Important Part A & Part B questions

UNIT 1 CONSTITUTION OF ALLOYS & PHASE DIAGRAMS.

1. What is an alloy? [D-09, N-06]

A metal alloy or simply an alloy, is a mixture of two or more metals or metal and a non-metal.

2. State Hume-Rothery's rules for formation of Substitutional Solid Solutions. (Any two). [M/J 06, N-06] [M-13]

SIZE FACTOR: The atoms must be of similar size with less than 15% difference in atomic radius.

CRYSTAL STRUCTURE: The materials must have the same crystal structure.

3. State Gibb's Phase Rule: [M-11, D-11, N-16]

$$F = C - P + 2.$$

F = Degrees of Freedom
C = No. of components.
P = No. of phase present in the system.

4. What are Cooling curves? [D_12, N_09]

Cooling Curves are obtained by plotting the measured temperatures at equal intervals during the cooling period of a melted to a solid.

5. Define Ferrite [N_06, N_10, M_15]

Ferrite is a primary solid solution based on α-Iron having BCC Structure. maximum Solubility of Carbon in Iron is 0.025% of Carbon at 723°c.

6. Define Austenite [N_06, M_11]

Austenite is a primary solid solution based on γ-iron having FCC Structure. The maximum Solubility of carbon in FCC Iron is about 2% at 1140°C

7. Define Cementite [M_14, N_10]

Cementite is the name given to the Carbide of Iron (Fe_3C). It is hard, brittle, intermetallic compound of Iron with 6.69% of carbon.

8. Define Pearlite

Pearlite is the eutectoid mixture of Ferrite & cementite. It is formed when austenite decomposes during cooling. It contains 0.8% of carbon.

9. Define Martensite [N_07]

Martensite is a super saturated solid solution of carbon in α-Iron. It is formed when a steel is very rapidly cooled from the Austenite state.

10. What is Steel? [D_09, M_12]

The Ferrous alloy having the carbon composition ranging from 0.008 to 2% is known as Steel.

11. Define Phase [M_16, D_15]

A Phase is defined as any physically distinct, homogeneous and mechanically separable portion of a substance.

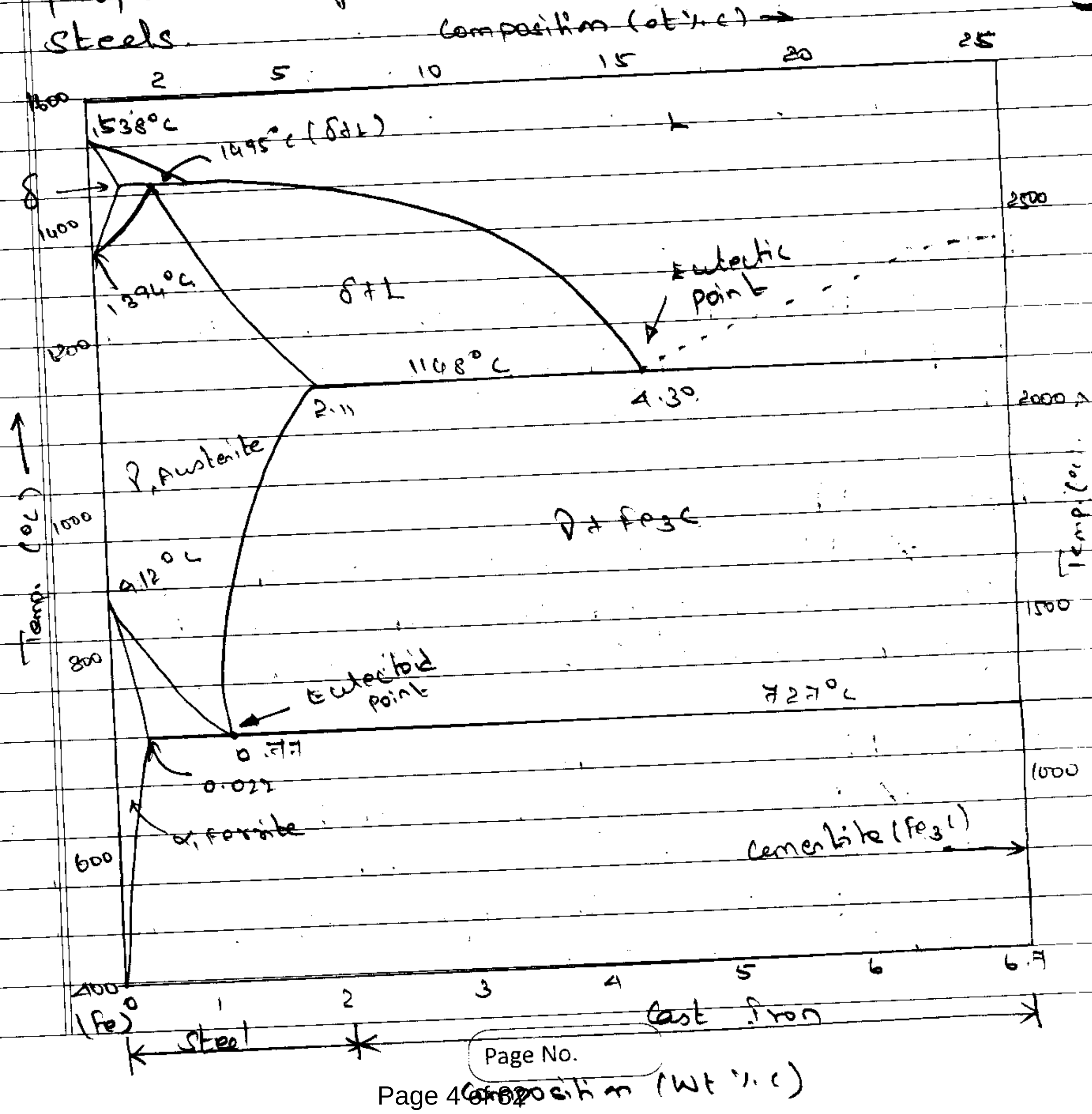
12. Define Phase diagram [D_07, M_11]

A Phase diagram can be defined as a plot of composition of phase as a function of temperature in any alloy system under equilibrium condition.

Part - B.

(1) Iron - Iron Carbide Equilibrium diagram:
[M_06, D_11, D_13, M_15]

Iron - Iron Carbide equilibrium diagram is very much useful in understanding the microstructures and properties of cast Irons and carbon steels.



The three important Invariant reactions associated with the Fe - Fe_3C diagram are peritectic, eutectic, and eutectoid reaction.

* Peritectic Reaction:

$$\text{Liquid} + \delta\text{ Ferrite} \underset{}{\overset{1495^\circ c}{\rightleftharpoons}} \gamma \text{ Austenite.}$$

* At this reaction point, liquid of 0.53% c combines with δ - Ferrite of 0.09% c to form γ austenite of 0.17% c.

* This peritectic reaction, which occurs at 1495°c, can be written.

* The peritectic reaction affects only solidification of steels with less than 0.55% c

* Eutectic Reaction:

* The reaction point, liquid of 4.3%. forms γ austenite of 2.08% c and the intermetallic compound Fe_3C, which contains 6.67% c.

* This eutectic reaction, which occurs at 1148°c.

$$\text{Liquid} (4.3\% c) \overset{1148^\circ c}{\rightleftharpoons} \gamma \text{ Austenite} + Fe_3C.$$

* Eutectoid Reaction:

* The reaction point, solid austenite of 0.8% C produces α ferrite with 0.02% C and Fe_3C that contains 6.67% C.

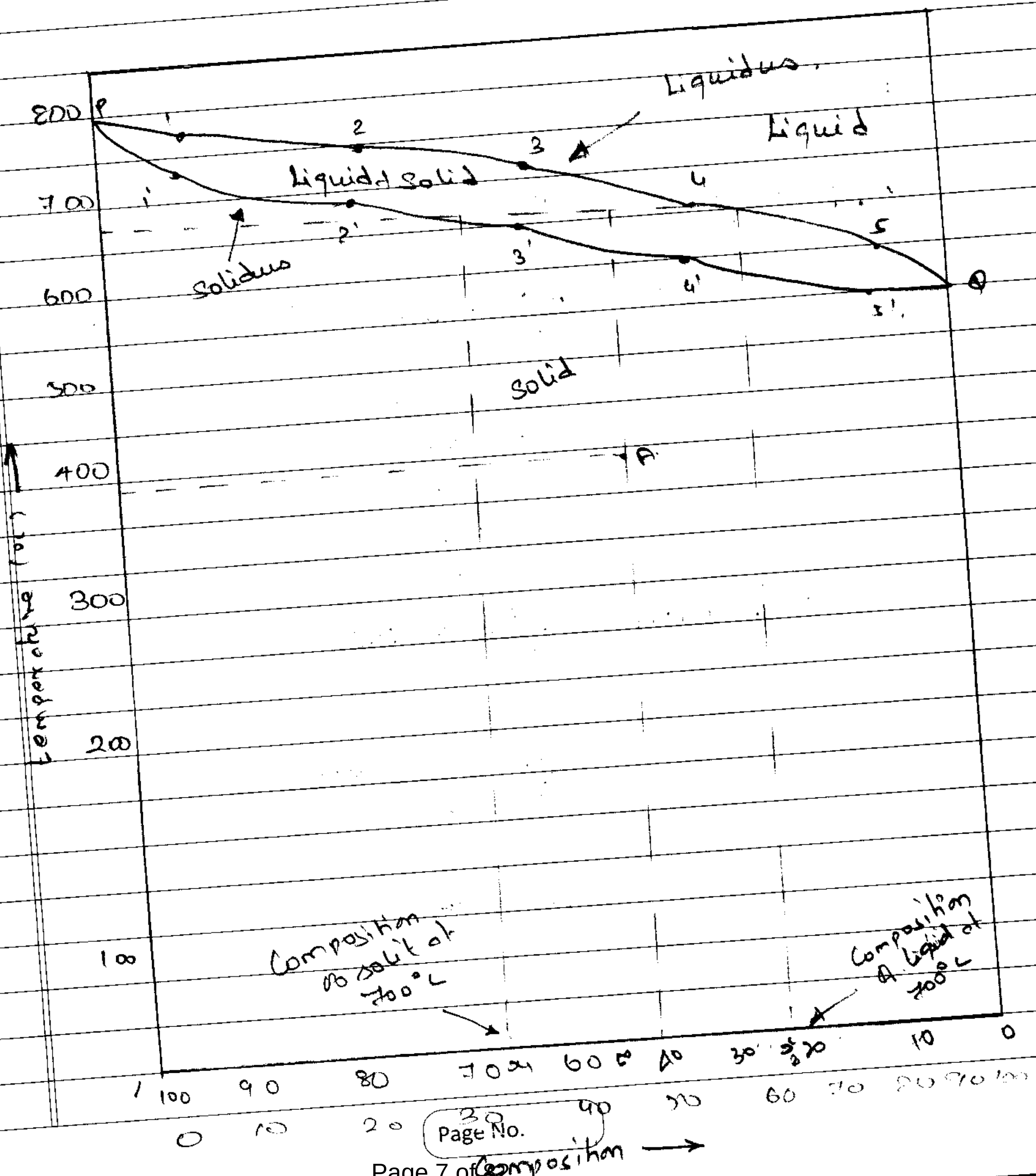
* The eutectoid reaction, which occurs at 723°C.

$$\gamma \text{ Austenite} \underset{}{\overset{723^\circ C}{\rightleftharpoons}} \alpha \text{ ferrite} + Fe_3C$$

2. Two metals A & B have 100% mutual solubilities in the liquid & solid states. The melting point of pure metals A & B are 800°C & 600°C respectively. Details of start & end of solidification of various alloys [N-16, M-14, N-07]

ALLOY COMPOSITION	TEMP. OF START	TEMP. OF END
90% A + 10% B	798°C	750°C
70% A + 30% B	785°C	705°C
50% A + 50% B	757°C	675°C
30% A + 70% B	715°C	645°C
10% A + 90% B	650°C	615°C

Determine the relative amount & concentration of phases present in an alloy of 40% A & 60% B at 700°C & 400°C



To Find Number of Phases

At 40% A – 60% B.

