

GOVERNMENT COLLEGE OF ENGINEERING, KALAHANDI



DEPARTMENT OF ELECTRICAL ENGINEERING

**Lecture notes on Electrical Energy Conservation
and Auditing**
Submitted By
Dr. Soudamini Behera

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5th Semester

Electrical Energy Conservation and Auditing

Module I:

(12 Hours)

Electrical energy conservation: Energy economics- discount rate, payback period, internal rate of return, net present value, and life cycle cost. Energy generation, energy distribution, energy usage by processes, technical and economic evaluation, understanding energy costs, classification of energy conservation measures, plant energy performance, benchmarking and energy performance, matching energy usage to requirement, maximizing energy system efficiency, optimizing the input energy requirements, fuel and energy substitution, and energy balancing.

EB billing- HT and LT supply, transformers, electric motors- motor efficiency computation, energy efficient motors, pumps, fans, blowers, compressed air systems, refrigeration and air conditioning systems, cooling towers, electric heaters (space and liquid), DG-sets, illuminating devices, power factor improvement, and harmonics.

Module II:

(12 Hours)

Electrical energy audit: Energy consumption pattern and scenario of any region; Energy auditing: Need, types, methodology and approaches; Preliminary energy audit methodology (initial site visit and preparation required for detailed auditing, detailed energy audit activities, information and data collection, process flow diagram and process steps); Procedure and techniques: Data gathering, evaluation of saving opportunities, and energy audit reporting; and Energy audit instruments.

Module III:

(06 Hours)

Illumination: Illumination, luminous flux, lumen, luminous intensity, candela power, brightness, glare, types of lighting (incandescent, CFL, and LED), requirements of lux for various purposes, determine the method of lighting, select the lighting equipments, and calculate the lighting parameters.

Text Books:

- [1] Callaghn, P. W." Design and Management for Energy Conservation", Pergamon Press, Oxford, 1981.
- [2] Dryden. I. G. C., " The Efficient Use of Energy", Butterworths, London, 1982.
- [3] Energy Economics -A. V. Desai (Wiley Eastern).
- [4] Handbook of Energy Efficiency - CRC Press

Reference Books:

- [1] Energy Technology, OP Gupta, Khanna Book Publishing
- [2] Handbook of Energy Audits Albert Thumann, William J. Younger, Terry Niehus, 2009.
- [3] Handbook on Energy Audit and Environment Management, Y P Abbi and Shashank Jain, TERI, 2006.

Module - III

Illumination

Illumination? -

The process of measuring light levels and analyzing light fixtures to identify ways to improve energy efficiency.

The goal of an illumination audit is to reduce energy consumption and costs, improve lighting quality and reduce environmental impact.

Here are some steps involved in an illumination audit:

walk-through? -

Observe the quantity and quality of light in the space.

measure illumination levels? -

Use a lightmeter to measure illumination levels at task areas and for general lighting.

Analyze light fixtures? -

Record the type, quantity, location and height of lamps and fixtures.

Identify inefficiencies? -

Note areas where lighting levels are too high, lights are left on unnecessarily or visual discomfort may be inhibiting productivity or safety.

Luminous flux ϕ - (ϕ)

measures the total amount of light emitted from a source in all directions.

It is a measure of the total amount of visible light it emits.

It's measured in lumens (lm). (unit)

Luminous flux is different from radiant flux, which is the total power of light emitted by a light source.

Luminous flux can be used for lighting designs.

Ex: - measure luminous flux per lamp.

Lumen = light o/p = Brightness

The higher the lumen value, the brighter the bulb.

Ex: - A typical 100 watt incandescent light bulb emits about 1700 lumens.

Luminous flux can be measured using a photometer sphere.

Symbol = ϕ

By international agreement or IEC standard the luminous flux or lamp lumen is measured when the lamp is operated under standard conditions.

Luminous flux also depends on the 'luminous intensity' or 'illuminating power' of the source.

A measure of perceived power of light.

Luminous flux (ϕ): - Total light emitted in all directions.

