ELECTRICAL AND ELECTRONICS ENGINEERING LAB

LABORATORY MANUAL

B.TECH
(II YEAR – I SEM)

(2018-19)

Department of Mechanical Engineering

MALLA REDDY COLLEGE
OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

Recognized under 2(f) and 12 (B) of UGC ACT 1956
Affiliated to JNTUH, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2015 Certified)
Maisammaguda, Dhulapally (Post Via. Kompally), Secunderabad – 500100, Telangana State, India

ELECTRONICS & COMMUNICATION ENGINEERING

VISION

To evolve into a center of excellence in Engineering Technology through creative and innovative practices in teaching-learning, promoting academic achievement & research excellence to produce internationally accepted competitive and world class professionals.

MISSION

To provide high quality academic programmes, training activities, research facilities and opportunities supported by continuous industry institute interaction aimed at employability, entrepreneurship, leadership and research aptitude among students.

QUALITY POLICY

- **Impart up-to-date knowledge to the students in Electronics & Communication area to make them quality engineers.**
- **Make the students experience the applications on quality equipment and tools.**
- **Provide systems, resources and training opportunities to achieve continuous improvement.**
- **Maintain global standards in education, training and services.**

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1: PROFESSIONALISM & CITIZENSHIP
To create and sustain a community of learning in which students acquire knowledge and learn to apply it professionally with due consideration for ethical, ecological and economic issues.

PEO2: TECHNICAL ACCOMPLISHMENTS
To provide knowledge based services to satisfy the needs of society and the industry by providing hands on experience in various technologies in core field.

PEO3: INVENTION, INNOVATION AND CREATIVITY
To make the students to design, experiment, analyze, interpret in the core field with the help of other multi disciplinary concepts wherever applicable.

PEO4: PROFESSIONAL DEVELOPMENT
To educate the students to disseminate research findings with good soft skills and become a successful entrepreneur.

PEO5: HUMAN RESOURCE DEVELOPMENT
To graduate the students in building national capabilities in technology, education and research.

PROGRAMME SPECIFIC OBJECTIVES (PSOs)

PSO1
To develop a student community who acquire knowledge by ethical learning and fulfill the societal and industry needs in various technologies of core field.

PSO2
To nurture the students in designing, analyzing and interpreting required in research and development with exposure in multi disciplinary technologies in order to mould them as successful industry ready engineers/entrepreneurs

PSO3
To empower students with all round capabilities who will be useful in making nation strong in technology, education and research domains.

PROGRAM OUTCOMES (POs)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design / development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multi disciplinary environments.
12. **Life- long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Laboratory Rules

General Rules of Conduct in Laboratories:

1. You are expected to arrive on time and not depart before the end of a laboratory.
2. You must not enter a lab unless you have permission from a technician or lecturer.
3. You are expected to comply with instructions, written or oral, that the laboratory Instructor gives you during the laboratory session.
4. You should behave in an orderly fashion always in the lab.
5. You must not stand on the stools or benches in the laboratory.
6. Keep the workbench tidy and do not place coats and bags on the benches.
7. You must ensure that at the end of the laboratory session all equipment used is stored away where you found it.
8. You must put all rubbish such as paper outside in the corridor bins. Broken components should be returned to the lab technician for safe disposal.
9. You must not remove test equipment, test leads or power cables from any lab without permission.
10. Eating, smoking and drinking in the laboratories are forbidden.
11. The use of mobile phones during laboratory sessions is forbidden.
12. The use of email or messaging software for personal communications during laboratory sessions is forbidden.
13. Playing computer games in laboratories is forbidden.

Specific Safety Rules for Laboratories:

1. You must not damage or tamper with the equipment or leads.
2. You should inspect laboratory equipment for visible damage before using it. If there is a problem with a piece of equipment, report it to the technician or lecturer. DO NOT return equipment to a storage area
3. You should not work on circuits where the supply voltage exceeds 40 volts without very specific approval from your lab supervisor. If you need to work on such circuits, you should contact your supervisor for approval and instruction on how to do this safely before commencing the work.
4. Always use an appropriate stand for holding your soldering iron.
5. Turn off your soldering iron if it is unlikely to be used for more than 10 minutes.
6. Never leave a hot soldering iron unattended.
7. Never touch a soldering iron element or bit unless the iron has been disconnected from the mains and has had adequate time to cool down.
8. Never strip insulation from a wire with your teeth or a knife, always use an appropriate wire stripping tool.
9. Shield wire with your hands when cutting it with a pliers to prevent bits of wire flying about the bench.

LIST OF EXPERIMENTS

SECTION-A: ELECTRICAL ENGINEERING

INTRODUCTION TO ELECTRONIC DEVICES

SECTION-B: ELECTRONICS ENGINEERING

SECTION-A

1. MAGNETIZATION or OPEN CIRCUIT CHARACTERISTICS OF D.C SHUNT GENERATOR

AIM:

To obtain the no load characteristics of a DC shunt generator and to determine the critical field resistance.

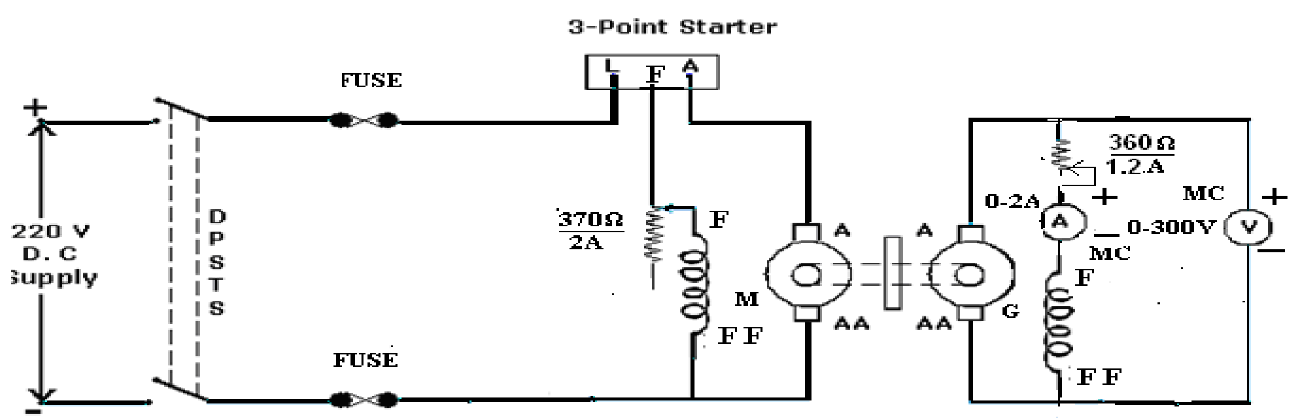
NAME PLATE DETAILS:

S.NO	Characteristics	D.C Motor	D.C Generator
1	Voltage	220V	220V
2	Current	13.6A	20A
3	Speed	1500rpm	1500rpm
4	Power	5HP	3KW

APPARATUS:

S.NO	Name Of The Equipment	Type	Range	Quantity
1	Voltmeters	MC	0-300V	2NO
2	Ammeters	MC	0-2A	1NO
3	Rheostats	WW	370 Ω /2A	2NO
4	Tachometers	Digital	0-10000rpm	1NO

CIRCUIT DIAGRAM:



THEORY:

Magnetization curve is relation between the magnetizing forces and the flux density B. this is also expressed as a relation between the field current and the induced e.m.f , in a D.C machine. Varying the field current and noting corresponding values of induced e.m.f can determine this.
For a self-excited machine the theoretical shape of the magnetization Curve is as shown in the figure. The induced e.m.f corresponding to residual magnetism exists when the field current is zero. Hence the curve starts, a little above the origin on y-axis. The field resistance line R_{sh} is a straight-line passing through the origin.
If field resistance is increased so much that the resistance line does not cut the OCC at all then obviously the machine will fail to exite .If the resistance line just lies along the slope, then machine will just excite. The value of the resistance represented by the tangent to the curve is known as critical field resistance Rc for a given speed.

CRITICAL FIELD RESISTANCE: it is the resistance of the field winding of the generator below which generator fail to build up the voltage.
First OCC is plotted from the the readings then tangent is drawn to its initial position .The slope of this curve gives the critical field resistance.

From the graph the critical field resistance Rc=AB/BC.

PROCEDURE:

1. Connect the circuit as per the circuit diagram shown in fig.
2. Keep the motor field rheostat Rsh at minimum position and generator field rheostat at maximum position.
3. Check that the belt on the pulley is free so that there is no load on the pulley.
4. Switch on the DPST swatch. Start the motor slowly by using starter.
5. Adjust the current so that the motor runs at its rated speed.
6. Now vary the generator field rheostat to increase the field current and take the no load voltage and field current readings.
7. Take the no load voltage values until field gets saturated.
8. Finally set the field rheostats to initial positions then switch off the supply.
9. Draw the graph between generated voltage and field current. Find the critical field resistance from the tangent line.

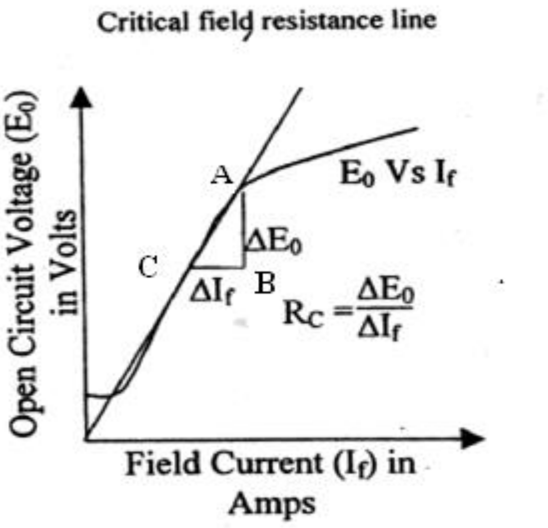
TABULAR COLUMN:

Residual Voltage = Speed=

SNO	I_f(A)	E_g(V)

MODEL GRAPH:

Draw the graph between generated voltage at no load and field current. By taking Generated voltage Eg in volts on Y axis and field current If in amps on X-axis.



