SIDDHARTH INSTITUTE OF ENGINEERING & TECHNOLOGY: PUTTUR-517 583

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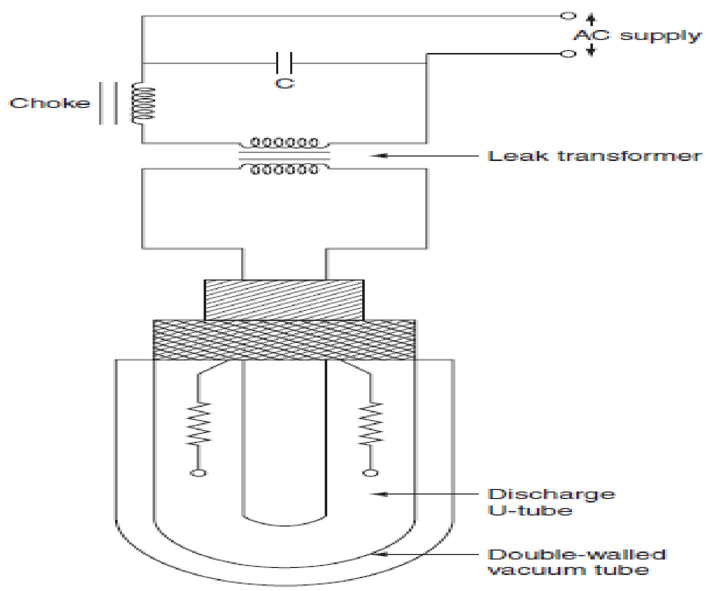
QUESTION BANK (ANSWERS)

Subject with Code :APPLICATIONS OF ELECTRICALPOWER (20EE0243)
Course & Branch. B.Tech - ECE
Year & Semester : ** IV B.Tech. & I - Semester **Regulation: R20

UNIT-I
ILLUMINATION

1	a)	**Draw and explain the operation of sodium vapor lamp with neat diagram.**	**[5M]**
		Ans. A sodium vapor lamp is a cold cathode and low-pressure lamp. A sodium vapo discharge lamp consists of a *U*-shaped tube enclosed in a double-walled vacuum flask, to keep the temperature of the tube within the working region. The inner *U*-tube consists of two oxide-coated electrodes, which are sealed with the ends. These electrodes are connected to a pin type base construction of sodium vapor lamp is shown in Fig  Working : Initially, the sodium is in the form of a solid, deposited on the walls of inner tube. When sufficient voltage is impressed across the electrodes, the discharge starts in the inert gas, i.e., neon; it operates as a low-pressure neon lamp with pink color. The temperature of the lamp increases gradually and the metallic sodium vaporizes and then ionizes thereby producing the	

		monochromatic yellow light. This lamp takes 10–15 min to give its full light output. The yellowish output of the lamp makes the object appears gray. In order to start the lamp, 380 – 450 V of striking voltage required for 40- and 100-W lamps. These voltages can be obtained from a high reactance transformer or an auto transformer.The efficiency of sodium vapor lamp is lies between 40 and 50 lumens/W. Normally, these lamps are manufactured in 45-, 60-, 85- and 140-W ratings.The average light output of the lamp is reduced by 15% due to aging These lamps are mainly used for highway and street lighting, parks,railway yards, general outdoor lighting, etc. Advantages : • Its efficiency is high. • Longer life. • It can be easily disposed of. • The operating temperature is low. • Energy-efficient. Disadvantages : The **disadvantages of sodium vapor lamps** include the following. • Color temperature • It needs ballast • It needs controlling elements for controlling glare. • It is not applicable in color identification areas. • Sodium element is dangerous because it can catch fire in contact with air. • It needs an extra transformer	
	b)	**A lamp having a uniform cp of 100 in all direction is provided with a reflector which directs 60% of the light uniformly on to a circular area of10m diameter. The lamp is hung 5m above the area. Calculate the illumination at the center**	**[5M]**
		Given that Candle power of the lamp, cp = 300 Height of the lamp, h = 5m Efficiency of the reflector = 60 %. The illumination at the Centre without reflector $E = \frac{cp}{h^2} = \frac{100}{5^2} = 4$ lux. The illumination at the centre with reflector is also same. since the reflector directs the light uniformly on the surface. $\boxed{\therefore E = 4 \text{ lux}}$	

2		State and explain laws of illumination briefly.	[10M]

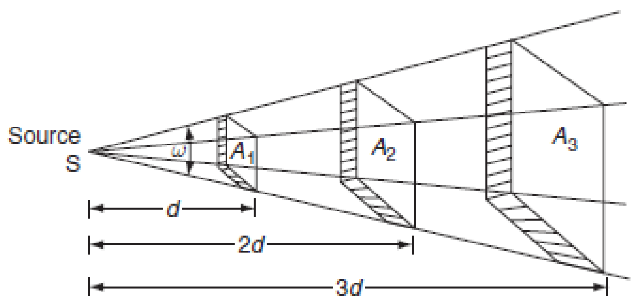
This law states that ‘the illumination of a surface is inversely proportional to the square

of distance between the surface and a point source’.

Proof:
Let, ‘*S*’ be a point source of luminous intensity ‘*I*’ candela, the luminous flux emitting

from source crossing the three parallel plates having areas *A* *A* , and *A* square meters, 1 2 3

which are separated by a distances of *d*, 2*d*, and 3*d* from the point source respectively as
shown in Fig. 6.10.



For area A_1, solid angle $\omega = \dfrac{A_1}{d^2}$.

aching the area A_1 = luminous intensity × solid angle

$= I \times \omega = I \times \dfrac{A_1}{d^2}$.

∴ Illumination 'E_1' on the surface area 'A_1' is:

$$E_1 = \frac{\text{flux}}{\text{area}} = \frac{IA_1}{d^2} \times \frac{1}{A_1}$$

$$\therefore E_1 = \frac{I}{d^2} \quad \text{lux.}$$

Similarly, illumination 'E_2' on the surface *area* A_2 is:

$$E_2 = \frac{I}{(2d)^2} \quad \text{lux}$$

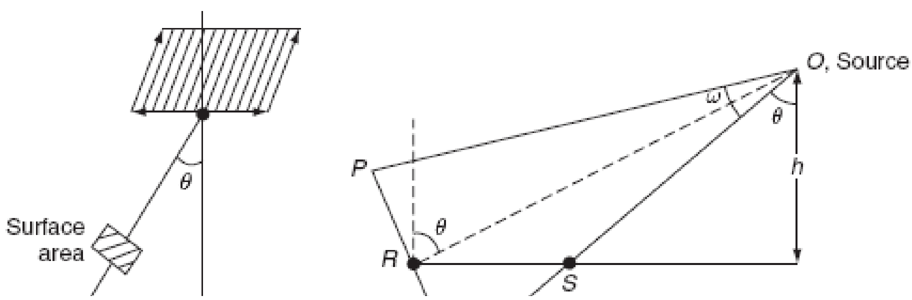
and illumination 'E_3' on the surface area A_3 is:

$$E_3 = \frac{I}{(3d)^2} \quad \text{lux.}$$

$$E_1 : E_2 : E_3 = \frac{1}{d^2} : \frac{1}{(2d)^2} : \frac{1}{(3d)^2}.$$

Lambert's cosine law

This law states that 'illumination, E at any point on a surface is directly proportional to the cosine of the angle between the normal at that point and the line of flux'.



Let

PQ = The surface area normal to the source and inclined at 'θ' to the vertical axis.

RS = The surface area normal to the vertical axis and inclined at an angle θ to the source 'O'.

$PQ = RS \cos\theta.$

$\therefore$ The illumination of the surface $PQ, E_{PQ} = \dfrac{\text{flux}}{\text{area of } PQ}$

$$= \frac{I \times \omega}{\text{area of } PQ} = \frac{I}{\text{area of } PQ} \times \frac{\text{area of } PQ}{d^2} \quad [\therefore \omega = \text{area}/(\text{radius})^2]$$

$\therefore$ The illumination of the surface $RS, E_{RS} = \dfrac{\text{flux}}{\text{area of } RS} = \dfrac{\text{flux}}{\text{area of } PQ/\cos\theta}$

$[\therefore PQ = RS \cos\theta]$

$$= \frac{I}{d^2}\cos\theta.$$

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

$$\text{or } d = \frac{h}{\cos\theta}.$$

Substituting '*d*' from the above equation in Equation (6.10):

$$\therefore E_{RS} = \frac{I}{(h/\cos\theta)^2} \times \cos\theta = \frac{I}{h^2}\cos^3\theta \qquad \textbf{(6.11)}$$

$$\therefore E_{RS} = \frac{I}{d^2}\cos\theta = \frac{I}{h^2}\cos^3\theta \qquad \textbf{(6.12)}$$

where d is the distance between the source and the surface in m, h is the height of source from the surface in m, and I is the luminous intensity in candela.

2		b) Six lamps are used to illuminate a certain room. If the luminous efficiency of each lamp is 12 lumens/watt and the lamps have to emit a total lux of 10,000 lumens, calculate (i) The mean spherical luminous intensity (ii) The cost of energy consumed in 3 hours if the charge for electrical energy is 50 paise per unit.	

Given that

Luminous Efficiency = 12 lumens/watt.

Flux, ϕ = 10,000 lumens

i) Mean Spherical Luminous intensity

$$I = \frac{F}{4\pi} = \frac{10{,}000}{4\pi}$$

$\boxed{I = 7853.98}$ Candela.

		ii) cost of Energy consumed in 3 hours For 1 unit 50 paise = Rs 0.50/- Lamp Efficiency, $\eta = \frac{\text{Total flux}}{\text{Electrical i/p}}$ $= \frac{10,000}{12}$ $= 833.33$ watts/lamp cost per unit = 1 kwh = Rs 0.50/- for (833.33 watts) * (3 hours) = 833.33 × 3 = 2500 wh = 2.5 kwh cost for 2.5 kwh for lamp = (2.5) (x) (0.50) = Rs 1.25/- for 6 lamps = 1.25 × 6 = Rs 7.50/-	
3	a)	If a lamp of 200 cp is placed 1m below a plane mirror which reflects 90% of light falling on it, determine illumination at a point 3 m away from the foot of the lamp which is hung 4 m above ground.	

At point A,

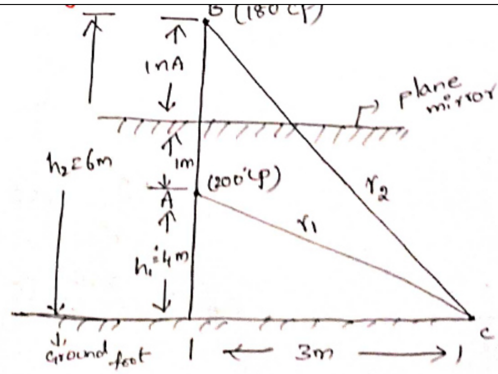
$I_1 = 200\ cp$

$h_1 = 4m$

$d_1 = 3m$

$r_1 = \sqrt{h_1^2 + d_1^2}$

$r_1 = \sqrt{4^2 + 3^2} = 5m.$



$$\cos\theta_1 = \frac{h_1}{r_1} = \frac{4}{5} = 0.8$$

At point 'B'

$I_2 = 90\%$ of I_1

$$= \frac{90}{100}(200)$$

$h_2 = 6m$

$d_2 = 3m$

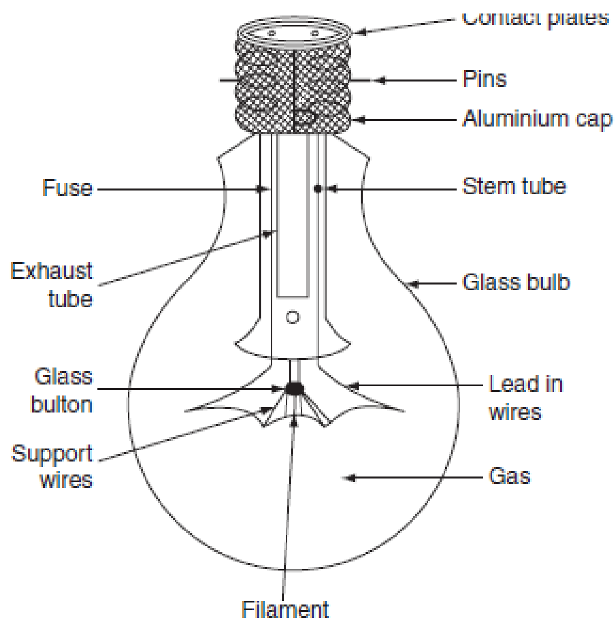
$$r_2 = \sqrt{h_2^2 + d_2^2}$$

$$= \sqrt{6^2 + 3^2}$$

$r_2 = 6.71m.$

$$\cos\theta_2 = \frac{h_2}{r_2} = \frac{6}{6.71} = 0.894$$

		Illumination at point 'c', $E_c = E_1 + E_2$ $$E_c = \frac{I_1}{r_1^2}\cos\theta_1 + \frac{I_2}{r_2^2}\cos\theta_2$$ $$= \frac{200}{(5)^2}(0.8) + \frac{180}{6.71}(0.894)$$ $$= 6.4 + 3.57$$ $$\boxed{E_c = 9.974 \text{ lux.}}$$	
	b)	Explain with sketch the principle and operation of incandescent lamp and enumerates its advantages and disadvantages.	
		Incandescent lamps When the filaments of these lamps are heated to high temperature, they emit light that falls in the visible region of wavelength. Tungsten-filament lamps are operating on this principle The chemically pure tungsten is very strong and fragile. In order to make it into ductile, tungsten oxide is first reduced in the form of gray power in the atmosphere of hydrogen and this powder is pressed in steel mold for small bars; the mechanical strength of these bars can be improved by heating them to their melting point and then hammered at red-hot position and re-rolled into wires. Construction :the construction of the pure tungsten filament incandescent lamp. It consists of an evacuated glass bulb and an aluminum or brass cap is provided with two pins to insert the bulb into the socket. The inner side of the bulb consists of a tungsten filament and the support wires are made of molybdenum to hold the filament in proper position. A glass button is provided in which the support wires are inserted. A stem tube forms an air-tight seal around the filament whenever the glass is melted.	

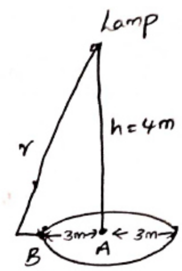


Operation

When electric current is made to flow through the fine metallic tungsten filament, its temperature increases. At very high temperature, the filament emits both heat and light radiations, which fall in the visible region. The maximum temperature at which the filament can be worked without oxidization is 2,000°C, i.e., beyond this temperature, the tungsten filament blackens the inside of the bulb. The tungsten filament lamps can be operated efficiently beyond 2,000°C, it can be attained by inserting a small quantity of inert gas nitrogen with small quantity of organ. But if gas is inserted instead of vacuum in the inner side of the bulb, the heat of the lamp is conducted away and it reduces the efficiency of the lamp. To reduce this loss of heat by conduction and convection, as far as possible, the filament should be so wound that it takes very little space. This is achieved by using a single-coil filament instead of a straight wire filament.