Luminous flux intensity : — (I)

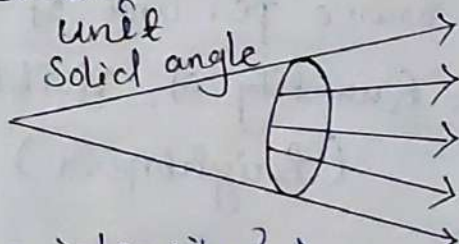
- ① Luminous intensity is also called as illuminating power.
- ② Luminous intensity is the intensity of a light source that can be estimated by human eye.
- ③ It is denoted by 'I'.
- ④ Luminous intensity of given source is always constant.
- ⑤ Luminous intensity of a point source of light is defined as the luminous flux emitted from the source per unit solid angle.

$$I = \frac{d\phi}{d\omega} \rightarrow \begin{array}{l} \text{luminous flux} \\ \downarrow \\ \text{solid angle} \end{array}$$

- ⑥ Unit of luminous intensity is candela (cd).

$$I = \frac{F}{4\pi} = \text{Total flux}$$

- ⑦ Unit of luminous intensity is also called standard candle or candela.

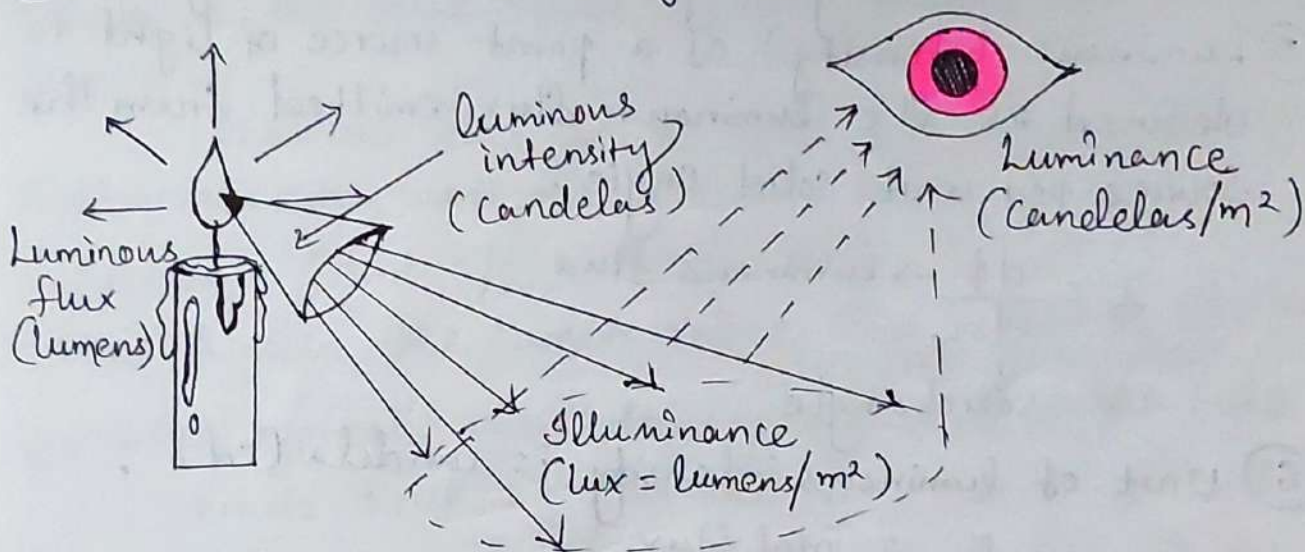


- ⑧ Luminous intensity is a measure of the amount of light emitted by a source in a particular direction. It is a fundamental concept in photometry.

- ⑨ Applications : — Architectural lighting, Automotive lighting & Stage lighting.

Illuminance (E) :-

- ① Luminous flux per unit area.
 - ② It is measured in lux.
 - ③ $E = \frac{I}{d^2}$ → luminous intensity
- ↓
illuminance
- ④ It is the amount of light that falls on a surface.



Lumen :-

The lumen is the SI derived unit of luminous flux, a measure of the total quantity of visible light emitted by a source per unit of time.

Unit of lumen = Quantity of visible light
(brightness)

Candela power :-

Candela is the International SI unit for measuring the luminous intensity of light sources, such as light bulbs and torches.