PRECAUTIONS:

1) The rheostat is connected such that minimum resistance is included in field circuit of motor.
2) The rheostat is connected such that maximum resistance is included in field circuit of generator.
3) Starter handle is moved slowly.

RESULT:

EXERCISE QUESTIONS:

1. *The magnetization curve of a d.c. shunt generator running at 1000 r.p.m. is as follows :*

Field Amperes : (A)	0.25	0.5	1.0	1.5	2.0	2.5	3.0
E.M.F. Volts : (V)	36.0	72.0	138.0	188.0	225.0	250.0	270.0

Find (i) the value of field resistance to give 240 V on no load (ii) The speed at which the generator just fails to build up.

VIVA QUESTIONS:

1. What is meant by critical field resistance?
2. Residual magnetism is necessary for self excited generators or not.
3. Why this test is conducted at constant speed?

5. SPEED CONTROL OF DC SHUNT MOTOR

AIM:
To control the speed of a DC shunt motor using the following methods
i). field flux control
ii). Armature voltage control

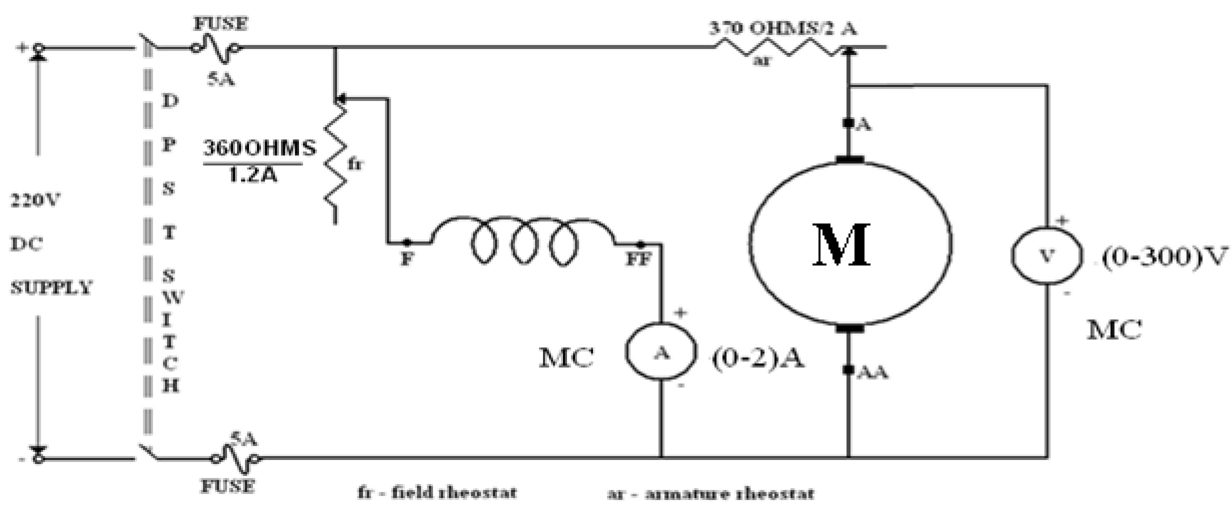
NAME PLATE DETAILS:

CHARECTERISTIC	RATING
Voltage	220V
Speed	1500rpm
current	1.2A

APPARATUS:

S.No	NAME OF THE EQUIPMENT	Type	Range	Qty
1	DC shunt motor	DC	220V	1
2	Rheostat	Wire wound	370Ω/2.5A	2
3	Ammeter	MC	(0-2)A	1
4	Voltmeter	MC	(0-220)V	1
5	Tachometer	Digital	(0-30000)rpm	1

CIRCUIT DIAGRAM:



THEORY:

The term speed control means intentional sped variation, carried out manually or automatically. DC motors are most suitable for wide range speed control and are therefore indispensible for many adjustable speed drives. The speed of a motor is given by

$W_m = (V_t - I_a R_a)/K_a \phi$

Where K_a – armature constant = $PZ/2\pi A$

And ϕ is the flux per pole.

Hence it follows that, for a DC motor, there are basically three methods of speed control and these are:

1. Variation of resistance in armature circuit
2. Variation of the field flux
3. Variation of armature terminal voltage.

Variation of the field flux:

This method of speed control, also called as flux weakening method or filed current control method gives speeds above the base speed only. Base speed is nothing but the rated speed of the machine. This is one of the simplest and economical methods and is, therefore extensively used in modern electric drives. Under steady state running conditions, if the field circuit resistance is increased, the field current and hence the field flux are reduced. Since the rotor speed cannot change suddenly due to inertia, a decrease in field current causes a reduction of counter emf. As a result of it, more current flows through armature. The percentage increase in armature current is much more than the percentage decrease in the field current. In view of this, the electromagnetic torque is increased and this being more than the load torque, the motor gets accelerated. The disadvantages of this method are:

a. The armature may get over heated at higher speeds, because the increased armature current results in more ohmic losses whereas cooling by ventilation does not improve proportionally.
b. If the field flux is weakened considerably, the speed becomes very highand due to these changes; the motor operation may become unstable.

Variation of armature terminal voltage:

If the voltage applied to the armature changes the speed changes directly with it. Using this method, speeds below rated speeds are attained.

PROCEDURE:

1. Make the connections as per the circuit diagram.
2. Keep the field rheostat in minimum position and armature in maximum position and close the DPST switch.
3. Bring the motor to rated speed using field rheostat.
4. At this point take a note of the voltmeter and tachometer readings.
5. Now start varying the armature rheostat in steps and for each step note down the voltmeter and tachometer readings. Take 10 to 15 such readings and bring back the armature rheostat to initial position.

6. Bring back the field rheostat to initial position. Using the armature rheostat set the motor at rated speed.
7. Vary the field rheostat in steps and for each step note down the ammeter and tachometer readings. Take 10 to 15 such readings.
8. Set both the rheostats to their initial positions and open the DPST switch.

TABULAR COLUMN:

Armature voltage control:

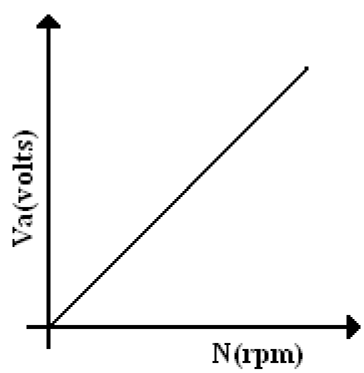
S.No	Va(Armature Voltage(volts))	N(Speed(rpm))

Field Flux Control:

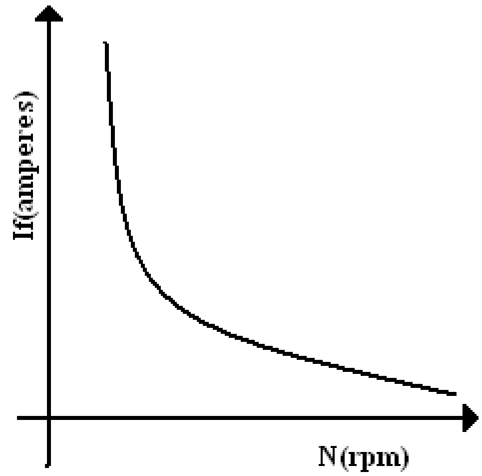
S.No	If(Field current(amperes))	N (Speed(rpm))

MODEL GRAPHS:

Armature Voltage Control:



Field Flux Control:



PRECAUTIONS:

1. We should start the motor under no load
2. Take the reading without parallax error.
3. The connections must be tight.

RESULT:

EXERCISE QUESTIONS:

1.A 500 V shunt motor runs at its normal speed of 250 r.p.m. when the armature current is 200 A. The resistance of armature is 0.12 ohm. Calculate the speed when a resistance is inserted in the field reducing the shunt field to 80% of normal value and the armature current is 100 ampere

VIVA QUESTIONS:

1. What are the three methods of speed control?
2. What is the main purpose of speed control?
3. Why is three point starters not used in this circuit?
4. What is the method opted to get speeds above rated speed?
5. How is flux per pole related to the speed of the machine?

3. SWINBURNE'S TEST ON D.C SHUNT MACHINE

AIM: To perform Swinburne's test on the given D.C machine and predetermine the efficiency at any desired load both as motor and as generator.