4	a)	A 250 CP lamp is hung 4m above the center of a circular area of 6m diameter. Calculate the illumination at the (i) Centre of area. (ii) Periphery of the area. (iii) Average illumination	**[10M]**
		$I = 250$ CP , $h = 4m$, $d = 6m$	

$I = 250\ cp$, $h = 4m$, $d = 6m$



i) Illumination at centre of area

$$E_A = \frac{250}{4^2} = \frac{I}{r^2}$$

$$E_A = 15.625 \text{ lux.}$$

This is max illumination.

ii) Illumination on the periphery of the area :

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

(or)

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

From fig

$$r = \sqrt{(4)^2 + (3)^2} = 5m$$

$$\cos\theta = \frac{h}{r} = \frac{4}{5} = 0.8$$

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

$$E_B = \frac{250}{(5)^2} (0.8) = 8 \text{ lux.}$$

(iii) Average Illumination :

$$\text{Flux, } \phi = I\omega$$

where, ω = Solid angle subtended by the area at lamp.

$$\omega = 2\pi(1-\cos\theta)$$
$$= 2\pi(1-0.8)$$
$$\omega = 1.256 \text{ steradian.}$$

$$\text{Avg Illumination} = E_{Avg} = \frac{\phi}{A} = \frac{I\omega}{\left(\frac{\pi D^2}{4}\right)}$$
$$= \frac{(250)(1.256)}{\left(\frac{\pi (6)^2}{4}\right)}$$
$$\boxed{E = 11.1 \text{ lux.}}$$

	b)	Explain the various factors to be taken into account for designing schemes for (i) Factory lighting (ii) Street lighting	

Factory lighting

In case of factory lighting,

1.The illumination should be adequate enough on the working plane

2.The distribution of light should also be good.

3.Simple and easy cleaned fittings should be employed.

4.The lighting should be made uniform and glare less as far as possible.

STREET LIGHTING

Street lighting not only requires for shopping centers, promenades, etc. but also necessary for the following.

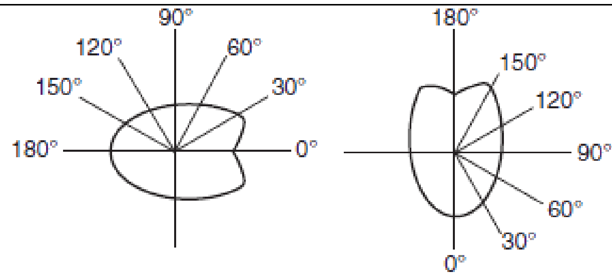
1.In order to make the street more attractive, so that obstructions on the road clearly visible to the drivers of vehicles.

2.To increase the community value of the street.

3.To clear the traffic easily in order to promote safety and convenience.

5		A machine shop 40m×20m is to have an illumination of 160lux on working plane. The lamps are mounted on 6m above the working plane. Give the layout of a suitable installation. a) Using filament lamp. b) Using 50 watts fluorescent lamp. Assume necessary data.	[5M]
		A machine shop area A = (40m x 20m) Illumination, E = 160 lux height, h = 6m. a) Using filament lamp: → Assume 40 W filament lamp and luminous Efficiency 50 lumens/watt. Illumination, $E = \frac{flux}{Area} = \frac{Lumens}{Area}$ Assume Lumens Efficiency = 50 lumen/watt. ∴ Total lumens = E * A = 160 * 40 * 20 = 128000' lumens. Total wattage req with given luminous Efficiency $= \frac{12800}{50} = \frac{lumens}{luminous\ Efficiency}$ = 2560 Watts. 40 W lamps required $= \frac{2560}{40} = 64$ lamps	[5M]

		length wise spacing $= \frac{40}{16} = 2.5m$ width wise spacing $= \frac{20}{4} = 5m.$ (b) 50 W Fluroscent lamp : $\therefore$ Total wattage required $= 2560$ W $\therefore$ Number of 50W fluroscent lamps required $= \frac{2560}{50} = 51.2$ $= 52$ bulbs length wise spacing $= \frac{40}{13} = 3.1m$ $\therefore$ width wise spacing $= \frac{20}{13} = 1.54$ m.	
6	a)	Write short notes on polar curves.	**[10M]**
		The luminous flux emitted by a source can be determined using the intensity distribution curve. Till now we assumed that the luminous intensity or the candle power from a source is distributed uniformly over the surrounding surface. But due to its s not uniform in all directions. The luminous intensity or the distribution of the light can be represented with the help of the polar curves. The polar curves are drawn by taking luminous intensities in various directions at an equal angular displacement in the sphere. A radial ordinate pointing in any particular direction on a polar curve represents the luminous intensity of the source when it is viewed from that direction. Accordingly, there are two different types of polar curves and they are: 1. A curve is plotted between the candle power and the angular position, if the luminous intensity, i.e., candle power is measured in the horizontal plane about the vertical axis, called 'horizontal polar curve'. 2. curve is plotted between the candle power, if it is measured in the vertical plane and the angular position is known as 'verticalpolar curve'.	

		(a) Horizontal polar curves (b) Vertical polar curves	
	b	A filament lamp of 500W is suspended at a height of 4.5 m above the working plane and gives uniform illumination over an area of 6 m diameter. Assuming an efficiency of the reflector as 70% and efficiency of lamp as 0.8 watt per candle power, determine the illumination on the working plane	
		Wattage of the filament lamp = 500 W Height $h = 4.5 m$ Diameter, $d = 6 m$ Efficiency of reflector = 70% Efficiency of lamp = 0.8 W per cp. Illumination on the working plane = $\dfrac{\text{Flux Emitted by reflector}}{\text{Area of working plane.}}$ C.P of the lamp = $\dfrac{\text{wattage of lamp}}{\text{Efficiency of lamp}}$ $= \dfrac{500}{0.8} = 625$ c.p. Luminous o/p of lamp = $4\pi * CP$ $= 4\pi \times 625$ $= 2500\pi$ lumens.	

Flux Emitted by the reflector = Efficiency of reflector × Total luminous o/p of the lamp

$= 0.7 \times 2500\pi$

$= 1750\pi$ lumens

$\therefore$ Illumination on the working plane $= \frac{1750\pi}{9\pi} = 194.44$ lumen/m^2

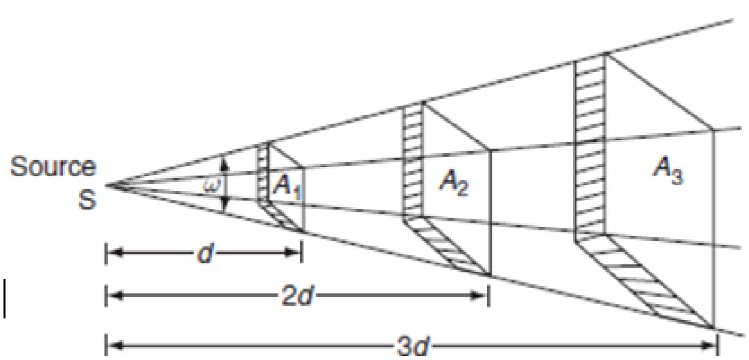
7		State the laws of illumination. Explain the laws with the help of suitable diagrams and derive an equation of the same.	[10M]

Inverse square law

This law states that 'the illumination of a surface is inversely proportional to the square of distance between the surface and a point source'.

Proof:

Let, '*S*' be a point source of luminous intensity '*I*' candela, the luminous flux emitting from source crossing the three parallel plates having areas A_1 A_2, and A_3 square meters, which are separated by a distances of *d*, 2*d*, and 3*d* from the point source respectively as shown in Fig. 6.10.



For area A_1, solid angle $\omega = \frac{A_1}{d^2}$.

Luminous flux reaching the area A = luminous intensity × solid angle

$$= I \times \omega = I \times \frac{A_1}{d^2}.$$

∴ Illumination 'E_1' on the surface area 'A_1' is:

$$E_1 = \frac{\text{flux}}{\text{area}} = \frac{IA_1}{d^2} \times \frac{1}{A_1}$$

$$\therefore E_1 = \frac{I}{d^2} \quad \text{lux.}$$

Similarly, illumination 'E_2' on the surface *area* A_2 is:

$$E_2 = \frac{I}{(2d)^2} \quad \text{lux} \qquad (6$$

and illumination 'E_3' on the surface area A_3 is:

$$E_3 = \frac{\text{I}}{(3d)^2} \quad \text{lux.}$$

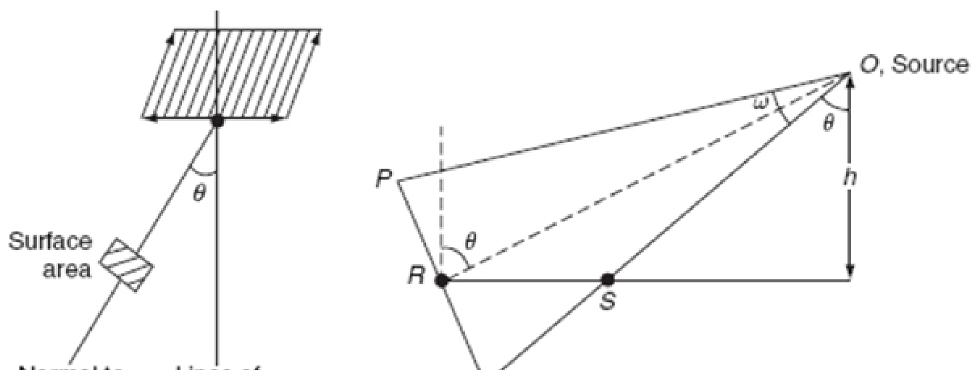
$$E_1 : E_2 : E_3 = \frac{1}{d^2} : \frac{1}{(2d)^2} : \frac{1}{(3d)^2}.$$

Lambert's cosine law

This law states that 'illumination, E at any point on a surface is directly proportional to
the cosine of the angle between the normal at that point and the line of flux'.

Proof:

While discussing, the Lambert's cosine law, let us assume that the surface is inclined at an angle 'θ' to the lines of flux as shown in Fig. 6.11.



$PQ = RS \cos\theta.$

$\therefore$ The illumination of the surface $PQ, E_{PQ} = \dfrac{\text{flux}}{\text{area of } PQ}$

$$= \frac{I \times \omega}{\text{area of } PQ} = \frac{I}{\text{area of } PQ} \times \frac{\text{area of } PQ}{d^2} \quad \left[\because \omega = \text{area}/(\text{radius})^2\right]$$

$$= \frac{I}{d^2}.$$

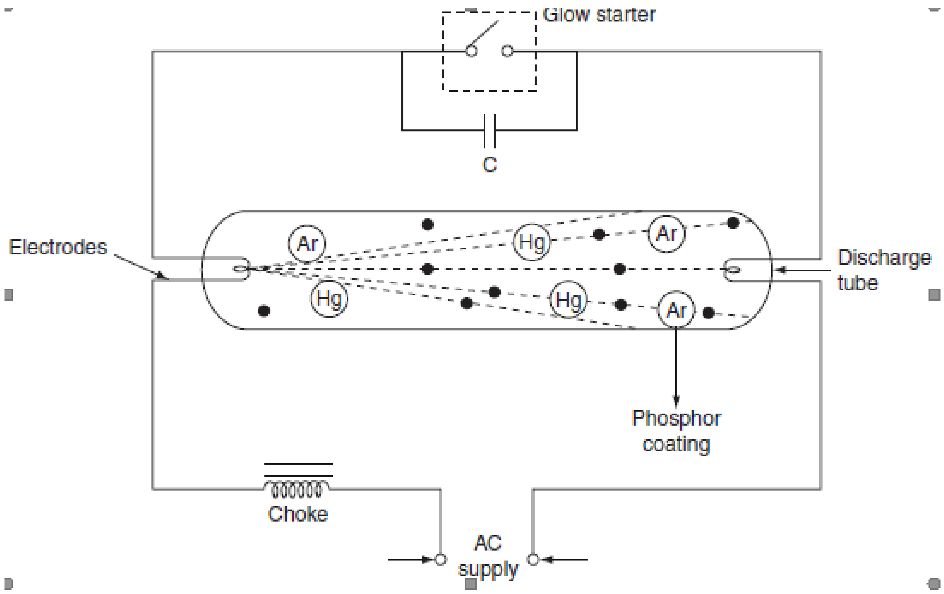
$$\cos\theta = \frac{h}{d}$$

$$\text{or } d = \frac{h}{\cos\theta}.$$

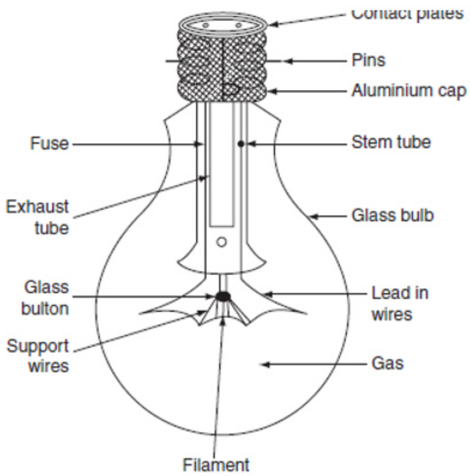
		$\therefore E_{RS} = \dfrac{I}{(h/\cos\theta)^2} \times \cos\theta = \dfrac{I}{h^2}\cos^3\theta$	
8	a	A room measuring 30m×15m is to be illuminated by 10 lamps and the average illumination is to be 85 lux. Determine the MSCP of each lamp if the utilization and depreciation factors are 0.5 and 0.8 respectively	
		Room Area, $A = 30 \times 15 = 450 m^2$ Avg Illumination, $E = 50$ lum/m^2 MSCP = ? U.F = 0.5, DF = 0.8 Total lumens required = $\dfrac{A \times E \times \text{waste light factor} \times DF}{U.F}$ w.r Lumens/Lamp = $\dfrac{A \times E \times \text{waste light Factor} \times DF}{UF}$ $= \dfrac{450 \times 85 \times 0.8}{0.5}$ (∵ waste light factor = 1) = 61,200 lumens M.S.C.P = $\dfrac{\text{Total lumens}}{4\pi}$ $= \dfrac{61200}{4\pi} = 4870.14$ $\boxed{\text{MSCP} = 4870.14}$ candela.	

	b)	Briefly explain the requirement of good lighting scheme	**[5M]**
		In order to make a lighting scheme good, the following factors are to be considered while planning the lighting scheme – • Illumination Level • Absence of Glare • Uniformity of Illumination • Contrast • Color Rendering • Shadows **Illumination Level**The visibility of the objects depends upon the level of illumination, i.e., the magnitude of light falling over them and the light reflected by the objects. The illumination level in turn depends upon the following factors − • **Size of the object** – If the object is smaller in size, then greater is the level of illumination required for its proper visibility and vice-versa. • **Distance between the light source and the object** – If the distance between the light source and the object, then level of illumination required will be higher. • **Distance between the observer and the object** – Smaller distance between the observer and the object requires lower level of illumination and vice-versa. • **Color of object** – For the dark colored objects, the level of illumination required will be higher. • **State of object** – Stationary objects require lower level of illumination as compared to the moving objects. • **Period of observation** – Objects to be observed continuously for longer period require a higher degree of illumination.	

		Absence of Glare: Glare is the sensation experienced by human eyes when some light rays enter the eyes directly from a source of light. For example, car drivers use dipper at night when facing other vehicles to avoid the glare. **Uniformity of Illumination:**The human eyes have to adjust its aperture depending upon level of illumination within the field of vision. Therefore, it is also a requirement of a good lighting that it should have uniformity of illumination. **Contrast:**The abrupt contrast in the lighting scheme should be avoided. When we go from sunlight into a dark room, we require sufficient time to locate the things properly inside the room. This is due to abrupt change in the contrast of the illuminated surface. For this reason, a lighting scheme is said to be good only if it has no contrast because it causes strain on the eyes. **Color Rendering:**The color of the incident light affects the appearance of color of the object. Therefore, in a good lighting scheme, the composition of the light should be such that the color of the object appears natural and makes no difference from that under light. **Shadows:**The shadows play a vital role in the design of a lighting scheme. In case of industrial lighting, the deep and dark shadows can be source of an accident. On the other hand, the dull shadows are a necessity to give a three dimensional look to any solid object. Therefore, long and hard shadows should be eliminated as they cause fatigue on eyes.	
9	a	Explain with sketch the principle and operation of fluorescent lamp.	**[5M]**
		Fluorescent lamp is a hot cathode low-pressure mercury vapor lamp; the construction and working of the fluorescent lamp are explained as follows. **Construction:** It consists of a long horizontal tube, due to low pressure maintained inside of the bulb; it is made in the form of a long tube. The tube consists of two spiral tungsten electrode coated with electron emissive material and are placed at the two edges of long tube. The tube contains small quantity of argon gas and certain amount of mercury, at a pressure of 2.5 mm of mercury. The construction of fluorescent lamp. Normally, low-pressure mercury vapor lamps suffer from low efficiency and they produce an objectionable colored light. Such drawback is overcome by coating the inside of the tube with fluorescent powders. They are in the form of solids, which are usually knows as phosphors.	