It is used to monitor lighting in places like museums and galleries.

1 Candela = 12.57 lumens.

The light radiating capacity of a source is called its candle power.

$$CP = \frac{\text{lumens}}{\omega} \rightarrow \text{solid angle}$$

Brightness: —

Brightness refers to how much light appears to shine from something.

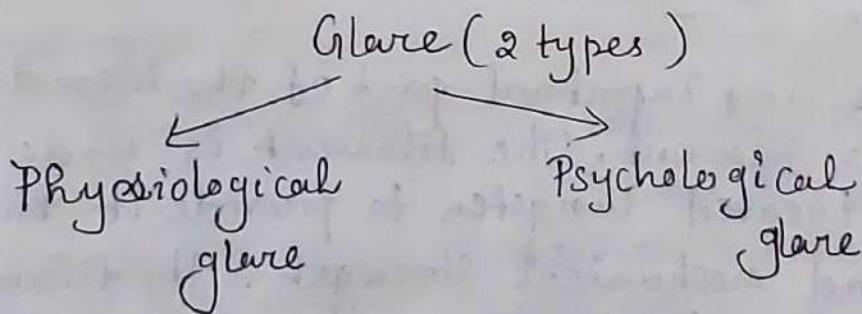
Its physical counterpart is luminance, which is the absolute intensity of light reflected towards the observer's eye.

Glare: —

It is a condition where there is too much light or an inappropriate distribution of light sources, which can make it difficult to see details on objects.

Glare can cause visual discomfort, fatigue and even injury.

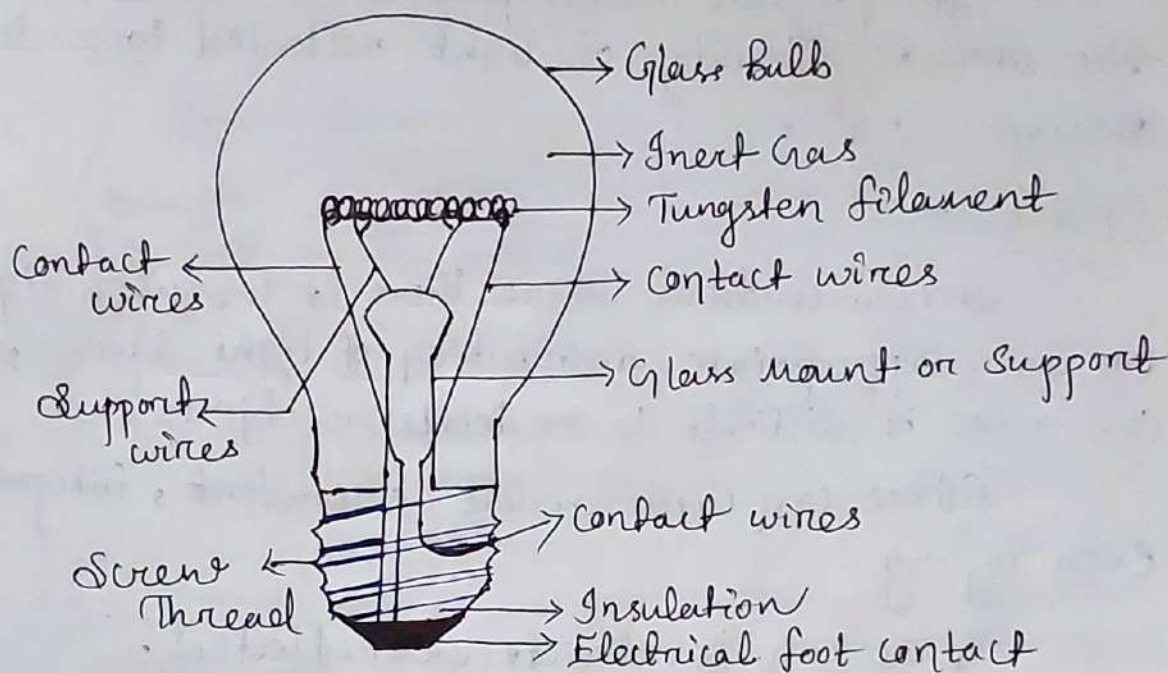
Glare can be direct or reflected.



