15LC09/15TC09 - Electrical Engineering

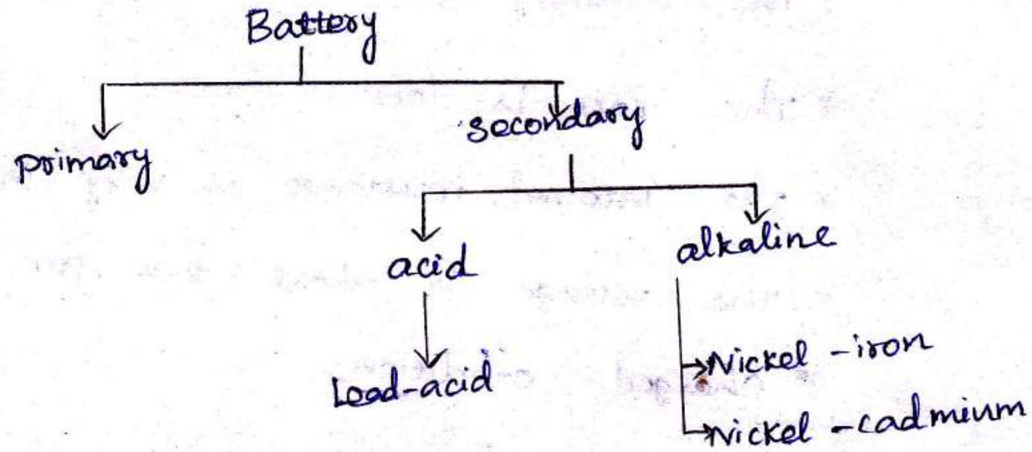
BE - ECE / ETE

Answer key

CIA - II

PART - A

A1. Battery classifications: (2)



These are all the classifications of batteries.

A2. Significance of seperators: (2)

A seperator is a permeable membrane placed between a battery's anode and cathode. The main function of a seperator is to keep the two electrodes apart to prevent electrical short circuits.

A3. Types of Automobile batteries:

* Wet/Flooded Batteries

* Hybrid
* Lead acid
* Dry - charged batteries
* maintanence free batteries

A4. Four advantages of Lead-acid Batteries: (2)

* The capacity is about 100-300 amperes
* The cost is low
* the internal resistance is very low
* the voltage is about 2.2V per cell for a fully charged condition.

A5. Types of Torpedo Batteries: (2)

There are three types of torpedo batteries. They are:

* Silver-Zinc Torpedo Batteries
* primary Torpedo Batteries
* Secondary Torpedo Batteries

A6. Two Advantages of fluorescent Lamp: (2)

* The life of the fluorescent tube is much more than the incandescent lamp
* Low power consumption
* High efficiency
* Using different fluorescent materials various coloured lights can be obtained.
* Instantaneous switching without any warming period.

A7. luminions flux: (2)

It is the energg in the form of light waves radiated per second from a luminous body (lamp). It is denoted by ϕ and measured in lumens. The value of luminous flux specifies the output and efficiency of a given light source.

A8. Candle power: (in terms of solid angle) (2)

Candle power is an absolute unit expressing luminous intensity equal to 0.981 candelas. It expresses levels of light intensity interms of the light emitted by a candle of specific size and constituens.

It is defined as no. of lumens emitted by a soure in a unit solid angle in a given direction.

$$\text{candle power } cp = \frac{\text{lumens}}{\text{solid angle } (\omega)}$$

A9. Given:- (2)

fluorescent lamp rating = 10W

luminous intensity = 35cd

Solution:-

(a) Luminous flux $F = 4\pi I$

$= 4\pi \times 35 \text{ cd}$

$\boxed{F = 440 lm}$

(b) Luminous efficiency $= F/P$

$= \frac{440 lm}{10W}$

$= 44 lm/W$

A10. Luminions intensity: (2)

It is a measure of the brightness for the source of light in comparision with the standard lamp. The luminons intensity of a point source is defined as the luminons flux radiated out per unit solid angle, in that direction.

Let $d\phi$ - luminons flux passing through the solid angle $d\omega$, then

$$\text{Luminons intensity } I = \frac{d\phi}{d\omega}$$

It is measured in candela.