			
		Working : At the time of starting, when both the lamp and the glow starters are cold, the mercury is in the form of globules. When supply is switched on, the glow starter terminals are open circuited and full supply voltage appeared across these terminals, due to low resistance of electrodes and choke coil. The small quantity of argon gas gets ionized, which establishes an arc with a starting glow. This glow warms up the bimetallic strip thus glow starts gets short circuited. Hence, the two electrodes come in series and are connected across the supply voltage. Now, the two electrodes get heated and start emitting electrons due to the flow of current through them. These electrons collide with the argon atoms present in the long tube discharge that takes place through the argon gas. So, in the beginning, the lamp starts conduction with argon gas as the temperature increases, the mercury changes into vapor form and takes over the conduction of current.	
	b	Write short notes on incandescent lamp	**[10M]**
		Incandescent lamps When the filaments of these lamps are heated to high temperature, they emit light that falls in the visible region of wavelength. Tungsten-filament lamps are operating on this principle The chemically pure tungsten is very strong and fragile. In order to make it into ductile, tungsten oxide is first reduced in the form of gray power in the atmosphere of hydrogen and this powder is pressed in steel mold for small bars; the mechanical strength of these bars can be improved by heating them to their melting point and then hammered at red-hot position and re-rolled into wires.	

Construction : The construction of the pure tungsten filament incandescent lamp. It consists of an evacuated glass bulb and an aluminum or brass cap is provided with two pins to insert the bulb into the socket. The inner side of the bulb consists of a tungsten filament and the support wires are made of molybdenum to hold the filament in proper position. A glass button is provided in which the support wires are inserted. A stem tube forms an air-tight seal around the filament whenever the glass is melted.



Operation

When electric current is made to flow through the fine metallic tungsten filament, its temperature increases. At very high temperature, the filament emits both heat and light radiations, which fall in the visible region. The maximum temperature at which the filament can be worked without oxidization is 2,000°C, i.e., beyond this temperature, the tungsten filament blackens the inside of the bulb. The tungsten filament lamps can be operated efficiently beyond 2,000°C, it can be attained by inserting a small quantity of inert gas nitrogen with small quantity of organ. But if gas is inserted instead of vacuum in the inner side of the bulb, the heat of the lamp is conducted away and it reduces the efficiency of the lamp. To reduce this loss of heat by conduction and convection, as far as possible, the filament should be so wound that it takes very little space. This is achieved by using a single-coil filament instead of a straight wire filament.

10 Write short notes on:

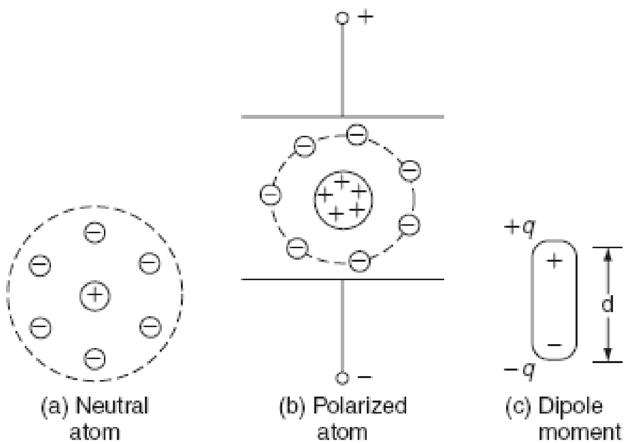
a) Define luminous flux.
b) Define Mean spherical candle power
c) Define lamp efficiency
d) Define space-height ratio
e) Define luminance.

		luminous flux : Luminous flux is a measure of the power of visible light produced by a light source or light fitting. It is measured in lumens (lm) **Mean spherical candle power** It is defined as the mean of the candle powers in all directions and in all planes from the source of light. **lamp efficiency** It is defined as the ratio of energy radiated in the form of light, produces sensation of vision to the total energy radiated out by the luminous body. Lamp efficiency is measured in lumen/watt. **space-height ratio** Space to height ratio is the ratio of space between luminaires (S) to their height above the working plane (Hm). **luminance.** Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. It describes the amount of light that passes through, is emitted from, or is reflected from a particular area, and falls within a given solid angle.	

UNIT - II
ELECTRICAL HEATING

1	a)	Briefly discuss the method of Dielectric heating.	**[8M]**
		When non-metallic materials i.e., insulators such as wood, plastics, and china glass are subjected to high-voltage alternating electric field, the atoms get stresses, and due to interatomic friction caused by the repeated deformation and the rotation of atomic structure (polarization), heat is produced. This is known as dielectric loss. This dielectric loss in insulators corresponds to hysteresis loss in ferro-magnetic materials. This loss is due to the Reversal of magnetism or magneto molecular friction. These losses developed in a material that has to be heated. An atom of any material is neutral, since the central positive charge is equals to the negative charge. So that, the centers of positive and negative charges coincide as long as there is no external field is applied, as shown in Fig. (a). When this atom is subjected to the influence of the electric field, the positive charge of the nucleus is acted upon by some force in the direction of negative charges in the opposite direction. Therefore, the effective centers of both positive and negative charges no longer coincident as shown in Fig. (b).	

		The electric charge of an atom equivalent to Fig.(b) is shown in Fig. (c).	

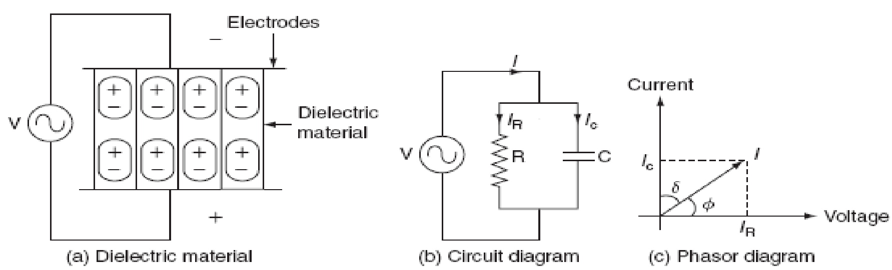


This gives raise to an electric dipole moment equal to $P = q\ d,$ where d is the distance between the two centers and q is the charge on the nucleus.

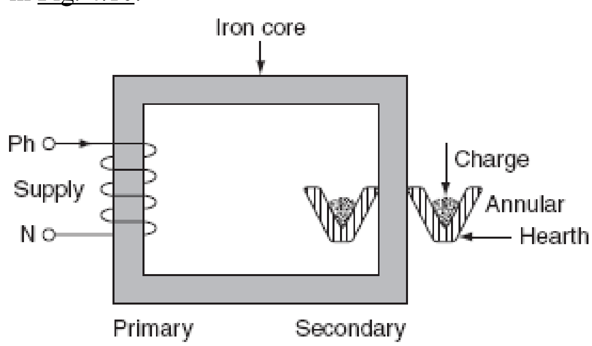
Now, the atom is said to be polarized atom. If we apply alternating voltage across the capacitor plate, we will get alternating electric field.

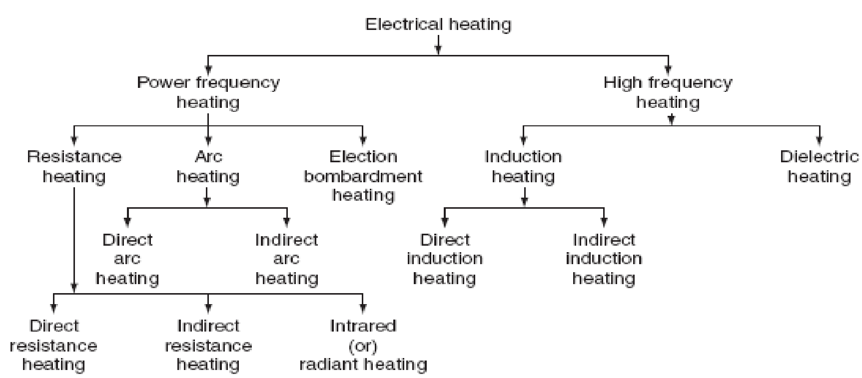
Electric dipoles will also try to change their orientation according to the direction of the impressed electric field. In doing so, some energy will be wasted as inter-atomic friction, which is called dielectric loss.

As there is no perfect conductor, so there is no perfect insulator. All the dielectric materials can be represented by a parallel combination of a leakage resistor 'R' and a capacitor 'C' as shown in Fig. 4.15 (a) and (b).



If an AC voltage is applied across a piece of insulator, an electric current flows; total current 'I' supposed to be made up of two components I_C and $I_R,$ where I_C is the capacitive current leading the applied voltage by 90° and I_R is in phase with applied voltage as shown in Fig. 4.15(c).

		Dielectric loss, $P_L = VI\cos\phi$ $= VI_R \quad [\because I_R = I\cos\phi]$ $= VI_C\tan\delta \quad \left[\because \tan\delta = \frac{I_R}{I_C}\right].$ $V \cdot \left(\frac{V}{X_C}\right)\tan\delta \quad \left[QI_C = \frac{V}{X_C}\right]$ $= V^2\omega C\tan\delta \qquad (4.13)$	
	b)	Briefly discuss the applications of resistance heating.	**[2M]**
		The major applications of the resistance heating are as − Drying Baking of potteries Commercial and domestic cooking Heat treatment of metals such as hardening, annealing, etc.	
2	a)	Describe direct core type furnace with neat sketch.	**[5M]**
		Direct core type induction furnace The core type furnace is essentially a transformer in which the charge to be heated forms single- turn secondary circuit and is magnetically coupled to the primary by an iron core as shown in Fig. 4.10.  The furnace consists of a circular hearth in the form of a trough, which contains the charge to be melted in the form of an annular ring. This type of furnace has the following characteristics: o This metal ring is quite large in diameter and is magnetically interlinked with primary winding, which is energized from an AC source. The magnetic coupling between primary and secondary is very weak; it results in high leakage reactance and low pf. To overcome the increase in leakage reactance, the furnace should be operated at low frequency of the order of 10 Hz. o When there is no molten metal in the hearth, the secondary becomes open circuited thereby cutting of secondary current. Hence, to start the furnace, the molten metal has to be taken in the hearth to keep the secondary as short circuit. o Furnace is operating at normal frequency, which causes turbulence and	

		severe stirring action in the molten metal to avoid this difficulty, it is also necessary to operate the furnace at low frequency. o In order to obtain low-frequency supply, separate motor-generator set (or) frequency changer is to be provided, which involves the extra cost. o The crucible used for the charge is of odd shape and inconvenient from the metallurgical viewpoint. o If current density exceeds about 500 A/cm^2, it will produce high-electromagnetic forces in the molten metal and hence adjacent molecules repel each other, as they are in the same direction. The repulsion may cause the interruption of secondary circuit (formation of bubbles and voids); this effect is known as *pinch effect.*	
	b)	Explain application of induction heating.	**[5M]**
		The induction heating is used in the following applications − 1.Inductive heating is used for surface heating, melting and soldering, etc. 2.Inductive heating is also used for heating of liquid conductors and gaseous conductors. 3.In semiconductor industries, the inductive heating is used for heating of silicon. 4.Inductive heating is used in inductive furnaces for heating the metals to their melting point. 5.The induction stoves used in kitchen works on the principle of inductive heating. 6.As the induction heating is contactless heating process. Therefore, induction heating is used in vacuum furnaces for making specialized steel and alloys that would get oxidized when heated in the presence of oxygen. 7.The induction heating is used in plastic injection modeling machines. 8.The induction heating is also used for tamper resistant cap sealing on bottles and pharmaceuticals. 9.Induction heating is used for welding of metals and sometimes plastics when they are doped with ferromagnetic ceramics.	
3	a)	What are the different types of heating? Write advantages of electric heating.	**[5M]**
		Heat can be generated by passing the current through a resistance or induced currents. The initiation of an arc between two electrodes also develops heat. The bombardment by some heat energy particles such as α, γ, β, and x-rays or accelerating ion can produce heat on a surface. Electric heating can be broadly classified as follows.  	

		Advantages: The various advantages of electric heating over other the types of heating are: 1.Economical 2.cleanliness 3.Pollution free 4.ease of control 5.uniform heating 6.High efficiency 7.Automatic Protection 8. Heating of non-conducting materials 9. Better working conditions 10. Less floor area 11. High temperature 12.safety	
	b)	A low frequency induction furnace whose secondary voltage is maintained constant at 10 volts, takes 400 kW at 0.6 pf, when the hearth is full. Assuming the resistance of the secondary to vary inversely as the height of the charge and reactance to remain constant, height up to which the hearth should be filled to obtain maximum heat.	**[5M]**
		Sol : Secondary current $I_2 = \frac{P}{V_2} \cos\phi$ $I_2 = \frac{400 \times 10^3}{10} = 0.667 \times 10^4$ A Impedance of the secondary circuit when hearth is full. $Z_2 = \frac{V_2}{I_2} = \frac{10}{0.667 \times 10^4} = 1.5 \times 10^{-4}\,\Omega$ Secondary resistance when hearth is full, $R_2 = Z_2 \cos\phi$ $= 1.5 \times 10^{-4} \times 0.6$ $= 0.9 \times 10^{-4}\,\Omega$ Reactance of the secondary circuit $X_2 = Z_2 \sin\phi$ $= 1.5 \times 10^{-4} \times 0.8$ $= 1.2 \times 10^{-4}\,\Omega$	

In the second, let the height of the charge be x times of the full hearth ie, $h = xH$

Since resistance varies inversely as the height of the charge.

$$= R_2 = \frac{R_1}{x} = \frac{0.9 \times 10^{-4}}{x} \ \Omega$$

Power drawn and hence heat produced will be max where Secondary resistance equal its reactance

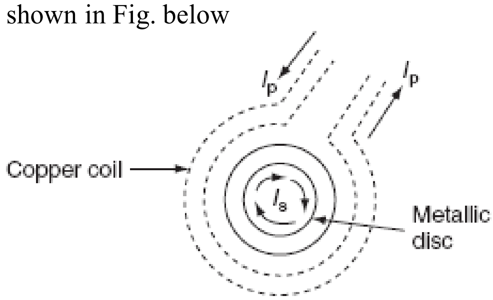
$$\therefore \frac{0.9 \times 10^{-4}}{x} = 1.2 \times 10^{-4} \quad \text{or} \quad x = \frac{3}{4}.$$

Hence, max heat would be produced in the charge when its height is 3/4 the height of the hearth.

4	a)	Discuss briefly about induction heating process.	[5M]

The induction heating process makes use of the currents induced by the electromagnetic action in the material to be heated. To develop sufficient amount of heat, the resistance of the material must be low, which is possible only with the metals, and the voltage must be higher, which can be obtained by employing higher flux and higher frequency. Therefore, the magnetic materials can be heated than non-magnetic materials due to their high permeability.

In order to analyze the factors affecting induction heating, let us consider a circular disc to be heated carrying a current of '*I*' amps at a frequency '*f*' Hz. As shown in Fig. below



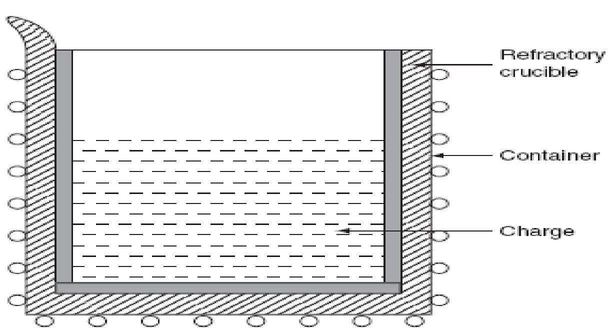
If the charge to be heated is non-magnetic, then the heat developed is due to eddy current loss,whereas if it is magnetic material, there will be hysteresis loss in addition to eddy current loss.Both hysteresis and eddy current loss are depended upon frequency, but at high-frequency hysteresis, loss is very small as compared to eddy currents.