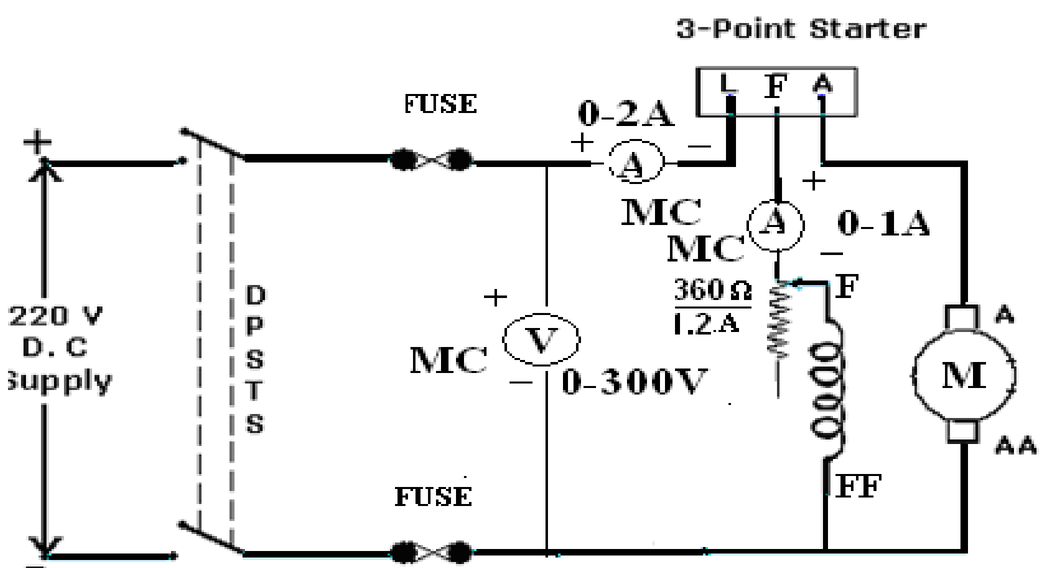
NAME PLATE DETAILS:

S.NO	Characteristic	D.C Motor
1	Voltage	220V
2	Current	20A
3	Speed	1500rpm
4	Power	5HP

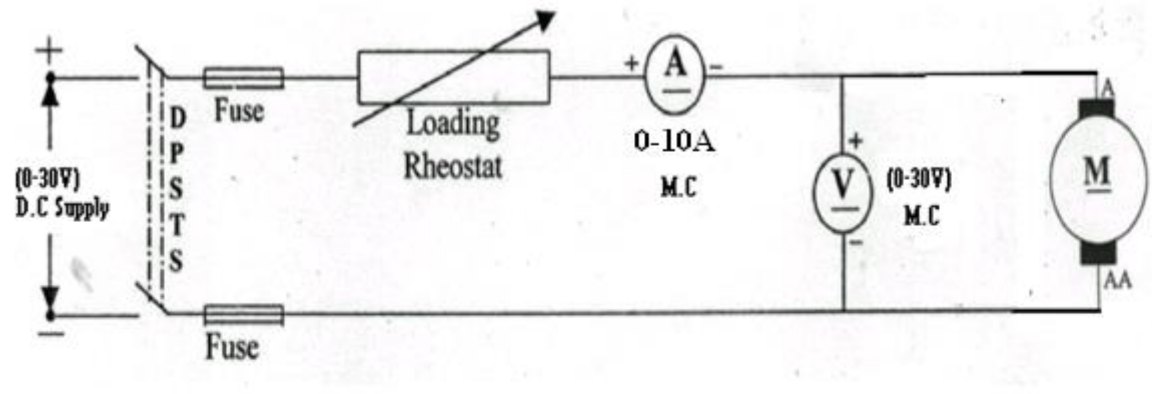
APPARATUS REQUIRED:

S.NO	Name Of The Equipment	Type	Range	Quantity
1	Ammeter	MC	0-2A,0-1A,0-10A	3NO
2	Voltmeter	MC	0-30V,0-300V	2NO
3	Rheostat	WW	370 Ω /2A	1NO
4	Tachometer	Digital	1000rpm	1NO

CIRCUIT DIAGRAM:



CIRCUIT DIAGRAM TO FIND ARMATURE RESISTANCE:



THEORY:

This test is to find out the efficiency of the machine .It is a simple indirect method in which losses are determined separately and from their knowledge, efficiency at any desired load can be predetermined. The only test needed is no-load test. This test cannot be performed on DC series motor. The machine is run as a no load shunt motor at rated speed and with a rated terminal voltage .However, this test is applicable to those machines in which flux is practically constant.

The constant losses in a dc shunt machine= Wc = stray losses (magnetic & mechanical losses) +shunt field copper losses.

$$W_c = \text{No load input} - \text{No load armature copper losses}$$

$$= VI_{L0} - I^2_{ao}R_a \text{ where } R_a \text{ is the armature resistance}$$

$$\text{And } I_{ao}=I_L-I_{sh}$$

PROCEDURE:

1) Make all the connections are as per the circuit diagram.
2) Keep the field rheostat in **minimum** resistance position.
3) Excite the motor with **220V, DC** supply by closing the **DPST** switch and start the Motor by moving the handle of 3-point starter from **OFF** to **ON** position.
4) By adjusting the rheostat in motor field bring the speed of the motor to its rated value. Note down the readings of Ammeter and Voltmeter at no load condition.
5) The necessary calculations to find efficiency of machine as motor & generator at any given value of armature current is done.

TO FIND ARMATURE RESISTANCE (Ra):

1) Connect the circuit per the circuit diagram
2) Keep the rheostat in maximum position.
3) Now excite the motor terminals by 30V supply by closing DPST switch.
4) Note down the readings of Ammeter and voltmeter.

MODEL CALCULATIONS:-

For motor:

$I_L = I_a + I_f$
No load losses = $W_o = VI_o - I^2_{ao}Ra$
Input = VI
Cu losses = $I_a^2 R_a$
Total losses =No load losses + cu losses
Output = Input-Total losses
%Efficiency (η) = (Output / Input)*100

For generator:

$I_a = I_L + I_f$
No load losses = $W_o = V I_o - I^2_{ao}Ra$
Output = VI
Cu losses = Ia^2 Ra
Total losses =No load losses + cu losses
Input =Output+ Total losses
%Efficiency (η) = (Output / Input)*100

TABULAR COLOUMN:

S.NO	Voltmeter reading V in Volts	Ammeter Reading I in Amps	Ammeter reading I_{sh}in Amps	Speed in RPM

ARMATURE RESISTANCE (Ra):

S.No	Voltage	Current

CALCULATION TABLE:

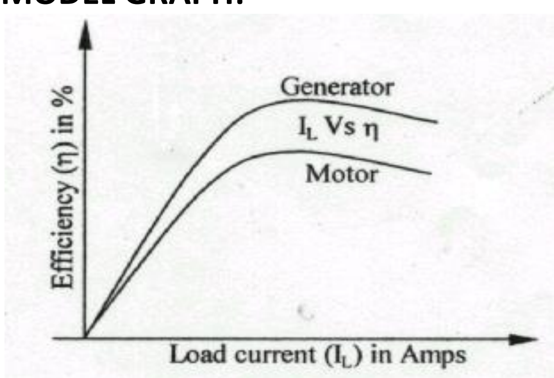
As a Motor:

S.NO	I_L (A)	$I_a=(I_L-I_{sh})$ in A	$W=I_a^2R_a$ in watts	Total losses	%Efficiency

As a Generator:

S.NO	I_L (A)	$I_a=(I_L+I_{sh})$ in A	$W=I_a^2R_a$ in watts	Total losses	%Efficiency

MODEL GRAPH:



PRECAUTIONS:

1. We should start the motor under no load
2. Take the reading without parallax error.
3. The connections must be tight.

RESULT:

EXERCISE QUESTIONS:

1. A 220v dc shunt motor at no load takes a current of 2.5A. The resistances of armature and shunt field are 0.8 Ω and 200Ω respectively. Estimate the efficiency of the motor when the input current is 20A. State precisely assumptions made

VIVA QUESTIONS:

1. Why the magnetic losses calculated by this method are less than the actual value?
2. Is it applied to D.C series machines?
3. Comment on the efficiency determined by this method.

4. BRAKE TEST ON D.C SHUNT MOTOR

AIM:
To conduct the brake test on a D.C shunt motor and to draw its performance curves.

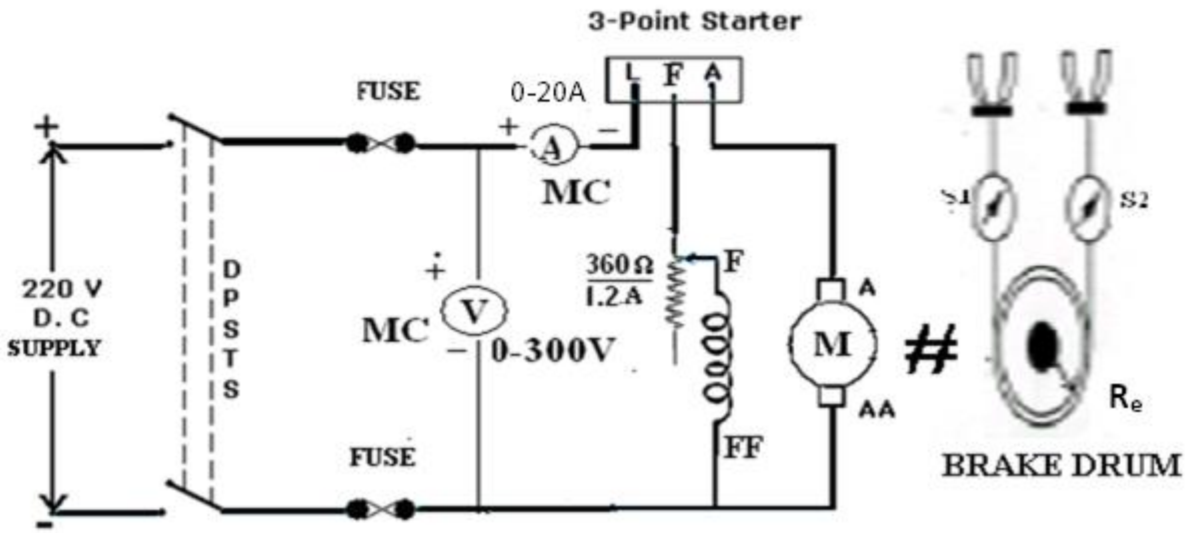
NAME PLATE DETAILS:

S.NO	Characteristic	D.C Motor
1	Voltage	220V
2	Current	20A
3	Speed	1500rpm
4	Power	5HP

APPARATUS REQUIRED:

S.NO	Description	Type	Range	Quantity
1	Ammeter	MC	0-20A	1NO
2	Voltmeter	MC	0-300V	1NO
3	Rheostat	WW	370 Ω /2A	1NO
4	Tachometer	Digital	0-10000rpm	1NO

CIRCUIT DIAGRAM:



THEORY:

This test is direct test to find the efficiency of the DC shunt motor. In this test the motor directly loaded by connecting brakes which are with pulley and motor is subjected to rated load and entire power is wasted. belt around the water cooled pulley has its ends attached to spring balances S1and S2.The belt tightening hand wheels h1 and h2 help in adjusting the load on the pulley so that the load on the motor can be varied.