PART-B

B1.
(a)
i) construction and working principle of lead acid battery: (6)

Construction:

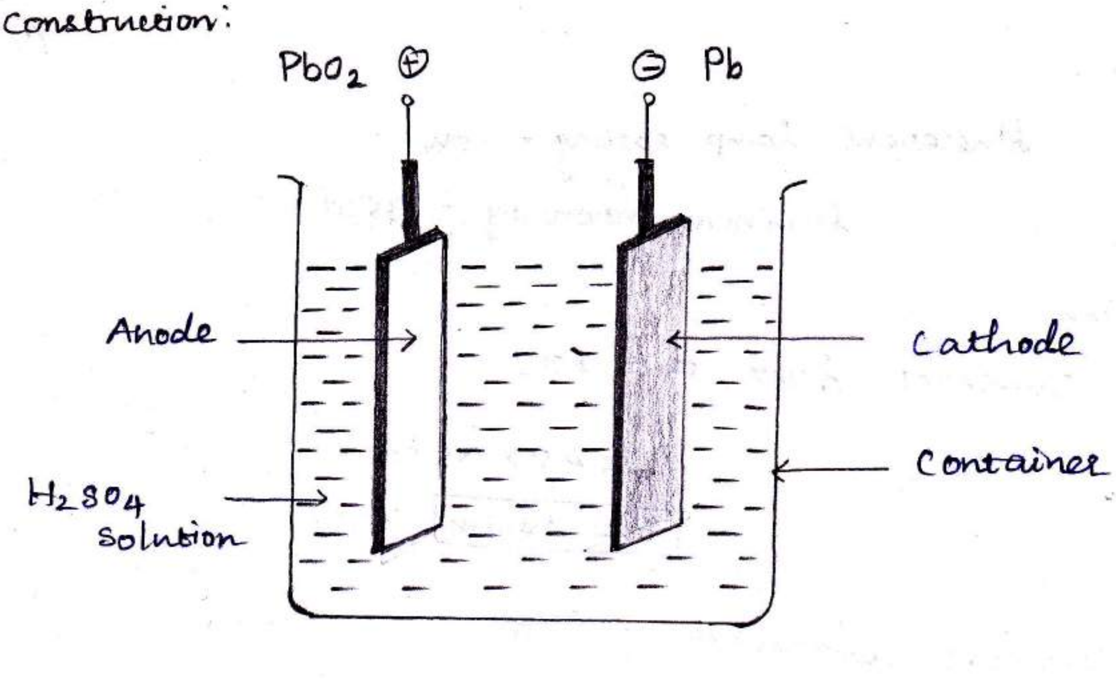


fig. a. Battery construction (2)

The varions parts of lead acid battery are,

Positive place or Anode: It is lead peroxide (PbO_2) plate of chocolate, dark brown colour.

Cathode: It is made up of pure lead (Pb) with grey colour.

Electrolyte: For the necessary chemical action aqueous solution of sulphuric acid (H_2SO_4) is used as an electrolyte.

Seperators: The positive and negative plates are arranged in groups and are placed alternatively. The seperators are used to prevent them from coming in contact with each other short circuiting the cell.

Container: The entire assembly of plates along with the solution is placed in the plastic or ceramic container.

The varions plates are welded to the plate connectors. The plates are immersed in H_2SO_4 solution. Each plate is a grid or frame work. (2)

Working principle:

* When the current passed for the first time through electrolyte, the H_2O in the electrolyte is electrolysed as,

$$H_2O \longrightarrow 2H^+ + O^-$$

* The hydrogen ions as positively charged get attracted towards one of the electrodes which acts as cathode. The oxygen ion as negatively charged gets attracted towards the other lead plate which act as anode. This oxygen chemically combines with lead to form PbO_2. So there exists a potential difference between the positive anode & cathode

which can be used to drive the external circuit. The energy obtained from chemical reaction is drawn out of the battery to the external circuit, which is called discharging.

* During discharging, the directions of the ions are reversed, the H^+ ions now move towards anode and the SO_4^- ions move towards cathode. This is because H_2SO_4 decomposes as,

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^-$$

* At anode hydrogen ions become free atoms and react with lead peroxide alongwith the H_2SO_4 & lead sulphate $PbSO_4$ results as,

$$PbO_2 + H_2SO_4 + 2H \longrightarrow PbSO_4 + 2H_2O \quad \text{at anode}$$

$$Pb + SO_4 \longrightarrow PbSO_4$$

(2)

(ii) Comparision of lead acid battery with Ni-cd & Ni-Fe batteries: (4)

S. No	particular	Lead acid	Ni-cd	Ni-Fe
1	positive & -ve plate	PbO_2 & Pb	$Ni(OH)_3$ & Cd	$Ni(OH)_3$ & Fe
2.	Electrolyte	H_2SO_4	KOH	KOH
3.	Internal resistance	low	low	high
4.	Ah efficiency	90–95%	70–80%	70–80%
5.	cost	Less expensive	Twice the Lead acid cell	Twice the Lead acid cell
6.	Life	1250 charges and discharges	very long life.	About 8 to 10 years
7.	mechanical strength	poor	Good	Good
8.	Ah capacity	depends on discharge rate & temp	Depends only on temperature	Depends only on Temperature.