The depth of penetration of induced currents into the disc is given by:

$$d = \frac{1}{2\pi}\sqrt{\frac{\rho \times 10^9}{\mu f}} \text{ cm}$$

i.e., $d \ \mu \dfrac{1}{\sqrt{f}}$,

where ρ is the specific resistance in Ω-cm, f is the frequency in Hz, and μ is the permeability of
the charge.

	b)	A slab of insulating material 150 sq cm in area and 1 cm thick is to be heated by dielectric heating. The power required is 400 W at 30 × 10^6 cps. Materials has permittivity of 5 and power factor of 0.05. Determine voltage necessary.	
		Sol: $P = 400W$, $Pf = 0.05$, $f = 30\times10^6$ Hz. $C = \frac{\varepsilon_0\varepsilon_r A}{d} = \frac{8.854\times10^{-12}\times5\times150\times10^{-4}}{1\times10^{-2}} = 66.4\times10^{-12}$ F Now, $P = 2\pi f C V^2 \cos\phi$ or $400 = 2\pi\times30\times10^6\times66.4\times10^{-12}\times V^2\times0.05$ or $V = 800V$	
5	a)	Explain with a neat sketch the principle of coreless type induction furnace.	**[7M]**
		It is a simple furnace with the absence core is shown in Fig. 4.13. In this furnace, heat developed in the charge due to eddy currents flowing through it. The furnace consists of a refractory or ceramic crucible cylindrical in shape enclosed within a coil that forms primary of the transformer. The furnace also contains a conducting or non- conducting container that acts as secondary. If the container is made up of conducting material, charge can be conducting or non-conducting; whereas, if the container is made up of non-conducting material, charge taken should have conducting properties. When primary coils are excited by an alternating source, the flux set up by these coils induce the eddy currents in the charge. The direction of the resultant eddy current is in a direction opposite to the current in the primary coil. These currents heat the charge to melting point and they also set up electromagnetic forces that produce a stirring action to the charge. ∴ The eddy currents developed in any magnetic circuit are given as: $W_e \propto B_m^2 f^2$, where B_m is the maximum flux density (tesla), f is the frequency in (Hz), and W_e is the eddy current loss (watts).  **Fig. 4.13** Coreless induction furnace	

		In coreless furnace, the flux density will be low as there is no core. Hence, the primary supply should have high frequency for compensating the low flux density. If it is operating at high frequency, due to the skin effect, it results copper loss, thereby increasing the temperature of the primary winding. This necessitates in artificial cooling. The coil, therefore, is made of hollow copper tube through which cold water is circulated. Minimum stray magnetic field is maintained when designing coreless furnace, otherwise there will be considerable eddy current loss. The selection of a suitable frequency of the primary current can be given by penetration formula. According to this: $t = \frac{1}{2\pi}\sqrt{\frac{\rho \times 10^9}{\mu f}}, \quad (4.11)$ where 't' is the thickness up to which current in the metal has penetrated, 'ρ' is the resistivity in Ω-cm,'μ' is the permeability of the material, and 'f' is the frequency in Hz. For the efficient operation, the ratio of the diameter of the charge (d) to the depth of the penetration of currents (t) should be more than '6', therefore let us take: $\frac{d}{t} = 8.$ $f = \frac{16 \times \rho \times 10^9}{\pi^2 \mu d^2}. \quad (4.12)$	
	b)	What are the causes of failure of heating element?	[3M]
		Age: Over time, the heating elements will degrade and become less effective. It is because they are constantly exposed to high temperatures. The heat will cause the heating elements to expand and contract, which will eventually lead to cracking and breaking. **Build-up of Scale:** The most common cause of failure is due to a build-up of scale on the heating element. This happens when water vapor in the air condenses on the element and then hardens, forming a layer of scale. This scale insulates the heating element and prevents it from transferring heat properly. **Corrosion:** This can happen when the element is exposed to chemically-active substances like chlorine or sulfur. Corrosion will damage the heating element and prevent it from working properly. **Oxidation:** Over time, the heating element can oxidize. This happens when the metal of the heating element reacts with oxygen in the air. Oxidation will damage the heating element and make it less effective. **Poor Maintenance:** Lack of proper maintenance is another common cause of heating element failure. If the heating element is not cleaned and lubricated regularly, it can become clogged with dirt and debris, causing them to overheat and eventually break down. **Wear and Tear:** With normal use, heating elements will eventually wear out. It is due to the repeated heating and cooling cycles that the element goes through. Eventually, the heating element will degrade and fail.	
6	a)	Explain the working of Ajax Wyatt vertical core furnace with a neat sketch.	[5M]

It is an improvement over the direct core type furnace, to overcome some of the disadvantages mentioned above. This type of furnace consists of a vertical core instead of horizontal core as shown in Fig. 4.11. It is also known as *Ajax–Wyatt induction furnace.*

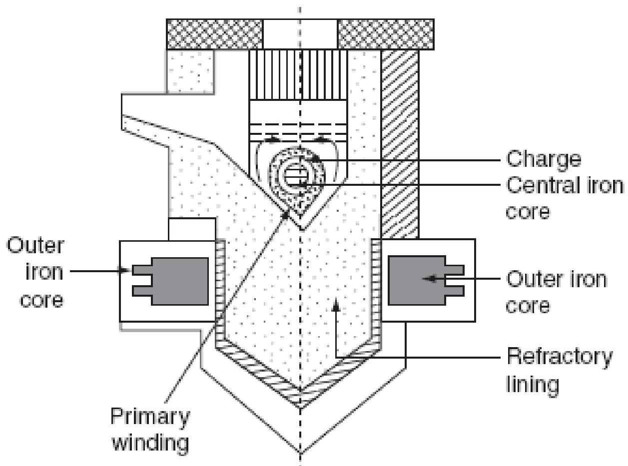


Fig. 4.11 Vertical core type furnace (Ajax–Wyatt induction furnace)

Vertical core avoids the pinch effect due to the weight of the charge in the main body of the crucible. The leakage reactance is comparatively low and the power factor is high as the magnetic coupling is high compared to direct core type.

There is a tendency of molten metal to accumulate at the bottom that keeps the secondary completed for a vertical core type furnace as it consists of narrow V-shaped channel.

The inside layer of furnace is lined depending upon the type charge used. Clay lining is used for yellow brass and an alloy of magnesia and alumina is used for red brass.

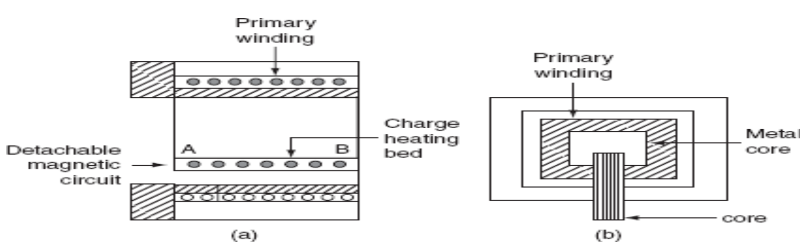
The top surface of the furnace is covered with insulating material, which can be removed for admitting the charge. Necessary hydraulic arrangements are usually made for tilting the furnace to take out the molten metal. Even though it is having complicated construction, it is operating at power factor of the order of 0.8–0.83. This furnace is normally used for the melting and refining of brass and non-ferrous metals.

	b)	Explain the principle of Induction heating. What are the applications of Induction heating.	**[5M]**

Principle of induction heating:

The induction heating process makes use of the currents induced by the electromagnetic action in the material to be heated. To develop sufficient amount of heat, the resistance of the material must be low, which is possible only with the metals, and the voltage must be higher, which can be obtained by employing higher flux and higher frequency. Therefore, the magnetic materials can be heated than non-magnetic materials due to their high permeability.

In order to analyze the factors affecting induction heating, let us consider a circular disc to be heated carrying a current of '*I*' amps at a frequency '*f*' Hz.

		If the charge to be heated is non-magnetic, then the heat developed is due to eddy current loss, whereas if it is magnetic material, there will be hysteresis loss in addition to eddy current loss. Both hysteresis and eddy current loss are depended upon frequency, but at high-frequency hysteresis, loss is very small as compared to eddy currents. Applications of induction Heating: Inductive heating is used for surface heating, melting and soldering, etc. Inductive heating is also used for heating of liquid conductors and gaseous conductors. In semiconductor industries, the inductive heating is used for heating of silicon. Inductive heating is used in inductive furnaces for heating the metals to their melting point. The induction stoves used in kitchen works on the principle of inductive heating. As the induction heating is contactless heating process. Therefore, induction heating is used in vacuum furnaces for making specialized steel and alloys that would get oxidized when heated in the presence of oxygen. The induction heating is used in plastic injection modeling machines. The induction heating is also used for tamper resistant cap sealing on bottles and pharmaceuticals. Induction heating is used for welding of metals and sometimes plastics when they are doped with ferromagnetic ceramics.	
7	a)	Describe Indirect core type furnace with neat sketch.	**[5M]**
		This type of furnace is used for providing heat treatment to metal. A simple induction furnace with the absence of core is shown in Fig. 4.12.  **Fig. 4.12** Indirect core type furnace The secondary winding itself forms the walls of the container or furnace and an iron core links both primary and secondary windings. The heat produced in the secondary winding is transmitted to the charge by radiation. An oven of this type is in direct competition with ordinary resistance oven. It consists of a magnetic circuit AB is made up of a special alloy and is kept inside the chamber of the furnace. This magnetic circuit loses its magnetic properties at certain temperature and regains them again when it is cooled to the same temperature. When the oven reaches to critical temperature, the reluctance of the magnetic circuit increases many times and the inductive effect decreases thereby cutting off the supply heat. Thus, the temperature of the furnace can be effectively controlled. The magnetic circuit 'AB' is detachable type that can be replaced by the other	

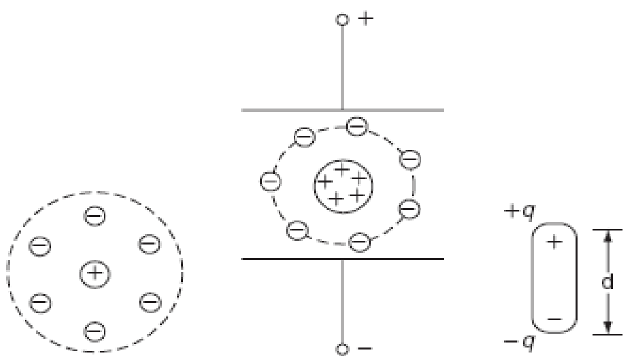
		magnetic circuits having critical temperatures ranging between 400°C and 1,000°C. The furnace operates at a pf of around 0.8. The main advantage of such furnace is wide variation of temperature control is possible.	
	b)	Briefly discuss the applications of Dielectric heating?	**[5M]**
		1.Preheating of Plastic Preforms: The raw material in the form of tablets or biscuits, commonly called plastic preforms, is required to be heated uniformly before putting them into the hot moulds so that whole mass becomes fluid at a time, otherwise if the raw material is put directly into the moulds, usually heated by steam, the outer skin of the preforms will become hot and start curing while the core of the material has not reached fluid temperature resulting in unequal hardening of the plastic and improper filling of moulds corners. Difficulty arises due to the fact that plastic raw material once cured cannot be softened again satisfactorily. Any method of heating depending upon conduction of heat from surface to the core would miserably fail because plastic is bad conductor of heat. Dielectric heating is the only method which can be used for preheating of plastic preforms to proper temperature uniformly. **2.Baking of Foundary Cores:** In foundaries resin type thermosetting binders are employed as they set almost instantaneously when brought to polymerizing temperature. The dielectric heating evaporates water rapidly from the core mix and at the same time raises the temperature of the core material to polymerization point. Hence dielectric heating is most suitable for baking foundary cores mixed with thermosetting resin type core binders. **3.Diathermy:** Dielectric heating is also employed for heating tissues and bones of the body required for the treatment of certain types of pains and diseases. **4. Sterlization:** The dielectric heating is quite suitable for sterilization of bandages, absorbent cotton, sterile gauge, instruments etc. **5. Textile Industry:** In textile industry the dielectric heating is employed for drying purposes. **6. Electronic Sewing:** Nowadays rain coats, umbrellas, food containers, medicine containers etc. are made from plastic film materials. In case of ordinary stitching by thread they will be no longer water tight and also become weak at seam. With adhesives curing times will be longer. In case of electronic sewing the films to be stitched are rolled in between cold rollers to which radio-frequency voltage is applied. The heat produced in the material seals it all along the line where mechanical pressure is applied. The cold rollers prevent the outer surface of the films from being softened.	

8		Discuss the principle, advantages and disadvantages of dielectric heating.	[10M]

Principle of dielectric heating:

When non-metallic materials i.e., insulators such as wood, plastics, and china glass are subjected to high-voltage alternating electric field, the atoms get stresses, and due to interatomic friction caused by the repeated deformation and the rotation of atomic structure (polarization), heat is produced. This is known as dielectric loss. This dielectric loss in insulators corresponds to hysteresis loss in ferro-magnetic materials. This loss is due to the Reversal of magnetism or magneto molecular friction. These losses developed in a material that has to be heated.

An atom of any material is neutral, since the central positive charge is equals to the negative charge. So that, the centers of positive and negative charges coincide as long as there is no external field is applied, as shown in Fig. (a). When this atom is subjected to the influence of the electric field, the positive charge of the nucleus is acted upon by some force in the direction of negative charges in the opposite direction. Therefore, the effective centers of both positive and negative charges no longer coincident as shown in Fig. (b). The electric charge of an atom equivalent to Fig.(b) is shown in Fig. (c).



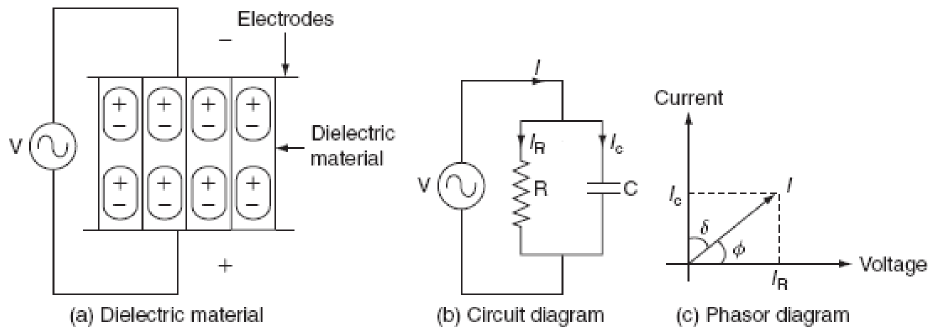
(a) Neutral atom (b) Polarized atom (c) Dipole moment

This gives raise to an electric dipole moment equal to $P = q\ d$, where d is the distance between the two centers and q is the charge on the nucleus.

Now, the atom is said to be polarized atom. If we apply alternating voltage across the capacitor plate, we will get alternating electric field.

Electric dipoles will also try to change their orientation according to the direction of the impressed electric field. In doing so, some energy will be wasted as inter-atomic friction, which is called dielectric loss.

As there is no perfect conductor, so there is no perfect insulator. All the dielectric materials can be represented by a parallel combination of a leakage resistor '*R*' and a capacitor '*C*' as shown in Fig. 4.15 (a) and (b).



