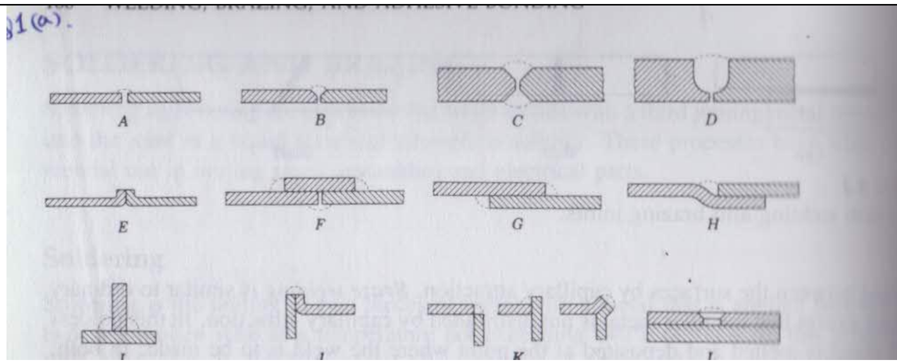
SUMMER – 14 EXAMINATIONS

Subject Code: **17455** **Model Answer** Page No: ____/ N

Important Instructions to examiners:

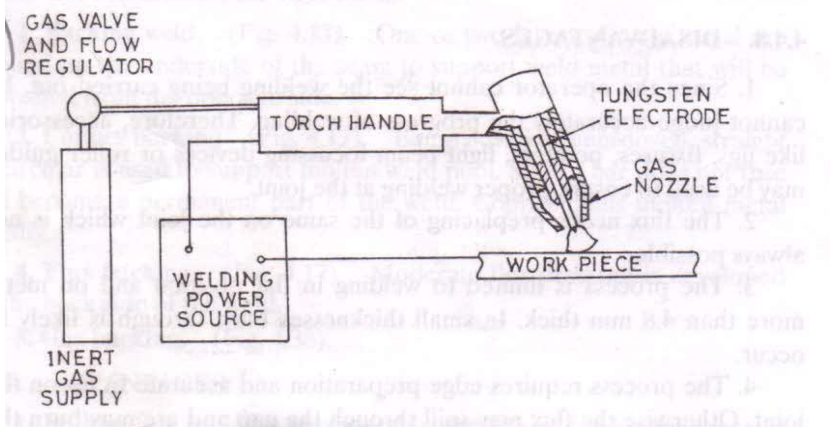
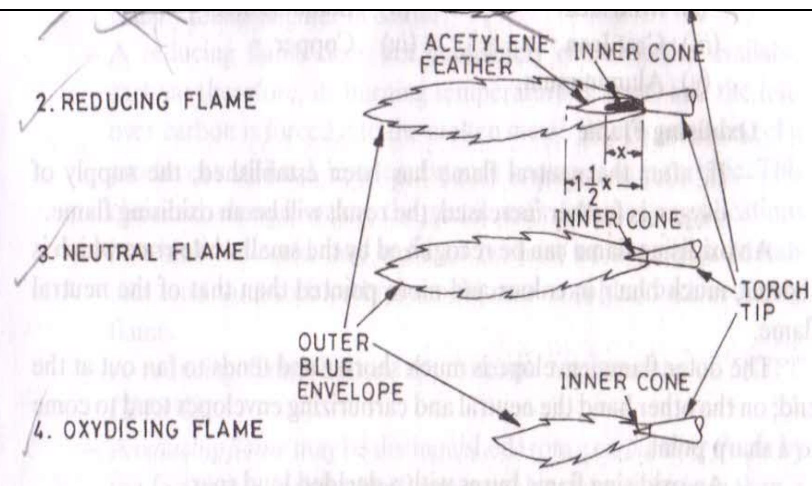
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. NO.	MODEL ANSWER	MARKS	TOTAL
1.	**Attempt any five**		**20**
a)	 A, Butt weld. B, Single vee. C, Double vee (heavy plates.) D, U-shaped (heavy casting). E, Flange weld (thin metal). F, Single strap butt joint G, Lap joint (single- or double-fillet weld). H, Joggled lap joint (single or double weld, I, Tee joint (fillet welds). J, Edge weld (used on thin plates). K, Corners weld metal). L, Plug or rivet butt joint	**2m (diagram)** **2 m (listing any four)**	**4**
b)	Section factors for power sources: The following factors influence the selection of a power source: 1. Available power (AC or DC, single phase, etc.). Where no power is available, a diesel engine driven DC generator may be used. 2. Available floor space. 3. Initial costs and running costs. 4. Location of operation (whether in the plant or in the field). 5. Personnel available for maintenance. 6. Versatility of equipment. 7. Required output. 8. Duty cycle. 9. Efficiency. 10. Type of electrodes to be used and metals to be welded, (e.g. non-ferrous materials and stainless steels are welded more effectively with DC than with AC). 11. Type of work	**4m (any 4)**	**4m**

c)	Weldability is the capacity of a material to be welded under the fabrication conditions imposed into a specific suitably designed structure and to perform satisfactorily in the intended service. Factors effecting are: Composition of the metal Brittleness and strength of metal at elevated temperature Thermal properties of metal Welding techniques,fluxing material and filler material Proper heat treatment before and after the deposition of the metal.	**2m (def.)** **2m (any 2)**	**4**
d)	1. Crack 2. Distortion. 3. Incomplete penetration/ fusion 4. Inclusions 5. Porosity and blow holes. 6. Poor fusion 7 Spatters. 8. Undercutting. 9. Overlapping Remedies 1. CRACK: For weld Metal Cracking Preheat Relieve residual stresses mechanically Minimize shrinkage stresses using backstep or block welding sequence Change welding current and travel speed Weld with covered electrode negative; butter the joint faces prior to welding. Change to new electrode; bake electrodes to remove moisture Reduce root opening; build up the edges with weld metal Increase electrode size; raise welding current, reduce travel speed Use filler metal low in sulfur Change to balanced welding on both sides of joint Fill crater before extinguishing the arc; use a welding current decay device when terminating the weld bead. 2 DISTORTION Reducing the metal weld volume to avoid overfill and consider the use of intermittent welding Minimising the number of weld runs Positioning and balancing the welds correctly round the axis Using backstep or skip welding techniques, which involves	**4m (any 4 defects with 1 remedies each)**	**4m**

	laying short welds in the opposite direction Making allowance for shrinkage by pre-setting the parts to be welded out of position Planning the welding sequence to ensure that shrinkages are counteracted progressively Shortening the welding time 3 INCOMPLETE PENETRATION/ FUSION: Remedies of incomplete fusion Follow correct welding procedure specification Maintain proper electrode position Reposition work, lower current, or increase weld travel speed Clean weld surface prior to welding 4 INCLUSIONS This defect can only be repaired by grinding down or gouging out and re-welding. 5 POROSITY AND BLOW HOLES OR GAS POCKETS Use low-hydrogen welding process; filler metals high in deoxidizers; increase shielding gas flow Use preheat or increase heat input Clean joint faces and adjacent surfaces Use specially cleaned and packaged filler wire, and store it in clean area Change welding conditions and techniques Use copper-silicon filler metal; reduce heat input Use E60I0 electrodes and manipulate the arc heat to volatilize the zinc ahead of the molten weld pool Use recommended procedures for baking and storing electrodes Preheat the base metal Use electrodes with basic slagging reactions 6 SPATTER Spatter can be minimized by correcting the welding conditions and should be eliminated by grinding when present. 7 UNDER-CUITING Undercutting can be avoided with careful attention to detail during preparation of the weld and by improving the welding process. It can be repaired in most cases by welding up the resultant groove with a smaller electrode. 8 OVERLAPPING		