(iii) construction of Nickel-Iron Battery: (5)

In this cell,

positive plate → Nickel hydroxide [$Ni(OH)_3$]

Negative plate → Spongy iron [Fe]

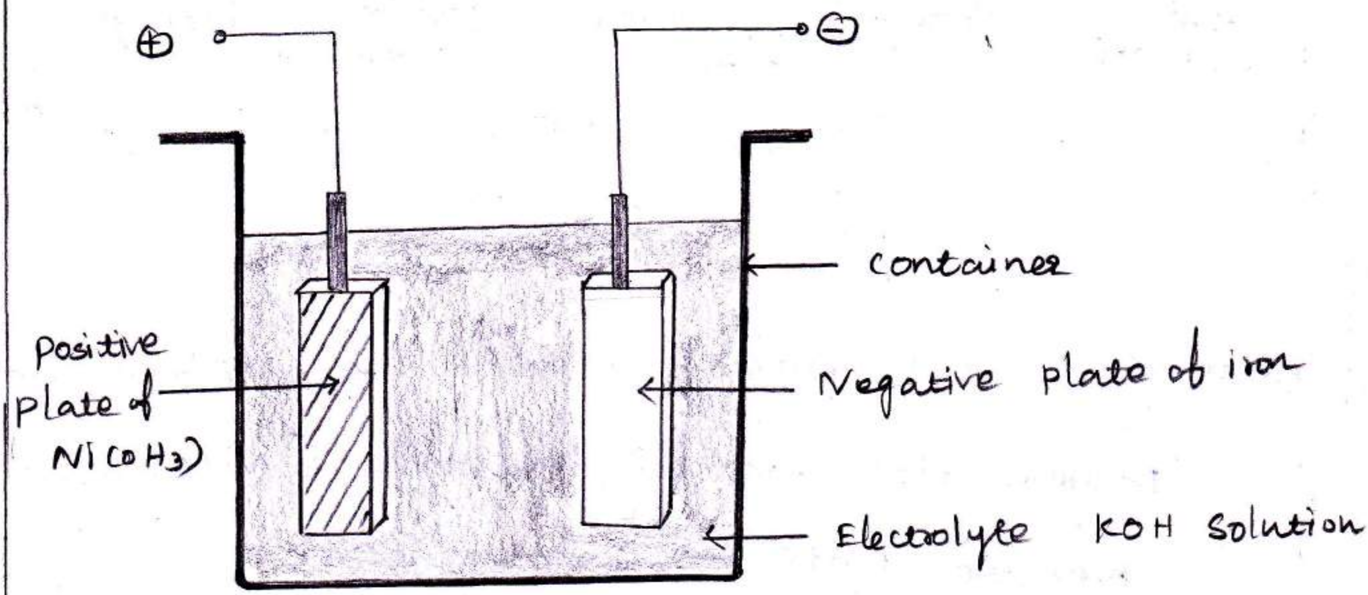


fig. b. construction of Nickel-iron cell (2)

* The electrolyte is an alkali of 21% solution of potassium hydroxide solution (KOH). The insulated rods are used to seperate the positive & negative plates.

working principle:

* In a charged condition, the material of positive plate is ($Ni(OH)_3$) and that of negative plate is iron. when it is connected to load and starts discharging, the nickel hydroxide gets converted to lower nickel hydroxide as $Ni(OH)_2$

while the iron on negative plate gets converted to ferrous hydroxide. when charged again, reversible reaction takes place, regaining the material on each plate. (2)

$$2\,Ni(OH_3) + 2\,KOH + Fe \underset{\text{charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} 2\,Ni(OH_2) + 2\,KOH + Fe(OH_2)$$

+ve plate | electrolyte | -ve plate | positive plate | electrolyte | -ve plate

Eqn 9. Total reaction (1)

(B1) (b) (i) construction and working principle of Ni-cd battery: (6)

positive plate → Nickel hydroxide [Ni(OH)$_3$]

Negative plate → Cadmium (Cd).