The number of phase

$P = 2$.

Relative amount of phase

Applying Lever's Rule

$$\% \text{ solid} = \frac{MP}{OP} \times 100$$

$$= \frac{40-24}{67.5-24} \times 100$$

$$= 36.78\%$$

$$\% \text{ of liquid} = \frac{OM}{OP} \times 100$$

$$= \frac{(67.5-40)}{(67.5-24)} \times 100$$

$$= 63.22\%$$

Composition of Phases

Composition of Solid Phase is
(67.5% A − 32.5% B)

Composition of liquid phase
24% A − 76% B.

For an alloy of 40% A & 60% B at 400°c

Number of Phases:

For an alloy of 40% A − 60% B at 400°c there is only solid phase exists.

Number of phases P = 1.

Relative amount of phases.

Relative amount ⇒ 100% Since there is only one phase is present.

3) Expline about the MICRO - CONSTITUENTS OF IRON and Steel:-

[M_14, N_08, D_11]

* When steel is heated above the austentic temperature and is allowed to cool under different conditions, the austenic is steel transforms into a variety of Micro constituentes discussed below:-

* The Study of these Micro consitutes is essential in order to understand Fe -C equilibrium diagram and T.T.T diagram.

* The various Micro-consituets are

(a) Austenite) (b) Ferrite
(c) Cementite (d) Ceadobcrite
(e) Pearlite (f) Bainite
(g) Martensite (h) Troostile
(i) Sorbite:

(a) Austenite:

elements
(eg) Mn, Ni, etc:

✓ Carbon is in interstitial solid solution where Mn, Ni, Cr, etc

✓ Austenite can dissolve maximum 2% of carbon

✓ Austenite has:

* Tensile Strength 10500 kg/cm²
* Elongation 10% in 50 mm
* Hardness Rockwell C40:

✓ Austenite is normal not stable at room temperature. under room temp

✓ Microstructure of austenite at room temperature and is non-magnetic and soft.

(b) Ferrite:

✓ Ferrite is B.C.C iron phase with very limited solubility for carbon.

✓ Ferrite is the softest structure that appears on the Fe-C equilibrium diagram:-

* Tensile strength 2800 kg/cm²
* Elongation 40% in 50m.
* Hardness:

(c) Cementite:-

✓ Cementite or iron carbide chemical formula Fe_3C, contains 6.67% carbon by weight

✓ It is typical hard and brittle

✓ It is the hardest structure that appears on the iron carbon equilibrium

d) Ledeburite:

✓ ledeburite is the eutectic mixture of austenite and Cementite
It Contain 4.3% carbon.

↗ perlite has the following

* Elongation 20% in 50mm
* Hardness : Rockwell c20:

Bainite

↗ Bainite is the constituent produced in a steel when austenite transforms at a transform below that which is produced and above that which Martensite is formed:

↗ Bainite forms on isothermal transformation at temperature below the nose of TTT diagram

(9) Martensite:

↗ Martensite is considered to be highly stressed α - iron when is saturated with carbon:

↗ Martensite forms as a result of shear - type transformation with virtually no diffusion:-

→ Martensite possesses an acicular or needle-like structure:

(h) Troostite:

→ Troostite is a mixture of radial lamellae of ferrite and cementite and differ from pearlite only in one degree of fineness:-

→ The constitution also known as troostite pearlite is produced by the decomposition of austenite when cooled:-

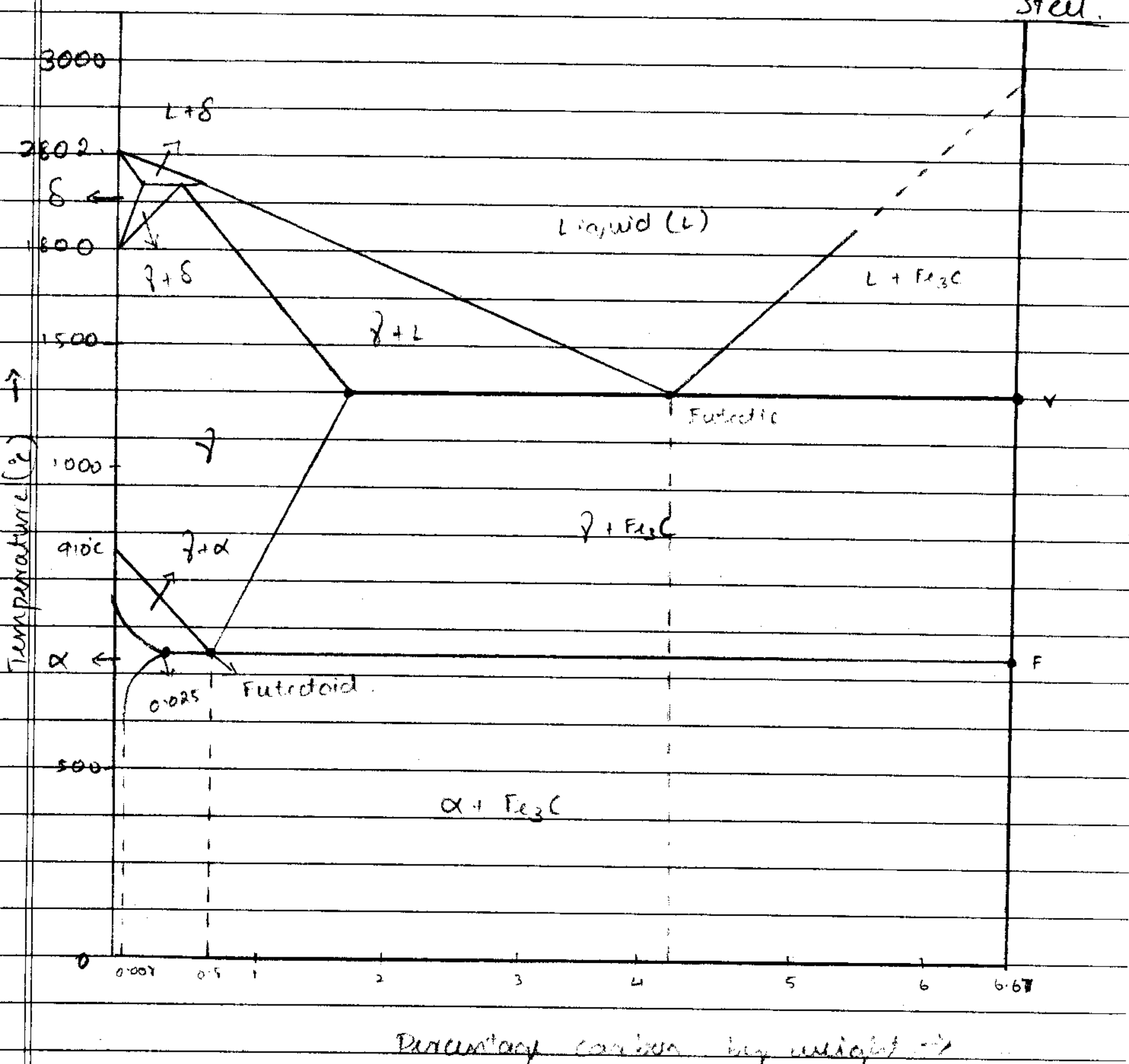
(i) Sorbite:-

→ Sorbite is the micro structure consist of ferrite and finely divided cementite produced on tempering martensite above 450°C

→ The constitute also known as sorbitic pearlite, is produced by decomposition when cooled.

Q.4) Explain in detail about the transformation takes place in the structures of steel and cast iron. [M-12, D-09] [M-16]

Transformation which takes place in the structures of steel.



Steel containing 0.4% carbon is a hypoeutectoid steel and is completely austenite above A_3 upper critical temperature line. As it is cooled below A_3 line the iron belongs to change form FCC to BCC.

The BCC crystals retain a small amount of carbon and are reffered as crystals of ferrite.

As the cooling proceeds, ferrite crystals grow in size at expense of austenite.

Consider transformation of an eutectoid steel containing 0.83% carbon. It will remain austenite upto the point. The transformation will begins and end at same temperature, 1333°F. Since eutectoid steel contains 0.83% carbon, it follows that the final transformed structure.

Consider the transformation of a hypereutectoid steel containing 1.2% carbon. As the temperature drops and steel crosses the line at a point d and moves towards e, the excess carbon above the amount required to saturate austenite is perpertive as cementite primarly in it.

As the temperature drops below 1333 °F, the austenite has become less rich in carbon. It contains only less rich in carbon. The structure of a hypereutectoid steel at room temperature consists of cementite and pearlite.

So far there were only with regard to structures produced in steels by slow cooling from austenite under equilibrium conditions.

In normal foundary practice the rate to prevent transformation of austenite above 600°F martensite forms on further conditions. Martensite is a hard, strong and brittle material.

If castings are cooled at still faster rate in normal foundary practice, the rate of cooling is slightly faster and as a result more cementite plates are nucleated and individuals lamellae of pearlite become thinner.

Transformations which takes place in the Structure of a cast Iron:

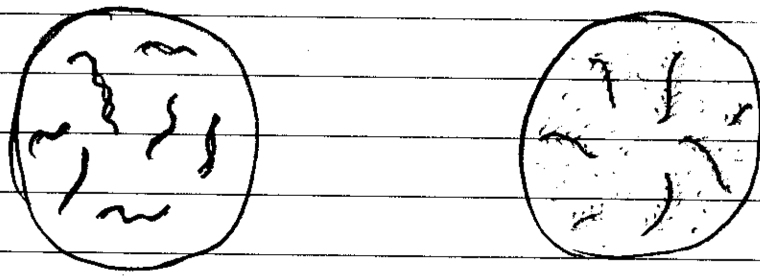
Cast iron containing 3% carbon is when cooled under rapid rate as a thin section of a sand casting, from a temperature of about 2500°F. it begins solidified.

As the alloy contains below solidus, ledeburite freezes and cementite precipitates from austenite to martensite state.

Cooling of the alloy below the given it involves the transformation of remaining austenite of eutectoid composition to pearlite as explained for steels.

The structure of alloy at room temperature consists of cementite, austenite, martensite and transformed to ledeburite.

As cooling continues reaction will be austenite and graphite flakes grow. At 1333°F, remaining austenite remains at the same structure at room temperature.



Microstructures of pearlite grey cast iron.

This phase changes is the same alloy when cooled at very slow rate similar to the discussed method. Cooling will be sufficiently slow to permit graphite flakes from the one stage to another. Instead of pearlite the matrix of the alloy solidified is this case is ferrite and graphite flakes embedded in it.

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Unit II
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UNIT - II HEAT TREATMENT

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Two Marks :-

1. Differentiate Normalizing with full annealing [M-16, M-19]

	Normalizing	Full annealing
(i)	Normalizing is more economical than full annealing (since no furnance is required to control the cooling rate).	Full annealing is costly.
(ii)	Normalising is less time consuming.	Full annealing is more time consuming.
(iii)	It provides a fine grain structure.	It provides a coarse grain structure.