Types of lighting :-

Incandescent lamp :-

An incandescent lamp, also known as an incandescent light bulb or incandescent light globe. It is a light bulb that produces light by heating a thin metal filament until it glows.



Construction :-

The most important part of the incandescent lamp is its filament. The filament is made of specially treated tungsten to provide it the necessary ductility and mechanical strength. The filament material has a low temperature coefficient of resistance which is positive.

For the tungsten filament, the cold resistance is about $\frac{1}{5}$ th of the hot resistance of the filament and its operating temperature is about 2700°C to

3000°C. The melting point of tungsten is 3400°C. It can work at such a high temperature.

In the incandescent lamp, the tungsten filament supported by the thin support wires, is enclosed in a glass cover which is either evacuated or filled with an inert gas. The inert gas used to fill the lamp is argon and nitrogen, which prevents the oxidation of the filament.

The incandescent lamps below 40W are not filled with the gas. The type and color used for the glass cover produce a vital effect on the quality of light produced by the incandescent lamp.

Working :-

Light is emitted by the heating of a filament. The electric current is passed through a thin metal filament, which causes the filament to heat. Once the filament is heated, it flows to emit light. Argon gas is used in an incandescent lamp.

Advantages :-

- ① These lamps are not costly.
- ② Light output is high.
- ③ Manufacturing cost is less.

Disadvantages :-

- ① Incandescent lamps have short life span.
- ② Not suitable for large areas.

Applications :-

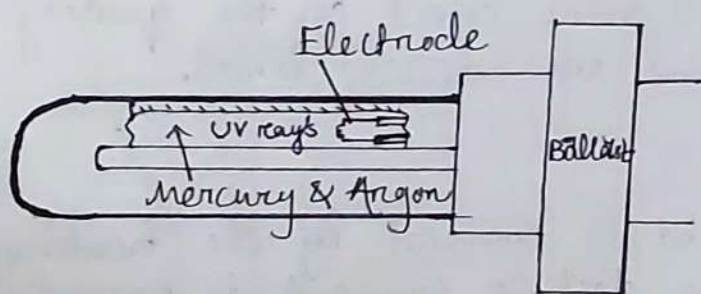
- ① used in household & commercial lightings.
- ② Table lamps, hallway lighting, desk lamps

Compact fluorescent lamps (CFLs)? —

CFLs are energy saving light bulbs that use less energy and last longer than traditional incandescent bulbs.

It works on the principle of gas discharge, CFLs consume very less power.

Construction and working? —



CFLs are widely used for residential as well as commercial lighting. A typical CFL consists of a gas filled tube with two electrodes mounted in an end cap. The tube contains a mixture of argon gas, mercury vapour and liquid mercury at low pressure. The tube is also coated on the inside with three different phosphors.

When the electric supply is connected to the electrodes, an electric arc is created between two electrodes. The electric arc produces the flow of electrons. When the mercury atoms inside the tube are bombarded by these electrons produce ultraviolet radiation. The phosphor coating inside the tube give off light when exposed to the UV radiation.

The circuit of the CFL contains a ballast which provides the initial voltage required to create the starting arc and then limit the current to prevent the lamp from self-destruction.

An electric current passes through a tube containing a small amount of mercury vapour and argon gas, producing ultraviolet light. This light excites a fluorescent coating on the inside of the tube, which then emits visible light.

Applications ? —

It is used in commercial settings like hallways, offices & warehouses.

Advantages ? —

- ① CFLs have longer lifespan.
- ② CFLs produce less heat.
- ③ CFLs lamps start immediately.

Disadvantages ? —

- ① CFLs initial cost is high.
- ② CFLs are not environment friendly.

Light-emitting diode (LED): —

The lighting emitting diode is a p-n junction diode. It is a specially doped diode and made up of a special type of semiconductors. When the light emits in the forward biased, then it is called a light-emitting diode.



It releases light when current passes through it.