Output power of the motor = (S1-S2)*Re*9.81*w (watts)
S1, S2 = weights on the pulley.
Re= Effective radius of the pulley.
w=motor speed in rad/sec.
If V is the terminal voltage IL is the line current
Power in put =V*I_L watts.
Efficiency (%η)=(w(S1-S2)*Re*9.81/V*I_L)*100

PROCEDURE:

1. All the connections are as per the circuit diagram.
2. **220V**, DC supply is given to the motor by closing **DPST** switch.
3. Move the 3-point starter handle form **'OFF'** to **'ON'** position slowly and motor starts running.
4. Vary the field rheostat until the motor reaches its rated Speed and take voltmeter and ammeter readings.
5. Apply the land by break drum pulley and for each applications of load the Corresponding Voltmeter (V), Ammeter (I), spring forces S1 & S2 and Speed (N) Readings are noted.
6. Calculate output & efficiency for each reading.
7. Note down all the readings in the tabular form carefully.
8. Remove the load slowly and keep the rheostat as starting position and switch **'OFF'** the supply by using **DPST** switch.

S. NO	Voltage (V)	Current (A)	Input =VI watts	Forces in KG	Net force F =	Torque(T) =F*Re*9.81	Speed in RPM	O/p= 2πNT/60 (Watts)	%Efficiency η=output/inp

				S_1	S_2	S1~S2 in kg	(N-M)	(N)		ut
1 2 3 4 5 6 7										

TABULAR COLUMN:

GRAPH:

The graph is drawn between

a) Output in Watts Vs Speed(N) in RPM

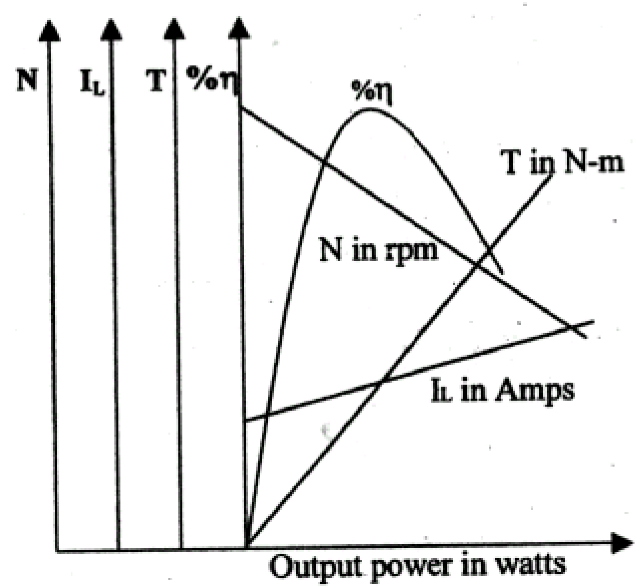
b) Output in Watts Vs Torque (T) in N-m

c) Output in Watts Vs Current (I) in A

d) Output in Watts Vs Efficiency (%η)

By taking output in Watts on X axis and speed, Torque, current, Efficiency onY- axis .

Electrical characteristics:



PRECAUTIONS:

1. Initially 3-point starter should be kept at ‘OFF’ position and later it must be varied slowly and uniformly from ‘OFF’ to ‘ON’ position.
2. The field regulator must be kept at its minimum output position.
3. The brake drum of the motor should filled with cold water.
4. The motor should be started without load.

RESULT:

EXERCISE QUESTIONS:

1. In a brake test the effective load on the branch pulley was 38.1kg, the effective diameter of the pulley 63.5cm and speed 12 r.p.s. the motor took 49A at 220V. Calculate the output power and the efficiency at this load

VIVA QUESTIONS:

1 .Why a 3-point starter is used for starting a D.C shunt motor?
2. If a 3-point starter is not available, how can a D.C motor be started?
3. Explain the function of overload release coil in 3-point starter

5. OC & SC TESTS ON 1 – PHASE TRANSFORMER

AIM:
To conduct Open circuit and Short circuit tests on 1-phase transformer to pre-determine the efficiency, regulation and equivalent parameters.

NAME PLATE DETAILS:

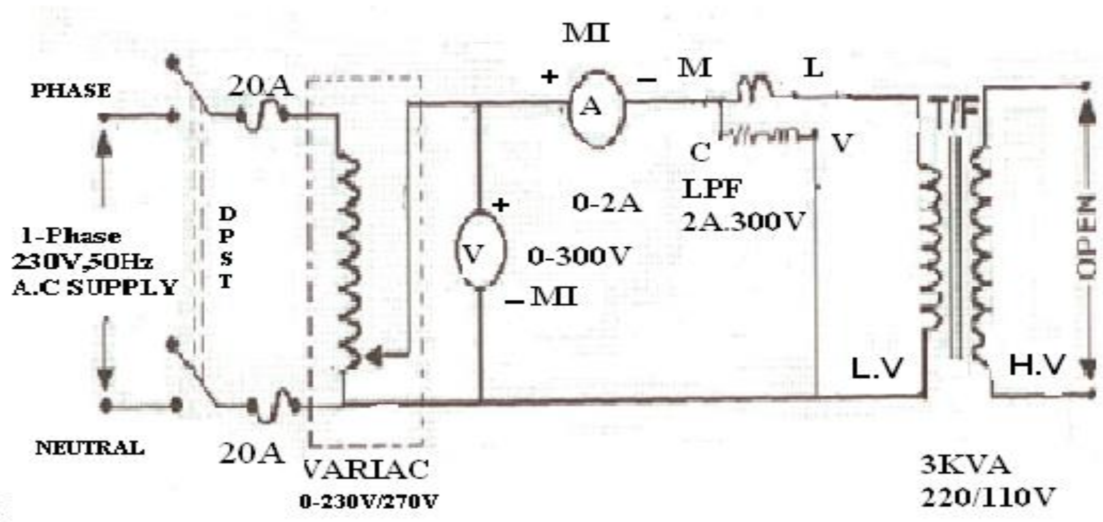
Voltage Ratio	220/110V
Full load Current	13.6A
KVA RATING	3KVA

APPARATUS:

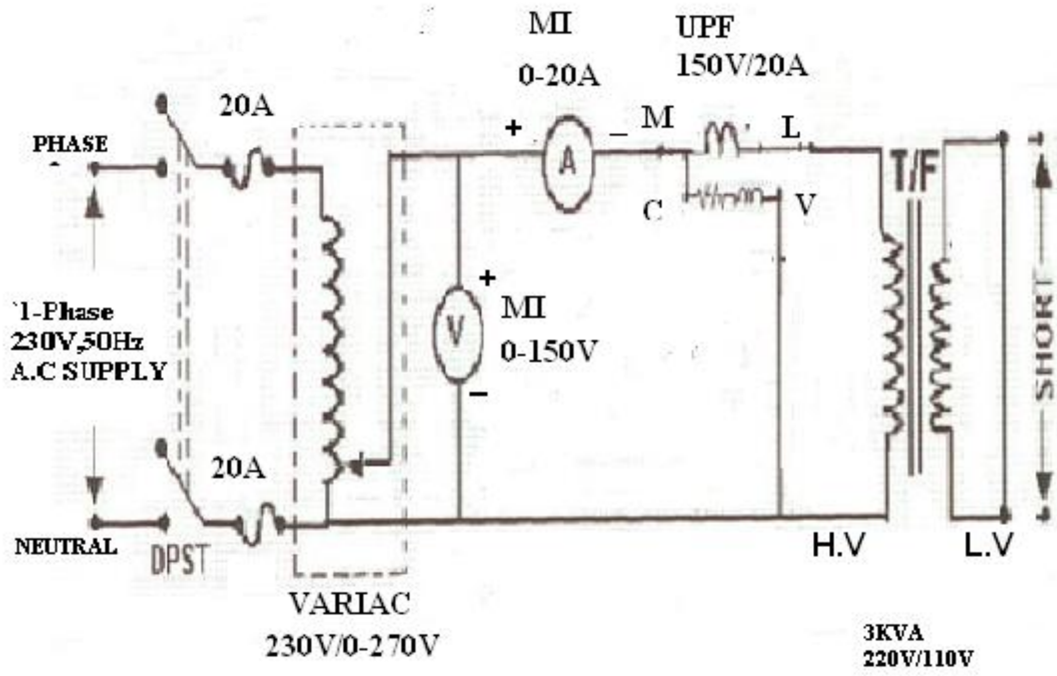
S.NO	Description	Type	Range	Quantity
1	Ammeter	MI	0-20A 0-5A	2NO
2	Voltmeter	MI	0-150V 0-300V	2NO
3	Wattmeter	LPF UPF	2A,!50V 20A,300V	2NO
4	Auto transformer	-	230/0-270V	1NO
5	Transformer	-	220V/110V	1NO

CIRCUIT DIAGRAM:

OPEN CIRCUIT TEST:



SHORT CIRCUIT TEST:



THEORY:

Transformer is a device which transforms the energy from one circuit to other circuit without change of frequency.

The performance of any transformer calculated by conducting tests .OC and SC tests are conducted on transformer to find the efficiency and regulation of the transformer at any desired power factor.

OC TEST:

The objectives of OC test are

1. To find out the constant losses or iron losses of the transformer.
2. To find out the no load equivalent parameters.

SC TEST:

The objectives of OC test are

1. To find out the variable losses or copper losses of the transformer.
2. To find out the short circuit equivalent parameters.

By calculating the losses and equivalent parameters from the above tests the efficiency and regulation can be calculated at any desired power factor.

PROCEDURE (OC TEST):

1. Connections are made as per the circuit diagram
2. Initially variac should be kept in its minimum position
3. Close the DPST switch.
4. By varying Auto transformer bring the voltage to rated voltage

5. When the voltage in the voltmeter is equal to the rated voltage of HV winding note down all the readings of the meters.
6. After taking all the readings bring the variac to its minimum position
7. Now switch off the supply by opening the DPST switch.