If an AC voltage is applied across a piece of insulator, an electric current flows; total current 'I' supposed to be made up of two components I_C and I_R, where I_C is the capacitive current leading the applied voltage by 90° and I_R is in phase with applied voltage as shown in Fig. 4.15(c).

$$\text{Dielectric loss, } P_L = V I \cos\phi$$

$$= V I_R \qquad [\because I_R = I\cos\phi]$$

$$= V I_C \tan\delta \qquad \left[\because \tan\delta = \frac{I_R}{I_C}\right].$$

$$V \cdot \left(\frac{V}{X_C}\right)\tan\delta \qquad \left[QI_C = \frac{V}{X_C}\right]$$

$$= V^2 \omega C \tan\delta \qquad \textbf{(4.13)}$$

where 'V' is the applied voltage in volts, 'f' is the supply frequency in Hz, ε_0 is the absolute permittivity of the medium = 8.854×10^{-12} F/m, ε_r is the relative permittivity of the medium = 1 for free space, A is the area of the plate or electrode (m^2), d is the thickness of the dielectric medium, and δ is the loss angle in radian.

From Equation (4.14):

$$P_L \propto V^2 \quad \text{and} \quad P_L \propto f. \qquad \textbf{(4.15)}$$

Normally frequency used for dielectric heating is in the range of 1–40 MHz. The use of high voltage is also limited due to the breakdown voltage of thin dielectric that is to be heated, under normal conditions; the voltage gradient used is limited to 18 kV/cm.

Advantages:

1.If the material to be heated is homogeneous, and the alternating (or varying) electric field is uniform, heat is developed uniformly and simultaneously throughout the entire mass of the charge.

2.As materials heated by this process are non-conducting, so by other methods heat cannot be conducted to inside so easily.

		Disadvantages: 1. Since heat produced in dielectric heating very much depends upon the type of material, the product size, the power density, etc., so we can heat only those materials which have a high dielectric loss. It is not possible to heat a transparent or reflective material by this method. 2. The cost of equipment required for dielectric heating is so high that we use this method only where other methods are impracticable or too slow. 3. The overall efficiency of dielectric heating is very low (about 50%). 4. High frequencies may cause radio interference.	
9	a)	What are the disadvantages of direct core type induction furnace?	**[5M]**
		The direct core type induction furnace has the following main drawbacks − 1.In case of direct core type induction furnace, the magnetic coupling between the primary winding and the secondary winding is poor, which results in high leakage reactance and hence the low power factor. 2.The crucible used for holding the charge is of odd shape, which is not convenient from the metallurgical point of view. 3.As the direct core type induction furnace requires low primary frequency as the normal supply frequency causes the turbulence of the charge. Therefore, it requires either a motor-generator set or a frequency converter, which increases the cost of the heating. 4.There is pinching effect, i.e., formation of bubble and voids, in case of direct core type induction heating. 5.The direct core type induction furnace cannot function if its secondary circuity is not closed. Thus, for starting the furnace, a complete ring of the charge is formed around the core. Also, to start the furnace, an iron ring or a lining of graphite may be placed in the crucible.	
	b)	Determine the amount of energy required to melt brass at the rate of one ton per hour in a single phase Ajax Wyatt furnace. Specific heat of brass is 0.094 Kcal/ Kg/^{o}C. Latent heat of fusion is 40 Kcal/Kg, initial temperature is 24 ^{o}C, melting point of brass is 920 ^{o}C. Assume efficiency to be 65 %.	

Sol: Weight of brass to be melted = 1000 kg

Heat required to raise the temperature from 24°c to 920°c $= ms(t_2 - t_1)$

$= 1000 \times 0.094 \times (920 - 24)$

$= 84224$ kcal.

Heat required for melting, $40\,mL = 1000 \times 40 = 40{,}000$ kcal

Total Heat required $= 84224 + 40{,}000$

$= 1{,}24{,}224$ kcal

Now 4.18 J = 1cal & 1 Joule/sec = 1 watt

$$\text{Energy input} = \frac{1{,}24{,}224 \times 10^3 \times 4.18}{10^3 \times 3600 \times 0.65} = 221.9 \text{ kWh}$$

$$\text{Power} = \frac{\text{Energy}}{\text{time}} = \frac{221.9}{1} = 221.9 \text{ KW.}$$

10 Write short notes on:

a) Infrared heating **[2M]**

b) pinch effect in induction heating. **[2M]**

c) various modes of heat transfer. **[2M]**

d) advantages of coreless induction furnace **[2M]**

e) disadvantages of direct core type induction furnace **[2M]**

a)Infrared heating:

In this method of heating, the heat energy is transferred from source (incandescent lamp) and
focused upon the body to be heated up in the form of electromagnetic radiations. Normally, this
method is used for drying clothes in the textile industry and to dry the wet paints on an object.

b)pinch effect in induction heating:

If current density exceeds about 500 A/cm^2, it will produce high-electromagnetic forces in the molten metal and hence adjacent molecules repel each other, as they are in the same direction. The repulsion may cause the interruption of secondary circuit (formation of bubbles and voids), this effect is known as pinch effect.

c)various modes of heat transfer:

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

1. conduction,
2. convection, or
3. radiation.

Conduction

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

Convection

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

Radiation

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

d)Advantages of coreless induction furnace

Following are the advantages of coreless furnace over the other furnaces:
- Ease of control.
- Oxidation is reduced, as the time taken to reach the melting temperature is less.
- The eddy currents in the charge itself results in automatic stirring.
- The cost is less for the erection and operation.
- It can be used for heating and melting.
- Any shape of crucible can be used.
- It is suitable for intermittent operation.

e)Disadvantages of direct core type induction furnace

The disadvantages of direct core type induction furnaces are as follows:
1.high leakage reactance.
2.Low effect
3.Pimch effect
4.odd crucible shape.

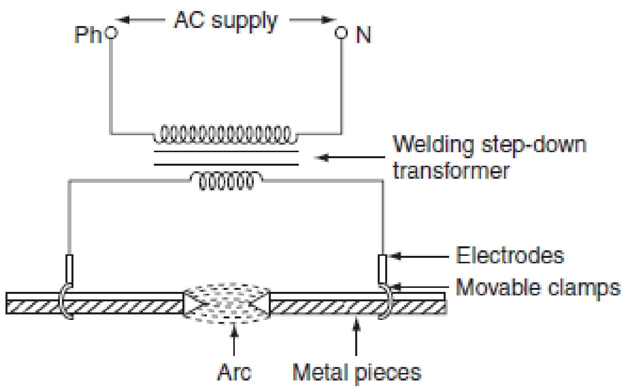
UNIT – III

ELECTRIC WELDING

1	a)	Write briefly about flash welding.	**[5M]**

Flash Welding:

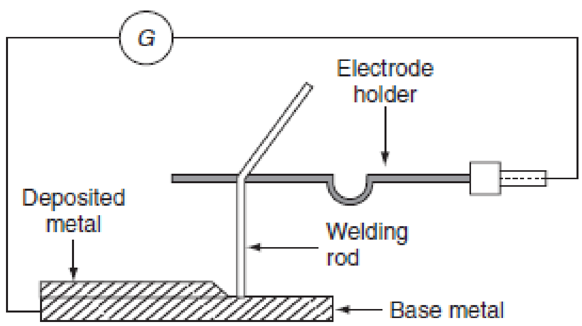
Flash butt welding is a combination of resistance, arc, and pressure welding. This method of welding is mainly used in the production welding. A simple flash butt welding arrangement is shown in Fig. below.

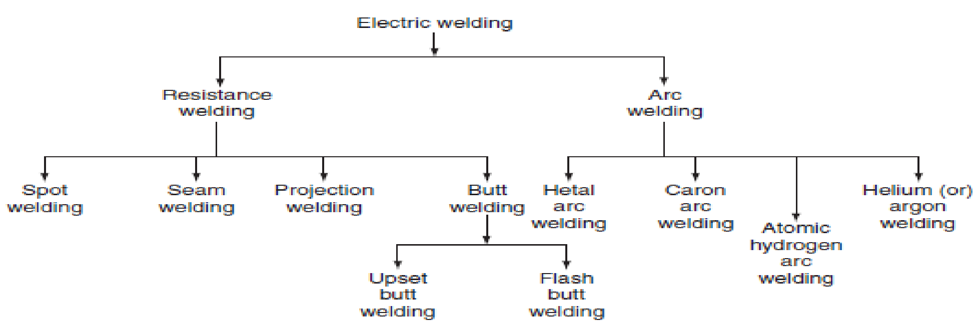


In this method of welding, the two pieces to be welded are brought very nearer to each other under light mechanical pressure. These two pieces are placed in a conducting movable clamps. When high current is passed through the two metal pieces and they are separated by some distance, then arc established between them. This arc or flashing is allowed till the ends of the workpieces reach melting temperature, the supply will be switched off and the pieces are rapidly brought together under light pressure. As the pieces are moved together, the fused metal and slag come out of the joint making a good solid joint.

	b)	Differentiate between A.C and D.C welding.	**[5M]**

S.No	A.C. Welding	D.C.Welding
1.	Motor generator set or rectifier is required in case of the availability of AC supply.	Only transformer is required.
2.	The cost of the equipment is high.	The cost of the equipment is low.
3.	Arc stability is more.	Arc stability is less.
4.	The heat produced is uniform.	The heat produced is non uniform.
5.	Both bare and coated electrodes can be used	Only coated electrodes should be used.
6.	The operating power factor is high.	The power factor is low. So, the capacitors are necessary to improve the power factor.
7.	It is safer since no load voltage is low.	It is dangerous since no load voltage is high.
8.	The electric energy consumption is 5–10 kWh/kg of deposited metal.	The electrical energy consumption is 3–4 kWh/kg of deposited metal.
9.	The efficiency is low due to the rotating parts.	The efficiency is high due to the absence of rotating parts.

2	a)	Briefly discuss the welding electrodes of various metals.	[5M]
		A welder needs an electrode to generate an electric current to do arc welding. In welding, an electric current is conducted through an electrode which is used to join the parent metals. Basically, depending upon the process there are two types of welding electrodes: 1.Consumable Electrodes 2.Non-Consumable Electrodes Consumable electrodes have low melting point. These types of welding electrodes are preferred to use in Metal Inert Gas (MIG) welding. For making consumable electrodes, materials such as mild steel and nickel steel are used. Consumable electrodes are Bare Electrodes, Coated Electrode These types of welding electrodes are also referred to as Refractory electrodes. There are again two sub-types of non-consumable electrodes: Carbon or Graphite electrodes ad Tungsten electrodes.	
	b)	Explain briefly the arc welding process.	[5M]
		Electric arc welding is the process of joining two metallic pieces or melting of metal is obtained due to the heat developed by an arc struck between an electrode and the metal to be welded or between the two electrodes as shown in Fig. below  In this process, an electric arc is produced by bringing two conductors (electrode and metal piece) connected to a suitable source of electric current, momentarily in contact and then separated by a small gap, arc blows due to the ionization and give intense heat. The heat so developed is utilized to melt the part of workpiece and filler metal and thus forms the weld. In this method of welding, no mechanical pressure is employed; therefore, this type of welding is also known as *'non-pressure welding'*. The length of the arc required for welding depends upon the following factors: o The surface coating and the type of electrodes used. o The position of welding. o The amount of current used. When the supply is given across the conductors separated by some distance apart, the air gap present between the two conductors gets ionized, as the arc welding is in progress, the ionization of the arc path and its surrounding area increases. This increase in ionization decreases the resistance of the path. Thus, current increases with the decrease in voltage of arc. This *V-I* characteristic of an arc is shown in Fig. (b), it also known as *negative resistance characteristics of an arc.* Thus, it will be seen that this decrease in resistance with increase in current does not remain the arc steadily. This difficulty cab	

		be avoided, with the supply, it should fall rapidly with the increase in the current so that any further increase in the current is restricted. For the arc welding, the temperature of the arc should be 3,500°C. At this temperature, mechanical pressure for melting is not required. Both AC and DC can be used in the arc welding. Usually 70–100 V on AC supply and 50–60 V on DC supply system is sufficient to struck the arc in the air gap between the electrodes. Once the arc is struck, 20–30 V is only required to maintain it. However, in certain cases, there is any danger of electric shock to the operator, low voltage should be used for the welding purpose. Thus, DC arc welding of low voltage is generally preferred. Electric arc welding is extensively used for the joining of metal parts, the repair of fractured casting, and the fillings by the deposition of new metal on base metal, etc. Various types of electric arc welding are: 1. Carbon arc welding. 2. Metal arc welding. 3. Atomic hydrogen arc welding. 4. Inert gas metal arc welding. 5. Submerged arc welding.	
3		Explain the different methods of electric welding and their relative advantages.	**[10M]**
		Welding: It is defined as the process of joining two metal pieces, in which the electrical energy is used to generate heat at the point of welding in order to melt the joint. **Methods of welding:** The classification of welding process is shown in fig below.  **Advantages:** Some of the advantages of welding are: o Welding is the most economical method to permanently join two metal parts. o It provides design flexibility. o Welding equipment is not so costly. o It joins all the commercial metals. o Both similar and dissimilar metals can be joined by welding. o Portable welding equipment are available.	**[5M]**

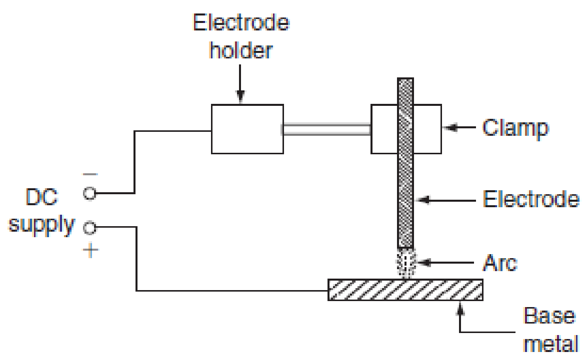
4		Discuss about the techniques used for arc welding.	[10M]

Various types of electric arc welding are:

1. Carbon arc welding.
2. Metal arc welding.
3. Atomic hydrogen arc welding.
4. Inert gas metal arc welding.

Carbon arc welding

It is one of the processes of arc welding in which arc is struck between two carbon electrodes or the carbon electrode and the base metal. The simple arrangement of the carbon arc welding is shown in Fig.



In this process of welding, the electrodes are placed in an electrode holder used as negative electrode and the base metal being welded as positive. Unless, the electrode is negative relative to the work, due to high temperature, there is a tendency of the particles of carbon will fuse and mix up with the base metal, which causes brittleness; DC is preferred for carbon arc welding since there is no fixed polarity maintained in case of AC.

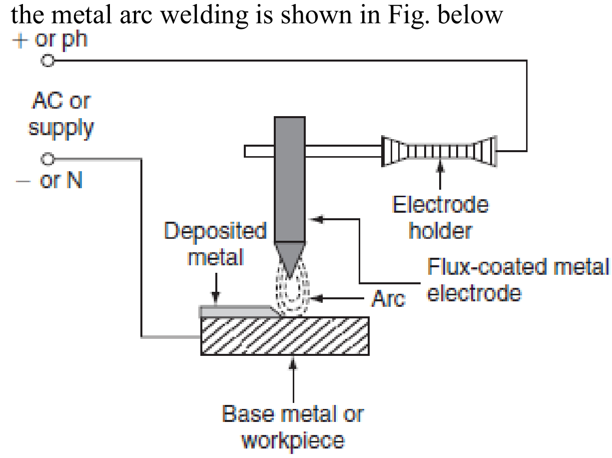
In the carbon arc welding, carbon or graphite rods are used as electrode. Due to longer life and low resistance, graphite electrodes are used, and thus capable of conducting more current. The arc produced between electrode and base metal; heat the metal to the melting temperature, on the negative electrode is 3,200°C and on the positive electrode is 3,900°C.

This process of welding is normally employed where addition of filler metal is not required. The carbon arc is easy to maintain, and also the length of the arc can be easily varied. One major problem with carbon arc is its instability which can be overcome by using an inductor in the electrode of 2.5-cm diameter and with the current of about of 500–800 A employed to deposit large amount of filler metal on the base metal.

Filler metal and flux may not be used depending upon the type of joint and material to be welded.