2. What is the purpose of spheroidizing heat treatment? [D-10, D-09]

(i) To soften steels
(ii) To increase ductility and toughness
(iii) To improve machinability and formability.
(iv) To reduce hardness, strength and wear resistance.

3. Define carburizing. [D-10, M16]

Carburizing is the process in which carbon atoms are introduced onto the surface of low carbon steels to produce a hard case of surface, while the interior or core remains soft.

4. Define the term critical cooling rate. What are the factors affecting it? [N-06, D-10]

(i) The slowest rate of cooling of austenite that will result in 100% martensite transformation is known as the critical cooling rate.

(ii) Factors affecting are :-

- Chemical composition of steel
- Hardening temperature
- Metallurgical nature [i.e. Purity] of steel

5. Define hardenability and case depth. [M-12, M-16]

(i) The hardenability is defined as the property of a material by virtue of which it is able to resist abrasion, indentation and scratching.

(ii) Case depth is the thickness of the hardened layer on a specimen.

6. What changes in physical and mechanical properties occur due to annealing? [N-11, D-14]

(i) Annealing alters ductility, toughness, electrical, magnetic or other properties.

(ii) It induces softness

(iii) It refines grain structure.

(iv) It relieves stresses.

7 Define tempering. [D-10]

Tempering is the process of heating a martensite steel at an temperature below the eutectoid transformation temperature for a specified time period, and is cooled slowly to room temperature.

8 When will you prefer carbonitriding? [N-09, M-11]

(i) Carbonitriding is an ideal process for hardening small components where great resistance to wear is necessary.

(ii) The steels that are commonly carbonitrided are the low-carbon and low-carbon alloy steels.

9 A low carbon steel in the normalised condition is stronger than the same steel in the annealed condition. Why? [M-06, D-16]

Unlike full annealing, the rate of cooling in normalising is more rapid. Also normalising process provides a homogeneous structure consisting of ferrite and pearlite for low carbon steels. That's why normalising produces harder and stronger steels than full annealing.

10. Case carburising heat treatment is not generally carried out for medium carbon steels. Why? [D-06, M-16]

We know that carburizing process is a diffusion treatment process. For diffusion to take place, the host metal must have a low concentration of the diffusing species and there must be a significant concentration of the diffusing species at the surface in the host metal. Since the medium carbon steels lack the above said criteria, they are not generally carburised.

Explain Isothermal transformation [M-14, M-16]

TTT Diagram - TEMPERATURE TIME TRANSFORMATION

* The Fe-C phase diagram does not show time as variable

* Hence it cannot show the effects of various cooling rates upon the ~~struction~~ structure of various grades of steel

* This diagram is also called TTT diagram (or) Time Temperature Transformation - diagram (or) S-curve (or) C-curve

CONSTRUCTION OF A TTT DIAGRAM:-

Step 1 : Obtain a large no. of relatively small specimens of same material

Step 2 : Austenitize the samples in the furnace at a temp above the eutectoid temp

Step 3 : Then quench (i.e) rapid cool the samples in a liquid salt bath at the desired temp below the eutectoid

Step 4 :- After various time intervals, remove the samples from the salt bath one at a time and quench into water at room temp

Step 5 :- Now examine the microstructure after each transformation time at room temp. The result obtain in the reaction

Step 6 :- Now repeat the above procedure for the isothermal transformation at progressively low temp.

TTT Diagram for a Eutectoid Steel.

* The TTT diagram consist essentially of 2 C shaped curve.

1. The left-hand C-shaped curve indicates the time necessary for isothermal transformation of austenite to begin

2. The right-hand C-shaped curve indicates the time required for the transformation to be completed.

~~* Two parallel lines near the foot of dia are~~

* The TTT diagram of eutectoid steel indicating various structures resulting from transformation at various temp

* The following interpretation can be made.

1) Isothermal transformation of eutectoid steel at temp b/w 723°c and about 550°c produce pearlite micro-structure.

2) As the transformation temp is decreased in this range the pearlite changes from coarse to a fine structure.

3) Rapid quenching of eutectoid steel from temperature above 723°c, where it is the austenitic condition transform the austenite into martensite.

4) If eutectoid steels in the austenitic condition are hot-quenched to temp in 550°c to 250°c range are isothermally transform, a structure b/w pearlite and martensite called bainite

5) Bainite in non-carbon alloys can be defined as an austenitic decomposition product that has a non-lamellar eutectoid structure of α-ferrite and cementite (Fe_3C)

6) For eutectoid carbon steels, a distinction is made b/w upper bainite and lower bainite

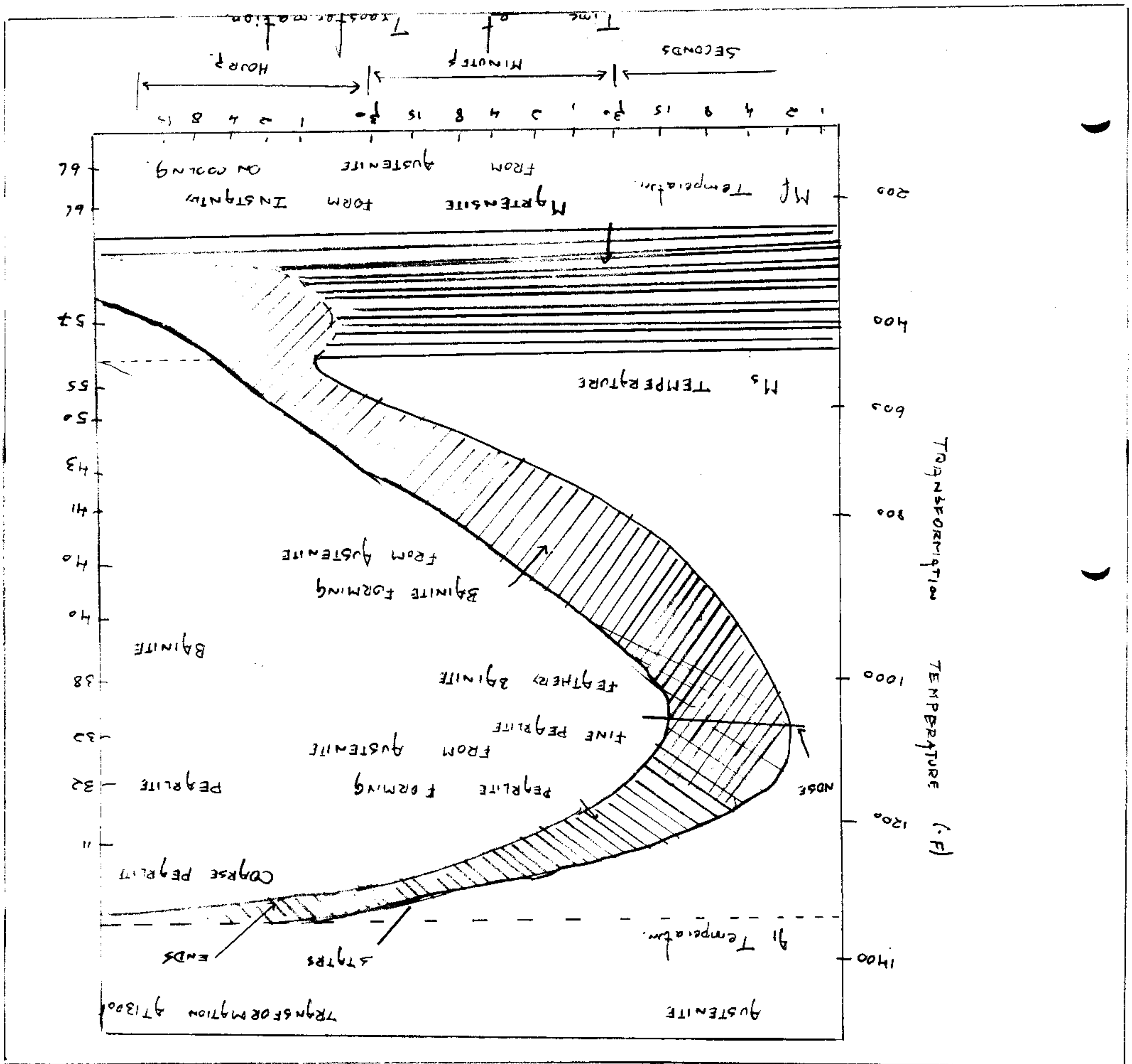
upper bainite – formed b/w 550°C and 350°C, It has large, rod like cementite regions

Lower bainite – formed b/w 350°C and 250°C. It has much finer cementite particles

7) As the transformation temp is decreased, the carbon atoms cannot diffuse as easily. Hence the lower bainite structure has smaller particles of cementite

SIGNIFICANCE OF TTT Diagram in Heat Treatment of Steel

* The TTT diagram is most useful in giving an overall picture of transformation.
* Using a TTT diagram one can plan practical heat treatment operation.



AUSTENITE
TRANSFORMATION AT 1300
A1 Temperature
STARTS
ENDS
COARSE PEARLITE
PEARLITE FORMING FROM AUSTENITE
PEARLITE
NOSE
FINE PEARLITE
FEATHERY BAINITE
BAINITE
BAINITE FORMING FROM AUSTENITE
Ms TEMPERATURE
Mf Temperature
MARTENSITE FORM INSTANTLY FROM AUSTENITE ON COOLING
TRANSFORMATION TEMPERATURE (°F)
1400
1200
1000
800
600
400
200
11
32
32
38
40
40
41
43
50
55
57
66
66
1 2 4 8 15 30 1 2 4 8 15 30 1 2 4 8 15
SECONDS
MINUTES
HOURS
Time of Transformation

Explain Jominey Test in detail [M-11, D

2 HARDENABILITY - JOMINY END QUENCHED TEST:

* Hardenability is the property of steel which determines the depth and distribution of hardness. obtained by quenching.