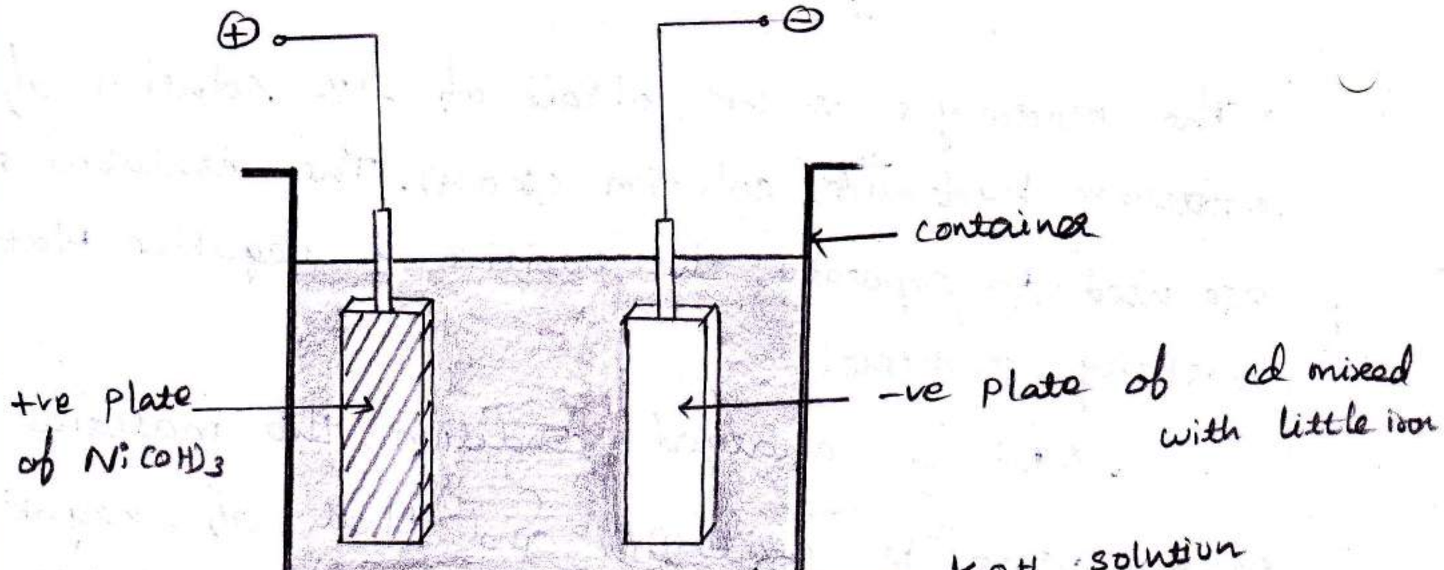


fig. c. construction of Ni-cd cell (2)

* The electrolyte used is again 21% solution of KOH in distilled water. The specific gravity of the electrolyte is about 1.2.

* Little iron is added to cadmium to get -ve plate. The iron prevents the caking of active material and losing its porosity.

working :

* In this cell also, in working condition $Ni(OH)_3$ gets converted to lower nickel hydroxide as $Ni(OH)_2$ while cadmium hydroxide $Cd(OH)_2$ gets formed at the negative plate. During charging reverse reaction takes place. The electrolyte does not undergo any (3) chemical change.

$$\underset{+ve\ plate}{2Ni(OH)_3} + \underset{Electrolyte}{2KOH} + \underset{-ve\ plate}{Cd} \underset{charge}{\overset{discharge}{\rightleftharpoons}} \underset{positive\ plate}{2Ni(OH)_2} + \underset{Electrolyte}{2KOH} + \underset{-ve\ plate}{Cd(OH)_2}$$

(1)

Eqn. 2. Total reaction

(ii) comparision of primary and secondary cells: (4)

primary cells	secondary cells
* Electrical energy is directly obtained from chemical energy	* Electrical energy is present in the cell in the form of chemical energy and then converted to electrical energy.
* The chemical actions are irreversible.	* The chemical reactions are reversible.
* Polarization is present	* polarization is absent
* Low efficiency	* Efficiency is high
* capacity is low	* Higher capacity
* Less cost	* High initial cost
* No maintanance required	* Frequently charging & other maintenance required.
* Eg. dry cell, mercury cell, zinc-chloride cell	* Eg. Nickel-iron, lead acid and Nickel-cadmium.

(iii) Ampere-hour efficiency: (5)

* It is defined as ratio of output in ampere-hours during discharging to the input in ampere-hours during charging. It is denoted as η_{Ah}. (1)

$$\eta_{Ah} = \frac{\text{Ampere-hours on discharge}}{\text{Ampere-hours on charge}}$$

$$\% \, \eta_{Ah} = \left[\frac{\text{current} \times \text{Time on discharge}}{\text{current} \times \text{Time on charge}}\right] \times 100$$

* For lead-acid battery, it ranges between 80% to 90%.

(2)

Watt-hour efficiency:

* It is defined as the ratio of output in watt-hours during discharging to the input in watt-hours during charging. It is denoted as η_{wh}.

$$\eta_{wh} = \frac{\text{watt-hours on discharge}}{\text{watt-hours on charge}}$$

$$\% \, \eta_{wh} = \left\{\frac{\text{Voltage during discharge (avg)} \times \text{current} \times \text{time at discharge}}{\text{voltage during charge (avg)} \times \text{current} \times \text{time at charge}}\right\} \times 100$$

$$\% \, \eta_{wh} = \eta_{Ah} \times \frac{\text{average voltage during discharge}}{\text{average voltage during charge}}$$

* For lead acid battery, watt-hour efficiency ranges between 70% to 80%.