	The overlap can be repaired by grinding off excess weld metal and surface grinding smoothly to the base metal. 9 REMEDIES OF SLAG INCLUSIONS Clean surface and previous weld bead Power wire brush the previous weld bead Avoid contact between the electrode and the work; use larger electrode Increase groove angle of joint Provide proper gas shielding Reposition work to prevent loss of slag control Change electrode or flux to improve slag control Use undamaged electrodes		
e)	PRINCIPLES OF SOLDERING The principles of soldering include the following: Soldering is very much similar to brazing and its principle is same as that of brazing. The major difference lies with the filler metal, the filler metal used in case of soldering should have the melting temperature lower than 450°C. The surfaces to be soldered must be pre-cleaned so that these are faces of oxides, oils, etc. An appropriate flux must be applied to the surfaces and then surfaces are heated. Filler metal called solder is added to the joint, which distributes between the closely fitted surfaces. Strength of soldered joint is much lesser than welded joint and less than a brazed joint. The soldering operation is performed by bringing molten solder in contact with the preheated surfaces and heating the joint area to a good wetting temperature. This is roughly 55 to 80° C above the melting point of the solder alloy itself. Under these conditions, good wetting can occur. The solder is then left to cool and freeze as quickly as possible in order to avoid disturbing the joint during solidification and causing internal micro cracks to form. The soldered joint is then cleaned to remove any undesirable flux residues on the surfaces and to ensure the integrity of the soldered joint.	**4m**	**4m**
f)	Electrode Coatings. Electrodes coated with slagging or fluxing materials are necessary in welding alloys and nonferrous metals. Some of the elements in these alloys are unstable and are lost if there is no protection against oxidation. Heavy coatings permit the use larger welding rods, stronger current, and higher welding speed. Coating compositions may be classified as organic and inorganic, although sometimes both types may be used. Inorganic coatings can be further subdivided into flux	**4m**	**4m**

	compounds and slag-forming compounds		
g)	TIG welding process It is an arc welding process where in coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job. A shielding gas (argon helium, nitrogen, etc.) is used to avoid atmospheric contamination of the molten weld pool. Filler metal, if required, should be added by dipping the filler rod in the weld pool..The electrode tip reaches within a distance of 3 to 2 mm from the job, a spark jumps across the air gap between the electrode and the job.. The welding torch and filler metal are generally kept inclined at angles of 70-80 and10-20° respectively with the flat work piece. A leftward welding technique may be used. Introducing and withdrawing of filler rod into the molten weld pool may disturb the inert gas shielding, entrain air, oxidize filler rod end and thus contaminate the weld pool  TIG welding equipment.	**2m (expln.)** **2m (for diag)**	**4m**
2.	**ATTEMPT ANY Four**		**16**
a)	 Types of Welding Flames.	**2m (for any one sketch with exp)**	**4m**

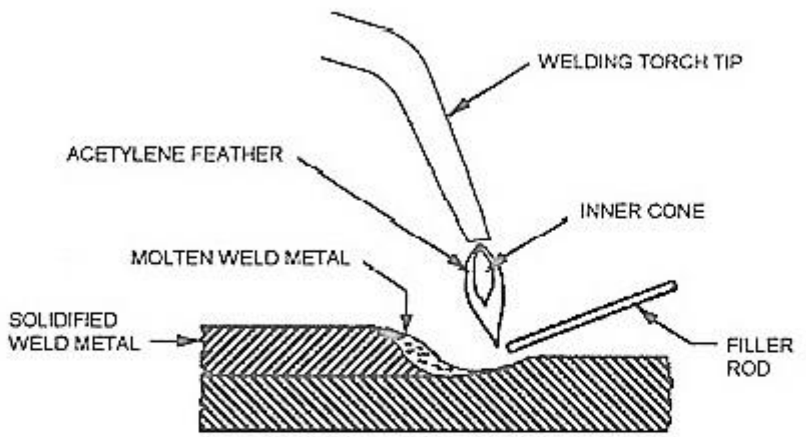
	Types of Welding Flames. 1.Neutral Flame(Acetylene oxygen in equal proportional) 2.Oxidising Flame(Excess of oxygen) 3.Reducing Flame(Excess of acetylene) 1 Neutral Flame - A neutral flame is produced when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip. (More accurately the oxygen-to-acetylene ratio is 1.1 to 1). The temperature of the neutral flame is of the order of about 5900°F (3260°C). The flame has a nicely defined inner cone which is light blue inColour. It is surrounded by an outer flame envelope, produced by the combination of oxygen in the air and superheated carbon monoxide and hydrogen gases from the inner cone. This envelope is usually a much darker blue than the inner cone. A neutral flame is named so because it effects no chemical change in the molten metal and therefore will not oxidize or carburize the metal. - The neutral flame is commonly used for the welding of: (i) Mild steel (ii) Stainless steel (iii) Cast Iron (iv) Copper (v) Aluminimum. 2 Oxidizing Flame - If, after the neutral flame has been established, the supply of oxygen is further increased, the result will be an oxidising flame.An oxidising flame can be recognized by the small white cone which is shorter, much bluer in colour and more pointed than that of the neutral flame.The outer flame envelope is much shorter and tends to fan out at the end; on the other hand the neutral and carburizing envelopes tend to come to a sharp point. An oxidising flame burns with a decided loud roar. An oxidising flame tends to be hotter than the neutral flame. This is because of excess oxygen and which causes the temperature to rise as high as 6300°F.The high temperature of an oxidizing flame would be an advantage if it were not for the fact that the excess oxygen, especially at high temperatures, tends to combine with many metals to form hard, brittle, low strength oxides. Moreover, an excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance. - For these reasons, an oxidising flame is of limited use in welding. It is not used in the welding of steel. A slightly oxidising flame is helpful when welding most (i) Copper-base metals (ii) Zinc-base metals, and (iii) A few types of ferrous metals, such as manganese steel and cast Iron. The oxidizing atmosphere, in these cases, creates a base-metal oxide that protects the base metal. For example, in welding brass, the zinc has a tendency to separate and fume away. The formation of a covering copper oxide prevents the zinc from dissipating.	**2m (for stating)**	

	3 Reducing Flame - If the volume of oxygen supplied to the neutral flame is reduced, the resulting flame will be a carburizing or reducing flame, i.e. rich in acetylene. A reducing flame can be recognized by acetylene feather which exists between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is usually much brighter in colour .A reducing flame does not completely consume the available carbon; therefore, its burning temperature is lower and the left- over carbon is forced into the molten metal. With iron and steel it produces very hard, brittle substance known as iron carbide. This chemical change makes the metal unfit for many applications in which the weld may need to be bent or stretched. Metals that tend to absorb carbon should not be welded with reducing flame.- A reducing flame has an approximate temperature of 5500^0F (3038°C).- A reducing flame may be distinguished from a carburizing flame by the fact that a carburizing flame contains more acetylene than a reducing flame.A reducing flame, on the other hand, does not carburize the metal; rather it ensures the absence of the oxidizing condition. It is used for welding with low alloy steel rods and for welding those metals, (e.g. non- ferrous) that do not tend to absorb carbon. This flame is very well used for welding high carbon steel.		
b)	Arc said to be stable if it is uniform and steady. A stable arc will produce good weld bead and a defect-free weld nugget. The stability of a welding arc is governed by: (a) Suitable matching of arc and power source characteristics. A little variation in arc length, i.e., arc voltage should not extinguish the arc. (b) Continuous and proper emission of electrons from the electrode (say cathode) and thermal ionization in the arc column. Emissivity of pure tungsten cathode is improved by making it thoriated or zirconiated. (c) Position and movements of cathode and anode spots. (d) Arc length and arc current. (e) Electrode tip geometry in TIG welding. Electrodes with geometry as in have more stable arc as compared to those having as (j) In AC welding; (i) Steadiness of current as regards its magnitude and wave shape. (ii) Use of surge injection or high frequency units in TIG welding. (iii)Use of arc stabilizing materials in the coating mixture of flux cover-ed electrodes. (g) Conditions promoting Arc Blow. (h) Presence of dampness, oil, grease, etc. on the surface of work piece. (i) Limited practice on the part of the welder.	**2m** **2m (any 2 points)**	**4m**
c)	1)Size limitation of the parts to be brazed is of major importance.since area to be brazed must be heated, large cast sections or large heavy plates cannot be easily brought up to temperature.	**4m (any 4)**	**4m**