Metal arc welding

In metal arc welding, the electrodes used must be of the same metal as that of the work-piece to be welded. The electrode itself forms the filler metal. An electric arc is stuck by bringing the electrode connected to a suitable source of electric current, momentarily in contract with the workpieces to be welded and withdrawn apart. The circuit diagram for the metal arc welding is shown in Fig. below



The arc produced between the workpiece and the electrode results high temperature of the order of about 2,400°C at negative metal electrode and 2,600°C at positive base metal or workpiece.

This high temperature of the arc melts the metal as well as the tip of the electrode, then the electrode melts and deposited over the surface of the workpiece, forms complete weld.

Both AC and DC can be used for the metal arc welding. The voltage required for the DC metal arc welding is about 50–60 V and for the AC metal arc welding is about 80–90 V

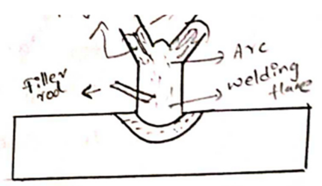
In order to maintain the voltage drop across the arc less than 13 V, the arc length should be kept as small as possible, otherwise the weld will be brittle. The current required for the welding varies from 10 to 500 A depending upon the type of work to be welded.

The main disadvantage in the DC metal arc welding is the presence of arc blow, i.e., distortionof arc stream from the intended path due to the magnetic forces of the non-uniform magnetic field with AC arc blow is completely reduced.

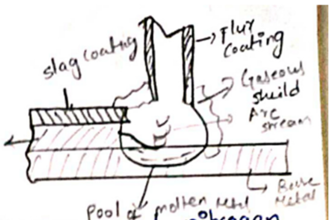
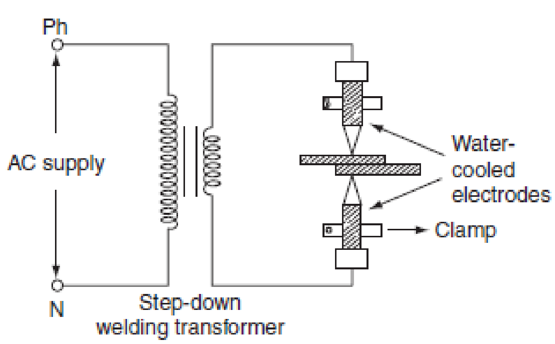
Atomic Hydrogen arc welding

Atomic Hydrogen welding :

- In this system, heat is obtained from an alternating current arc drawn b/n two tungsten electrodes in an atmosphere of hydrogen



As the hydrogen gas passes through the arc, the hydrogen molecules are broken up into atoms and they recombine on contact with the cooler base metal generating intense heat sufficient to melt the surfaces to be welded together with the filler rod, if used.

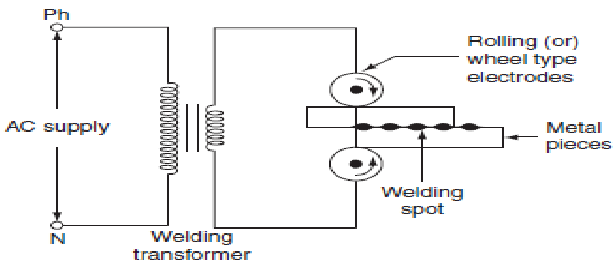
		Inert gas arc welding  In this System, molten weld metal is protected from the action of atmosphere by an Envelope of chemically reducing (or) inert gas. As molten steel has an affinity for oxygen and nitrogen it will, if exposed to the atmosphere, enter into the combination with these gases forming oxides and nitrides. Due to this injurious chemical combination metal becomes weak, brittle and corrosion resistance.	
5		Describe with a neat sketch the various methods of electric resistance welding.	
		Depending upon the method of weld obtained and the type of electrodes used, the resistance welding is classified as: 1. Spot welding. 2. Seam welding. 3. Projection welding. 4. Butt welding. *(i) Spot welding* Spot welding means the joining of two metal sheets and fusing them together between copper electrode tips at suitably spaced intervals by means of heavy electric current passed through the electrodes as shown in Fig. 5.3.  This type of joint formed by the spot welding provides mechanical strength and not air or water tight, for such welding it is necessary to localize the welding current and to apply sufficient pressure on the sheet to be welded. The electrodes are made up of copper or copper alloy and are water cooled. The welding current varies widely depending upon the thickness and composition of the plates. It varies from 1,000 to 10,000 A, and voltage between the electrodes is usually less than 2 V. The period of the flow of current varies	

widely depending upon the thickness of sheets to be joined. A step-down transformer is used to reduce a high-voltage and low-current supply to low-voltage and high-current supply required. Since the heat developed being proportional to the product of welding time and square of the current. Good weld can be obtained by low currents for longer duration and high currents for shorter duration; longer welding time usually produces stronger weld but it involves high energy expenditure, electrode maintenance, and lot of distortion of workpiece.

(ii) Seam welding

Seam welding is nothing but the series of continuous spot welding. If number spots obtained by spot welding are placed very closely that they can overlap, it gives rise to seam welding.

In this welding, continuous spot welds can be formed by using wheel type or roller electrodes instead of tipped electrodes as shown in Fig. 5.5.



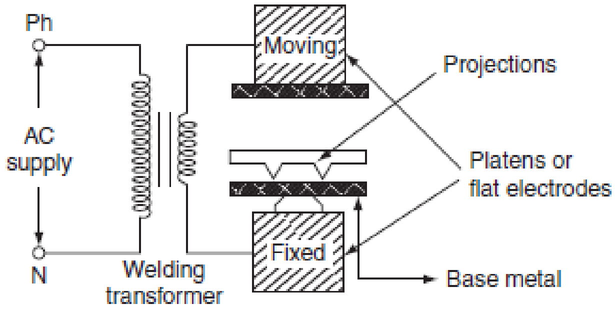
Seam welding is obtained by keeping the job under electrodes. When these wheel type electrodes travel over the metal pieces which are under pressure, the current passing between them heats the two metal pieces to the plastic state and results into continuous spot welds. In this welding, the contact area of electrodes should be small, which will localize the current pressure to the welding point. After forming weld at one point, the weld so obtained can be cooled by splashing water over the job by using cooling jets.

Seam welding is very important, as it provides leak proof joints. It is usually employed in welding of pressure tanks, transformers, condensers, evaporators, air craft tanks, refrigerators,varnish containers, etc.

(iii) Projection welding

It is a modified form of the spot welding. In the projection welding, both current and pressure are localized to the welding points as in the spot welding. But the only difference in the projection welding is the high mechanical pressure applied on the metal pieces to be welded, after the formation of weld. The electrodes used for such welding are flat metal plates known as *platens*.

The two pieces of base metal to be weld are held together in between the two platens, one is movable and the other is fixed, as shown in Fig. 5.7.



One of the two pieces of metal is run through a machine that makes the bumps or projections of required shape and size in the metal. As current flows through the two metal parts to be welded, which heat up and melt. These weld points soon reach the plastic state, and the projection touches the metal then force applied by the two flat electrodes forms the complete weld.

The projection welding needs no protective atmosphere as in the spot welding to produce successful results. This welding process reduces the amount of current and pressure in order to join two metal surfaces, so that there is less chance of distortion of the surrounding areas of the weld zone. Due to this reason, it has been incorporated into many manufacturing process.

(iv) Butt welding

Butt welding is similar to the spot welding; however, the only difference is, in butt welding, instead of electrodes the metal parts that are to be joined or butted together are connected to the supply.

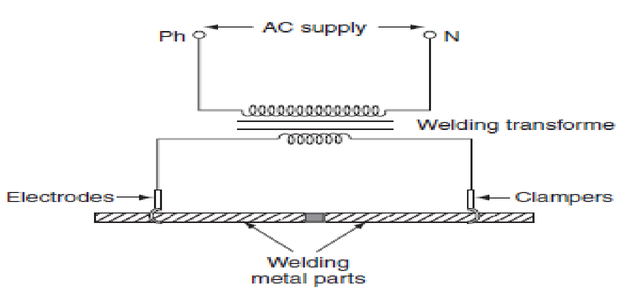
The three basic types of the butt welding process are:

a)Upset butt welding.

b)Flash butt welding.

a) Upset butt welding

In upset welding, the two metal parts to be welded are joined end to end and are connected across the secondary of a welding transformer as shown in Fig. 5.8.

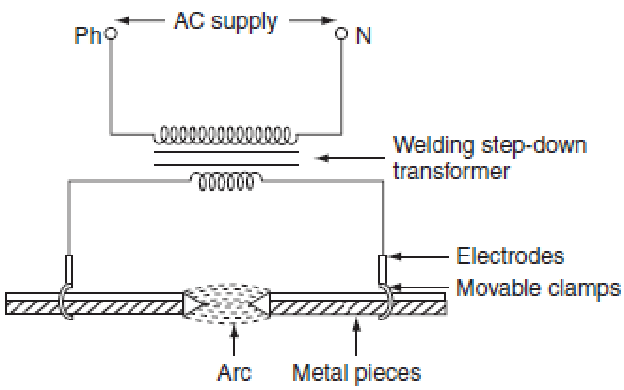


Due to the contact resistance of the metals to be welded, heating effect is generated in this welding. When current is made to flow through the two electrodes, heat will develop due to the contact resistance of the two pieces and then melts. By applying high mechanical pressure either manually or by toggle mechanism, the two metal pieces are pressed. When jaw-type electrodes are used that introduce the high currents without treating any hot spot on the job.

This type of welding is usually employed for welding of rods, pipes, and wires and for joining metal parts end to end.

(b) Flash butt welding

Flash butt welding is a combination of resistance, arc, and pressure welding. This method of welding is mainly used in the production welding. A simple flash butt welding arrangement is shown in Fig. 5.9.

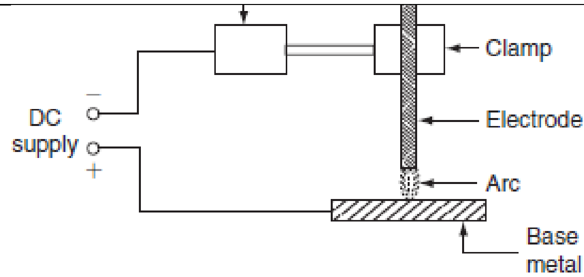


In this method of welding, the two pieces to be welded are brought very nearer to each other under light mechanical pressure. These two pieces are placed in a conducting movable clamps.
When high current is passed through the two metal pieces and they are separated by some distance, then arc established between them. This arc or flashing is allowed till the ends of the workpieces reach melting temperature, the supply will be switched off and the pieces are rapidly brought together under light pressure. As the pieces are moved together, the fused metal and slag come out of the joint making a good solid joint.

6	a)	Explain about metal arc welding, carbon arc welding methods with necessary illustrations.	**[5M]**

Carbon arc welding

It is one of the processes of arc welding in which arc is struck between two carbon electrodes or the carbon electrode and the base metal. The simple arrangement of the carbon arc welding is shown in Fig.



In this process of welding, the electrodes are placed in an electrode holder used as negative electrode and the base metal being welded as positive. Unless, the electrode is negative relative to the work, due to high temperature, there is a tendency of the particles of carbon will fuse and mix up with the base metal, which causes brittleness; DC is preferred for carbon arc welding since there is no fixed polarity maintained in case of AC.

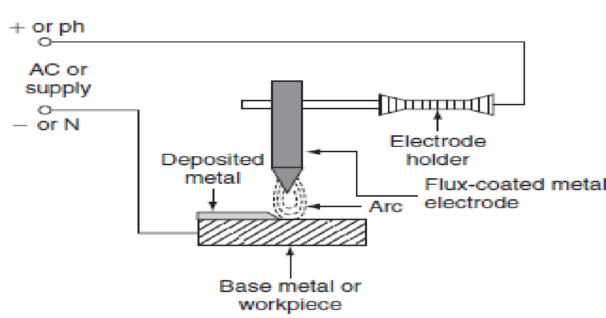
In the carbon arc welding, carbon or graphite rods are used as electrode. Due to longer life and low resistance, graphite electrodes are used, and thus capable of conducting more current. The arc produced between electrode and base metal; heat the metal to the melting temperature, on the negative electrode is 3,200°C and on the positive electrode is 3,900°C.

This process of welding is normally employed where addition of filler metal is not required. The carbon arc is easy to maintain, and also the length of the arc can be easily varied. One major problem with carbon arc is its instability which can be overcome by using an inductor in the electrode of 2.5-cm diameter and with the current of about of 500–800 A employed to deposit large amount of filler metal on the base metal.

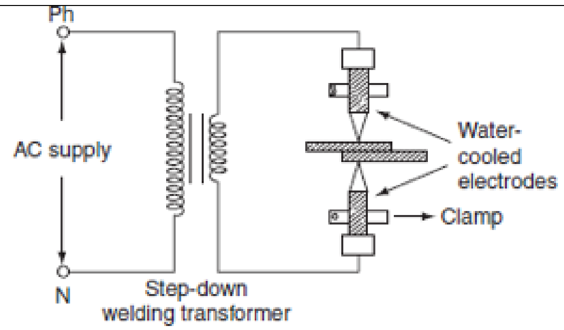
Filler metal and flux may not be used depending upon the type of joint and material to be welded.

Metal arc welding

In metal arc welding, the electrodes used must be of the same metal as that of the work-piece to be welded. The electrode itself forms the filler metal. An electric arc is stuck by bringing the electrode connected to a suitable source of electric current, momentarily in contract with the workpieces to be welded and withdrawn apart. The circuit diagram for the metal arc welding is
shown in Fig. below



		The arc produced between the workpiece and the electrode results high temperature of the order of about 2,400°C at negative metal electrode and 2,600°C at positive base metal or workpiece. This high temperature of the arc melts the metal as well as the tip of the electrode, then the electrode melts and deposited over the surface of the workpiece, forms complete weld. Both AC and DC can be used for the metal arc welding. The voltage required for the DC metal arc welding is about 50–60 V and for the AC metal arc welding is about 80–90 V In order to maintain the voltage drop across the arc less than 13 V, the arc length should be kept as small as possible, otherwise the weld will be brittle. The current required for the welding varies from 10 to 500 A depending upon the type of work to be welded. The main disadvantage in the DC metal arc welding is the presence of arc blow, i.e., distortionof arc stream from the intended path due to the magnetic forces of the non-uniform magnetic field with AC arc blow is completely reduced.	
	b)	What type of electric supply is suitable for electric arc welding?	**[5M]**
		Both AC and DC can be used in the arc welding. Usually, 70 – 100 V on AC supply and 50 – 60 V on DC system is sufficient to strike the arc in the air gap between the electrodes. Once the arc is struck, 20 – 40 V is only required to maintain it. The current rating is usually 50 – 1000 A. Two types of rotating machinery are used that supply power for arc welding. Generators produce direct current and Alternators provide alternating current. The final supply type however, can be further transformed by suitable means to meet requirements. Electrode positive is ideal when deeper penetration is required while electrode negative offers a faster rate of deposition. Since there is no constant fluctuation in the direction of current flow, DC welding produces a more stable arc when welding.	
7		Explain in detail about the following with respect to Welding: i) Spot welding ii) Seam welding iii) Butt welding iv) projection welding	**[10M]**
		(i) Spot welding: Spot welding means the joining of two metal sheets and fusing them together between copper electrode tips at suitably spaced intervals by means of heavy electric current passed through the Electrode.	