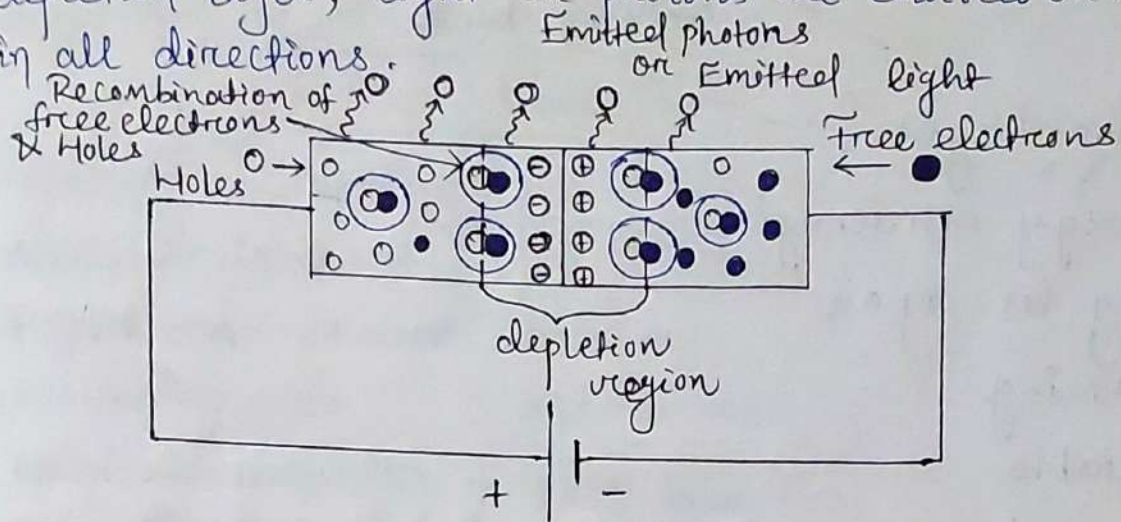
Construction of LED: —

It is designed through the deposition of three semiconductor material layers over a substrate. These three layers are arranged one by one where the top region is a p-type region, the middle region is active and finally, the bottom region is N-type. The three regions of semiconductor materials can be observed in the construction. In the construction the P-type region includes the holes; the N-type region includes electrons whereas the active region includes both holes and electrons.

When the voltage is not applied to the LED, then there is no flow of electrons and holes so they are stable. Once the voltage is applied then the LED will forward biased, so the electrons in the N-region and holes from P-region will move to the active region. This region is also known as the depletion region.

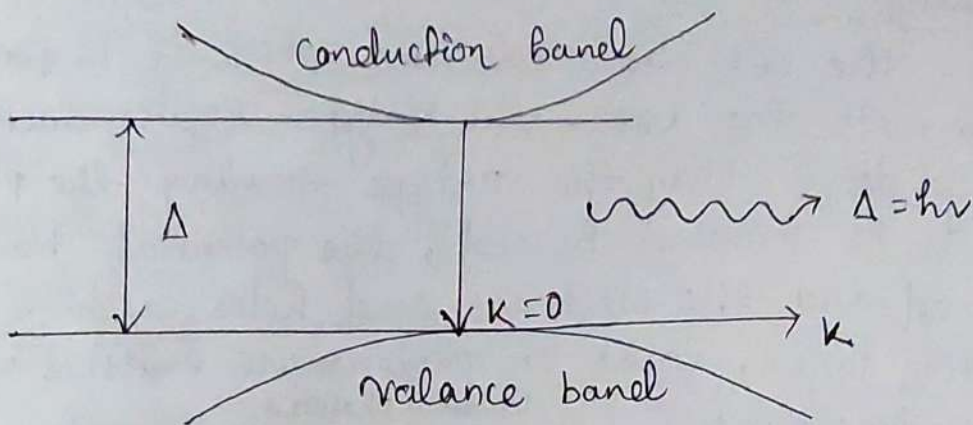
Working of LED :-

The LED diode works when it is forward biased. In this case, the n-type semiconductor is heavily doped than the p-type forming the p-n junction. When it is forward biased, the potential barrier gets reduced and the electrons and holes combine at the depletion layer, light or photons are emitted or radiated in all directions.