PROCEDURE (SC TEST):

1. Connections are made as per the circuit diagram.
2. Short the LV side and connect the meters on HV side.
3. Before taking the single phase, 230 V, 50 Hz supply the variac should be in minimum position.
4. Now close the DPST switch so that the supply is given to the transformer.
5. By varying the variac when the ammeter shows the rated current
(i.e. 13.6A) then note down all the readings.
6. Bring the variac to minimum position after taking the readings and switch off the supply.

O.C TEST OBSERVATIONS:

S.NO	V_0(VOLTS)	I_0(AMPS)	W_0(watts)

S.C TEST OBSERVATIONS:

S.NO	V_{SC}(VOLTS)	I_{SC}(AMPS)	W_{SC}(watts)

CALCULATIONS:

(a)Calculation of Equivalent circuit parameters:
Let the transformer be the step down transformer.

(i) Parameters calculation from OC test

$\cos\phi_0 = \frac{W_o}{V_o I_o} =$

$I_w = I_0 \cos\phi_0 =$

$R_0 = \frac{V_1}{I_w} =$

$I_\mu = I_0 \sin\phi_0 =$

$X_0 = \frac{V_1}{I_\mu} =$

$K = \frac{V_2}{V_1} =$

(ii) Parameters calculation from SC test

$R_{01} = \frac{W_{SC}}{I_{sc}^2} =$

$Z_{01} = \frac{V_{SC}}{I_{SC}} =$

$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} =$

b) Calculation to find Efficiency

$$\eta = \frac{n \times KVA \times \cos\phi}{n \times KVA \times \cos\phi + n^2 \text{ Cu. Loss} + \text{constant loss}}$$

Where 'n' represents % of full load.

(C)Calculation of Regulation at full load:

$$\% \ Regulation = \frac{I_1 R_{01} \cos\phi \pm I_1 X_{01} \sin\phi}{V_1} x\ 100 \equiv$$

'+' for lagging power factors

'_' for leading power factors

TABULAR COLUMN:

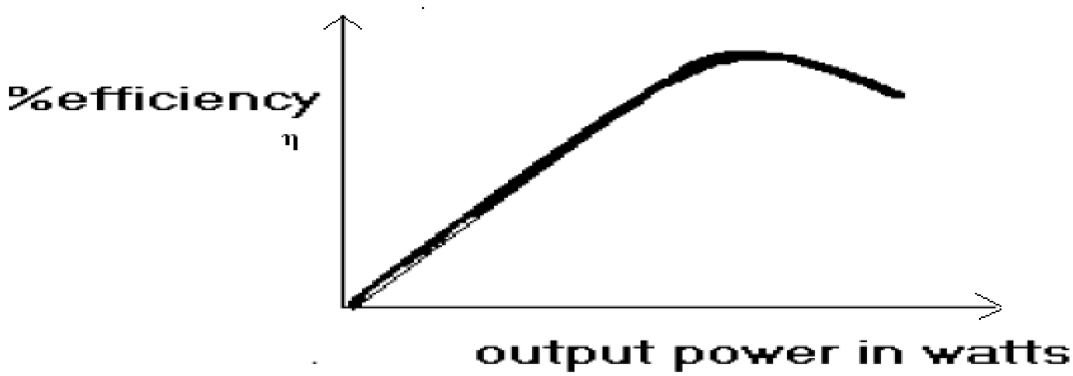
S.NO	% OF LOAD	EFFICIENCY
1	12.5	
2	25	
3	50	
4	75	
5	100	

TABULAR COLUMN:

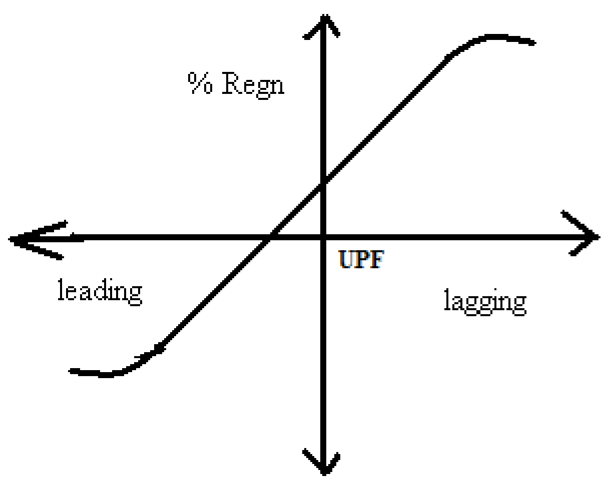
LAGGING POWER FACTOR			LEADING POWER FACTOR		
SNO	PF	%REG	SNO	PF	%REG
1	0.2		1	0.2	
2	0.3		2	0.3	
3	0.4		3	0.4	
4	0.5		4	0.5	
5	0.6		5	0.6	
6	0.7		6	0.7	
7	0.8		7	0.8	
8	0.9		8	0.9	
9	UNITY		9	UNITY	

MODEL GRAPHS:

1. EFFICIENCY V_S OUTPUT



2. REGULATION V_S POWER FACTOR



RESULT:

EXERCISE QUESTIONS:

1. The readings obtained from tests on 10 KVA, 450/120V, 50Hz transformer are
O.C. Test (LV Side): 120V, 4.2A, 80W
S.C. Test (HV Side): 9.65V, 22.2A, 120W
Determine the equivalent circuit constants.

VIVQUESTIONS:

1) What is a transformer?
2) Draw the equivalent circuit of transformer?
3) What is the efficiency and regulation of transformer?

6. BRAKE TEST ON 3 -PHASE INDUCTION MOTOR

AIM:
To perform Brake test on 3- phase induction motor to determine performance characteristics.

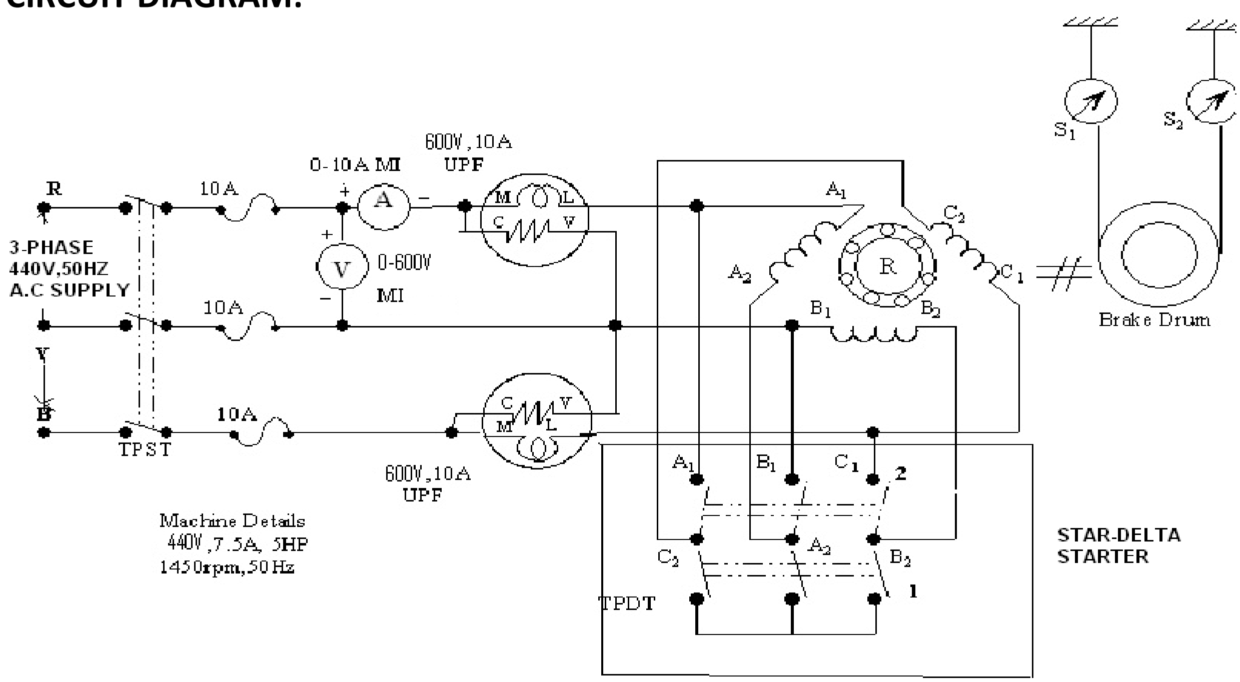
NAME PLATE DETAILS:

CHARECTERISTIC	RATING
Voltage	415V
Current	7.46A
Power	5HP
Speed	1500rpm
Frequency	50Hz

APPARATUS:

S.NO	NAME OF THE EQUIPMENT	Type	Range	Quantity
1	Ammeter	MI	0-20A	1
2	Voltmeter	MI	0-150V 0-300V	2
3	Wattmeter	LPF UPF	1/2A,!50V 5/10A,300V	2

CIRCUIT DIAGRAM:



THEORY:

It is the direct method to find the efficiency of the induction motor. In this test the breaking of the rotor is done with the help of the belt which surrounds the pulley by using spring balances. When the braking power is increased by tightening the springs then the line current is increased so the

Force on pulley (F) = (S1-S2)*9.81 (N)

Torque (T) =Force (F)* Re. N-m

Output power of the motor = (S1-S2)*Re*9.81*W (watts)

W=2πN/60.

S1, S2 = weights on the pulley.

Re= Effective radius of the pulley.

W=motor speed in rad/sec.

If V is the terminal voltage I_L is the line current and **cosΦ** is the power factor.

Power in put =$\sqrt{3}$V*I_L* **cosΦ** watts.