* Hardenability is a term used to describe ability of an alloy to be hardened by the formation of martensite

THE JOMINY END QUENCHED TEST - PROCEDURE

* In this test, a cylindrical specimen of diameter 25.4 mm and strength length 100 mm is austenised

* After taking from furnance, it is quickly mounted in a fixture

* The lower end is quenched by a jet of water of specified flow rate and temp

* The cooling rate is maximum at bottom end and diminished along the length of specimen

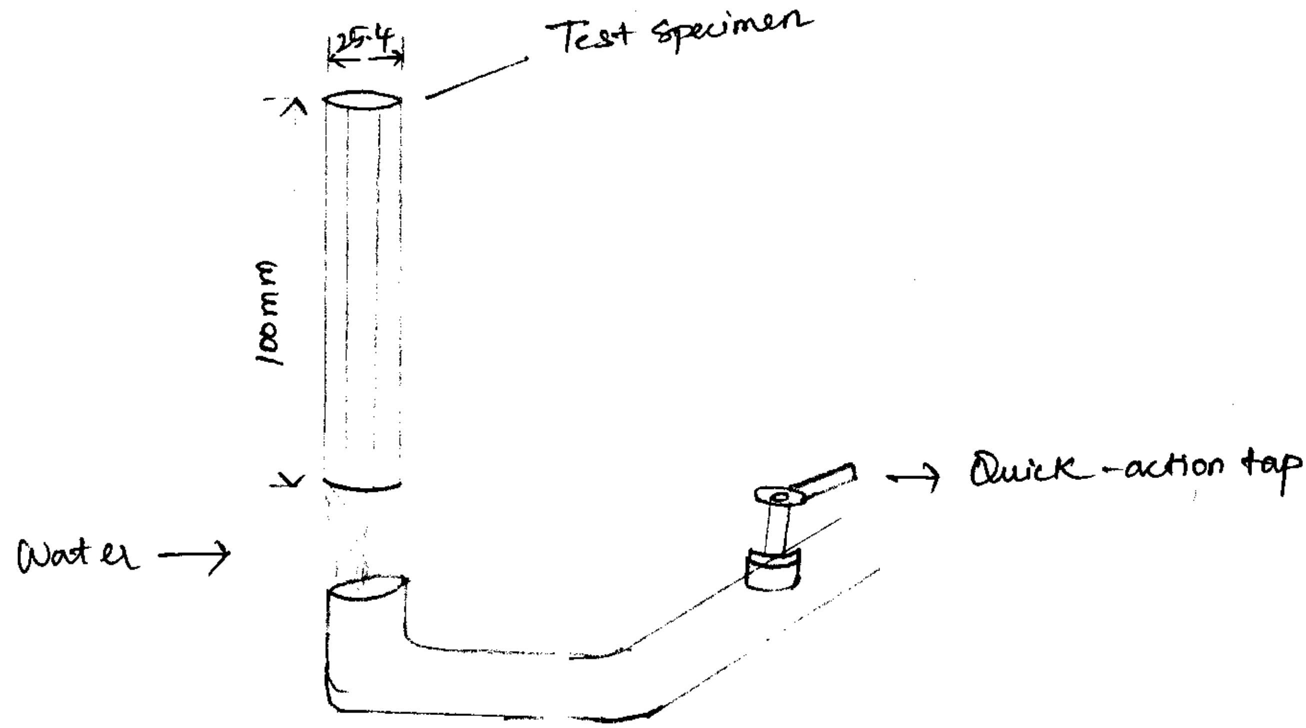
* After the specimen is cooled to room temp, shallow flats 0.4 mm deep are ground along specimen length

* Rockwell hardness method is used for 1st 500 mm, For 1st 128 mm, hardness reading are taken at 1.6 mm interval for remaining 38.4 mm, every 3.2 mm.

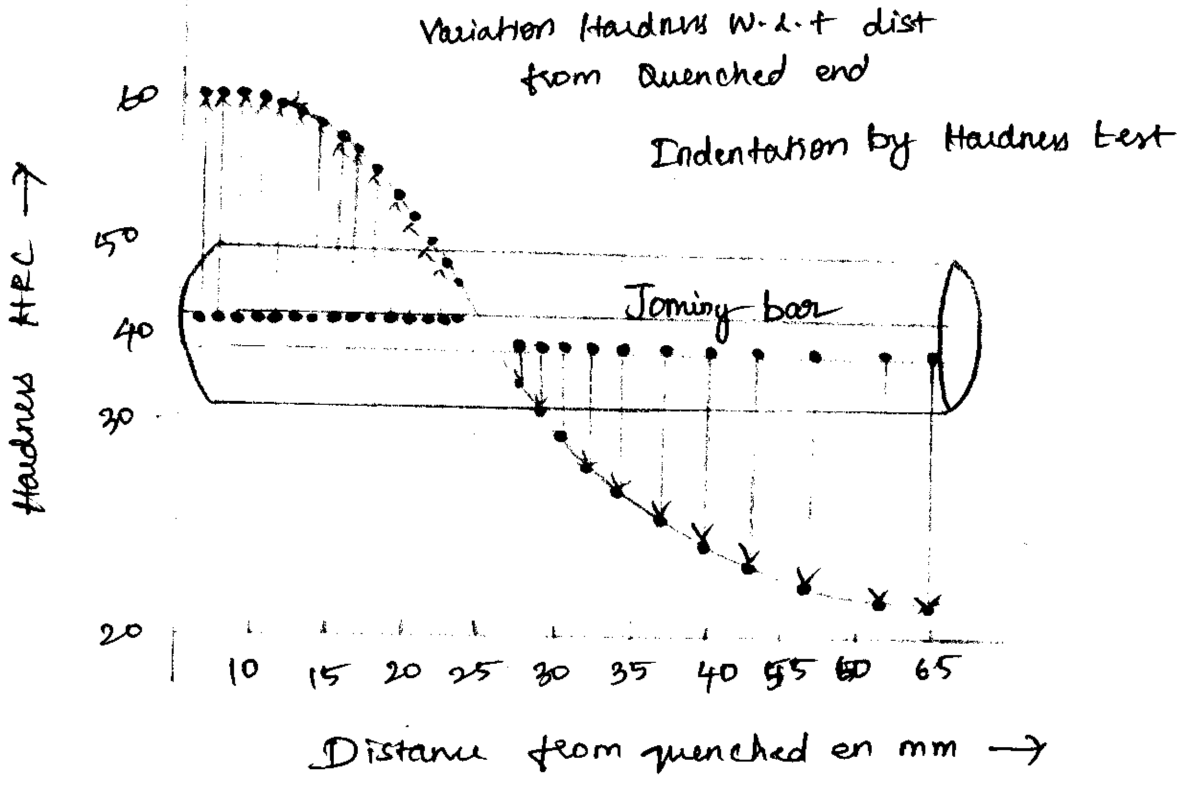
* A Hardenability curve can be drawn when hardness is potted in Y axis × the position from the quenched end in x axis.

* From this curve we can see that the quenched end is cooled most rapidly and exhibits the maximum hardness 100% martensite is formed at quenched end.

* Cooling rate decrease with the dist from the quenched end, and the hardness also decreases.



Apparatus used in test



3. Explain different types of Annealing.
1 Annealing:- [M-14, D-09]

Annealing primarily is the process of heating a metal, which is in a metastable or distroted structure state, to a temperature which will remove the instability or distrotion and then cooling so that the room temperature structure is stable and or strain free

Purpose:-

* Reducing Hardness.
* Improving Machineablity.
* Removing desired microstructure
* Removing residual stresses.
* Removing gases.

Stress Relieving:-

✓ Stress Relieving annealinng relieves stresses produced by casting, quenching, mahining, cold working, welding etc.

✓ It is applied for all non-ferrous and ferrous metals.

✓ Stress relieving does not affects the metallurgical structure of the casting.

✓ Stress relief is also known as "Recovery.

Process Annealing:-

✓ Process annealing is usually subcritical annealing.

✓ It is applied to remove the effect of cold works, to soften and permit Further cold work as in sheet and wire industries.

✓ Ferrous alloys are heated to the temperature (500° - 650°c) and then cooled usually in air in order to soften the alloy for further cooling working in wire drawing.

✓ Process annealing is generally carried out in either batch - type or continous furances usually with an inert atmosphere of burnt coal gas.

Spheroidise Annealing:-

✓ Spheroidise Annealing or spheroidizing involves subjecting steel to a selected temperature cycle, usually within or near the transformation range in order to produce a spheroidise. [Globular Form of Carbides in steel].

Spheroidizing

* Improves Machinability
* Facilities a subsequent cold working operations.
* Obtains a desired structure.
* Improves surface Finishing.

✓ A spheroidized steel has a lower hardness and tensile strength.

Spheroidizing is extensively employed for high carbon steels.

Heating the steels and the preholding it for lower critical line between (650 and 700°C)

Full Annealing:-

✓ Full annealing implies annealing a ferrous alloy by austenitizing and then cooling slowly through the transformation range.

✓ Austenitizing temperature for hypoeutectoid steels is usually between 723°C (1337°F) and 910°C (1670°C)

✓ Hypereutectoid steels, its temperature is between 723°C [1333°F) and 1130°C [2066°F).

Full annealing.

* Refines grains.
* Removes strains
* Induces softness.
* Improves machinability, formability
* Improves electrical and magnetic properties

Normalizing:-

✓ Normalising or air quenching consists in heating steel to about 40-50°c above its upper critical temperature. (A_3 and A_{cm} line).

✓ Normalising differs from full annealing in that of cooling is more rapid and there is no extended soaking period.

✓ Normalising produced microstructure consists of ferrite (white network) and pearlite (dark areas) for hypoeutectoid (up to about 0.8%)

Purpose:
* Produces a uniform structure.
* Reduces internal stresses.

✓ In general, improves engineering properties of steels.

Hardening:-

✓ Hardening is that heat treatment of steel which increases its hardness by quenching.

✓ Tools and machine parts required to undergo heavy duty service.

✓ Hardening followed by tempering.

* Hardness steel to resist wear.
* Enables steel to cut other metals.
* Improves strengths and ductility.

✓ The degree of hardness produced in steels depends on.

* Composition of steel (0.35 to 0.50 %)
* Quenching temperature.

4) Explain the carburizing process in detail [M-10]

Carburizing:-

✓ Carburizing is a method of introducing carbon into solid iron-base alloys such as low carbon steels in order to produce a hard case (surface).

✓ It is also known as Cementation.

Characteristics:-

✓ Case depth is about 0.05 inches (1.27 mm).

✓ Hardness after heat treatment

Typical uses:-

✓ Gears
✓ Camshafts
✓ Bearings.

Methods

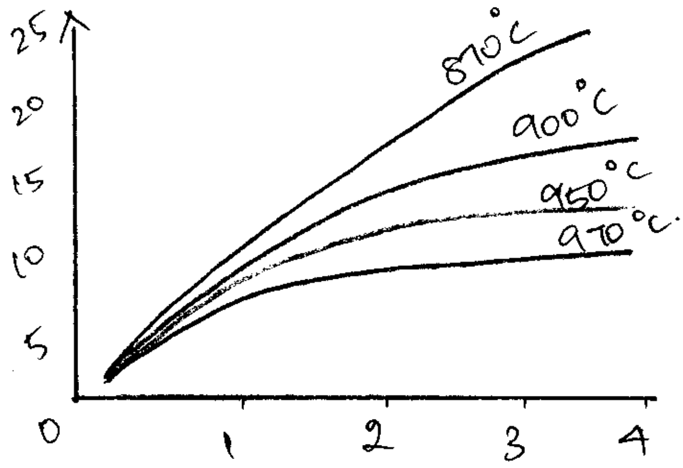
✓ Pack Carburizing
✓ Gas Carburizing
✓ Liquid Carburizing.

Pack Carburizing:-

✓ Pack carburizing involves packing the components into cast Iron or steel boxes.

✓ Carburizing medium consists essentially of wood or bone charcoal. or charred leather. which may be amount up to 40% of total composition.

✓ Carburizing temperature is between 900 and 950°C and kept in temperature up to 5 hrs.



Mechanism:-

(i) Formation of Carbon Monoxide (CO).

(ii) Dissoulation of CO.

$$2CO \rightleftharpoons CO_2 + C_{atm}.$$

(iii). Enrichment of steel layer.

$$3Fe + 2CO \rightleftharpoons Fe_3C + CO_2$$

May be electroplated with copper to a thickness of 0.075 - 0.10 mm.

Gas carburizing:-

* Gas carbuzing can be applied in mass production.
* It is readily adaptable to ally types.
* In gas carburizing, components are heated about 900°C for 3 or 4 hours.
* The most commonly used atmosphere for gas

✓ 20% CO ✓ 40% Hydrogen.

✓ 40% Ni

Following are major reactions takes place,

* $3Fe + 2CO \rightleftharpoons Fe_3C + CO_2$
* $Fe_3C + 2H_2 \rightleftharpoons 3Fe + CH_4$.

$3Fe + CO + H_2 \rightleftharpoons Fe_3C + H_2O$.

* $CO_2 + CH_4 \rightleftharpoons CO + 2H_2$
* $CH_4 + 3Fe \rightleftharpoons Fe_3C + 2H_2$.