(2)

B2 (a) (i) construction of Fluorescent Lamp: (6)

+ The figure d shows the constructional details of fluorescent lamp. It consists of a long glass tube which is internally coated with a suitable amount of fluorescent powder. A small amount of mercury along with a little quantity of argon gas is also filled in the tube.

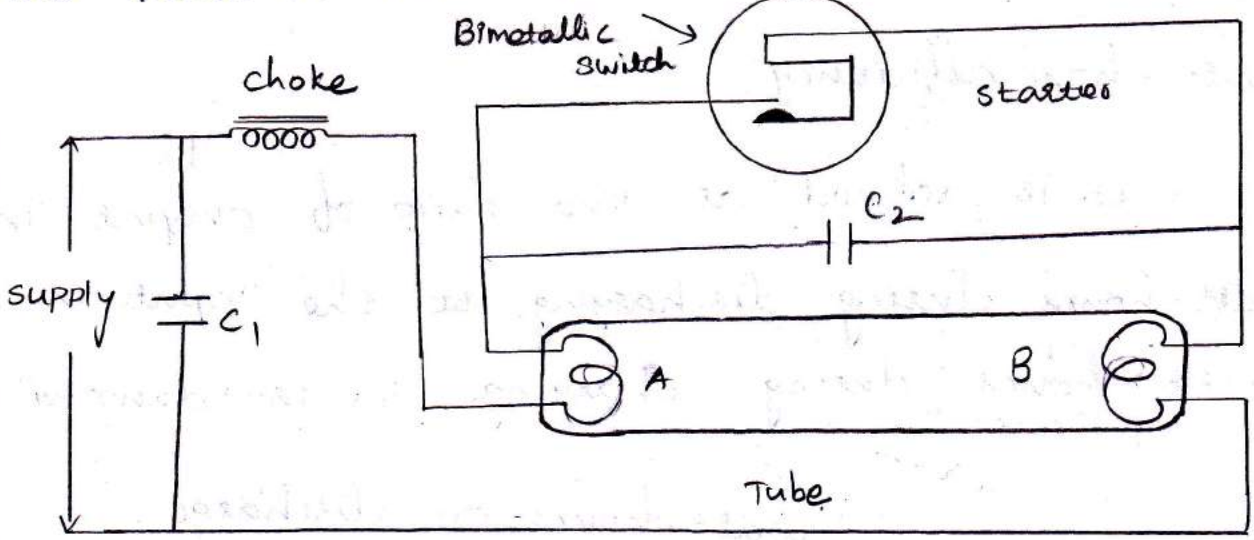


fig. e. Fluorescent tube

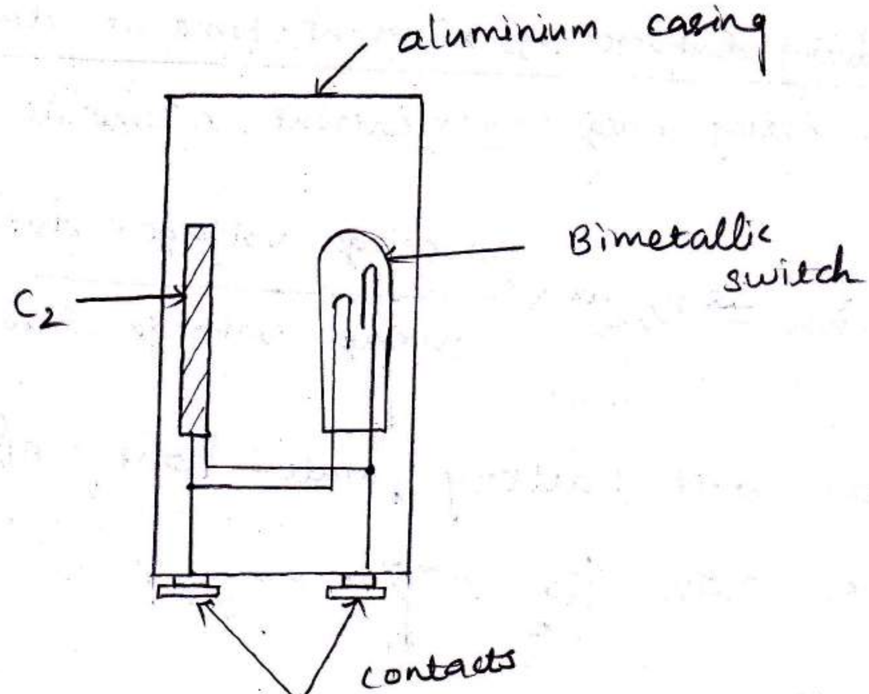


fig. f. Glow type Starter

(2).