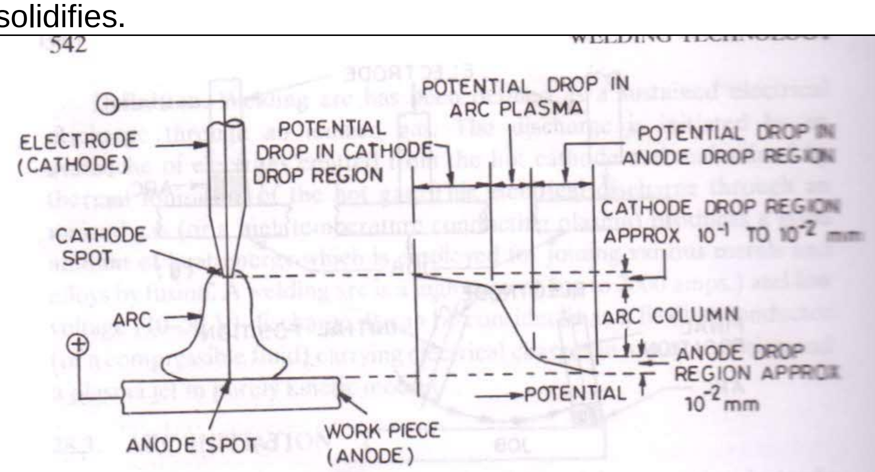
	2. Brazing requires tightly mating parts to ensure capillary flow of the filler metal. This involves expensive machining to attain the desired fit. 3. Flux residues if not properly removed can cause corrosion. 4. Brazed joints do not give satisfactory results when used at elevated temperatures. 5. A certain degree of skill is required to perform the brazing operations; personnel limitations may rule out the process. 6. Very large assemblies, although brazable, may be made more economically by welding . 7) Brazing fluxes and filler rods may evolve toxic fumes and poisonous vapours.		
d)	1.Peening 2.Vibratory stress-relief 3. Thermal treatment 4. Thermo-mechanical treatment 5. Overstressing techique	**4m (any 4)**	**4m**
e)	(see table below)	**4m (any 4)**	**4m**

Sr.no.	Welding	Soldering
1	These are the strongest joints used to bear the load. Strength of a welded joint may be more than the strength of base metal	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally
2	Temperature required is upto 3800 ^{0}C of welding zone.	Temperature requirement is upto 450 ^{0}C.
3	Workpiece to be joined need to be heated till their melting point.	No need to heat the workpieces.
4	Mechanical properties of base metal may change at the joint due to heating and cooling	No change in mechanical properties after joining
5	Heat cost is involved and high skill level is required	Cost involved and skill requirements are very low.
6	Heat treatment is generally required to eliminate undesirable effects of welding	No heat treatment is required.
7	No preheating of workpiece is required	Preheating of workpieces be/ore

	<table><tr><td></td><td>before welding as it is carried out at high temperature</td><td>soldering is good for making good quality joint.</td></tr></table>		
f)	ADVANTAGES OF GAS WELDING 1. It is probably the most versatile process. It can be applied to a wide variety of manufacturing and maintenance situations. 2. Welder has considerable control over the temperature of the metal in the weld zone. When the rate of heat input from the flame is properly coordinated with the speed of welding, the size, viscosity and surface tension of the weld puddle can be controlled, permitting the pressure of the flame to be used to aid in positioning and shaping the weld. 3. The rate of heating and cooling is relatively slow. In some cases, this is an advantage. 4. Since the sources of heat and of filler metal are separate, the welder has control over filler-metal deposition rates. Heat can be applied prefer- entially to the base metal or the filler metal. 5. The equipment is versatile, low cost, self-sufficient and usually portable. Besides gas welding, the equipment can be used for preheating, postheating, braze welding, torch brazing and it is readily converted to oxygen cutting. 6. The cost and maintenance of the welding equipment is low when compared to that of some other welding processes. DISADVANTAGES OF GAS WELDING 1. Heavy sections cannot be joined economically. 2. Flame temperature is less than the temperature of the arc. 3. Fluxes used in certain welding and brazing' operations produce fumes that are irritating to the eyes, nose, throat and lungs. 4. Refractory metals (e.g., tungsten, molybdenum, tantalum, etc.) and reactive metals (e.g., titanium and zirconium) cannot be gas welded. 5. Gas flame takes a long time to heat up the metal than an arc. 6. Prolonged heating of the joint in gas welding results in a larger heat-affected area. This often leads to increased grain growth, more distortion and, in some cases, loss of corrosion resistance. 7. More safety problems are associated with the handling and storing of gase. 8. Acetylene and oxygen gases are rather expensive. 9. Flux shielding in gas welding is not so effective as an inert	**2m (any 2 adv)** **2m (any 2 dis adv)**	**4m**

<table>
<tr><td></td><td>gas shielding in TIG or MIG welding.</td><td></td><td></td></tr>
<tr><td>3.</td><td>ATTEMPT ANY TWO</td><td></td><td>16</td></tr>
<tr><td>a)</td><td>OXY ACETYLENE WELDING


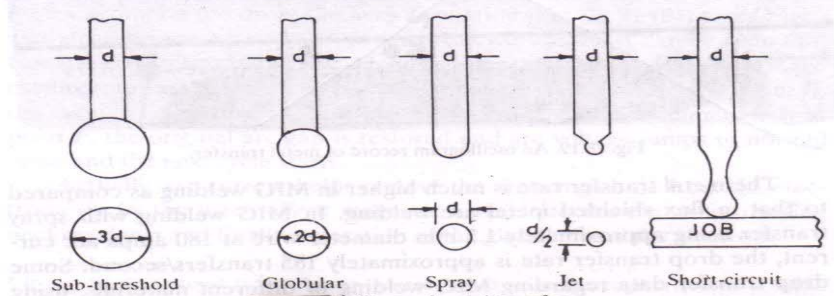
- When acetylene is mixed with oxygen in correct proportions in the welding torch and ignited, the flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal.
- The oxy-acetylene flame reaches a temperature of about 3200°C and thus can melt all commercial metals which, during welding, actually flow together to form a complete bond. A ruler metal rod is generally added to the molten metal pool to build up the seam slightly for greater strength
- Oxy-acetylene welding does not require the components to be forced together under pressure until the weld forms and solidifies.</td><td>4m (diag)

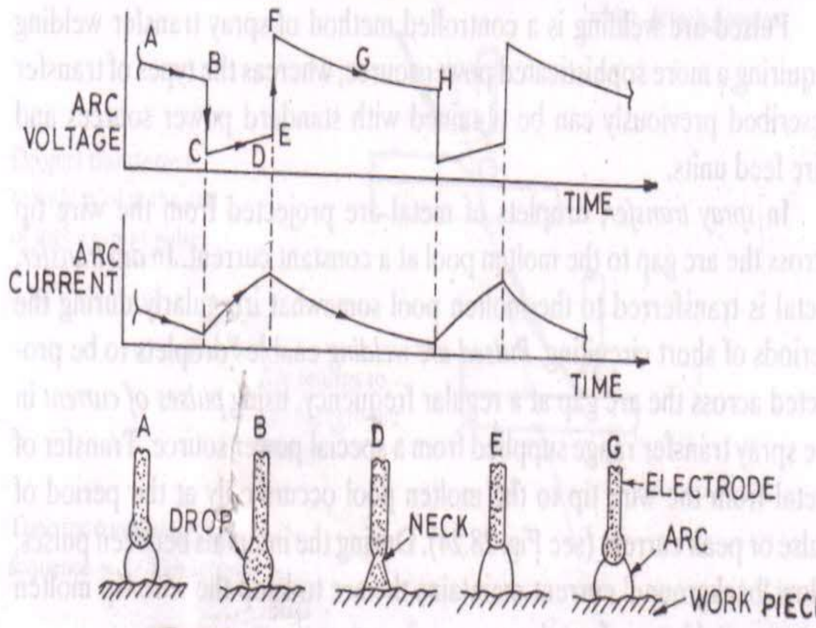
4m (expl.)</td><td>8m</td></tr>
<tr><td>b)</td><td>