Advantages:-

✓ Pack carburizing cannot be acurately controlled with regard to case depth.

✓ Labour costs are lower than in pack carburizing.

✓ Time is required less.

Disadvantages:-

✓ When compared to pack carburizing higher skilled personnel are required to maintain the controls.

Liquid carburizing:-

✓ Carburizing is liquid baths is of comparatively recent origin and is an overgrowth of older process of cyaniding.

✓ Liquid carburizing is employed principly for relatively shallow cases (0.10-0.25)

$$2NaCN + 2O_2 \rightarrow Na_2CO_3 + 2N + CO.$$

Advantages:

* Rapid Heat transfer
* Low distrotion.
* Negligble surface oxidation.
* Rapid absorbion of carbon.

Disadvantages:-

* Cyanide salts are highly poisonous
* Molten cyanide explotes on contants with water.
* Parts need through washing after treatments to prevent rusting.

Applications:-

Gas carburizing is particularly suitable for mass production of thin cases in small and medium size parts.

① . What is an alloy? How many components are found in an alloy? [M-10, M-16]

A Metal alloy, or simply an alloy is a mixture of two or more metal and a non-metal. Two (or) more components in an alloy.

② . State the reactions and actual system in the monotectoid and syntectic. [M-14, N-09]

Monotectoid reaction

$$\text{Solid } 1 \underset{\text{Heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \text{Solid } 2 + \text{Solid } 3$$

Syntectic reaction

$$\text{Liquid } 1 + \text{liquid } 2 \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \text{solid } 1 .$$

③ Write a short note on flame hardening method [M-16]

Flame hardening is a process of selective hardening with combustible gas flame as the source of heat for austenitizing.

④ Discuss about the grey cast Iron. [N-06, N-09]

Typical composition of grey cast Iron is given below.

carbon – 2.5 to 4 %.

1

Silicon - 1 to 3 %.

Manganese - 0.4 to 1 %.

Phosphorous - 0.15 to 1 %.

Sulphur - 0.02 to 0.15 %.

Remaining is Iron.

---

(5) State peritectic and peritectoid reactions :- [M-16]

Peritectic reaction

$$\text{Liquid} + \text{solid } 1 \underset{\text{Heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \text{solid } 2$$

Peritectoid reaction

$$\text{Solid } 1 + \text{solid } 2 \underset{\text{Heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \text{solid } 3$$

---

(6). Explain the term "inducting hardening" :- [D-15, N-11]

The induction hardening is a process of selective hardening using resistance to induced eddy currents as the source of heat.

---

(7). Mention any four attractive properties of engineering ceramics [M-06]

(a) High resistance to abrasion and wear

(b) High strength at high temperature.

(c) Good chemical stability

(d) Good electrical insulation characteristics.

(8). What is eutectoid reaction? [M-16]

Eutectoid reaction can be written as

$$\text{liquid} \underset{\text{Heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \gamma_{iron}\ (\text{Austenite}) + Fe_3C\ (\text{cementite})$$

(9) Differentiate carburizing and nitriding. [M-14, N-09]

In the carburising process the diffusing hardening element is carbon. In nitriding process the diffusion involves nitrogen.

(10). Classify the different hardness testing methods. [N-11]

(i) Brinell hardness test

(ii) Vickers hardness test and

(iii) Rockwell hardness test.

3

1. Explain the classification of cast iron in detail? [M-16, N-07]

1. **Classification of cast Iron:**

The cast Iron classified into four types. There are.

* Grey CI
* White CI
* Mallarable CI
* Nodular CI

Grey CI:

The grey cast iron consist of graphite flakes surrounded by a ferrite (or) pearlite matrix.

Composition:

Carbon content in cast iron (2-4 %); and the Mn content in cast iron 0.4-1 %; Si content 1-3 %. P content in grey cast iron 0.15 - 1 %; S content in grey cast iron 0.02 - 0.15 %; Then the finally remaining Irons all so in this grey cast Iron.

Properties:

* Grey cast irons are weak and brittle in tension.

5

* Graphite flakes → voids → brittle material.

* compressive strength is greater than the tensile strength.

* cast iron grade 20 = 138 MPa
  cast iron grade 40 = 276 MPa

* Good corrosion resistance

* Good fluidity

* Excellent machinability.

Applications:

* Engine blocks

* Engine cylinder

* Brake drums

* Cam shaft.

---

2. White cast iron:

White cast iron consist of silver appearence surrounded by cementite in pearlite materix.

Composition:

C = 1.8 - 3 %

Mn = 0.25 - 0.8 %

Si = 0.5 - 1.9 %

$P = 0.05 - 0.2\%$

$S = 0.1 - 0.3\%$

and remaining Irons:

Properties:

* very hard and brittle

* high alasion resistance

* cant be machined easily

Application:

white cast iron used in

* rolls

* wear plates

* Pump lining

* cam shaft.

---

3. **Malleable cast Iron:**

During heat treatment cemenite in white CI breaks into ferrite and graphite.

Composition:

$C = 2 - 3\%$

$Mn = 0.2 - 0.6\%$

$Si = 0.6 - 1.3\%$

$P = 0.15\%$

S = 0.1 %

remaining irons.

Properties:

* Grade 32510 yield strength 32.5×10^3

* 10 % elongation

* good ductility, not brittle as grey CI.

* high young's modulus

* Low thermal co-effcient

* excellent machinability.

Application:

* Brake shoes

* Pedals

* Levers

* axle housing

* connecting rods

* gear

* door hings.

4. NODULER CAST IRON:

Adding Mg to molten CI . (ie) grey CI before casting Mg ⟶ graphite ⟶ spelical (or) noduler.

Composition:

C = 3.2 - 4 %.

Mn = 0.2 - 0.5 %

Si = 1.8 - 3 %.

P = 0.08 %.

S = 0.01 %.

remaining irons.

Properties:

* Good ductility
* Toughness
* Grade 60-40-18

  SGCI 60×10^3 - tensile strength 40×10^3 psi - yeild strength .18 % elognation.

* Good fatigue
* Corrosion resistance.

APPLICATIONS:

* Gears
* roller
* flanges pipe fittings

24) Explain the precipitation Hardening? [M-14, P-12] mech B1.

4) Precipitation Hardening :-

* precipitation hardening, also known as age hardening, is the most important method of improving the physical properties of some of the non-ferrous alloys by solid state reaction.

* It is mostly applicable to the alloys of aluminium, magnesium and nickel. It is occasionally used for the alloys of Copper and Iron.

* Examples of alloys that are hardened by precipitation treatments include aluminium - copper, copper - beryllium, copper - tin, and magnesium - aluminium.

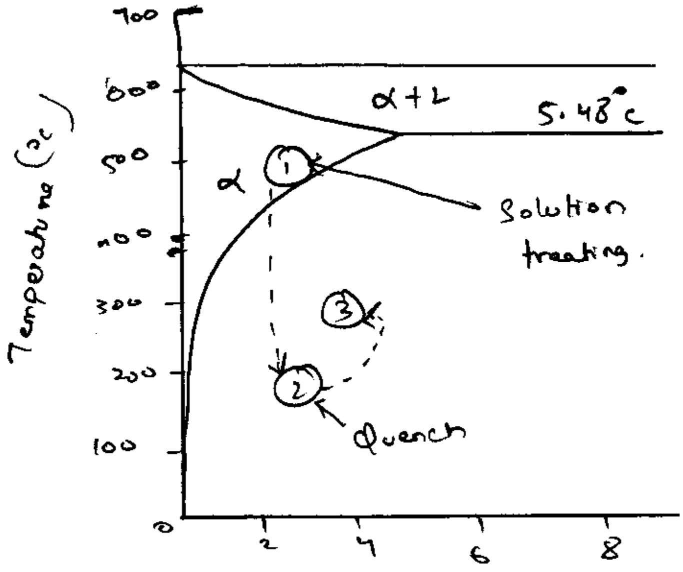
* The process is called precipitation hardening because the fine precipitate particles of new phase are formed in this hardening process.

Process of precipitation Heat Treatment.

The process of precipitation heat treatment consists of three steps. The three step process is explained for an aluminium alloy, say Al - 4% Cu alloy (called duralumin) below.

The Al - Cu phase equilibrium diagram. also shows the three steps in the precipitation hardening heat treatment together with the microstructure that are produced.

11



Step 1 :- Solution treatment.

* First the alloy is heated above the Solvus temperature to obtain its Solid Solution

* The alloy is held at this temperature until a homogenous solid solution α is produced.

* This Step dissolves the θ precipitate and reduce any Segregation present in the original alloy.

Step 2 :- Quenching Process.

* After Solution treatment the alloy (which contains only α Structure) is quenched.

* on this rapid cooling, there is no Sufficient time for diffusion of Cu atoms to form the precipitate particles. Therefore a Super Saturated Solid Solution α_{ss} (containing excess Cu) is obtained at room temperature. It Should noted that α_{ss} is not a stable Structure.

Step 3 :- Ageing Process

* Finally, the Supersaturated Solid Solution α_{ss} is heated below the Solvus temperature

* At this ageing temperature, the diffusion of unstable α_{ss} may take place and precipitate particles can form

* Then, if we hold the alloy for a sufficient time at the ageing temperature, the stable $\alpha + CuAl_2$ (θ) structure is produced.

* This fine precipitate particles of $CuAl_2$ increase the hardness and strength of the alloy.

13

Explain various copper alloys in detail. [M-14, N-08]

Copper Alloys.

Combination of copper with some other alloys like Zinc, Nickel, Tin

Copper + Zinc → Brass.

Copper + Nickel → Cupra

Copper + Tin → Bronze.

The important copper alloys are

1. Brasses (copper-zinc alloys).
2. Bronzes (copper-tin alloys).
3. Gun-metals (copper-tin-zinc alloys)
4. Cupro nickels (copper-nickel alloys).

1. Brass

High ductility but lower thermal conductivity and electrical conductivity property compared to copper.

Types of Brass alloy.

Mundz metal (60% Cu, 40% Zn).

Noval brass (59% Cu, 40% Zn, 1% Sn).

Gilding metal (90% Cu, 10% Zn).

Catriage metal (70% Cu, 30% Zn).

15

2. Bronze

Bronze is an alloy of copper and tin.

It's a good corrosive resistance and high ductility.

Types of Bronze

Bell Bronze (78% Cu + 22% Sn).

Aluminum Bronze (189% Cu + 0.35Sn + 7% Al + 3.5Fe).

Leaded Bronze (75% Cu + 5% Sn + 18% Pb + 2% Ni.

3. GUN METALS.

Gun metals are alloys of copper, tin and zinc

A zinc acts as a deoxidiser and it also improves fluidity during casting

Since zinc is considerably cheaper than tin, the total cost of the alloy is reduced.

Types of Gun Metals.

Admiralty gun metal (88% Cu + 10% Sn + 2% Zn + 2Ni)

Leaded gun metal (85% Cu + 5% Sn + 5% Zn + 5Pb + 2Ni)

4. Cupronickels

Cupronickels are alloys of copper and nickel

The metals copper and nickels mix in all proportions in the solid state.

They have better corrosion resistance than many other copper alloys in sea water

They can be hot-worked or cold worked.

Types of Cupronickels

Monel metal (29% Cu + 68% Ni + 1.25% Fe + 1.25% Mn)

'K' monel (29% Cu + 66% Ni + 2.75% Al + 0.4% Mn + 0.6% Ti).