* There are two electrodes A and B made up of coiled tungsten filament coated with an electron emitting material. The control circuit of the tube contains glow type starter, choke L and two capacitors C_1 and C_2.

* Figure b shows a cut section of a glow type starter. There are 2 electrodes of which one is fixed while other is U shaped bimetallic strip made of two different metals. These electrodes are sealed in a glass bulb which is filled with a mixture of helium and hydrogen. the contacts are normally open. (2)

working:

* When supply is switched ON, as electric arc is established between the electrodes of the starter due to flow of current through small air gap b/w the electrodes. Due to the arc heat is produced which is sufficient to bend the bimetallic strip which makes contact with fixed electrode. This closes the circuit and therefore choke carries large current. Once the electrodes close, arc vanishes and bimetallic strips cools down again.

* Now the electrodes become hot & due to cooling choke circuit opens. The ct through the choke coil is suddenly reduced to small value. This change in current

filled in inner tube to make discharge self starting. sodium vapour is chemically very active. The glass of the tube is made up of suitable material to resist this action.

* To maintain the correct temp in the discharge, it is placed in an evacuated outer tube. The outer tube reduces the heat loss. The transformer included in the circuit heats the cathode while the choke stabilizes the discharge.

(2)

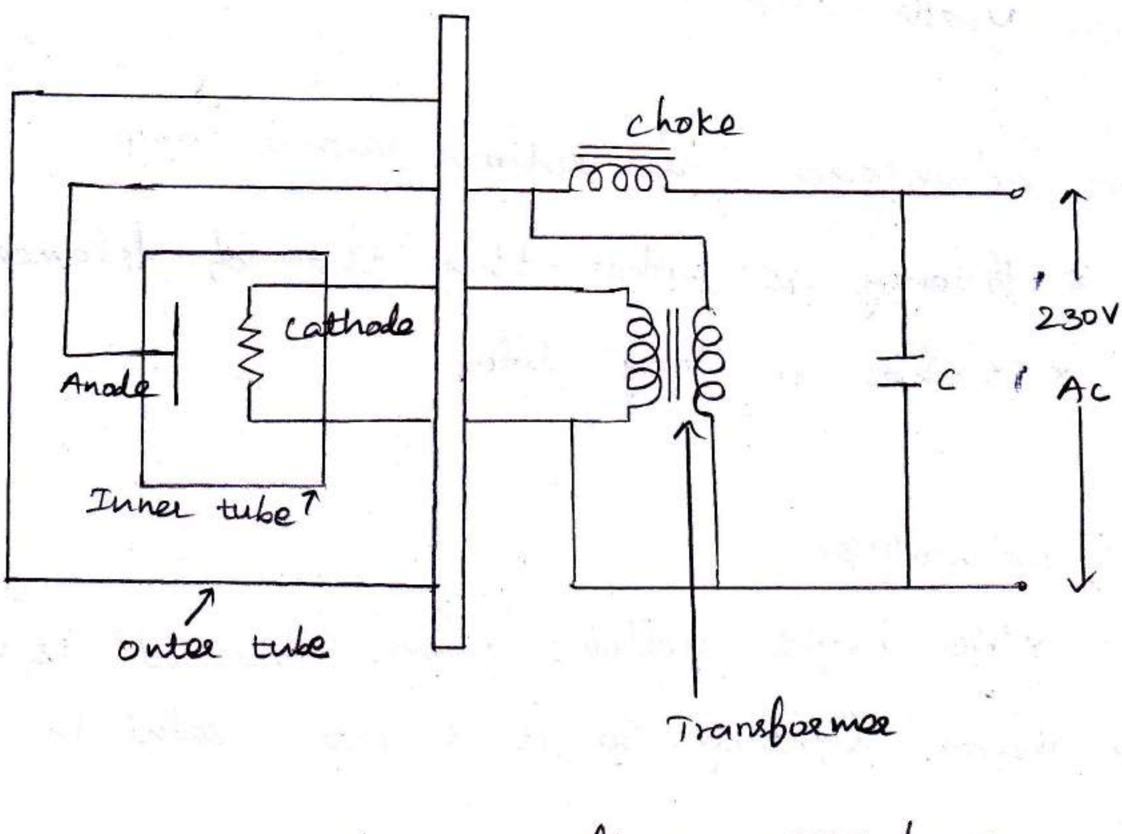


fig. 9. sodium vapour lamp

(2)

working:

* when the lamp is switched on, the discharge is first established through the neon or argon gas, this gives out reddish colour. After some time that heat is developed due to this discharge which vaporizes sodium vapour. In this way lamp starts its normal operation, giving yellow colour. Capacitor C is connected to have a better power factor. The operating temperature of this is about 300°C. These lamps are commonly used for illumination of roads, good yards, airports etc. (1)

(iii) Two advantages of sodium vapour Lamp: (4)

* Efficiency is higher than that of filament lamps
* It has a long life.