Regions of a welding arc.
The arc constitutes a mechanism by which elections are emitted from the cathode, they pass through the hot ionized arc</td><td>4m (diag)</td><td>8m</td></tr>
</table>

	column and are transferred to the anode where they get condensed and absorbed. there are three distinct regions of a welding arc, namely cathode drop region or cathode fall space, arc column arc plasma region and anode drop region or anode fall space. The arc column is situated in between anode and cathode drop regions which are spread over an approximate distances of 10-2 mm and 10-1 to 10-2 mm respectively The cathode is negative, anode is positive and arc column is electrically neutral as it contains equal number of ions and electrons. In a welding arc, the electrons are emitted from the cathode, get accelerated in the.cathode drop region and gain energy. As they enter arc column, they lose their energy by colliding with gas atoms and molecules which in turn get ionised, i.e. electrons and positive ions are separated. The ions and electrons then move towards cathode and anode respectively and get concentrated over there. The three regions of the welding arc will be discussed briefly as follows: 1. Cathode drop zone. It is contained within two imaginary planes, one just at the end of cathode spot and the other at the beginning of arc plasma column. 2 Arc Plasma Column. Arc column is that portion of the welding arc which is situated between anode and cathode drop regions . Arc column consists of a radiating mixture of electrons, ions (+) and highly excited neutral atoms and molecules. 3Anode Drop Zone. It is situated in between the anode spot and the place where the arc column finishes: This region forms the electrical connection between the arc plasma column and the anode.	**4m (expl.)**	
c)	WELDING OF MILD STEEL. - Mild steels be welded using the following processes: (a) Flux Shielded Metal Arc Welding. (b) Oxy-acetylene Welding. (c) Resistance Welding. (d) Thermit Welding. (e) Submerged Arc Welding. (a) When using flux shielded Metal Arc Welding (i) Low hydrogen electrodes may be employed to reduce weld cracking.. (ii) Preheating temperatures between 150 to 260 ^{0}C are recommended to eliminate and reduce the hard and brittle areas. , The heavier the section thickness and the greater the carbon	**4 m (state any 4)** **4m (expl. any one method)**	**8m**

	content of steel, the higher would be the preheating temperatures. (iii) After welding, the job should be allowed to cool to room temperature slowly by being buried in sand or asbestos. (iv) Post-heating the job (after welding) between 595 and 675°C for one hour per 25 mm of section thickness. Improves the metallurgical structure Increases the ductility Reduces residual welding stresses. (b) When employing Oxy-acetylene Welding - (i) An excess of acetylene is used in the gas flame. (ii) No flux is used. (iii) An alloy steel or high tensile steel welding rod may be used. (iv) Little problem is created by the formation of hard and brittle constituents as a result of cooling. (v) Welding is carried out similar to that for low carbon steels. (vi) Post heat-treatment improves quality of the welded joint. (c) When employing Resistance Welding Special provisions are made in the welding cycle for preheating and postheating. These provisions retard the cooling rate while the weld is under pressure and result in greater ductility and strength in the completed weld. (d) Thermit Welding is done generally using forging thermit. The increase in carbon from the base metal produces a weld of higher tensile strength but lower ductility as compared to a weld made with low carbon steel as the base metal. (e) Submerged Arc Welding (i)Uses welding rods and fluxes same as those used for low carbon steels. (ii) Employs preheating of thick sections to reduce hardness of heat affect zone.		
4.	**ATTEMPT ANY TWO**		**16**
a)	TYPES OF METAL TRANSFER There are two main types of metal transfer: (a) Free Flight Transfer. In which metal drops get detached from the electrode, pass through the arc and fall on the job. This category of metal transfer can further be classified as follows:	**2m (state the 2 types)**	**8m**

	 [redacted]. Types of metal transfer. (i) Sub-threshold type. The drop diameter is approximately equal to three times the electrode core wire diameter. (ii) Globular type. The drop diameter is approximately twice the electrode core wire diameter. This type of transfer is observed in both flux shielded metal arc welding and MIG welding processes. Globular transfer is observed at low arc currents or with longer arcs. The globules may pass freely through the welding arc or depending upon their size and arc gap they may short-circuit the arc. The number of drops transferred/second are very less. Globular transfer is associated with spatter loss and shallow penetration height. (iii) Spray type. In this case the drop diameter is approximatcly equal to electrode core wire diameter. The rate of drop transfer is much higher than that in globular transfer. There is a continuous spray of drops from the electrode to the job. This type of transfer occurs at high arc currents and low arc lengths. Spray transfer is observed in both flux-shielded metal arc welding and MIG welding. A mixture of argon and oxygen promotes spray transfer in MIG welding. Though associated with some spatter, spray mode of transfer produces a stable are, good weld bead, deep penetration, a strong joint and is recommended for thicker plates. (iv) Jet type. In jet type of transfer the drop diameter is approximately equal to half the diameter of the wire. In this case the electrode end becomes tapered and a jet of drops comes out from the electrode .The temperature of the droplet formed from a steel electrode just as it detaches, ranges from 1800-2000 ^{0}C.The size of a droplet ranges between 0.5 to 5 mm. The velocity at which drop transfer takes place depends upon drop size. (b) Short-circuiting or Dip Transfer	**6m (3m for any one diag. with 3m for expl.)**	

	drop grows, hangs, thus arc resistance and arc voltage start reducing.  Oscillograms and steps of short-circuiting transfer. In short-circuiting type of metal transfer, the arcing end of the electrode starts melting, develops to a spherical shape, makes 'contact with the molten pool in the base metal and gets detached from the' electrode. When the hanging drop touches the base metal, the circuit is shorted and the arc extinguishes. .During this period A to B, the drop grows, hangs and thus the arc voltage decreases. At point B short circuit occurs, arc extinguishes and the voltage drops down. Short circuit remains from C to E, during which current increases because of reduced resistance between electrode and workpiece. There should be a sufficient increase in current so that neck does not freeze. At point F once again the drop formation starts, drop grows, hangs, thus arc resistance and arc voltage start reducing. Short circuit transfer is generally recommended on thinner sheets, of course thicker gauges can also be welded using large wire diameter (1.5 mm or around). This mode of transfer is suitable especially when welding intricate shapes and in positions other than flat.		
b)	Various processes used for welding stainless steels are Oxy-acetylene welding Shielded metal arc welding Inert gas metal arc welding Gas tungsten arc welding Submerged arc welding Plasma arc welding	**4m (state the processes)** **4m**	**8m**