* PROPERTIES :-

  ⇒ Good resistance to Organic Solvents

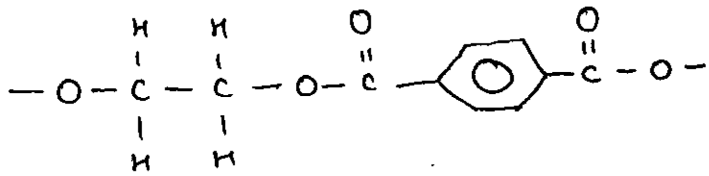
  ⇒ Almost Impermeable to water Vapour.

* TYPICAL APPLICATION :-

  Used for pipes, Seals and gaskets in Chemical Engineering pore.

2. POLYETHYLENE TERAPHTHALATE :- [M-16, D-15]

* ISRO Abbreviation :- PET
* Polymer Name :- Polyethylene Teraphthalate
* Trade Name :- Polyester, Mylar, Cellanar, Dacron.
* REPEATED UNITS :-



* PROPERTIES :-

  * High Strength, high Stiffness Thermoplastics
  * Produced as fibres as transparent films and as moulding Material.
  * Excellent fatigue and wear Strength
  * Good resistance to humidity, acids, grease, oils and solvents.

* TYPICAL APPLICATION :-

  Fibres, Photographic, Films, recording tapes, boil-in-bang Containers, beverage Containers, Soft drinks, bottles, Electrical Connectors.

3. POLYURETHANES :-

* ISRO Abbreviation :- PUR
* Polymer Name :- Polyurethanes
* REPEATED UNITS :-

$$-O-\overset{\overset{O}{\|}}{C}-\overset{\overset{H}{|}}{N}-R-\overset{\overset{H}{|}}{N}-\overset{\overset{O}{\|}}{C}-O-$$

* PROPERTIES :-
  - ⇒ Very good wear resistance
  - ⇒ Resistance to oils, greases and Petrol.
* TYPICAL APPLICATION :-

Hose, car bumpers, Shoe heel tips, hammer heads gears, furniture and insulation.

4. POLYCARBONATE :-

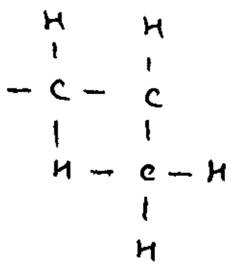
* ISRO Abbreviation :- PC
* Polymer Name :- Polycarbonate
* Trade Name :- Lexan, Merlon
* PROPERTIES :-
  - ⇒ Very good impact resistance and ductility.
  - ⇒ Dimensionally Stable.
  - ⇒ Transparent and low water absorbance.
  - ⇒ Low fatigue and wear Resistance.
  - ⇒ Can be attacked by some Organic Solvents and are Susceptible to Stress Cracking.

* TYPICAL APPLICATION :-

Safty helmets, Shields and goggles, lenses, glazing, lenses, lighting fittings, CD's, Car head lamp mouldings, Instrument Castings and Machine housings, Sterisable Medical Components and Kitchen materials.

5. POLYPROPYLENE :-

* Isro Abbreviation :- PP
* Polymer Name :- Poly Propylene
* Trade Name :- Profax, Tenite, Moplan, Escon, Propylux
* REPEATED UNITS :-



* PROPERTIES :-

=> High Strength and Stiffness than Polyethylene
=> Excellent fatigue Resistance
=> Light weigh
=> Poor resistance to ultraviolet light.

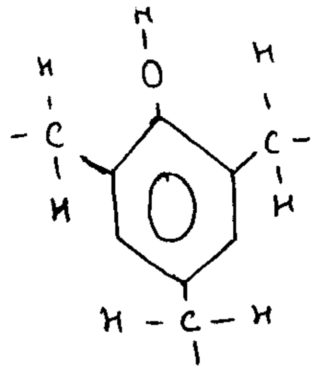
* TYPICAL APPLICATION :-

Used for Buckets, bowls, battery Cases, bottle Crates, toys, bottle Cap, automotive parts, Vaccum Cleaner bodies. In fibre foam for rops and Carpeting.

8) Explain any five Thermosetting Polymer in detailed. [M-16, N-07]

1. PHENOL FORMALDEHYDE :-

* ISRO Abbreviation :- PF
* Polymer Name :- Phenol formaldehyde
* Trade Name :- Bakelite, Durez, Resinox
* REPEATED UNITS :-



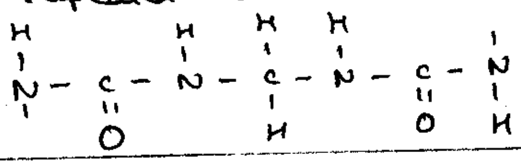
* PROPERTIES :-
  - ⇒ High rigid and Stable upto 150°c
  - ⇒ Low thermal conductivity
  - ⇒ Good Electrical insulators.
  - ⇒ Good resistance to oils, greases and Many Solvents.

* TYPICAL APPLICATION :-

Electrical plugs, Sockets, Switches, door knobs, and handles, adhesive Coatings and laminates.

2. UREA FORMALDEHYDE :-

* ISRO Abbreviation :- UF
* Polymer Name :- Urea formaldehyde
* Repeated Unit :-



PROPERTIES :-

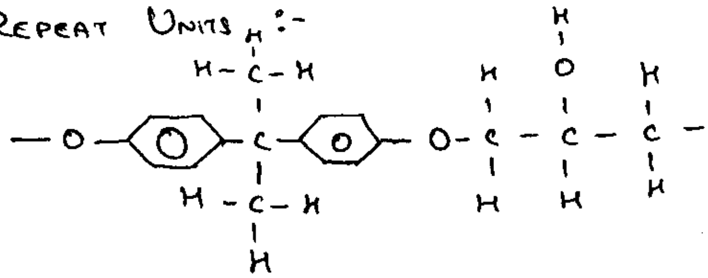
- ⇒ Hard and rigid
- ⇒ Good electrical insulators
- ⇒ Good resistance to most Chemicals
- ⇒ Pigments Can be added to give variety of Colours.

· TYPICAL APPLICATION :-

Electrical devices, circuit breakers, Switchers and the like. Used in the Manufacture of laminates as adhesives and as binding agents in Shell moulding Sands. Used for bottle Caps, Cups, Saucers, plates etc... as they do not impart a taste to foodstuffs.

3. EPOXIDES :-

- * ISRO Abbreviation :- EP
- * Polymer Name :- Epoxides
- * Trade Name :- Epon, Epi-rez, Araldite.
- * REPEAT UNITS :-



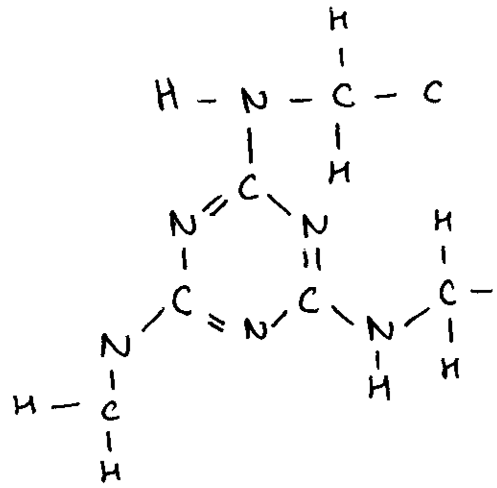
- * PROPERTIES :-
  - ⇒ Very hard and rigid
  - ⇒ Excellent Combination of Mechanical properties and Corrosion resistance.
  - ⇒ Dimensionally Stable.

*** Typical Application :-**

Used as adhesives as rigid moulded parts for electrical applications, automotive components, circuit boards, sporting goods and as a composite for many applications in aerospace - structural panels, helicopter rotor blades, rocket motor castings, etc...

4. Melamine Formaldehyde :- [M-14, N-08]

- * Isro Abbreviation :- MF
- * Polymer Name :- Melamine Formaldehyde
- * Repeated Units :-



Properties :-

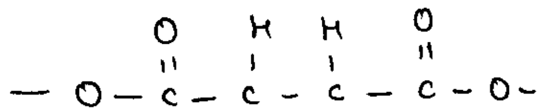
As same as of urea formaldehyde.

Application :-

As same as of urea formaldehyde.

5. POLYESTERS :-

* POLYMER NAME :- Polyesters
* TRADE NAME :- Selectron, Laminac, Paraplex
* REPEATED UNITS :-



PROPERTIES :-

- Excellent electrical properties.
- Low cost
- Often fibre reinforced.
- Can be formulated for room or high temperature use.

TYPICAL APPLICATION :-

Safety helmets, fibre glass boats, Machine Covers, Structural panels, electrical Mouldings and decorative laminates.

4. Explain in Detail about Engineering Ceramics :- [M-16 D-11]

Engineering Ceramics :-

* Engineering ceramics, are also known as technical / industrial ceramics or advanced ceramics, are those ceramics that are specially used for engineering application or in industries.

* Engineering ceramics are mainly oxides, carbides, sulphides, and nitride of metal.

Classification of Engineering Ceramics :-

* Alumina (Al_2O_3)
* Silicon Carbide
* Silicon nitride
* Partially stabilized zirconia (PSZ) and
* Sialons.

1. Alumina (Al_2O_3) :-

* Alumina is nothing but aluminium oxide (Al_2O_3) which is the oldest engineering ceramic.

* Alumina is produced from bauxite ($Al_2O_3 \cdot 2H_2O$) which is the main ore from which metallic aluminium is manufactured.

Characteristics of alumina : Typical mechanical and physical properties of alumina are shown below. Some notable properties are

i] Aluminas have excellent hardness, water resistance and chemical inertness properties.

ii] They are more stiffer than steels.

iii] They are more stronger in compression than many hardened tool steel.

iv] The retain 50% of their room temperature strength at elevated temperature (about 1093°C) v] They posses very good environmental resistance.

vi] They are susceptible to overheating because they are poor thermal conductors.

vii] They posses low neutron absorption cross-section. This properties enable to find application in nuclear equipment.

Aplication of aluminas :-

i] High alumina ceramics are used for the manufacture of spark plug insulator, ceramic/metal assemblies in vaccum tubes, substrates for the deposition of electronic microcircuits and metal cutting tool tip.

ii] They are suitable for any type of load bearing application. They are used for rocket nozzles, pump impellalors, pump liners, check valves, nozzles subject to erosion, and for support member in electrical and electronic devices.

iii] Some unique application of alumina are in dental and medical use, including restoration of teeth, bone filler, and orthopaedic implants.

iv] These materials find application in nuclear equipment.

v] Much of the alumina produced is used in military armour plating. These armour plates protect against missiles fired from high-powered rifles.

2 Silicon Carbide (SiC) :-

* Silicon carbide (SiC) is hard, semiconducting ceramic material. In fact, it is the hardest of traditional abrasive material.

* Silicon carbides have been used as abrasives for grinding wheels and found abrasive papers for many years.

Types of Silicon Carbide :-

(i) α - SiC :

The α silicon carbide is made by the reduction of silica sand with carbon in an arc furnace. It has a hexagonal crystalline structure.

(ii) β - SiC :-

The β- silicon carbide is produced by a vapour phase reactions. It has a cubic crystalline structure.

Types of silicon carbide ceramics :-

Depending upon the mode of manufacture, the following different types of silicon carbide ceramics are available:

1. Reaction bonded silicon carbide
2. Clay - bonded silicon carbide
3. Hot - pressed silicon carbide
4. Sintered silicon carbide
5. Recrystalled silicon carbide
6. Nitride - bonded silicon carbide

Characteristics of silicon carbides :

1. Silicon carbides have higher tensile strength, stiffness, hardness, lower density than aluminium oxides.

2. They provide outstanding oxidation resistance at temperatures even above the melting point of steel.

3. They possess the highest thermal conductivity when compar
with most engineering ceramics.
4. They have better dimensional stability and polishability
5. They are abrasion resistant and wear resistant
6. They are also chemical resistance.
7. They are not very tough.
8. They are expensive with limited availability of shapes and sizes.