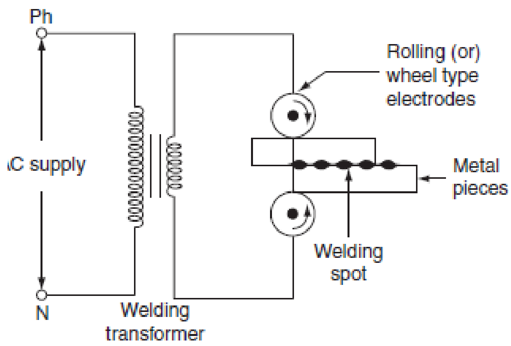


This type of joint formed by the spot welding provides echanical strength and not air or water tight, for such welding it is necessary to localize the welding current and to apply sufficient pressure on the sheet to be welded. The electrodes are made up of copper or copper alloy and are water cooled. The welding current varies widely depending upon the thickness and composition of the plates. A step-down transformer is used to reduce a high-voltage and low-current supply to low-voltage and high-current supply required. ince the heat developed being proportional to the product of welding time and square of the current. Good weld can be obtained by low currents for longer duration and high currents for shorter duration.

ii) Seam welding : Seam welding is nothing but the series of continuous spot welding. If number spots obtained by spot welding are placed very closely that they can overlap, it gives rise to seam welding. In this welding, continuous spot welds can be formed by using wheel type or roller electrodes instead of tipped electrodes

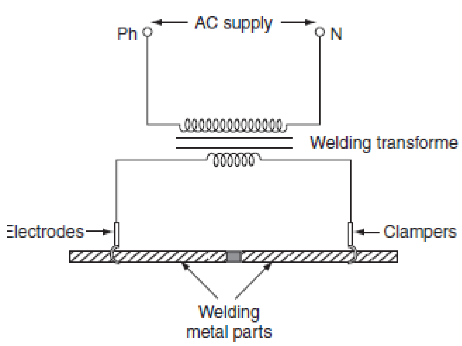
Seam welding is obtained by keeping the job under electrodes. When these wheel type electrodes travel over the metal pieces which are under pressure, the current passing between them heats the two metal pieces to the plastic state and results into continuous spot welds. In this welding, the contact area of electrodes should be small, which will localize the current pressure to the welding point. After forming weld at one point, the weld so obtained can be cooled by splashing water over the job by using cooling jets.

Seam welding is very important, as it provides leak proof joints. It is usually employed in welding of pressure tanks, transformers, condensers, evaporators, air craft tanks, refrigerators, varnish containers, etc.

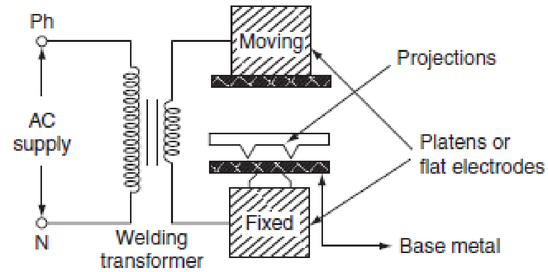
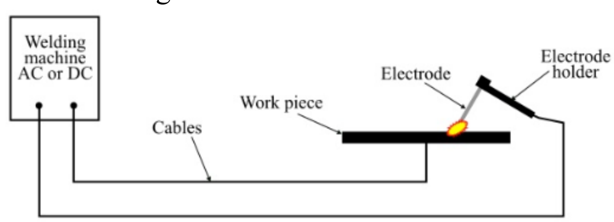


iii) Butt welding

Butt welding is similar to the spot welding; however, the only difference is, in butt welding, instead of electrodes the metal parts that are to be joined or butted together are connected to the supply.

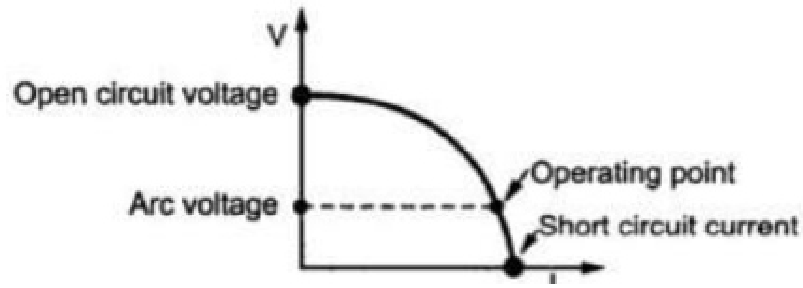


*(iii) Projection welding :*It is a modified form of the spot welding. In the projection welding, both current and pressure are localized to the welding points as in the spot welding. But the only difference in the projection welding is the high mechanical pressure applied on the metal pieces to be welded, after the formation of weld. The electrodes used for such welding are flat metal plates known as *platens*. The two pieces of base metal to be weld are held together in between the two platens, one is movable and the other is fixed.

		 One of the two pieces of metal is run through a machine that makes the bumps or projections of required shape and size in the metal. As current flows through the two metal parts to be welded, which heat up and melt. These weld points soon reach the plastic state, and the projection touches the metal then force applied by the two flat electrodes forms the complete weld. The projection welding needs no protective atmosphere as in the spot welding to produce successful results. This welding process reduces the amount of current and pressure in order to join two metal surfaces, so that there is less chance of distortion of the surrounding areas of the weld zone. Due to this reason, it has been incorporated into many manufacturing process.	
8	a)	Write about various types of equipment used for electric welding.	**[6M]**
		The various equipment required for the electric arc welding (AC and DC) are shown in the figure and described below.  **Welding Machine:**The welding machine used for electric arc welding can either be an AC or DC welding machine. **AC Welding Machine:**The AC arc welding machine has a step-down transformer to reduce the input supply voltage of 220 V to 80 V. **DC Welding Machine:**The DC arc welding machine commonly consists of a *motor-generator set*. Where, the motor is a squirrel cage induction motor and the generator is the differential compound DC generator to give drooping characteristics.	

		Electrode Holder: The electrode holder is the equipment used for holding the electrode at a desired angle. **Leads or Cables:** The cables or leads carry the electric current from the welding machine to the work-piece. The cable used for welding process are made of copper or aluminium and are flexible.	
	b)	What are the advantages of using coated welding electrodes?	**[4M]**
		Advantages of Coated Electrodes • Can be Used with AC Supply. ... • Helps in Maintaining the Arc. ... • Shielding the Molten Metal from Oxidization. ... • Can be Used for High Welding Current. ... • Prevents the Spattering of Metal. ... • Overhead and Vertical Welding is Easy. ... • Sudden Cooling of the Weld is Prevented.	
9	a)	What is the technique of weld metal deposition by electric arc?	**[5M]**
		In a basic arc welding process, the power supply is switched on, and the electrode is brought near the base material. Then, intense heat is generated to produce the electric arc. The heat then melts the base metal, electrode core and flux coating. The flux coating then provides a shielding environment to weld.	
	b)	What are the qualities of a good weld?	**[5M]**
		The sign of a quality and secure weld is that you will not see the weld at all. If there is any visible evidence of a weld, it will be in the form of a bead that has no holes or cracks and is uniform overall. A high-quality weld is made using high-quality materials. • No cracks or holes found in the bead. • The bead has uniform waves, width and height. • The finished product satisfies the design dimensions and has almost no distortion. • The welding meets the required strength.	
10	a)	Write short notes on: **a) Welding transformer characteristics** .	**[10M]**

Volt – ampere characteristics of welding transformer:



b) **Spot welding**.

Spot welding means the joining of two metal sheets and fusing them together between copper electrode tips at suitably spaced intervals by means of heavy electric current passed through the Electrode.

c) arc stability

A stable arc has three main features: a constant shape of droplets, constant length of arc, and low amount of spatter. When welding with a short arc, there can be a lack of fusion and the deposition rate is low.

d) arc welding accessories

Welding gloves, aprons and helmets, dust masks, extraction systems and other safety equipment.

Chipping hammers and wire brushes.

Gas nozzles and contact tips for MIG/MAG welding.

Tungsten rods for TIG/GTAW welding.

Abrasive discs for angle grinders.

Electrodes for resistance spot welding.

e) advantages of resistance welding.

The advantage of Resistance welding is its high operation speed, high volume, low cost and the elimination of filler material in every welds.

UNIT - IV
ELECTROLYSIS

1	a)	What is electrolysis? Give advantages of using this processing method.	[5M]
		Electrolysis is a technique that uses **direct current (DC)** power to power chemical reactions that are not otherwise spontaneous. Cations are reduced at the cathode and anions are oxidized at the anode. **Explanation:** Advantages of electrolysis: 1. Electrolysis is used to permanently remove facial hair from the body. 2. This electrolysis is an effective way to remove hair compared to creams, ointments, waxes, and medicines. 3 .Electrolysis is cheaper than other methods and the results are generally permanent. 4. The electrolyte used protects the metal from corrosion and rust. 5. Electrolysis makes metals attractive and gives them an expensive look. 6. Many of the useful substances are produced by the electrolysis process. 7.Chlorine can be produced by electrolyzing a solution of salt. Hydrogen is also produced by the electrolysis of water. 8. Heavy water such as deuterium oxide used in nuclear reactors is also produced by electrolysis of water. 9. Electrolysis is a safe and effective way to remove hair. 10.Electrolysis of a metal solution yields pure metal. Impurities from the metal are removed by electrolysis. Some metals such as silver, copper, lead, zinc and nickel are refined or refined by an electrolytic refining process	
	b)	Explain the widely used areas of electrolysis.	[5M]
		Electrolysis, as stated above, is a process of converting the ions of a compound in a liquid state into their reduced or oxidized state by passing an electric current through the compound. Thus, electrolysis finds many applications, both in experimental and industrial products. Some of the important ones are given below: 1) Determination of equivalent weight of substances. 2) Metallurgy of alkali and alkaline earth metals. 3) Purification of metals. 4) Manufacture of pure gases.	

		5) Manufacture of compounds like sodium hydroxide, sodium carbonate, potassium chlorate etc. 6) Electroplating for corrosion resistance, ornaments etc.	
2		Discuss the various applications of electrolysis in detail.	**[10M]**
		Determination of Equivalent Weight of Substances We know Faraday's second law states that the mass of substances deposited is proportional to their equivalent weight. The mass of any deposited substance can be, mathematically related as: $M_1/E_1=M_2/E_2$ The equivalent mass of an unknown metal or substance can be calculated by passing a known current through the solutions and determining the mass of substances (M1 and M2) deposited in their respective cells. If the equivalent mass of one substance is known, the equivalent mass of the unknown substance can be calculated from the above equation. **Electrolysis of Molten Salts** Metallurgy of alkali and alkaline earth and third group metals ores of metal is concentrated and converted mostly to oxides. Oxides are reduced with reducing agents such as carbon, aluminium etc. Since alkali and alkali earth metals have the largest reduction potentials, any other metals or their compounds cannot reduce them. The only way of isolation of alkali and alkali earth metals is to directly electrolyze their molten chlorides. Mixing with other halides, like calcium chlorides, reduces the melting point of pure halides. **Electrorefining – Purification of Metals** Metals obtained after concentration and reduction of ores have a purity of about 90-99%. An aqueous solution of the metal salt with the impure metal as the anode and the pure metal as the cathode is electrolyzed. The pure metal of more than 99% purity deposits on the cathode, and the impurities are collected at the bottom as mud. Copper and nickel are some examples of the metal purified by electrorefining. **Electroplating** An object can be coated to the required thickness with a select metal by electrolysis. The object to be coated is made of the cathode. An aqueous solution of the metal salt to be coated is the electrolyte. The same metal or any inert metal can be the anode. In electrolysis, metal ion from the electrolyte deposit on the object. The loss of metal ions in the solution will be compensated if the same metal made the anode. The deposition can be used to protect the metal from corrosion for making ornaments, etc. Coating iron with metals like zinc, lead, chromium, and nickel	

improves the corrosion resistance of iron. Gold and silver coating on cheaper metals is used for making ornaments.

It is also used in electrochemical machining (ECM). Here, an electrolytic cathode is used as a shaped tool for removing material by anodic oxidation from a workpiece. ECM technique is often used for deburring or for putting a permanent mark or logo on metal surfaces like tools or knives.

Electro-forming

Electroforming is a process of making a replica of objects using electrolysis. The object to be replicated is pressed in wax to make a mould. Graphite powder is coated uniformly to make it conductive. This is used as a cathode, and the salt of the metal to be deposited is taken as the electrolyte. After getting the required coating by electrolysis, the wax and the graphite are melted away.

Manufacture of Pure Gases

Aqueous salts on hydrolysis yield different products depending on the relative concentrations of salt and water. Electrolysis of concentrated brine (sodium chloride) forms pure hydrogen and chlorine gases. Pure chlorine gas is collected in the Chlor-alkali industries by the electrolysis of brine aqueous solution.

Pure hydrogen and oxygen are obtained by hydrolysis of water in the presence of acid or base or inert salt of alkali and alkaline earth metals. The percentage of hydrogen for commercial use is manufactured by the electrolysis of water worldwide.

Continuous electrolysis of water removes all the normal hydrogen isotopes leaving the deuterium ions. The deuterium oxide leftover after electrolysis of normal water is ‘heavy water’. Heavy water is used as a moderator in nuclear reactors producing electrical energy from nuclear reactions.

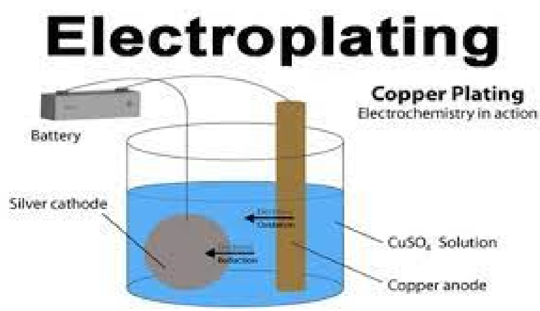
Manufacture of Compounds

Compounds like sodium hydroxide, sodium hydrosulphite, potassium permanganate, potassium chlorate, ammonium per-sulphate, heavy wateretc., are manufactured by electrolysis. Sodium hydroxide is a side product in the chloralkali industries, preparing chlorine gas by the electrolysis of brine.

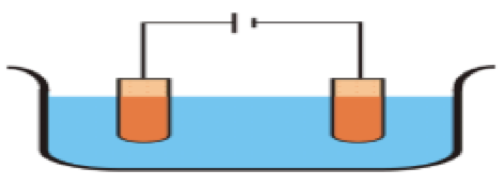
Potassium permanganate is obtained by the electrolysis of potassium manganite solution. Ammonium sulphate or ammonium bisulphate on electrolysis forms ammonium persulphate.