Efficiency (%η)=(w(S1-S2)*Re*9.81/$\sqrt{3}$V*I_L***cosΦ**)*100

%slip=(Ns –N)/Ns

Where Ns is the synchronous speed and N is the speed of the motor.

PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. Observing precautions close the TPST switch.
3. Apply he rated voltage to the stator windings of 3 Phase induction motor with the help of starter.
4. Note down the readings of all meters on no-load.
5. Load the induction motor in steps using the brake-drum arrangement. At each step note down the readings of all meters up to full load of the motor.
6. Gradually release the load and switch OFF the supply.
7. Using thread, measure the circumference of the brake-drum when motor is at rest.

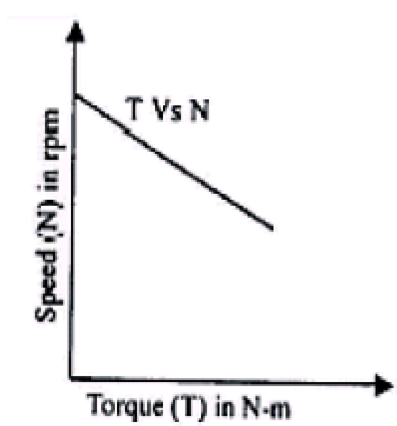
TABULAR COLUMN:

S. No.	Voltage V (volts)	Current I (Amps)	Wattmeter reading (W)		Speed N (rpm)	Spring balance reading		%Slip	Power factor	Torque N-m	Output Watts	% η
			W_1	W_2		S_1 Kg	S_2 Kg					

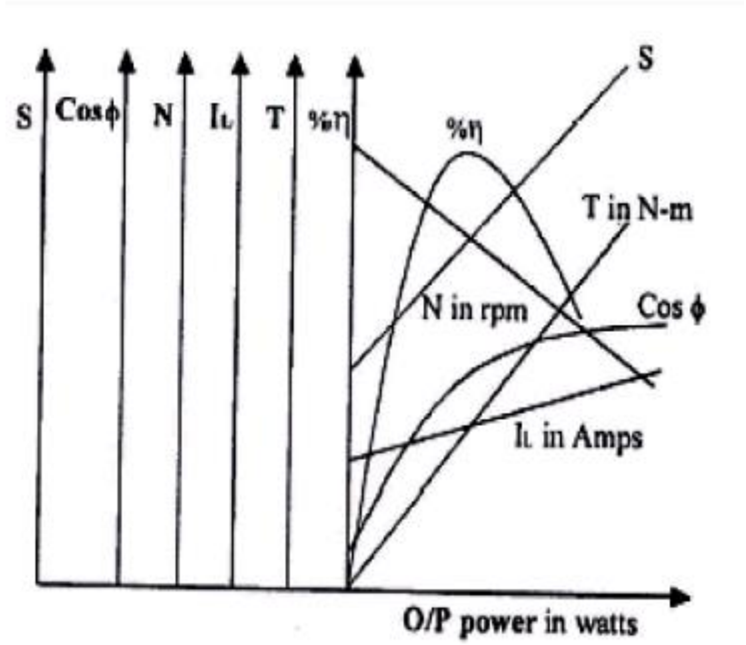
MODEL GRAPHS:

1. Output Vs Efficiency
2. Output Vs Torque
3. Slip Vs Torque

Mechanical Characteristics



Performance Characteristics



RESULT:

EXERCISE QUESTIONS:

1. A 6 pole 3ϕ induction motor develops 30hp including 2 hp mechanical losses at a speed of 950 r.p.m. on 550V, 50Hz Mains. The P.F. is 0.88 lagging.
Find:
1) Slip
2) Rotor Cu loss
3) Total input if stator losses are 2kw
4) η
5) Line current

VIVA QUESTIONS:

1) What is motor?
2) Why test is conducted on motor?
3) What is brake test and what is the disadvantage of brake test?

7. REGULATION OF ALTERNATOR BY SYNCHRONOUS IMPEDANCE METHOD

AIM: To predetermine the regulation of 3-phase alternator by using synchronous impedance method by conducting O.C and S.C tests.

NAME PLATE DETAILS:

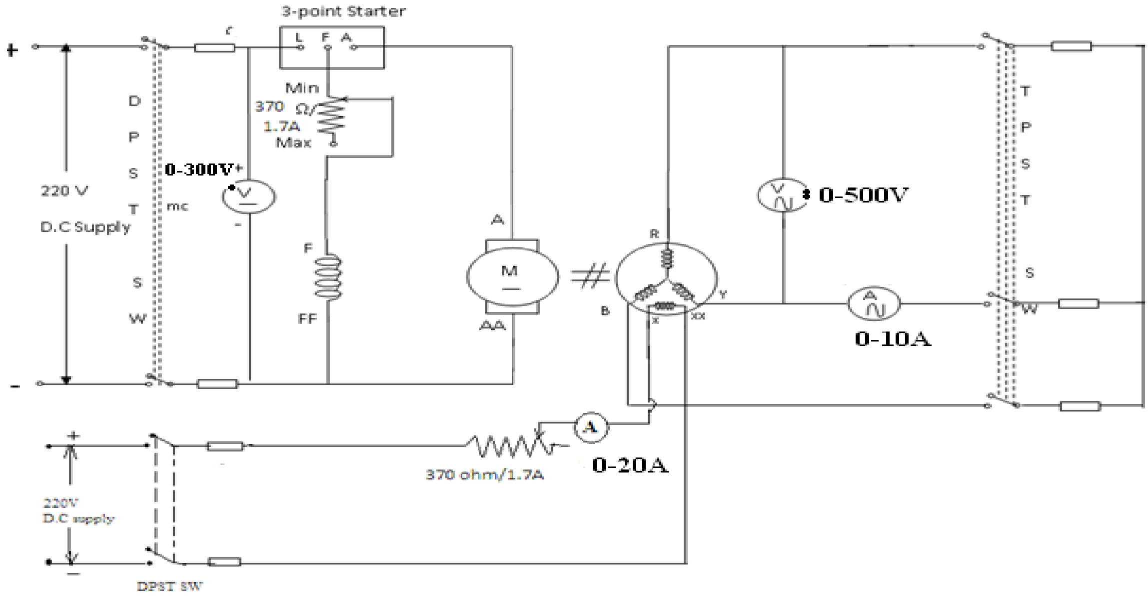
CHARACTERISTIC	DC MOTOR	ALTERNATOR
Voltage	220V	415V
Current	20A	7.2A
Power	5HP	3KVA
Speed	1500rpm	1500rpm
Frequency	-	50Hz

APPARATUS REQUIRED:

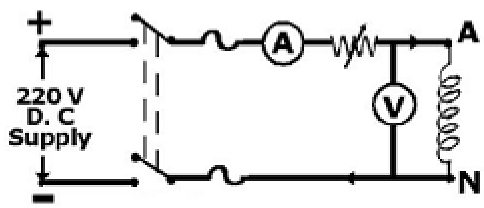
S.No	NAME OF THE EQUIPMENT	RANGE	TYPE	QUANTITY
1	Voltmeter AC	0-500V	MI	1
2	Ammeter AC	0-10A	MI	1
3	Voltmeter DC	0-300V	MC	1
4	Ammeter DC	0-20A	MC	2
5	RPM Meter	---	DIGITAL	1
6	Connecting wires	---	---	Required

CIRCUIT DIAGRAM;

OC &SC TEST:



TO FIND ARMATURE RESISTANCE:



Procedure:

1.OC test:

i)Connections are made as shown in the given circuit diagram for OC and SC test.
ii)With the rectifier in the zero voltage position TPST switch open and the rheostat in their proper position,the dc supply to the motor is switched ON.
iii)The dc motor is brought to rated speed of the alternator by properly varying the field rheostat by motor.
iv)Now the alternator field is exited by applying the dc voltage through the rectifier in steps.At each step,note down the field current and corresponding generated voltage.This procedure is repeated till the voltage generated is much beyond rated value
v)Reduce the alternator field excitation to zero level

2.SC test:

i)With the rectifier in the minimum voltage position the TPST switch is closed.
ii)Increase field excitation gradually till the SC current of the alternator reaches the rated current of alternator
iii)Notedown all the meter readings

b) Armature Resistance:

S.No.	I (A)	V (volts)	$R_{dc} = V/I\ \Omega$

Percentage regulation at ________ load at different power factors

Power factor (Cosϕ)	E_0 (V)		% Reg	
	Lagging	Leading	Lagging	Leading

RESULT:

EXERCISE QUESTIONS:

1. A 1200KV, 6600V, 3phase star connected alternator has its armature resistance as 0.25Ω per phase and its synchronous reactance as 5Ω per phase. Calculate its regulation if it delivers a full load at i) 0.8 lagging and ii) 0.8 leading power factor.

VIVA QUESTIONS:

1) What is alternator and what is regulation?

2) How we can determine the regulation by using synchronous impedance method?

INTRODUCTION TO ELECTRONIC DEVICES

1. BASIC ELECTRONIC COMPONENTS

1.1. COLOUR CODING OF RESISTOR:

Colour Codes are used to identify the value of resistor. The numbers to the Colour are identified in the following sequence which is remembered as **BBROY GREAT BRITAN VERY GOOD WIFE (BBROYGBVGW)** and their assignment is listed in following table.