Application of Silicon carbides:-

1. Silicon carbides are widely used as abrasives for grindin
wheels and for bonded abrasive papers.
2. They are used for precision optical mirrors and spac
fixtures for the semiconductors industry.
3. They are also used for coating for metals, composit
and other ceramics to provide protections at very high temperature. Example they are used for nuclear reactor fu
element, mechanical seals, bearings and engine comp
4. They are also formed as fibres and whiskers for use as reinforcement in composite material.
5. They are used for refractory tubes and containers.

3. They possess low thermal conductivity which make them as good thermal insulators.

4. They have thermal expansion and modulus of elasticity similar to that of steels.

Application of PSZs :-

1. PSZs are used for superalloy rotor blades in jet turbines.

2. Since PSZs are "environmentally friendly" inside the human body, they are finding use in implantology. They are used for the manufacture of artificial hip joints.

3. Nowadays PSZs replace metal in internal combusion engines.

5. Sialons ($Si_3 Al_3 O_3 N_5$) :-

* The name sialon is an acronym derived from the ingredients involved, namely Si-Al-O-N.

* That is the sialon are derivatives of silicon nitride. Sialons are formed when aluminium and oxygen partially substitute for silicon and nitrogen in silicon nitride.

* The general form of the material is $Si_{6-z} Al_z O_z N_{8-z}$. When z=3, the formula obtained is $Si_3 Al_3 O_3 N_5$, which is termed as sialon.

Characteristics of Sialons :-

1. Sialons retain their hardness at higher temperature than does alumina.

2. They are tough and have higher strength.

3. They possess good mechanical properties.

4. They are relatively light-weight materials with low coefficient of thermal expansion.

Application of Sialons :-

1. Sialons are used for cutting tool material, dies for drawing wire and tubes, rock-cutting and coal-cutting equipment, nozzles and welding shields.

2. They are used for the manufactured of thermo couple sheaths, radiants heater tubes, impeller, small Crucible and other purpose involving temperature upto 1250°

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1) Define elasticity and plasticity [M-12]

Elasticity is the property of a material by virtue of which it is able to retain its original shape and size after the removal of the load.

Plasticity is the property of a material by virtue of which a permanent deformation takes place, whenever it is subjected to the action of external forces

2) Define ductility and Malleability [M-16, D-15]

Ductility is the property of a material by virtue of which it can be drawn into wires before rupture takes place.

Malleability is the property of a material by virtue of which it can withstand deformation under compression without rupture.

3) Define the term brittleness and hardness. [M-16, N-07]

Brittleness is the property of a material by virtue of which it can withstand deformation under compression without rupture

Hardness is the property of a material by virtue of which it is able to resist abrasion, indentation, machining and scratching.

4) What do you mean by toughness and stiffness [M-09, D-16]

Toughness is the property of a material by virtue of which it can absorb maximum energy before fractures takes place.

Stiffness is the property of a material by virtue of which it resist deformation.

5) what is the effect of the grain size on the mechanical properties of the material [M-14]

The material having smaller grains (ie) fine grained structure) have high yield strength, high tensile strength, and more hardness. Also fine grain results in better resistance to cracking and better surface finish.

The materials having larger grains (ie coarse grained structure), exhibit better workability, hardenability, forgeability and creep resistance. But coarse grains result in poor surface finish, less tough and have greater tendency to cause distortion

6) Define the terms Slip and twinning [D-09]

Slip may be defined as the Sliding of blocks of the crystal over another along definite crystallographic planes called slip planes

Twinning is the process in which the atoms in a part of a crystal subjected to stress, rearrange themselves so that one part of the crystal becomes a mirror image of the other part.

7) State the Schmid's law. [M-16]

The stress required at a given temperature to initiate slip in a pure and perfect single crystal, for a material is constant. This is known as Schmid's law.

8) What is meant by fracture. [M-11, D-13]

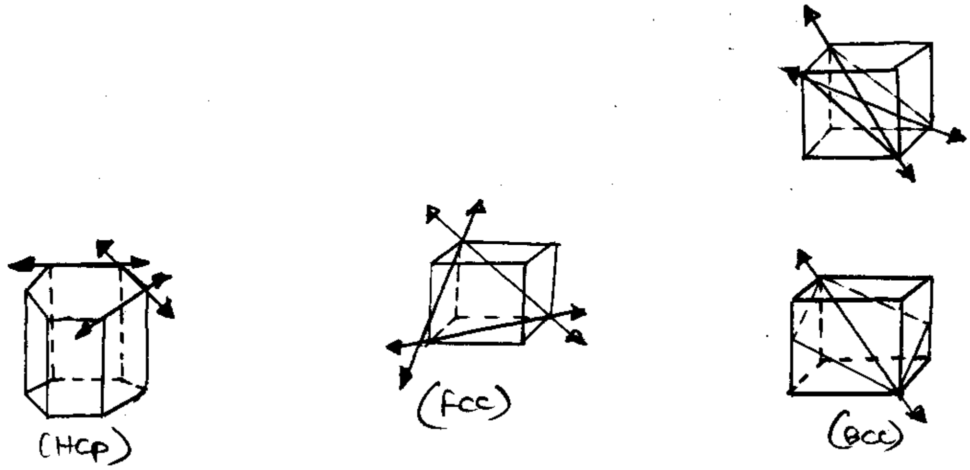
Fracture is the mechanical failure of the material which will produce the separation or fragmentation of a solid into two or more parts under the action of stresses.

9) Distinguish between brittle fracture and ductile fracture [D-14]

S.No	Brittle fracture	Ductile fracture
1.	It occurs with negligible plastic deformation	1. It occurs with large plastic deformation
2.	It occurs at the point where micro crack is more	2. It occurs in some localised region where the deformation is very large.
3.	The rate of crack popagation is rapid	3. The rate of crack popagation is slow
4.	Failure is due to the direct stress	4. Failure is due to the shear stress

10) what is S-N diagram? what is the significance of it? [M-16]

The S-N diagram is a graph obtained by plotting the number of cycles of stress reversals (N) required to cause fracture against the applied stress level (S). Using S-N diagram, the fatigue life of a material can be determined.



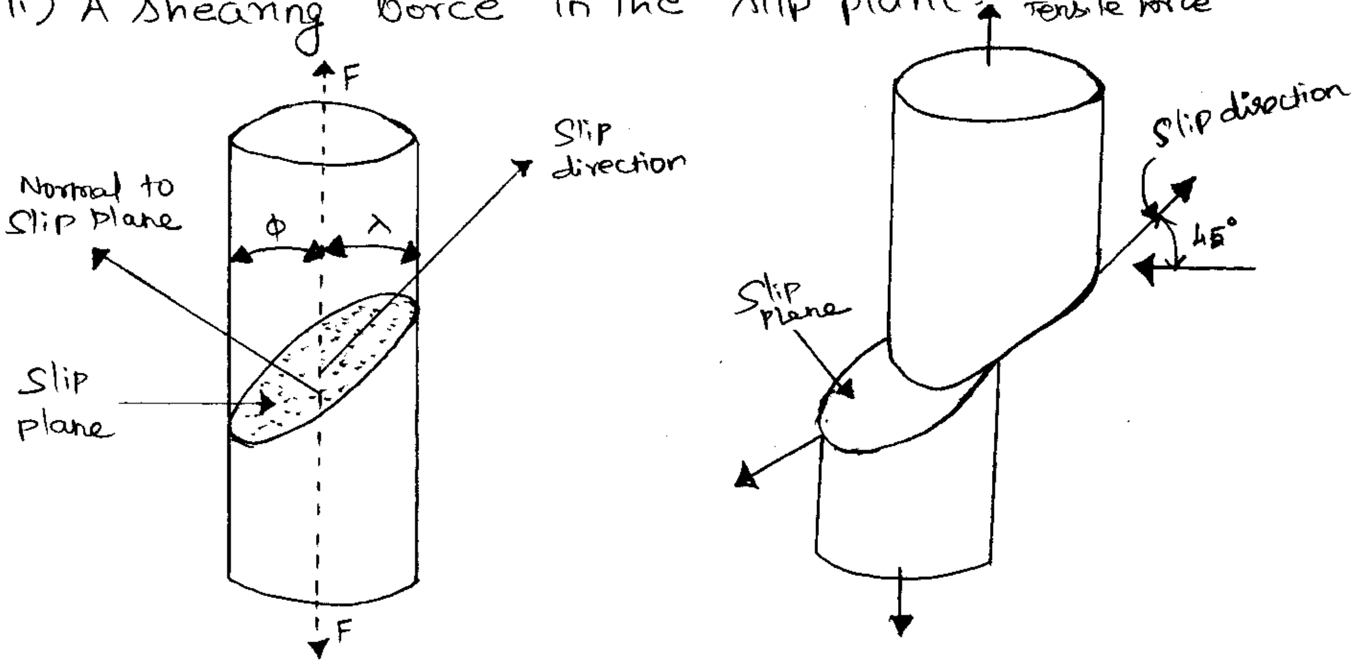
The mechanism of slip requires growth and movements of dislocation line and hence energy is required. The energy required to move a dislocation is proportional to Gb^2 where 'G' is the shear modulus of the material through which the dislocation moves and 'b' is the Burger's vector.

The shear stress required to produce slip on a crystal plane is called the critical shear stress denoted by τ_c.

Deformation of single crystals by slip:-

Normally we deal with polycrystalline metals but a much fundamental information on the nature of slip can be obtained by studying the behaviour of single, crystals of metals in stress. these single crystals (i.e, they are crystals without grain boundary) can be grown under carefully controlled laboratory conditions and they can be machined as test specimens

Consider a cylinder shaped single crystal subjected to a tensile force F. The load is acting in the direction of axis. The tensile force gets resolved in the following ways. i) A force normal to the slip plane ii) A shearing force in the slip plane.



From the Figure 5.3 it is clear that φ is the angle between the direction of force and normal to the slip plane. λ is the angle between direction of force and the slip direction.

Since the slip plane is inclined at an angle φ to the cross section of the crystal, its area is given by :

$$\text{Area of slip plane} = \frac{A}{\cos\phi}$$

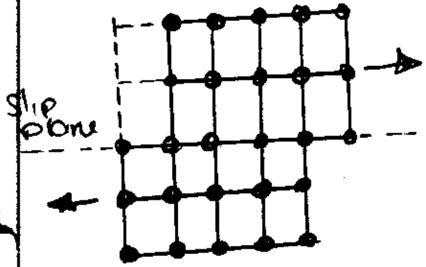
Where A - Cross sectional area of the Crystal

The component of the axial load acting in the slip plane and in the slip direction is $F\cos\lambda$.

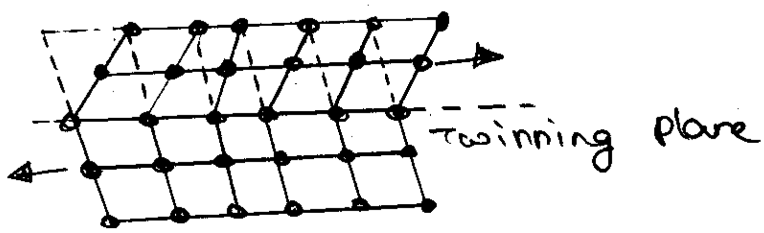
Twinning :

A second important plastic deformation mechanism which occurs in metals is called twinning, slip is caused due to a line defect, twinning is caused due to plane defect.