	Resistance welding Brazing. Oxy-acetylene Welding - Since gas welding generally heats rather slowly and does not confine the heat to a narrow zone, it is not particularly suitable for welding austenitic stainless steels. oxy-acetylene welding can be employed to some extent to weld materials less than about 3 mm thick. - Nozzle tip one or two sizes smaller than that used for ordinary steel with neutral just slightly reducing flame is employed for welding austenitic stainless steels. Since austenitic stainless steel has 50% higher coefficient of expansion and lower thermal conductivity than carbon steel one important factor is the control of expansion and contraction by the use of suitable jigs, fixtures, and chill plates as well as the use of tack welding. Properly designed joints help this control and avoid warping. - Filler rods for welding may either (i) be obtained by cutting strips from the base metal, or (ii) they may be of columbium 18-8 type. The filler rod should contain 1 to 1.5% more chromium (than the parent metal] to compensate any oxidation losses that occur during welding. Shielded Metal Arc Welding Introduction - Shielded metal arc welding is probably the most widely used process for stainless steels. Its principal advantage is flexibility. The disadvantages, however, are (i) The slag blanket constitutes a potential source of inclusions. (ii) Visibility during welding is impaired by slag. - If the molten pool is not adequately protected from atmospheric oxidation, certain essential alloying elements (such as chromium) may be oxidized and pass into the slag thereby rendering weld metal deficient in corrosion-resisting properties.electrodes, generally, contain a higher percentage of chromium as compared to base metal. -The flux should not contain carbonaceous materials (because they will add carbon in weld metal). Moreover, the flux must have adequate fluidity and dissolving power to fuse undesirable oxides from the molten metal. Surface preparation - Edges to be welded need no preparation unless they are more than 3.2 mm thick.	**(any one expl.)**	

	Sheets 4.8 mm thick need only a single bead to be deposited from one side and should be given a Vee angle of 45° to 60° leaving about 1.6 to 2.4 mm (root face) unbevelled at the bottom, and a root gap as wide as the sheet is thick. Sheets over 4.8 mm thick need two beads or more, and about 2.4 mm distance as the root face (or, for double Vees, in the centre). - Depending upon plate thickness, square butt, single V (with or without root face), single U, and double V joints with or without copper chill bar (placed at the bottom of the plates to be welded) may be employed for welding purposes. - For welding thinner sheets tack welds may be employed, the tacks being 50-150 mm apart according to the thickness of the sheet; closer spacing being used with thinner pieces. The tack welds should penetrate right through and be flat on the surface so that it is possible to deposit weld metal upon them without causing irregularity of the weld. Inert Gas Metal Arc Welding - Inert gas metal arc process is very well suited for welding austenitic stainless steels. Continuously fed electrode avoids inter ruptions in welding and the use of shielding gas instead of a flux eliminates the need for slag removal and enables the operator to watch the welding operation. when it, is compared to shielded metal arc welding, the equipment costs more and is less portable and gas metal-arc operations must be shielded from drafts. Gas metal arc welding is used in the fabrication of stainless steel tanks and pressure vessels. In gas metal arc welding the electrode wire is supplied on spools or reels. The electrode metal contains all the alloying elements required in the weld metal. Contrary to flux shielded metal arc welding, there is little if any loss in alloying elements between the electrode and the weld deposit in this process. - Gas metal arc welding offers a variety of means by which transfer of weld metal can be effected: spray transfer, short-circuiting transfer and pulsed-arc mode of metal transfer. - Various gases and gas mixtures employed for shielding of molten pool are argon, argon + oxygen, argon + helium etc. - Square butt, single V with or without root face, single U and double V grooves arc commonly used in gas metal arc welding of stainless steel.		

	Hot cracking tendency in the stainless steels of high nickel eon- lent can be reduced by the use of stringer beads instead of weave beads. Where this is not sufficient a welding rod of lower nickel content (about 9% nickel) is employed. - For economic reasons, the heaviest electrode size that will produce good results should be used Submerged Arc Welding - Submerged arc welding is characterized by high deposition rates and high welding speeds, which result in good economy. How- ever, the principal disadvantage of the process is its inflexibility. Weld deposits which are free from frequent starts and stops and uniform as to width and composition show excellent resistance to corrosion. High welding speeds tend to reduce carbide precipitation adjacent to the weld. - Submerged arc welding of austenitic stainless steels employs the same equipment and procedure as used for carbon steels but due consideration is also given to the following characteristics of this material: (i) Lower thermal and electrical conductivity, (ii) Higher expansion rate. (iii) Susceptibility of certain austenitic stainless steels to hot cracking. Welds containing more than about 4% ferrite are .generally immune to cracking. (iv) Corrosion resistance desired in stainless steel welds. - The larger beads in fully austenitic steels are responsible for the increased crack sensitivity. Cracking may be related to impurities in the weld metal and to the solidification pattern of the bead. Increased silicon content may cause hot shortness or fissuring. Basic- type flux minimizes this effect. Carbon and manganese increase crack resistance. Welds that solidify in the dendritic pattern are more susceptible to cracking than those which solidify in cellular pattern. Cellular pattern is obtained with thin, wide beads deposited at low travel speeds. Resistance Welding - Austenitic stainless steels are successfully resistance welded by spot, seam and projection methods. Generally the weld time and current are less than those used for welding carbon steel, but electrode force is usually greater. - Since appreciable formation of intergranular carbide is not		

	likely to occur in resistance welds during the short weld times used for most resistance welding applications, therefore, spot, seam and projection welds in austenitic stainless steel have high corrosion resistance in most atmospheric conditions. - Because of low electrical conductivity of stainless steel as compared to plain carbon steels, a lower welding current or a shorter weld time, or both, should be employed. - The low thermal conductivity of austenitic stainless steel (i) Conserves welding heat and therefore promotes welding operations. (ii) Produces a steeper thermal gradient than in mild steel welds. - Coefficient of thermal expansion of stainless steel (10.6 to 11.4 micro-in per inch per OF) being higher as compared to that of plain low-carbon steel (8.1 micro-in per inch per ^{O}F), the dimensional changes and the slower heat diffusion in austenitic stainless steel result in greater thermal stress, which leads to warping. - Since the contact resistance of stainless steel is higher than that of carbon steel, greater electrode force is needed to make good resistance welds. - Austenitic stainless steel possesses low magnetic permeability. As larger masses of this material enter the-throat of say spot or seam welding machine, it is not necessary to increase the welding current to compensate for changes in reactance, as is commonly done in welding strongly magnetic steels. Brazing Brazing of stainless steels is now performed as a routine operation. - Stainless steel can be brazed, when welding is impracticable, using a silver-brazing alloy. - Brazing can join stainless steel to a variety of dissimilar metals to which it cannot be satisfactorily welded. - The quality of brazed joints can often be improved by judicious selection of brazing thermal process, brazing temperature, filler metal composition and protective atmosphere or flux. - In brazing, carbide precipitation can be minimized by making thermal cycle as short as possible. - Silver alloy (ii) is probably the most widely used of the silver alloys. Silver brazed joints cannot be used for high temperature service. Recommended maximum service temperature is 205°C. If corrosion resistance in service is sufficiently critical, either an		

	extra low-carbon type or a columbium-tantalum-stabilized type filler rod should be used. - Nickel-base filler rods are preferred where extreme heat and corrosion resistance are required, e.g., in the manufacture of jet and rocket engines, chemical processing equipment, etc. A filler rod with melting point around 650^0C is recommended to minimize the heat-affected-zone in the base metal.		
c)	1. Crack 2. Distortion. 3. Incomplete penetration 4. Inclusions 5. Porosity and blow holes. 6. Poor fusion 7. Poor weld bead appearance. 8. Spatter. 9. Undercutting. 10. Overlapping 1. Crack: The main causes of crack formation are as follows: 1. Rigidity of the joint, i.e., joint members not free to expand or contract when subjected to welding heat and subsequent cooling (localized stresses). 2. Poor ductility of base metal. 3. Hardenability, high S and C percentage of base metal. 4. Concave weld bead. 5. Fast arc travel speed. 6. Electrode with high H2 content. DISTORTION The various factors leading to distortion are: 1. More number of passes with small diameter electrodes. 2. Slow arc travel speed. 3. Type of joint. A V joint needs more metal to be deposited to fill the groove as compared to a U joint, thus leading to comparatively more distortion. 4. High residual stresses in plates to be welded. 5. Welding sequence being improper. Use of jigs and fixtures, clamps, presetting, wedging and proper tacking may minimize distortion. INCOMPLETE PENETRATION Various causes of incomplete penetration are as follows: 1. Improper joints. (For example, it is simpler to obtain full	**4m (any 4 defects)** **4m (for 2 causes for each defect)**	**8m**