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Grey	White
0	1	2	3	4	5	6	7	8	9

Table1: Colour codes of resistor

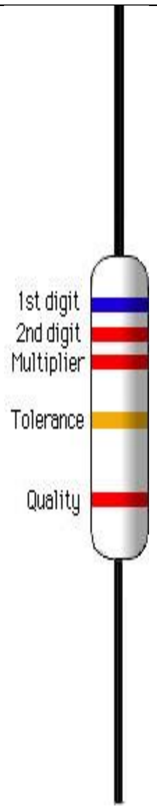
	First find the tolerance band, it will typically be gold (5%) and sometimes silver (10%).
	Starting from the other end, identify the first band - write down the number associated with that color
	Now read the next color, so write down a its vale next to the first value.
	Now read the third or 'multiplier exponent' band and write down that as the number of zeros.
	If the 'multiplier exponent' band is Gold move the decimal point one to the left. If the 'multiplier exponent' band is Silver move the decimal point two places to the left. If the resistor has one more band past the tolerance band it is a quality band.
	Read the number as the '% Failure rate per 1000 hour' This is rated assuming full wattage being applied to the resistors. (To get better failure rates, resistors are typically specified to have twice the needed wattage dissipation that the circuit produces). Some resistors use this band for temco information. 1% resistors have three bands to read digits to the left of the multiplier. They have a different temperature coefficient in order to provide the 1% tolerance. At 1% the temperature coefficient starts to become an important factor. at +/-200 ppm a change in temperature of 25 Deg C causes a value change of up to 1%

Table2: procedure to find the value of resistor using Colour codes

1.2. COLOUR CODING OF CAPACITORS

An electrical device capable of storing electrical energy. In general, a capacitor consists of two metal plates insulated from each other by a dielectric. The capacitance of a capacitor depends primarily upon its shape and size and upon the relative permittivity ε_r of the medium between the plates. In vacuum, in air, and in most gases, ε_r ranges from one to several hundred..

One classification of capacitors comes from the physical state of their dielectrics, which may be gas (or vacuum), liquid, solid, or a combination of these. Each of these classifications may be subdivided according to the specific dielectric used. Capacitors may be further classified by their ability to be used in alternating-current (ac) or direct-current (dc) circuits with various current levels.

- **Capacitor Identification Codes:** There are no international agreements in place to standardize capacitor identification. Most plastic film types (Figure1) have printed values and are normally in microfarads or if the symbol is n, Nanofarads. Working voltage is easily identified. Tolerances are upper case letters: M = 20%, K = 10%, J = 5%, H = 2.5% and F = ± 1pF.

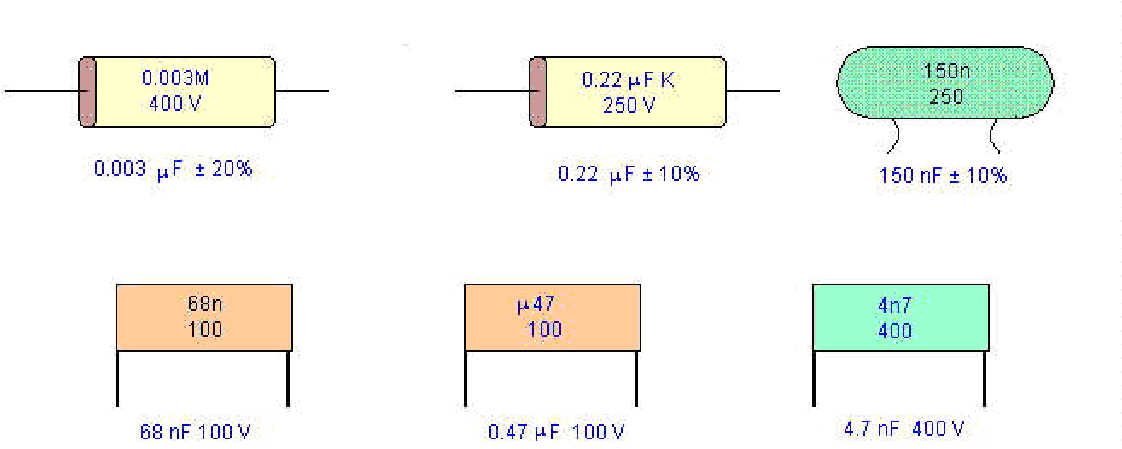


Figure 1: Plastic Film Types

A more difficult scheme is shown in Figure 2 where K is used for indicating Picofarads. The unit is picofarads and the third number is a multiplier. A capacitor coded 474K63 means 47 × 10000 pF which is equivalent to 470000 pF or 0.47 microfarads. K indicates 10% tolerance. 50, 63 and 100 are working volts.

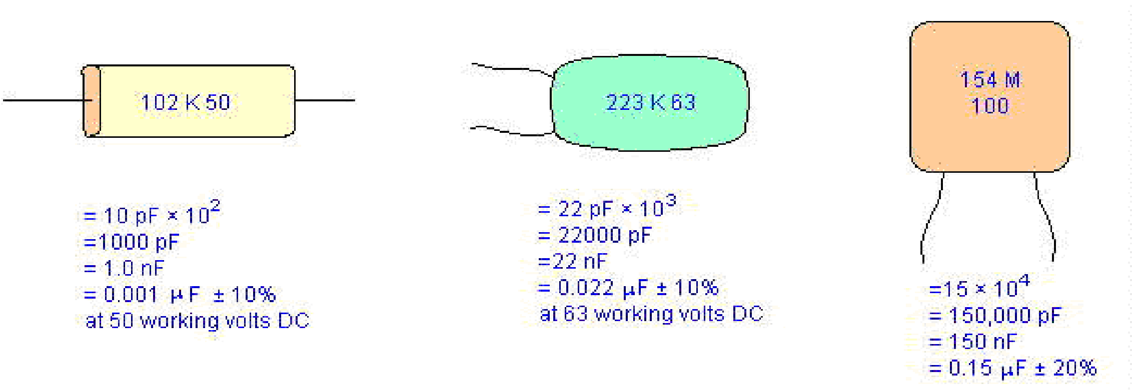


Figure 2: Pico farads Representation

Ceramic disk capacitors have many marking schemes. Capacitance, tolerance, working voltage and temperature coefficient may be found. which is as shown in figure 3. Capacitance values are given as number without any identification as to units. (uF, nF, pF) Whole numbers usually indicate pF and decimal numbers such as 0.1 or 0.47 are microfarads. Odd looking numbers such as 473 is the previously explained system and means 47 nF.

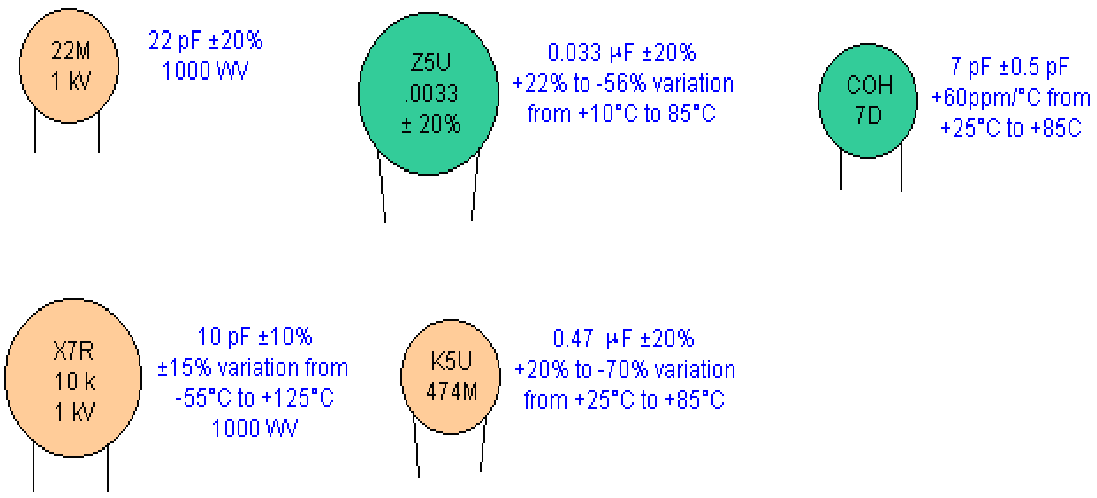


Figure3: ceramic Disk capacitor

Figure 4 shows some other miscellaneous schemes.

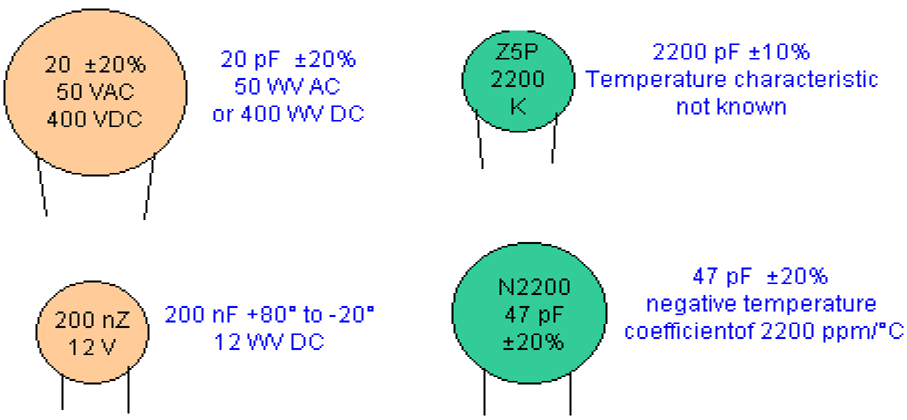


Figure 4: miscellaneous schemes.