In slip deformation all the atoms in a block moves through the same ~~direction~~ distance when slipping. In deformation by twinning the atoms present in each successive plane in a block moves though different distances. The difference between deformation by slip and deformation by twinning will be clear from the figure.



(a) Deformation by slip



b) deformation by twinnig

After the completion of the twinning process the direction of the lattice will change such that one half of the twin is a mirror image of the other half as can be seen in the above figure.

The crystallographic plane of symmetry between the undeformed and deformed parts of the ~~material~~ lattice that form mirror images

Resolved shear stress $\tau_r = \frac{Force}{Area}$

$$\tau_r = \frac{F\cos\lambda}{A/\cos\phi} = F/A \cos\phi \cos\lambda$$

$$\tau_r = \sigma\cos\phi \cos\lambda$$

where, $\sigma = F/A$ = applied tensile stress

$\frac{\tau_r}{\sigma}$ is called the Schmid factor 'm' and is the ratio of the resolved shear stress to the axial stress.

The value of τ_r is maximum when both λ and ϕ are 45°, under these conditions:

$$\tau_r = \sigma\cos 45^\circ \cos 45^\circ$$

$$\tau_r = \sigma \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{2}} = \frac{\sigma}{2} = \frac{\text{axial force}}{2}$$

The resolved shear stress is always less than the this value for any other angles of λ and ϕ and tends to become zero as either λ ro ϕ approaches 90°. When the resolved shear stress is zero, slip will not occur for these orientations since there is no shear stress on the slip plane. Crystals that are close to these orientations tend to fail by fracture rather than slip.

Critical resolved shear stress is essentially the yield stress of a single crystal and is equivalent to the yield stress of a polycrystalline metal or alloy determined by the stress strain test curve.

is called twinning plane or composite plane.

Like slip, twinning occurs along certain crystallo-
-graphic planes and directions. These planes and
twin directions.

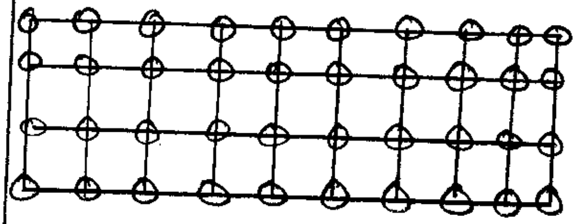
Mechanism of Twinning:-

In twinning process, the movement of atoms
is only a fraction of interatomic distance. The
dark circles, which indicate the arrangement
of atoms. The lines AB and CD represent
the planes of symmetry, from where the
twinning starts and ends respectively. These
planes are known as twinning planes.

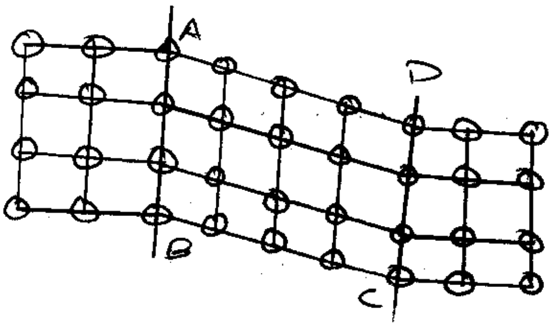
It has been observed that the crystal
twin about the twinning planes. And the atoms
in the regions to the left of the twinning
plane AB and right of the twinning plane CD
remain undisturbed.

Whereas in the twinned region, each
atom moves by a distance proportional to
its distance from the twinning plane AB.

The blank circles indicate the new position of the atoms.



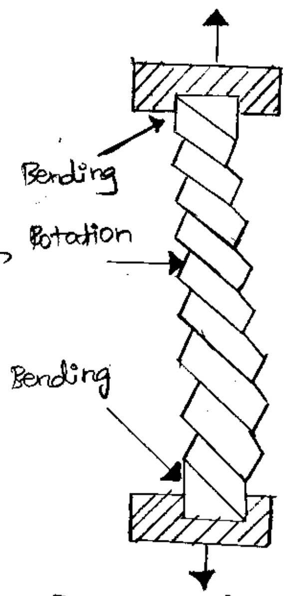
(a) Before twinning



(b) After twinning.

The twinning occurs due to the growth and movement of dislocations in the crystal lattice.

* It has been proved that in real Single (metal) crystals, Slip Starts under a Shear Stress, at Least two orders of magnitude lower than the values of 1.5 E (Modulus of Elasticity) calculated for a perfect crystal.



Representation of Slip in tension with Specimen ends Constrained.

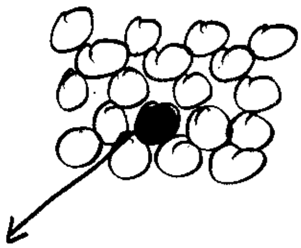
* The dislocation theory is the only one which explains from a single point of view the Slip Phenomenon and the various experimental Faces about Strength (referred above) and work hardening. The basic ideas are that local Slipping take place, Starting at points of high stress concentration and being helped by thermal Fluctuations of the atoms.

* The mechanism of slip involves a translatory motion along the sliding planes and rotation of the Specimen with respect to the axis of loading. Thus the angle between the axis of the tensile force and the slip planes changes during Stretching of the Specimen. The more Slip takes place, the more acute are the angles of slip planes.

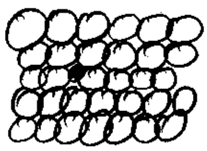
b) Interstitialcies

When a extra atom occupies the interstitial space within the crystal structure it is called interstitials.

An atom can enter the interstitial space or void only if it is smaller than the parent atom otherwise it will cause atomic distortion or strain because interstitial atom tends to push the surrounding atoms further apart. The interstitial atom may be either a normal atom from the same crystal called ~~self~~ self interstitial or an impure atom not present in the lattice site.



Interstitial atom



Interstitial by Foreign atom

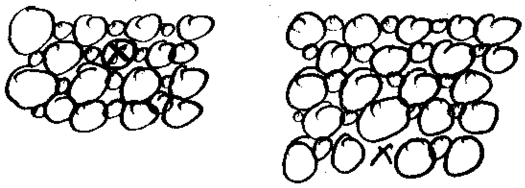
Imporities or composite defect:-

If a foreign atom occupies the position of the crystal atoms in the lattice structure it is called substitutional impority.

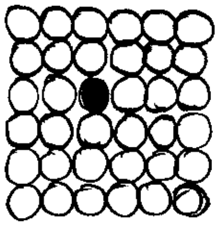
Schottky defect:-

In ionic crystals point defects are more complex due to need for maintaining electric neutrality. When two opposite charged ions are missing from an ionic crystal a cation -anion divacancy is created, this known as schokkty defect or schottky imperfection or ion pair vacconcies. Since a pair is missing electrical neutrality is maintained.

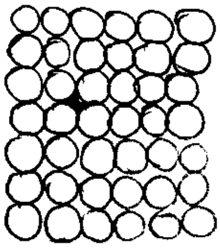
If a positive ion moves into an interstitial site in an ionic crystal a cation vacancy is created in the normal ion site, this vacancy -interstitial pair is called Frenkel defect. The schottky defects in ionic crystals causes an increases in electrical conductivity.



In order for substitution to take place the foreign atom should have within 15% of the parent atoms. If a foreign atom occupies the interstitial space present in the crystal lattice structure it is called as interstitial impurity.



Substitutional impurity.



Interstitial impurity

d) Electronic defects:-

They are caused as a result of errors in charge distribution in solids. These defects are free to move in the crystal under the influence of a electric field. This accounts for some electronic conductivity of certain solids and their increased reactivity. A vacancy or a interstitial impurity may produce an excess or a decrease of positive or negative charges.

The defect have the following effect on the propertie of the material

(i) Defect increase the hardness and tensile strength due to the distortion caused in the lattice

(ii) Increase in electrical conductivity

(iii) The presence of vacancies increase the kinetics of diffusion and phase transformation

4) (i) What do you mean by 'Engineering stress' and 'True stress'? Explain. [M-16, N-14, M-10]

Engineering stress: is the load at any elongation divided by the original cross-sectional area of gauge length.

True stress: is the load at any elongation divided by the cross-sectional area at that elongation.

(ii) Draw typical engineering stress versus engineering strain curves for ductile and brittle materials and explain.

Results of Tensile Test

(Calculation of Tensile properties)

The various tensile properties are calculated, with the help of stress-strain curve, using the following relations:

1. Elastic stress (or Elastic strength) (σ_e)

$$\sigma_e = \frac{\text{Elastic load}}{\text{original cross-sectional area}} = \frac{P_e}{A_o} \quad \ldots (1)$$

where $A_o = \left(\frac{\pi}{4}\right) D_o^2$, and

D_o = initial diameter of the given specimen.

2. Strain (ε)

$$\varepsilon = \frac{\text{change in length}}{\text{original length}} = \frac{L_f - L_o}{L_o} \quad \ldots (2)$$

where L_o and L_f represent the initial and final gauge lengths respectively.

3. Yield stress (or yield strength) (σ_s)

$$\sigma_s = \frac{\text{Yield load}}{\text{original cross-sectional area}} = \frac{P_s}{A_o} \quad \ldots (3)$$

4. ultimate stress (or ultimate tensile strength) (σ_u)

$$\sigma_u = \frac{\text{ultimate load}}{\text{original cross-sectional area}} = \frac{P_u}{A_o} \quad \ldots (4)$$

5. percentage elongation:

$$\%\ \text{elongation} = \frac{\text{final length} - \text{original length}}{\text{original length}} \times 100$$

$$= \frac{L_f - L_o}{L_o} \times 100 \quad \ldots (5)$$

6. percentage reduction in area:

$$\%\ \text{reduction in area} = \frac{\text{original area} - \text{final area}}{\text{original area}}$$

$$= \frac{A_o - A_f}{A_o} \times 100 \quad \ldots (6)$$

7. young's modulus of elasticity (E)

$$E = \frac{\text{stress at any point within elastic limit}}{\text{strain at that point}}$$

$$= \frac{\sigma_e}{\varepsilon} \quad \ldots (7)$$

8. Breaking /fracture stress (or Breaking strength) (σ_b)

$$\sigma_b = \frac{\text{Breaking load}}{\text{final cross-sectional area}} \quad \ldots (8)$$

9. Modulus of toughness:

$$\text{Modulus of toughness} = \left\{\begin{matrix}\text{ultimate} \\ \text{tensile} \\ \text{strength}\end{matrix}\right\} \times (\%\ \text{elongation}) \quad \ldots (9)$$

(ii) Differentiate between Ductile and brittle fracture.

Brittle fracture vs Ductile fracture.

The comparison between brittle and ductile fractures is presented in Table.

S.No	Brittle fracture	Ductile fracture
1.	It occurs with negligible plastic deformation.	It occurs with large plastic deformation.
2.	It occurs at the point where micro crack is more.	It occurs in some localised region where the deformation is very large.
3.	The rate of crack propagation is rapid.	The rate of crack propagation is slow.
4.	failure is due to the direct stress.	failure is due to the shear stress.
5.	It is characterised by seperation of normal to tensile stress.	It is characterised by the formation of cup and cone.
6.	fractured surface shows a sharp planar facet.	fractured surface is a rough dirty-grey contour.
7	The brittle fracture can be increased by decreasing temperature, increasing strain rate and work hardening.	The ductile fracture can be increased by dislocations and other defects in metals.