\cos\phi$

   i.e. less power factor = more current

   more power factor = less current

Effects of low power factor

less power factor = more current

more power factor = less current

For a given load, at constant voltage

$$P = IV\cos\phi$$

$$P = \sqrt{3}I_L V\cos\phi$$

$$\therefore I_L = \frac{P}{\sqrt{3}V\cos\phi}$$

Thus the high current due to low power factor affects the system.

Effects:

1. The rating of transformers and generators is directly proportional to the output current. So large transformers or generators are required to deliver same load at low p.f.
2. For same power to be supplied, the cross sectional area of bus-bar and the contact area of switch gear should be enlarged.
3. In low power factor, the transmission, distribution cables has to carry more current. So the size of the wire should be increased to maintain current density which increases materials cost.
4. There is more energy loss due to low power factor, which results in poor efficiency.
5. It results in large voltage drops in generators, transformers, transmission lines and distributers.

Advantages of power factor correction

1. Reduction in current through the device
2. Reduction in energy loss in the system
3. Reduction in size of conductor required for transmission and distribution
4. Reduction in kVA, loading of generator and transformers.
5. Reduction in material cost.
6. Increase in voltage level across load.

Methods for power factor correction

The power factor of the devices operating at low power factor can be increased by following ways.

1. By using static capacitor
2. By using synchronous or high power factor machines

1. By using static capacitor

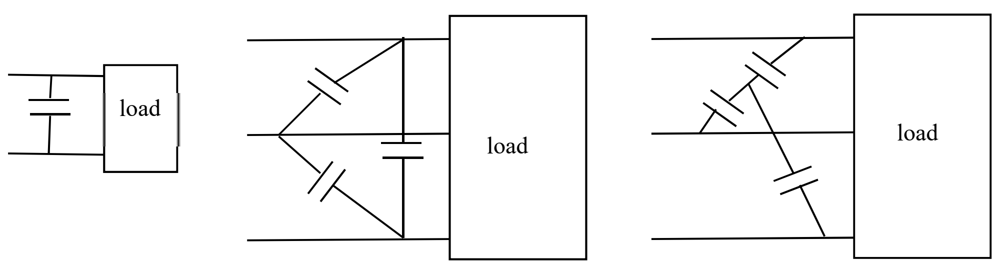
The power factor of the devices operating at low power factor can be increased by connecting a capacitor in parallel with the device.

Advantages

1. Low initial cost
2. Low maintenance cost
3. Easy installation (lighter in weight)
4. Can be operated in normal condition
5. Small losses and higher efficiency

Disadvantges

1. Short life (8-10 yrs)
2. Get damaged under high voltage or uneconomical repair.



The capacitor draws the current leading the voltage by approximately 90°. It neutralizes the quadrature (reactive) and wattless components of current drawn by the device across which it is connected.

Note: Parallel: Shunt capacitor

Factories. Plants, transmission lines
Series: Series capacitor
Long transmission lines

2. Use of synchronous or high power factor machines

i) Synchronous
Constant speed
High efficiency and uniform over variation
It has ability to maintain constant load voltages even in voltage variations. Due to increase in the line voltage, the leading reactive kVA decreases.

ii) Synchronous Condensers
One rexcited synchronous motor at no load condition
Also called synchronous phase comdenser and acts as capacitor

iii) Using high power factor motors

Assesements:

1) Define power factor.
2) Define phase angle.
3) What do you mean by leading and lagging phase?
4) In which type of load, do we have leading power factor? Show it with necessary phase diagram.
5) In which type of load, do we have lagging power factor? Show it with necessary phase diagram.
6) What are the causes of low power factor?
7) What are the effects of low power factor?
8) List the methods of improving the power factor.
9) What are the advantages of improving power factor?
10) Explain how a capacitor connected in parallel across a device improves the power factor?

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A handbook of electrical engineering, S.L.Bhatia
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UNIT -6

Tariff

Objectives:

The main objectives of this chapter are:

- **i.** To explain the concept of tariff and its factors.
- **ii.** To be familiar with different types of tariff.
- **iii.** To know the tariff system of Nepal and calculate the energy consumption.

Course Content:

Tariff

It is defined as the rate of charge for electrical energy consumption. Simply tariff means schedule of rates or charge for supply of electrical energy to different classes of customers.

Objectives:

The main objective of tariff system is to didtribute equally the cost of supplying energy amonge the various classification of use. To fulfill the objective of tariff, it must cover the following items

a) Satisfactory return on total capital investment.
b) Recovery of cost of capital investment in generating, transmitting and distributing equipments.
c) Recovery of cost of operation, supplies and maintenance.
d) Recovery of cost of metering equipments, billing and collecting costs.
e) Recovery of miscellaneous cost.

Factors to be considered for tariff

1) Proper return from each consumer.
2) Encourage customers to use the electricity.
3) Simple and easy to understand for public.
4) Acceptable to all consumers.
5) Encourage consumers to use power during off peak hours.
6) Satisfy consumers of all categories.
7) Penalized for low or poor power factor.