	penetration in U joint as compared to J butt joint). 2. Too large root face. 3. Root gap too small. 4. Too small bevel angle. 5. Less arc current. 6. Faster arc travel speed. 7. Too small angle β (Normal β is 70--80°). 8. Too large electrode diameter. 9. Longer arc length. 10. Incorrect polarity when welding with direct current. 11. Wrongly held electrode. It should be in the Centre of the joint. INCLUSIONS The various factors promoting entrapment of inclusions are as follows: 1.Too high or too low arc current. 2.Long arcs. 3.Too large electrode diameter. 4.Insufficient chipping and cleaning of previous passes in multipass welding 5.Under-cutting (it can entrap slag particles). 6.Wrongly placed tack welds. 7.Too small included angle of the joint POROSITY AND BLOW HOLES OR GAS POCKETS The various factors leading to porous welds are listed below: 1. Improper (coating on the) electrode. 2. Longer arcs. 3. Faster arc travel speeds. 4. Too low and too high arc currents. 5. Incorrect welding technique (stringer beads are more apt to porosity as compared to moderately weaved beads). 6. Electrode with damp and damaged coating. 7. Scale, rust, oil, grease, moisture, etc. if present on the job surface,i.e., unclean job surface. 8. Improper base metal composition (generally a high sulphur and carbon content will lead to porosity). POOR FUSION Various causes promoting-peer fusion are as follows: 1. Lower arc current. 2. Faster arc travel speed. 3. Improper weaving technique. 4. Presence of oxides, rust, scale and other impurities (on the surfaces to be welded), which do not permit the deposited		

	metal to fuse properly with the base metal. 5. Incorrect joint preparation (i.e., small included angle). 6. Incorrect electrode manipulation. POOR WELD BEAD APPEARANCE The following factors give rise to a poor bead appearance: 1. Limited practice on the part of the welder. 2. Arc length being not constant. 3. Improper welding technique and electrode manipulation. 4. Non-concentric and damaged electrode coating. 5. Magnetic arc blow (presence of undesired magnetic materials around the arc and work piece). 6. Job portion to be welded not easily accessible by the operator. 7. Poor earth and electrode holder (electric) connections. SPATTER The spatter may be due to 1. Excessive arc current. 2. Longer arcs. 3. Damp electrodes. 4. Electrodes being coated with improper flux ingredients. 5. Arc blow making the arc uncontrollable. 6. Bubbles of gas becoming entrapped in the molten globule of metal, expanding with great violence and projecting small drops of metal outside the arc steam. UNDER-CUITING The main causes of undercutting are as follows: 1. Wrong manipulation and inclination of electrode and excessive weaving. 2. Too large electrode diameter. 3. Higher currents. 4. Longer arcs. 5. Faster arc travel speeds. 6. Magnetic arc blow. 7. Rusty and scaly job surfaces. OVERLAPPING Overlapping occur due to 1. Lower arc current. 2. Slower arc travel speed 3. Longer arcs. 4. Improper joint geometry (i.e., root gap) 5. Incorrect electrode diameter. The electrode diameter should not be too large to be manipulated conveniently		

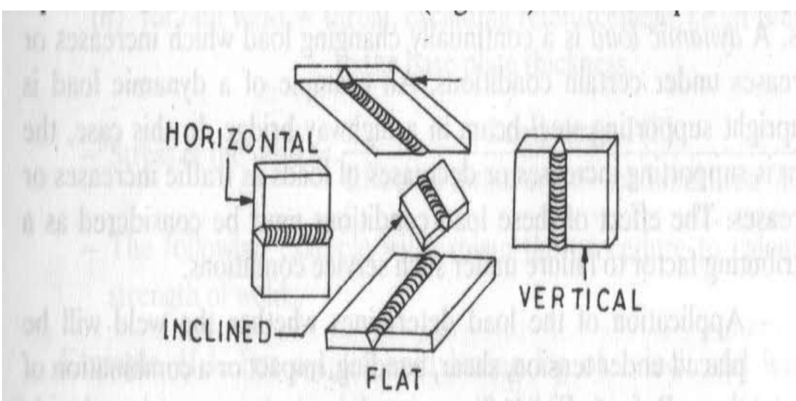
	and suitably		
5.	**ATTEMPT ANY FOUR**		**16**
a.	Effect of welding on properties of metal - Welding involves many metallurgical phenomena. Welding ope- ration somewhat resembles to casting. - In all welding processes, except cold welding, heating and cooling 'are essential and integral parts of the process. High degrees of superheat in the weld metal may be obtained in many fusion welding processes. Heat affected zone 1. The grain growth region 2. The grain refined region, . 3. The transition region The grain growth region. - Grain growth region is immediately adjacent to the weld metal zone (fusion boundary). - In this zone parent metal has been heated to a temperature well above the upper critical (A3) temperature. This resulted in grain growth or coarsening of the structure. (b) The grain refined region - Adjacent to the grain growth region is the grain refined zone. - The refined zone indicates that in this region, the parent metal has been heated to just above the A 3 temperature where grain refinement is completed and the finest grain structure exists. (c) The Transition zone In the transition zone. a temperature range exists between the lower critical temperature and upper critical temperature transformation temperatures where partial allotropic recrystallization takes place (c) Unaffected Parent Metal - Outside the heat affected zone is the parent metal that was not heated sufficiently to change its microstructure. **OR** Effects of various elements on welding rods is listed below. Carbon During solidification grain growth occurs, resulting to increase in, hardness and residual stresses. The metal shows cracks and brittleness. dutility is poor. Manganese The presence of 1.1% manganese raises the yield point and ultimate tensile strength of the weld to the maxi-	**4m** **4m (for any four constit uents)**	**4m**

	mum limit. Excessive manganese along with the carbon content increases hardness, hardenability and tendency to cracks. Silicon Silicon is a strong deoxidiser but excess amount acts as impurity in steels. Sulphur Sulphur readily combines with iron'and forms iron sulphide (FeS). It has low melting point and reduces adhesiveness between adjacent grains of the metal. Phosphorus Phosphorus forms iron phosphides steel. It decreases the plasticity of the metal. In cast iron welding phosphorus content from 0.5 to 1.0% is desirable. It increase fluidity of the molten metal and helps the filling grooves properly. Nickel The properties of nickel are similar to maganese.It increases strength, hardness, hardenability.. toughness and ductility of steel. Chromium Chromium forms complex carbides increases the hardness without decreasing the toughness when added in quantities up to 1.5 Vanadium It's a strong oxidizer When used as an alloy it strengthens the weldability and increases hardenability Tungsten Tungsten reacts with iron and forms complex carbides. It affects the properties of steel even in small quantities by increasing harnessand strength. Molybdenum The properties of molybdenum are similar to tungsten and act a cheaper substitute of tungsten.		
b)	(table below)	**4m (any 4)**	**4m**

Sr.no.	Brazing	Soldering
1	These are stronger than soldering but weaker than welding. These can be used to bear the load upto some extent.	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally
2	It may go to 600^0C in brazing.	Temperature requirement is upto 450 ^{0}C.
3	Workpieces are heated but below their melting point	No need to heat the workpieces.
4	May change in mechan ical properties of joint but it is almost negligible	No change in mechanical properties after joining
5	Cost involved and sill required are in between	Cost involved and skill requirements are