The emission of photons in an LED is explained by the energy band theory of solids, which dictates that light emission depends on the material's band gap being direct or indirect. Those semiconductor materials which have a direct band gap are the ones that emit photon. In a direct bandgap material, the bottom of the energy level of conduction band lies directly ^{above} the top most energy level of the valence band on the Energy Vs momentum.

When electrons and hole recombine, energy $E = h\nu$ corresponding to the energy gap Δ (eV) is escaped in the form of light energy or photons where h is the planck's constant and ν is the frequency of light.



Advantages :-

- Energy efficiency
- Long life span
- Dimming
- Reliable
- very cheap
- very simple electronic circuits.

Disadvantages :-

- Initial price (high)
- Temperature dependence
- voltage sensitivity
- Low power
- Blue pollution

Applications :-

- Used in displays, outdoor lighting, Industrial lighting, sensors, Automotive lighting.

Requirements of lux for various purposes :-

Lux is a unit used to measure the intensity of light hitting a surface, typically a wall or floor in a lighting design.

One lux is equivalent to one lumen per square meter. They differ from lumens, which measure the brightness of the light source.

$$1 \text{ LUX} = 1 \text{ lumen/m}^2$$

Reading : 200 lux
Office environment : 400 - 500 lux
Retail environment : 500 lux
Workshop area : 500 - 700 lux
Hospital operation : 1000 lux
Theater

Living rooms : 100 - 150 lux
Bed rooms : 60 - 100 lux
Kitchens : 250 - 300 lux
Bathrooms : 150 - 300 lux
Classrooms : 300 - 500 lux
Libraries : 500 lux
Laboratories : 750 - 1000 lux
Examination rooms : 700 - 1000 lux
Patient rooms : 100 - 200 lux

Lux is a unit of measurement for light intensity, where one lux is equal to one lumen per square meter.

Determine the method of lighting? —

① lumen method? —

Also known as the light flux method, this method is used to calculate the number of lamps and luminaires needed to achieve a specific illumination. It's a simplified method that's often used to plan indoor lighting systems.

② point-by-point method? —

This method is often used to calculate exterior lighting, such as in parking lots or walkways.

③ Zonal cavity method? —

This method takes into account the shape of the room, the colors of the room's surfaces, the lamps and the fixtures.

Inverse square law method also known as point-to-point method is applicable where the illumination at a point due to one or more sources of light is required. The candle power of the sources in the particular direction under direction being known.

If a polar curve of a lamp and its reflector giving the candle power of the lamp in different direction is known, then the illumination at any point within the range of the lamp can be determined from the Inverse square law.

Lumen method also called the ^{Light} Flux method is the method employed for lighting calculation is applicable to those cases where the sources of light are such as to produce an approximate uniform illumination over the working plane or where an average value is required.

Select the lighting equipments? —

LED lights? —

A popular choice due to their energy efficiency and good color rendition.

Light modifiers? —

Devices like diffusers and gels that can alter the quality of light to achieve different effects.

C-stands? —

Versatile stands with a sturdy construction, commonly used to support lighting equipment in photography.

Diffusers? —

Softens the light output, often used in photography to create a more even illumination.

Reflectors? —

Reflect light back onto a subject to fill in shadows.

Softboxes? —

A light modifier that diffuses light to create a softer, more even quality.

Light Stands:

Essential for positioning and adjusting lights precisely.

Automated lighting control systems?

Allow for precise control of lighting with features like dimming and color adjustments.

Calculate the lighting parameters?

$$\text{Lux level} = \frac{\text{Total light o/p (lumens)}}{\text{Area (Square meters)}}$$

$$\text{Total light o/p} = \text{lumens per fixture} \times \text{no. of fixtures}$$

$$N = \frac{F_1 \times A}{L_u \times L L F \times C U}$$

N = number of luminaires required

F_1 = required fc at task height

A = area of room in ft^2

L_u = Initial lumen o/p of luminaire

$L L F$ = light loss factor

$C U$ = coefficient of utilization