Types of Tariff:

1. **Flat Demand Tariff**

It is one of the earliest form of tariff in which the total demand and consumption is fixed. In this tariff, customers are charged on the basis of number of bulbs or total load installed. All the customers are treated the same and rate is fixed certain amount per lamp.

Eg,

If x = number of loads in kw or lamps

a = rate per kw or lamp

$\therefore$ charge = Rs. $x \times a$

2. **Simple Tariff**

The customer is charged on the basis of number of units used. In this system, the unnecessary use of energy is removed. But the rates are very high per unit.

3. **Flat Rate Tariff**

The different customers are charged at different rates. It is simple and understand by all.

If, energy consumed = x units

Rate = $Rs.a$ per unit

Total charge = $a \times x$

4. **Step Rate Tariff**

A group of tariff of decreasing unit charges for more energy consumption. For eg,

Rs 4/unit	<50 units
Rs 3.5/unit	51-100 units
Rs 3/unit	>100 units

Disadvantages:

There may be unnecessary use of energy to cross the limit.

5. **Block Rate Tariff**

   A given block of energy is charged at higher rates. For eg,

First 25 units	Rs.4/unit
Next 40 units	Rs.3.5/unit
Above	Rs.3/unit

6. **Two part tariff**

   In this type of tariff system, a customer has to pay fixed charge irrespective of consumption of electrical energy.

   Total charge = Fixed charge + Running charge (Extra charge)

   The rate for fixed consumption and extra consumption are different.

7. **Maximum Demand Tariff**

   This system is very similar to two part tariff. In this, maximum demand is measured instead of estimating.

8. **Three part tariff**

   Total charge = Fixed charge + Semifixed + Variable

   Fixed Charge : Expenses on giving supply(Accounting , billing)

   Semifixed : On the basis of maximum demand

   Variable : On the basis of energy consumed

9. **Off peak tariff**

   Peak hours : Morning and early evening

   Off-peak : Night time

This tariff encourages the consumers to use the electricity during off-hours by giving discounts. By doing this, the electricity production plants should not be kept idle or the plants doesn't need to be operated at low efficiency.

10. Power Factor Tariff

The tariffs are determined on the basis of power factor of loads. It is less used (rarely).

Surcharge (Extra charge) – On Each 0.01 fall in power factor

Discount – Each 0.01 increase in power factor

Tariff System in Nepal

The tariff system used in Nepal is the mix up of two part and a block rate tariff system. Like in two part tariff the first part which is fixed includes the service charge which is determined on the basis of energy consumption. And the second part is a variable charge in which the cost for electrical energy consumption is calculated on the basis of block rate tariff. For this, the energy consumption is categorized into 7 different blocks on the basis of load demand of the consumers. And the rate for each blocks are different and is shown below

Rate of Electrical Consumption

Kwh	5A		15A		30A		60 A	
(Monthly)	Service charge	Energy rate	Service charge	Energy rate	Service charge	Energy rate	Service charge	Energy rate
0-20	30	3	50	4	75	5	125	6
21-30	50	7	75	7	100	7	150	7
31-50	75	8.5	100	8.5	125	8.5	175	8.5
51-150	100	10	125	10	150	10	200	10
151-250	125	11	150	11	175	11	225	11
251-400	150	12	175	12	200	12	250	12
400 Above	175	13	200	13	225	13	275	13

Rate for three phase (3-ϕ) supply

1. 10 kVA

   Miminum – 400 units – Rs. 11 per unit - Rs 4400

   Above 400 units – Rs 12 per unit

2. 10kVA – 25kVA

Miminum – 600 units – Rs. 11.5 per unit - Rs 6900

Above 600 units – Rs 12.50 per unit

Numericals.

A customer has a load demand of 6A. The meter reading for a consumer in Ashwin is 7038 and that in Kartik is 7215.Find the total cost of the bill. Also find the amount he has to pay with 2% discount.

Sol^n

Energy consumption = 7215 – 7038

= 177 units

Now,

Charge for energy consumption = 20 X 3 + 10 X 7 + 20 X 8.5 + 100 X 10 + 27 X 11

= Rs. 1597

Service charge = Rs. 125

Total bill amount = Rs. (1597 + 125)

= Rs. 1722

After a discount of 2%,

Total charge = 1722 – 2% of 1722

= Rs. 1687.56

Assesment:

1) Define tariff.
2) What are the factors to be considered for determining the tariff.
3) What are the objectives of tariff?
4) List out the different types of tariff system? Explain them.
5) Name the tariif system used in Nepal. Explain it.

A customer has a load demand of 16A. If the meter reading for month of Baishakh is 9025 and that for the month of Jestha is 9281. Calculate the bill amount on the basis of tariff system of Nepal. Also calculate the amount paid by costomer at a discount of 2%.

Kwh	**5A**		**15A**		**30A**	
(Monthly)	**Service charge**	**Energy rate**	**Service charge**	**Energy rate**	**Service charge**	**Energy rate**
0-20	30	3	50	4	75	5
21-30	50	7	75	7	100	7
31-50	75	8.5	100	8.5	125	8.5
51-150	100	10	125	10	150	10
151-250	125	11	150	11	175	11
251-400	150	12	175	12	200	12
400 Above	175	13	200	13	225	13

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