	<table><tr><td></td><td>others two</td><td>very low.</td></tr><tr><td>6</td><td>No heat treatment is required after brazing</td><td>No heat treatment is required.</td></tr><tr><td>7</td><td>Preheating is desirable to make strongjoint as brazing is carried out at relatively low temperature</td><td>Preheating of workpieces be/ore soldering is good for making good quality joint.</td></tr></table>		
c)	BRAZING ALLOYS (FILLER METALS) a) It wets the base metals on which it is used in order to make a strong, sound bond. (b) Proper melting temperature and flow properties that permit distribution in properly prepared joints by capillary action, (c) A composition of sufficient homogeneity and stability to minimize separation by liquation under the brazing conditions to be encountered and free of excessively volatile constituents. d)desirable mechanical and physical properties in the joint such as strength and ductility e) etc	**4m (any 4)**	**4m**
d	- Aluminium and its alloys have certain welding characteristics which need some special attention during welding.The first and the foremost consideration is the effect of the thin film of oxide which is always present on the surface of aluminium.This film contains moisture which may react during fusion welding, with the liquid metal in the weld pool, to form further oxide and to liberate hydrogen which can cause porosity. - The methods employed for welding aluminium and aluminium alloy components are as following heads: 1. Oxy-Gas Welding. 2. Metallic Arc Welding. 3. MIG Welding. 4. TIG Welding. 5. Resistance Welding. 6. Solid-State Welding. 7. Carbon-arc Welding. 8. Atomic-hydrogen 9. Brazing. 1. OXY-GASWELDING - Oxy-acetylene process is quite suitable for wrought and cast alu- minium and aluminium alloys. - The choice of a suitable flux is essential to ensure success in aluminium welding. The flux must:	**1m** **3m (expln. any 2 methods)**	**4m**

	(i) Attack and dissolve the aluminium oxide film (melting point approximately 1930°C) which is always present on the surface of the metal. (ii) Prevent further oxidation during welding. (iii) Melt at a lower temperature than the base metal, so that it will dissolve the surface oxide before the metal melts. (iv) Be lighter when melted than aluminium, so that it will float any impurities to the surface, where they can be easily removed. 2. METALLIC ARC WELDING The metallic arc welding process for aluminium and its alloys has been developed more recently than gas welding owing chiefly to the inherently unstable nature of arcs between aluminium electro- des. In the arc welding of aluminium there remains a tendency to unsoundness in the welds. 3. MIG WELDING Introduction - An electric arc is struck between an aluminium or aluminium alloy continuously fed electrode (+) pulled from a spool by a wire-feeding mechanism and the job (-). A shielding gas is used to protect the weld pool.MIG welding deposits large quantities of weld metal in a short period of time. 4. TIG WELDING Introduction - TIG welding is the most commonly used method of weldingaluminium today. Thinner gauges of aluminium can be joined without a filler metal.TIG welding involves striking an arc between a tungsten (alloy) electrode and the workpiece to provide heat for joining. A separate filler rod is employed when welding thicker workpieces. TIG welding resembles gas welding because both employ a heat source independent of the filler (metal) electrode.Gas welding employs a flux whereas TIG welding makes use of an inert gas to prevent any reaction between the molten weld metal and the atmosphere. 5.RESISTANCE WELDING - Aluminium and aluminium' alloys whether they are cast or wrought, heat-treatable or non-heat-treatable, can be resistance welded, some more readily than others. Resistance welding pro cesses are especially useful in joining the high strength heat treatable alloys. . 6. SOLID STATE WELDING		

	(a) Cold Welding - In cold welding coalescence is produced by the external application of mechanical force alone. - Butt and lap joints are used. - Since intimate contact between joint surfaces is essential to obtain good welds, they must be free from oxide, etc. - Depending upon the type of alloy, pressures of 10.5 x 103 to 35 X 103 kg/cm2 are required to make a proper weld. 7. CARBON ARC WELDING - Carbon arc welding is particularly adapted to butt joints in the lighter gauge metals from 0.9 to 2 mm. - It can produce welds' of quality comparable to oxy-acetylene process. - Absence of distortion is a feature of this process. 8. ATOMIC-HYDROGEN WELDING - The high cost of this process is a contributing factor in its limited use today. - fillet or lap welds can be carried out on some of the aluminum alloys with a greater freedom from cracking or 'excessive heating of the welds.		
e)	 [redacted] Welding positions. WELDING POSITIONS Welding position gives an idea of the location of the workpiece which is to be welded. Location of a workpiece is generally decided with respect to weld slope and weld rotation . which are defined below. (i) Flat (down hand) position. In this position, the face of the weld is horizontal, welding is carried out from above, electrode pointing down- ward and weld bead is horizontal. In a flat position both slope and rotation are limited within 10 degrees. (2) Horizontal position. The plane of the workpiece is vertical,	**2m (for 2 diag)** **2m (expl. for each)**	**4m**

	and the deposited weld bead is horizontal . In this position, slope does not exceed 10 degrees, but rotation can vary from 10-90 degrees. (3) Vertical position. The plane of the workpiece is vertical and the deposited weld bead is also vertical . In vertical position sloperemains between 45 and 90 degrees and rotation may have any value from 0 to 180 degrees. (4) Overhead position. The plane of the workpiece is horizontal, welding is carried out from the underside, electrode pointing upward . In this position slope and rotation can vary from 0 to 45 and 90 to 180 degrees respectively. (5) Inclined position. In this case slope and rotation can vary from 10 to 45 and 0 to 90 degrees respectively. The workpiece is in an inclined plane .		
f)	CARE AND STORAGE OF ELECTRODES Utmost care is required in handling and storage of electrodes. Electrodes coating should neither get damped nor be damaged or broken. 1. Electrodes with damp coating will produce a violent arc, porosity and cracks in the joint.Electrodes with damaged coating will produce joints of poor mechanical properties. 2. To avoid damage to coating, (a) electrodes during storage should neither bend nor deflect, (b) electrode packets should not be thrown or piled over each other. 3. Electrodes should be stored in dry and well-ventilated store rooms.Storage temperature should be about 12°C above that of external air temperature with 0--60% humidity. Cellulose electrodes are not so critical but they should be protected against condensation and stored in a humidity of 0-90%. 4. Before use the electrodes may be dried as per manufacturer's recommendations e.g. BS : E 616 H or IS: M 616478H electrodes may be dried at IS0°C for 1 hour before use. 5. All electrodes, and especially costlier ones, should be used till they are left hardly 4O-50mm. 6. Electrodes should preferably be retained in original (manufacturer's) packing for identification. Loss of identity of electrodes can waste a lot of time in recognizing them correctly	**4m (any 4)**	**4m**
g	The basic equipment used to carry out gas welding arc: 1. Oxygen gas cylinder. 2. Acetylene gas cylinder. 3. Oxygen pressure regulator. 4. Acetylene pressure regulator. S. Oxygen gas hose(Blue). 6. Acetylene gas hose(Red). 7. Welding torch or blowpipe with a set of nozzles and gas lighter. 8. Trolleys for the transportation of oxygen and acetylene cylinders. 9. A set of keys and spanners. 10. Filler rods and fluxes. 11. Protective clothing for the welder (e.g., asbestos apron, gloves, goggles, etc.)	**4m (any 8)**	**4m**

<table>
<tr><td>6)</td><td>ATTEMPT ANY TWO</td><td></td><td>16</td></tr>
<tr><td>a.</td><td>
577