Dis advantages:

* The bright yellow colour obtained is not suitable for indoor lighting. So it is not useful in houses
* For necessary output, long tubes are required.
* For giving full output, some time (10 minutes) is required

8e (b)

(b)

(i) construction of mercury vapour Lamp: (6)

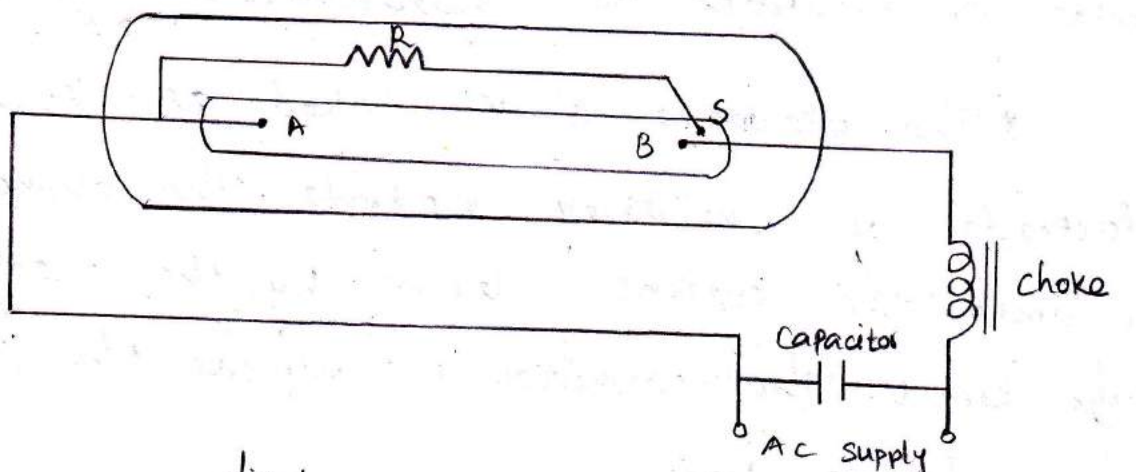


fig.h. Mercury vapour lamp (2)

* The lamp consists of two bulbs, inner bulb & outer bulb. The electric discharge takes place in the inner bulb. The outer bulb protects the inner bulb and reduces loss of heat. The inner bulb consists of a small amount of mercury and argon gas. The two electrodes E and B are made up of electron emitting material. Three electrodes B, E & S are provided in the inner bulb. The electrode 'E' is connected to electrode S through a high resistance. Choke (L) & capacitor C forms the control circuit of Lamp. (2)

working:

* When the supply is switched on, the initial discharge is established b/w electrodes B & S through the argon gas and then between electrodes B & E. The heat produced

due to this discharge is sufficient to vaporise mercury and discharge through the mercury vapour takes place. In this normal operation of the lamp, it emits or radiates its characteristics light.

* The electrode 'S' is called as starting electrode or auxilliary electrode. The choke serves to limit the current drawn by the electrodes to a safe limit. The capacitor C improves the power factor of the lamp.

* These lamps are widely used for outdoor street lighting where a high illumination is necessary, where the colour of the light is not important. (2)

(ii) Laws of Illumination: (5)

(i) Inverse square Law of Illumination:

* The law states that the illumination at a point on any surfaces is inversely propotional to the square of the distance between the surfaces and the light source provided that the distance is sufficiently large so that source can be considered as a point source.

Proof: Let consider surface of area A_1 & A_2 at a distance of r_1 & r_2 from point source O. The luminus intensity of point source is I & solid angle ω.