Electrocrystallization

This is a specialised application of electrolysis. In this process, conductive crystals are grown on one of the electrodes from oxidized or reduced species that are generated in situ. This technique is popularly used to manufacture single crystals of

		low-dimensional electrical conductors, such as linear chain compounds or charge-transfer salts.	
3.	a)	Discuss about the process of electro plating.	**[5M]**
		 Figure- 1, Figure- 1, schematically illustrates a simple electrochemical plating system. The —electro‖ part of the system includes the voltage/current source and the electrodes, anode and cathode, immersed in the —chemical‖ part of the system, the electrolyte or plating bath, with the circuit being completed by the flow of ions from the plating bath to the electrodes. The metal to be deposited may be the anode and be ionized and go into solution in the electrolyte, or come from the composition of the plating bath. Copper, tin, silver and nickel metal usually comes from anodes, while gold salts are usually added to the plating bath in a controlled process to maintain the composition of the bath. The plating bath generally contains other ions to facilitate current flow between the electrodes. The deposition of metal takes place at the cathode. The overall plating process occurs in the following sequence: 1. Power supply pumps electrons into the cathode. 2. An electron from the cathode transfers to a positively charged metal ion in the solution and the reduced metal plates onto the cathode. 3. Ionic conduction through the plating bath completes the circuit to the anode. 4. At the anode two different processes take place depending on whether the anode material is soluble, the source of the metal to be plated, or insoluble, inert. If the anode material is soluble, a metal atom gives up an electron and goes into the solution as a positively charged metal ion replenishing the metal content of the plating bath. If the anode is inert a negatively charged ion from the plating bath gives up an electron to the anode. 5. The electron flows from the anode to the power supply completing the circuit. The deposition of metal at the cathode requires an electron so the rate of deposition Fig-1. Electrochemical Plating depends on the flow of electrons, that is, the current flowing from the rectifier. The thickness of the deposit, therefore, depends on the current and the length of time the current is applied. This relationship is a result of Faraday‘s law which relates the weight of a substance	

		produced by an anode or cathode electrode reaction during electrolysis as being directly proportional to the quantity of electricity passed through the cell.	
	b)	Discuss about Faraday's laws of electrolytic process.	**[5M]**
		Faraday's Laws of Electrolysis From his experiments, Faraday deduced two fundamental laws which govern the phenomenon of electrolysis. These are: **(i)** **First Law.** The mass of ions liberated at an electrode is directly proportional to the quantity of electricity i.e. charge which passes through the electrolyte. **Or** The weight of a substance liberated from an electrolyte in a given time is proportional to the quantity of electricity passing through the electrolyte. That is W Q It , where I is the current and t is the time. W = Zit Where Z is a constant called electro-chemical equivalent. If I = 1 ampere and T= one second then, Z = W , which gives a definition of Z. The electro-chemical equivalent of a substance is the amount of that substance by weight liberated in unit time by unit current. **(ii)** **Second Law.** The masses of ions of different substances liberated by the same quantity of electricity are proportional to their chemical equivalent weights. **or,** If the same current flows through several electrolytes, the weights of ions liberated are proportional to their chemical equivalents. The chemical equivalent of a substance is the weight of the substance which can displace or combine with unit weight of hydrogen .Obviously, the chemical equivalent of hydrogen is 1 by definition.	
4.		Describe briefly the process of electrolysis and power supply for electrolysis.	**[10M]**
		Electrolytic Process **Definition of Electrolysis** An electrolyte is such a chemical that's atoms are normally closely bonded together but when it is dissolved in water, its molecules split up into positive and negative ions. The positively charged ions are referred as cations whereas negatively charged ions are referred as anions. Both cations and anions move freely in the solution. Principle of Electrolysis As discussed in the definition of electrolyte, whenever any electrolyte gets dissolved in water, its molecules split into cations and anions moving freely in the electrolytic solution. Now two metal rods are immersed in the solution and an electrical potential difference applied	

		between the rods externally preferably by a battery. These partly immersed rods are technically referred as electrodes. The electrode connected with negative terminal of the battery is known as cathode and the electrode connected with positive terminal of the battery is known as anode. The freely moving positively charged cations are attracted by cathode and negatively charged anions are attracted by anode. In cathode, the positive cations take electrons from negative cathode and in anode, negative anions give electrons to the positive anode. For continually taking and giving electrons in cathode and anode respectively, there must be flow of electrons in the external circuit of the electrolytic. That means, electric current continues to circulate around the closed loop created by battery, electrolytic and electrodes. This is the most basic principle of electrolysis  Electrolysis of Copper Sulfate Whenever copper sulfate or CuSO4 is added to water, it gets dissolved in the water. As the CuSO4 is an electrolyte, it splits into Cu+ + (cation) and SO4 − − (anion) ions and move freely in the solution. Now if two copper electrodes are immersed in that solution, the Cu+ + ions (cation) will be attracted towards cathode i.e. the electrode connected to the negative terminal of the battery. On reaching on the cathode, each Cu+ + ion will take electrons from it and becomes neutral copper atoms. Similarly the SO4 − − (anion) ions will be attracted by anode i.e. the electrode connected to the positive terminal of the battery. So SO4 − − ions will move towards anode where they give up two electrons and become SO4 radical but since SO4 radical can not exist in the electrical neutral state, it will attack copper anode and will form copper sulfate. If during electrolysis of copper sulfate, we use carbon electrode instead of copper or other metal electrodes, then electrolysis reactions will be little bit different. Actually SO4 can not react with carbon and in this case the SO4 will react with water of the solution and will form sulfuric acid and liberate oxygen. $2SO_4 + 2H_2O \rightarrow 2H_2SO_4 + O_2$ The process described above is known as electrolysis. In the above process, after taking electrons the neutral copper atoms get deposited on the cathode. At the same time, SO4reacts with copper anode and becomes CuSO4 but in water it cannot exist as single molecules instead of that CuSO4 will split into Cu++, SO4 − − and dissolve in water. So, it can be concluded that, during electrolysis of copper sulfate with copper electrodes, copper is deposited on cathode and same amount of copper is removed from anode.	
5.		It is required, to repair a worn-out circular shaft 15 cm in diameter and 32 cm long bv coating it with a layer of 1.6 mm of nickel. Determine the theoretical	**[10M]**

quantity of electricity required and the time taken if the current density used is 210 A/m^2. Electrochemical equivalent of nickel is 30.4×10^{-8} Kg/C of electricity and density of nickel is 8.9×10^3 Kg/m^3.

Solution. *Given :* d = 15 cm = 0.15 m ; l = 32 cm = 0.32 m ; Thickness of coating = 1.6 mm = 0.0016 m ; Current density, $\delta = 210\ A/m^2$; $Z = 30.4 \times 10^{-8}$ kg/C ; $\rho = 8.9 \times 10^3\ kg/m^3$.

Quantity of electricity required, Q :

Surface area of the shaft to be repaired,

$$A_s = \pi d \times l = \pi \times 0.15 \times 0.32 = 0.1508\ m^2$$

Mass of nickel to be deposited,

$$m = \text{Surface area} \times \text{thickness of coating} \times \text{density of nickel}$$
$$= 0.1508 \times 0.0016 \times 8.9 \times 10^3 = 2.147\ kg$$

Theoretical value of quantity of electricity required,

$$Q = \frac{M}{Z} = \frac{2.147}{30.4 \times 10^{-8}}\ A\text{-}s = \frac{2.147}{30.4 \times 10^{-8} \times 3600}\ A\text{-}h$$
$$= \mathbf{1961.8\ A\text{-}h.}\quad \textbf{(Ans.)}$$

Time taken, t :

Current density, $\delta = \dfrac{\text{Current } (I)}{\text{Surface area } (A_s)}$

or, $210 = \dfrac{I}{0.1508}$

$\therefore$ $I = 31.67$ A

Also, $Q = I \times t$

$\therefore$ $t = \dfrac{Q}{I} = \dfrac{1961.8}{31.67}$ = **61.94 hours. (Ans.)**

6.	a)	Explain the factors on which quality of electrodeposition depends.	**[5M]**

Factors Affecting the Quality of Electrodeposition

The factors on which the quality of electrodeposition depends are described below.

Nature of Electrolyte

The nature of electrolyte used in the electrodeposition process greatly affects the formation of smooth deposit. A smooth deposit can be provided by employing the electrolyte from which complex ions can be obtained.

Current Density

The process of electrodeposition depends upon the rate at which crystals grow and the rate at which fresh nuclei are formed. Therefore, the deposit of metal will be uniform and fine grained if the current density is used at the rate higher than at which the nuclei are formed.

The deposition will be strong and porous if the rate of nuclei formation is very high due to very high current density.

Conductivity

The electrolytic solution of good conductivity provides economy in power consumption and also reduces the tendency to form tress and rough deposits.

Temperature of Solution

The low temperature of the electrolytic solution results in the formation of small crystal of metal while the high temperature causes the formation of large crystals.

In addition, the high temperature gives the following beneficial results −

- Increased conductivity,
- Increased solubility of slats,
- Decreased occlusion of hydrogen in the deposit metal, etc.

Electrolytic Concentration

The increased concentration of electrolyte results in higher current density. Thus, by increasing the electrolytic concentration, a uniform and fine-grain deposit can be obtained.

Polarization

As we know, the rate of metal deposition increases with the increase in current density up to a certain limit after which electrolyte surrounding the base metal becomes so much depleted of metal ions that the further increase in the current density does not cause increase in rate of deposition. The use of current density beyond this limit results in the electrolysis of water and liberation of hydrogen on the cathode. This liberated hydrogen on the cathode blankets the base metal that reduces the rate of metal deposition. This phenomenon is known as **polarization**.

The polarization can be reduced by reversing the current at regular intervals.

Addition of Agents

The addition of acids or other substances to the electrolyte decreases the resistance of the electrolytic solution. Also, some additional agents like gums, dextrose, etc. influence the nature of the deposit. The nuclei of the crystal absorb the additional agents added in the electrolyte. This prevents its large growth and hence the deposition will be fine grained.

Throwing Power

		Throwing power is the ability of the electrolyte to produce uniform deposit on an article of irregular shape. As the distance between the various potions of the cathode and anode will be different because of irregular shape of the cathode. Therefore, it is necessary that the electrolyte should have relatively better throwing power so that uniform deposit can be produced. The throwing power of an electrolyte can be increased in two ways as − • By increasing the distance between the anode and cathode. • By reducing the voltage drop at the cathode surface.	
	b)	b) Explain the terms used in electrolytic processes: (i) Current efficiency (ii) Energy efficiency	**[5M]**
		Current Efficiency On account of the impurities which cause secondary reactions, the quantity of a substance liberated is less than that calculated from faraday‘s Law. Current efficiency is the ratio of the actual mass of a substance liberated from an electrolyte by the passage of current to the theoretical mass liberated according to Faraday's law. Current efficiency can be used in measuring electro deposition thickness on materials in electrolysis. Current efficiency is also known as faradic efficiency, faradic yield and columbic efficiency. Energy Efficiency On account of secondary reactions, the voltage actually required for the deposition or liberation of metal is higher than the theoretical value which increases the actual energy required. It is a process by which a metal is deposited over another metal or non-metal. Electro-plating is a very common example of such process.	
7.		Calculate the thickness of copper deposited on a plate area of 2.2 cm^2 during electrolysis if a current of 1 A is passed. for 90 minutes. E.C.E. of copper = 32.95 x 10^{-8} kg/C and density of copper is 8900 Kg/m^3.	**[10M]**
		Solution. Plate area, $A_s = 2.2\ cm^2 = 2.2 \times 10^{-4}\ m^2$ Current strength $= 1$ A Duration of passage of 1 A current, $t = 90$ minutes $= 90 \times 60 = 5400$ s E.C.E. of copper, $Z = 32.95 \times 10^{-8}$ kg/C Density of copper $= 8900\ kg/m^3$ **Thickness of copper deposited, t :** Mass of copper deposited, $m = ZIt$ $= 32.95 \times 10^{-8} \times 1 \times 5400 = 0.001779$ kg Volume of copper deposited, $V = \frac{\text{Mass}}{\text{Density}} = \frac{0.001779}{8900} = 0.1999 \times 10^{-6}\ m^3$ Thickness of copper deposited, $t = \frac{V}{A_s} = \frac{0.1999 \times 10^{-6}}{2.2 \times 10^{-4}} = 0.9086 \times 10^{-3}$ m $= 0.9086$ mm. (Ans.)	
8.	a)	Explain Electrodeposition of rubber in detail.	**[5M]**

		Electrolysis is also employed for *electro-deposition of rubber*. The rubber latex obtained from the tree consists of very fine colloidal particles of rubber suspended in water. These particles of rubber are negatively charged. On electrolysis of the solution, these rubber particles move towards the anode and deposit on it. In the form in which we commonly meet it, rubber is a remarkably resilient solid, distinguished also by high electrical-insulating properties ; therefore at first sight it is not a very promising material for an electrochemical process. But rubber originally appears in nature as latex, a milky or rather a creamy fluid that exudes from the inner bark of certain plants or trees when they are cut. Usually the latex is collected in open vessels and crude rubber is coagulated from this by a process that resembles somewhat the curdling of milk. The curd or coagulum is washed and sheeted mechanically at the plantations and is then exported in bales. Fresh latex is an unstable material that rapidly undergoes a series of chemical and physical changes that lead to coagulation unless this is overcome by preservatives such as ammonium. Due to the fact that the chief rubber roducing plants are tropic growth scientific investigation has been made only recently on the properties of latex If rubber is to be deposited on metal as a permanent covering, or if metal anodes are used for forming rubber products, a choice of various metals that behave differently as electrodes in rubber deposition can be exercised among three classes of metals, which are listed. Zinc is the most satisfactory metal, and the most promising procedure that has been developed is to give other metals a preliminary zinc-coating. Satisfactory adhesion of rubber to metal has been secured, and this opens a large and valuable field for the process.	
	b)	What are the various operations involved in electroplating.	**[5M]**
		Operations involved in electroplating : Various operations involved in electroplating are : 1. Cleaning operation. 2. Deposition of metal. 1. **Cleaning operation.** In case the object to be electroplated is not cleaned, polished and degreased, the deposit formed may not be well adherent to the base metal and is likely to peel off. Cleaning operation includes the following : • Removal of oil, grease, or other organic material. .... To accomplish this, soaps, hot alkali solutions, or organic solvents such as gasoline or carbon tetrachloride are used. • Removal of rust, scale, oxides, or other inorganic coatings adhering to the base metal/ work piece .... To accomplish this various acids, alkali and salt solutions are employed. • Mechanical preparation of the surface of the metal to remove the deposited metal, by polishing, buffing etc. ... To accomplish this mechanical abrasion and polishing are used. 2. **Deposition of metal.** In all types of metal deposition processes, *article to be electroplated is made cathode, solution is made up of salt of the metal to be deposited and anode is often of the same metal which is to be deposited.*	
9.	a)	Explain about Electro-polishing.	**[5M]**
		This process, in principle, *consists of making the work as anode in a suitable position.* This produces insoluble compounds, which are broken down by more anodic action on the hills than on valleys of the surface. In this way smoothening of surface takes place. • Aluminium workpiece which is to be polished after being properly buffed is subjected to two anodic treatments in series. In the first treatment job is made anode in fluoboric acid bath, this removes thin coating of metal from the surface uniformly. This surface is then given anodizing treatment in H_2SO_4 bath. This process produces an oxide film clear and transparent with reflectivity as much as 90 per cent. • In case of silver plated article, polishing is done after plating is over by reversing the current through bath at 4 to 5 times the current strength used for plating and at intermittent intervals every few seconds.	

	b)	b) What are the objectives of electroplating.	**[5M]**
		5.5.1.1. Electroplating *"Electroplating" is an art of depositing a superior or a more noble metal on an inferior or a base metal by means of electrolysis of an aqueous solution of a suitable electrolyte.* *Or* "Electroplating" is *defined as the electro-deposition of metal upon metallic surfaces.* Electroplating is done to *accomplish the following :* (*i*) To protect the metals against corrosion. (*ii*) To give reflecting properties reflectors. (*iii*) To give a shiny appearance to articles. (*iv*) To replace worn out material. • The electrolytic deposits are crystalline in nature. The crystals must be very fine in order to get firm, coherent and uniform deposits. For this purpose, suitable electrolytes should be used in the electrolytic bath and current density used should have an appropriate value. The temperature should also be maintained at a proper level. • The articles to be coated with nobler metals should be in as high a state of purity as possible.	
10.		Calculate the quantity of aluminum produced from aluminium oxide in 24 hours if the average current is 2800 A and. current efficiency is 95 per cent. Aluminiurn is trivalent and atomic weight is 27. The chemical equivalent weight and E.C.E of sliver are 107.98 and 111×10^{-8} Kg/C respectively.	**[10M]**
		Solution. Average current = 2800 A Current efficiency = 95% Valency of aluminium = 3 Atomic weight of aluminium = 27 Chemical equivalent weight of silver = 107.98 E.C.E. of silver = 111×10^{-8} kg/C Chemical equivalent weight of aluminium = $\frac{\text{Atomic weight}}{\text{Valency}} = \frac{27}{3} = 9$ $\therefore$ E.C.E. of aluminium, $Z = \frac{\text{E.C.E. of silver} \times \text{Chemical equivalent weight of aluminium}}{\text{Chemical equivalent weight of silver}}$ $= \frac{111 \times 10^{-8} \times 9}{107.98} = 9.252 \times 10^{-8}$ kg/C Mass of aluminium produced, $m = ZIt \times$ current efficiency $= 9.252 \times 10^{-8} \times 2800 \times (24 \times 60 \times 60) \times 0.95$ $=$ **21.26 kg. (Ans.)**	