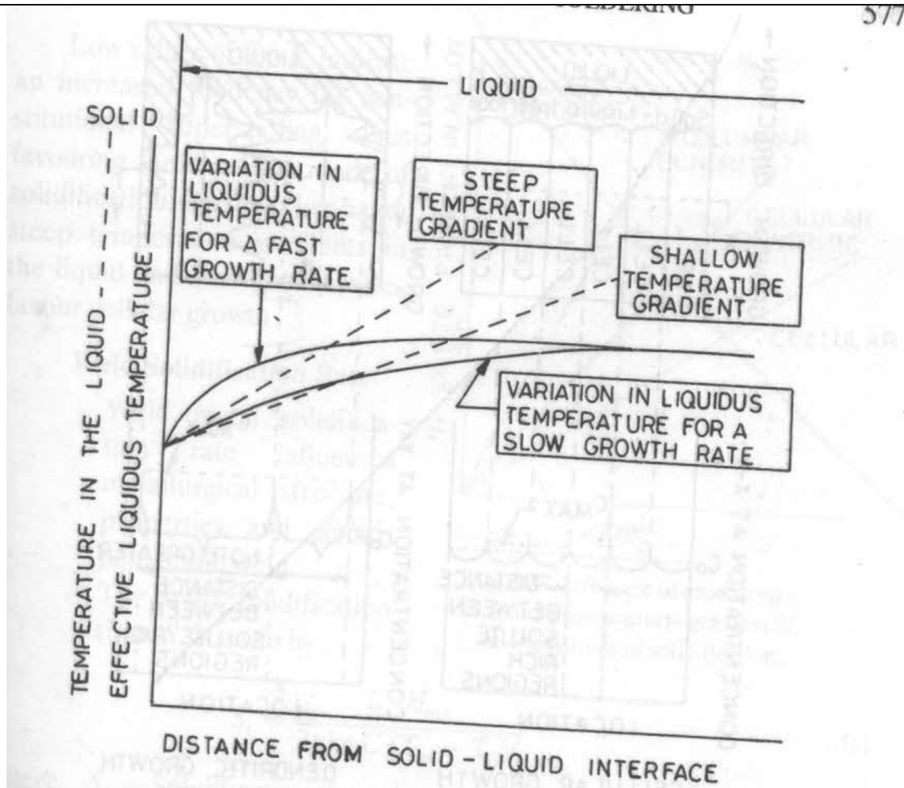


Fig. 29.6. Effect of growth rate and temperature gradient on constitutional supercooling.

WELD METAL SOLIDIFICATION

- The solidification of metals is usually considered to be a nucleation and growth process i.e., the transformation of a liquid phase to a solid normally occurs by a process of nucleation and growth

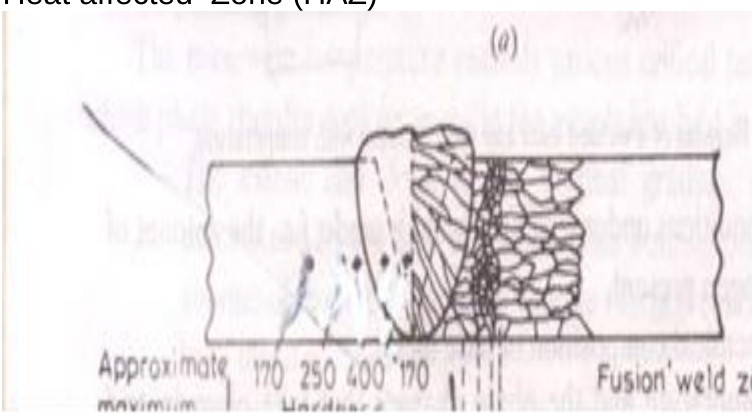
Nucleation involves the creation of critical sized particles, (j.e. nuclei) of the new, (i.e., solid) phase and considerable supercoiling is usually necessary before the first solid nuclei are formed from which growth may proceed.

This is true in the case of ingots and castings.

- In fusion welding processes, however, the nucleation event is not significant since the molten metal is contained in the base metal mold and therefore a solid-liquid interface is always present. This leads to the epitaxial growth of the weld metal from the adjacent, incompletely-melted grains of the base metal.

- In all metallic systems, solidification is accompanied by the evolution of heat. In a pure metal the rate of growth is determined solely by the rate of heat extraction from the solid-liquid inter- face. This situation, however, is of purely academic interest in welding, since this level of purity is
</td><td>4m (diag)

4m (expl.)</td><td>8m</td></tr>
</table>

	never achieved. - The level of purity in welding operations is such that Segregation always occurs on solidification. As the alloy cools through the solidification range, solute is rejected at the -l)lid-liquid inter- face. - Since very little mechanical mixing of the liquid occurs in the immediate vicinity of the advancing interface, the rejected solute must be redistributed in the liquid by diffusion. - The freezing process is so rapid that diffusional processes cannot effectively remove the excess solute near the interface. Hence, solute enrichment occurs at the moving interface until a dynamic equilibrium is reached. The resulting dynamic equilibrium provides an excess of solute in the liquid near the interface with the solute content decreasing to the nominal liquid composition at some distance from the interface. As a result, the effective liquidus temperature varies with distance from the interface		
b)	Heat affected Zone (HAZ)  - Adjacent to the weld metal zone is the heat-affected zone that is composed of parent metal that did not melt but was heated to a high enough temperature for a sufficient period that grain growth occurred. - Heat -affected zone is that portion of the base metal whose mechanical properties and microstructure have been altered by the heat of welding - The heat-affected zone is subjected to a complex thermal cycle (sudden heating followed by rapid cooling) in which all temperatures from the melting range of the steel down to comparatively much lower temperatures are involved and HAZ therefore consists of a series of graded structures ringing the weld bead. - HAZ, usually contains a variety of microstructures. In plain carbon steels these structures may range from very narrow	**4m (diag)** **4m (expl.)**	**8m**

	regions of hard martensite t6 coarse pearlite. This renders HAZ, the weakest area in a weld. Except where there are obvious defects in the weld deposit, most welding failures originate in the heat-affected zone. - The width of HAZ varies according to the welding process and technique; in arc welds it extends only a few mm from the fusion boundary, but in oxy-acetylene and electro slag welds it is somewhat wider. - The HAZ in low carbon steel of normal structure welded in one run with coated electrodes or by submerged arc process comprises three metallurgically distinguished regions. 1. The grain growth region 2. The grain refined region, . 3. The transition region The grain growth region. - Grain growth region is immediately adjacent to the weld metal zone (fusion boundary). - In this zone parent metal has been heated to a temperature well above the upper critical (A3) temperature. This resulted in grain growth or coarsening of the structure. (b) The grain refined region - Adjacent to the grain growth region is the grain refined zone. - The refined zone indicates that in this region, the parent metal has been heated to just above the A 3 temperature where grain refinement is completed and the finest grain structure exists. (c) The Transition zone In the transition zone. a temperature range exists between the lower critical temperature and upper critical temperature transformation temperatures where partial allotropic recrystallization takes place (c) Unaffected Parent Metal - Outside the heat affected zone is the parent metal that was not heated sufficiently to change its microstructure.		
c	Limitation: • Strength is very limited, as low-melting alloys are inherently of low strength • Low melting temperatures mean service is usually at high homologous temperatures, so creep is a problem • Uniform heating of the entire assembly by some soldering processes can be detrimental to heat-sensitive components • Production of multiple joints en masse can make inspection of every joint difficult or impractical and places high demands on process control • Microstructure often evolves considerably at high homologous temperatures or due to cycling temperatures	**4m (any 4)**	**8m**

	Applications: Soldering is used in plumbing, electronics, and metalwork from flashing to jewelry. Soldering provides reasonably permanent but reversible connections between copper pipes in plumbing systems as well as joints in sheet metal objects such as food cans, roof flashing, rain gutters and automobile radiators.Jewelry components, machine tools and some refrigeration and plumbing components are often assembled and repaired by the higher temperature silver soldering process. Small mechanical parts are often soldered or brazed as well. Soldering is also used to join lead came and copper foil in stained glass work. It can also be used as a semi-permanent patch for a leak in a container or cooking vessel. Electronic soldering connects electrical wiring and electronic components to printed circuit boards (PCBs)	**4m (any 4)**	