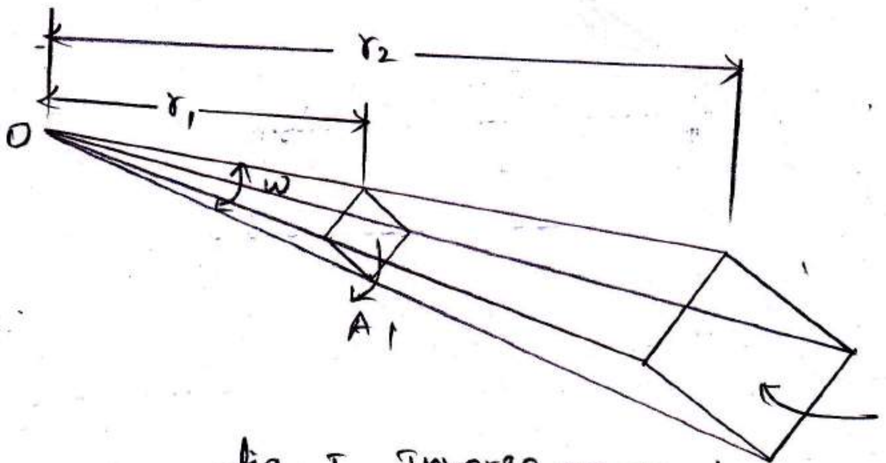


fig. I. Inverse sqare law

Luminous flux radiated in $\omega = I \times \omega lm$

$$\omega = \frac{A}{r^2} \quad | \quad A = \text{area}$$

$$A_1 = \omega \times r_1^2 \; ; \; A_2 = \omega \times r_2^2$$

∴ Illumination on surface of area $A_1 = \frac{\text{flux}}{\text{area}}$

$$= \frac{I\omega}{A_1} \; lm/m^2$$

$$E_1 = I / r_1^2$$

$|||^{ly}$

$$A_2 = I / r_2^2$$

$$\boxed{\frac{E_1}{E_2} = \frac{r_2^2}{r_1^2}}$$

The above eqn proves that illumination at a point on surface is inversely proportional to the square of its distance from that point source. (2)

Lambert's cosine law:

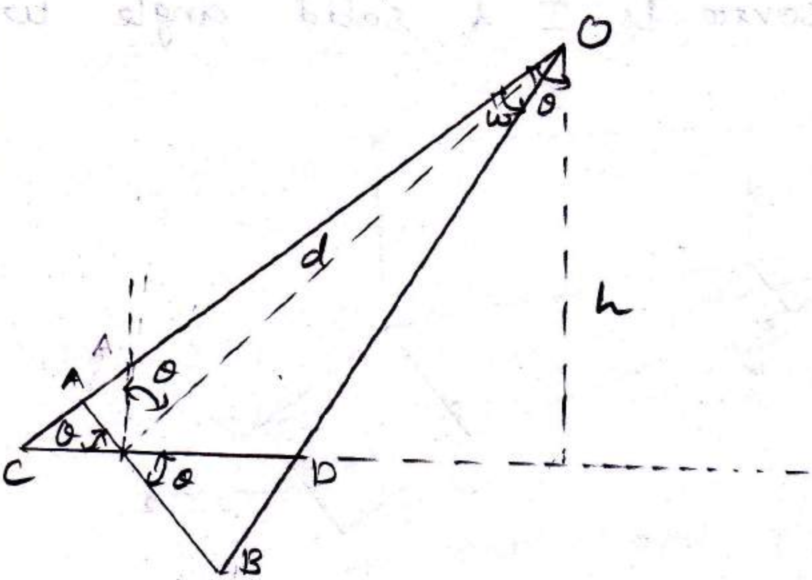


fig. 5. Lamber's cosine law.

* Illumination at a point on any surface is proportional to the cosine of angle which the incident luminous flux makes with the normal to the surface at that point.

proof:

Let AB ⊥ EO.

$$AB = CD \cos\theta$$

Illumination of AB $\cdot$ $E_{AB} = \frac{Flux}{Area} = \frac{I \times \omega}{Area\ AB}$

Illumination of CD $\cdot$ $E_{CD} = \frac{I\omega}{Area\ CD}$

$$= \frac{I\omega}{\left(\frac{Area\ AB}{\cos\theta}\right)} \quad (2)$$

$$E_{CD} = \frac{I\omega}{Area \cdot AB} \times \cos\theta$$

$$\boxed{E_{CD} = E_{AB} \times \cos\theta}$$

* The above eqn states that the illumination at a point on a surface is proportional to cosine of the angle which makes with the normal to the surface at that point.

Cosine cube law:

$$h = d\cos\theta \quad \text{[From fig. J]}$$

$$\text{Illumination of } CD = \frac{I\omega}{Area\ AB} \times \cos\theta$$

$$= \frac{I}{\left(\frac{Area\ AB}{\omega}\right)} \times \cos\theta$$

$$= \frac{I}{d^2}\cos\theta \quad \text{[by ISL]}$$

$$= \frac{I}{h^2/\cos^2} \times \cos\theta \quad \Big| \; d = \frac{h}{\cos\theta}$$

$$\boxed{E_{CD} = \frac{I}{h^2} \times \cos^3\theta} \quad (1)$$

∴ This expression is known as cosine cube law.

(b) (iii) Light: (4)

It is defined as a part of energy which is radiated from a body in the form of waves and sensed by human eyes. (1)

Radiant efficiency:

A body radiates energy when its temp is increased. The entire energy is not in the form of light but some may be in the form of other type of energy such as heat. So radiant ~~energy~~ efficiency is defined as the ratio of energy radiated as light by a body when its temperature is increased to the total energy radiated by the body.

$$\text{Radiant efficiency} = \frac{\text{Energy radiated as a light energy}}{\text{Total energy radiated by the body}}$$

M.K.

K.n.

(3)