➢ Electrolytic capacitor properties

There are a number of parameters of importance beyond the basic capacitance and capacitive reactance when using electrolytic capacitors. When designing circuits using electrolytic capacitors it is necessary to take these additional parameters into consideration for some designs, and to be aware of them when using electrolytic capacitors

- **ESR Equivalent series resistance:** Electrolytic capacitors are often used in circuits where current levels are relatively high. Also under some circumstances and current sourced from them needs to have low source impedance, for example when the capacitor is being used in a power supply circuit as a reservoir capacitor. Under these conditions it is necessary to consult the manufacturers' datasheets to discover whether the electrolytic capacitor chosen will meet the requirements for the circuit. If the ESR is high, then it will not be able to deliver the required amount of current in the circuit, without a voltage drop resulting from the ESR which will be seen as a source resistance.
- **Frequency response:** One of the problems with electrolytic capacitors is that they have a limited frequency response. It is found that their ESR rises with frequency and this generally limits their use to frequencies below about 100 kHz. This is particularly true for large capacitors, and even the smaller electrolytic capacitors should not be relied upon at high frequencies. To gain exact details it is necessary to consult the manufacturer's data for a given part.
- **Leakage:** Although electrolytic capacitors have much higher levels of capacitance for a given volume than most other capacitor technologies, they can also have a higher level of leakage. This is not a problem for most applications, such as when they are used in power supplies. However under some circumstances they are not suitable. For example they should not be used around the input circuitry of an operational amplifier. Here even a small amount of leakage can cause problems because of the high input impedance levels of the op-amp. It is also worth noting that the levels of leakage are considerably higher in the reverse direction.
- **Ripple current:** When using electrolytic capacitors in high current applications such as the reservoir capacitor of a power supply, it is necessary to consider the ripple current it is likely to experience. Capacitors have a maximum ripple current they can supply. Above this they can become too hot which will reduce their life. In extreme cases it can cause the capacitor to fail. Accordingly it is necessary to calculate the expected ripple current and check that it is within the manufacturer's maximum ratings.
- **Tolerance:** Electrolytic capacitors have a very wide tolerance. Typically this may be -50% + 100%. This is not normally a problem in applications such as decoupling or power supply smoothing, etc. However they should not be used in circuits where the exact value is of importance.
- **Polarization:** Unlike many other types of capacitor, electrolytic capacitors are polarized and must be connected within a circuit so that they only see a voltage across them in a particular way.

The physical appearance of electrolytic capacitor is as shown in Figure 5.The capacitors themselves are marked so that polarity can easily be seen. In addition to this it is common for the can of the capacitor to be connected to the negative terminal.

Figure 5: Electrolytic capacitor

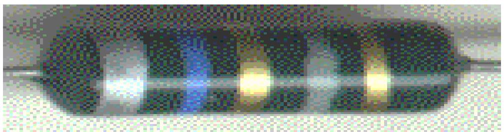
It is absolutely necessary to ensure that any electrolytic capacitors are connected within a circuit with the correct polarity. A reverse bias voltage will cause the centre oxide layer forming the dielectric to be destroyed as a result of electrochemical reduction. If this occurs a short circuit will appear and excessive current can cause the capacitor to become very hot. If this occurs the component may leak the electrolyte, but under some circumstances they can explode. As this is not uncommon, it is very wise to take precautions and ensure the capacitor is fitted correctly, especially in applications where high current capability exists.

1.3. COLOUR CODING OF INDUCTORS

Inductor is just coil wound which provides more reactance for high frequencies and low reactance for low frequencies.

Molded inductors follow the same scheme except the units are usually micro henries. A brown-black-red inductor is most likely a 1000 uH. Sometimes a silver or gold band is used as a decimal point. So a red-gold-violet inductor would be a 2.7 uH. Also expect to see a wide silver or gold band before the first value band and a thin tolerance band at the end. The typical Colour codes and their values are shown in Figure 6.

1000uH (1millihenry), 2%

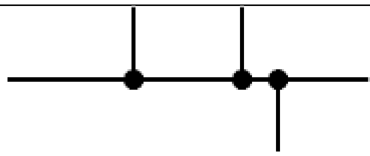
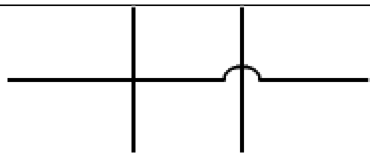


6.8 uH, 5%

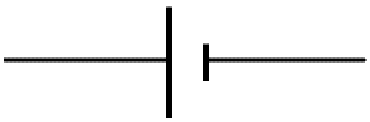
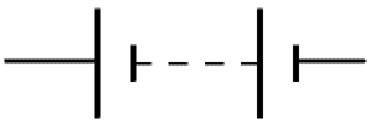
Figure 6: Typical inductors Colour coding and their values.

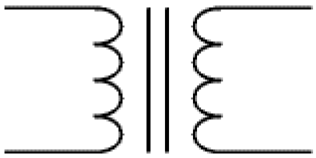
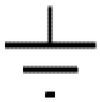
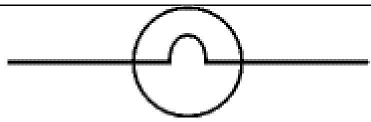
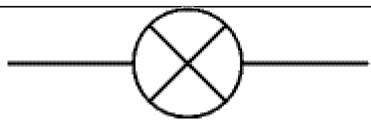
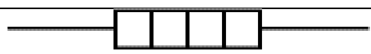
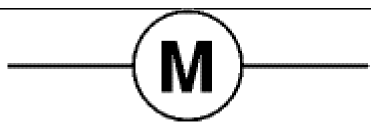
2. CIRCUIT SYMBOLS

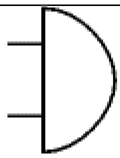
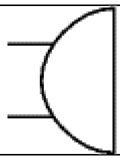
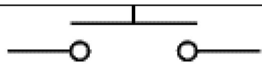
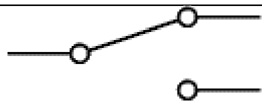
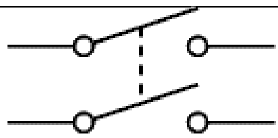
WIRES AND CONNECTIONS

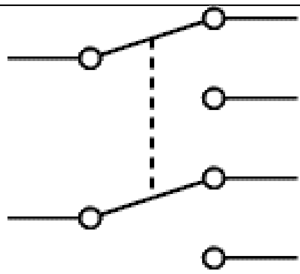
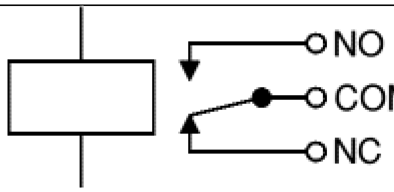
S.NO.	COMPONENT NAME	CIRCUIT SYMBOL	FUNCTION
1	WIRE		To pass current very easily from one part of a circuit to another.
2	WIRES JOINED		A 'blob' should be drawn where wires are connected (joined), but it is sometimes omitted. Wires connected at 'crossroads' should be staggered slightly to form two T-junctions, as shown on the right.
3	WIRES NOT JOINED		In complex diagrams it is often necessary to draw wires crossing even though they are not connected. I prefer the 'bridge' symbol shown on the right because the simple crossing on the left may be misread as a join where you have forgotten to add a 'blob'.

POWER SUPPLIES

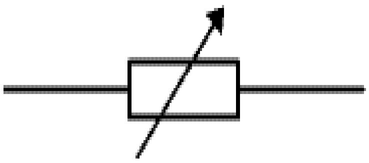
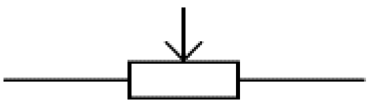
S.NO	COMPONENT NAME	CIRCUIT SYMBOL	FUNCTION
1.	CELL		Supplies electrical energy. The larger terminal (on the left) is positive (+). A single cell is often called a battery, but strictly a battery is two or more cells joined together
2.	BATTERY		Supplies electrical energy. A battery is more than one cell. The larger terminal (on the left) is positive (+).
3.	DC SUPPLY		Supplies electrical energy. DC = Direct Current, always flowing in one direction.

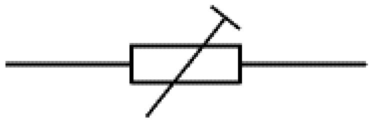
4.	AC SUPPLY		Supplies electrical energy. AC = Alternating Current, continually changing direction.
5.	FUSE		A safety device which will 'blow' (melt) if the current flowing through it exceeds a specified value.
6.	TRANSFORMER		Two coils of wire linked by an iron core. Transformers are used to step up (increase) and step down (decrease) AC voltages. Energy is transferred between the coils by the magnetic field in the core. There is no electrical connection between the coils.
7.	EARTH(GROUND)		A connection to earth. For many electronic circuits this is the 0V (zero volts) of the power supply, but for mains electricity and some radio circuits it really means the earth. It is also known as ground.
Output Devices: Lamps, Heater, Motor, etc.			
S.NO	**COMPONENT NAME**	**CIRCUIT SYMBOL**	**FUNCTION**
1.	LAMP(LIGHTING)		A transducer which converts electrical energy to light. This symbol is used for a lamp providing illumination, for example a car headlamp or torch bulb
2.	LAMP(INDICATOR)		A transducer which converts electrical energy to light. This symbol is used for a lamp which is an indicator, for example a warning light on a car dashboard.
3.	HEATER		A transducer which converts electrical energy to heat.
4.	MOTOR		A transducer which converts electrical energy to kinetic energy (motion).

5.	BELL		A transducer which converts electrical energy to sound.
6.	BUZZER		A transducer which converts electrical energy to sound.
7.	INDUCTOR(SOLINOID, COIL)		A coil of wire which creates a magnetic field when current passes through it. It may have an iron core inside the coil. It can be used as a transducer converting electrical energy to mechanical energy by pulling on something.
		Switches	
S.NO	**COMPONENT NAME**	**CIRCUIT SYMBOL**	**FUNCTION**
1.	PUSH SWITCH(PUSH TO MAKE)		A push switch allows current to flow only when the button is pressed. This is the switch used to operate a doorbell.
2.	PUSH TO BREAK SWITCH		This type of push switch is normally closed (on), it is open (off) only when the button is pressed.
3.	ON/OFF SWITCH(SPST)		SPST = Single Pole, Single Throw. An on-off switch allows current to flow only when it is in the closed (on) position.
4.	2 WAY SWITCH(SPDT)		SPDT = Single Pole, Double Throw. A 2-way changeover switch directs the flow of current to one of two routes according to its position. Some SPDT switches have a central off position and are described as 'on-off-on'.
5.	DUAL ON-OFF SWITCH(DPST)		DPST = Double Pole, Single Throw. A dual on-off switch which is often used to switch mains electricity because it can

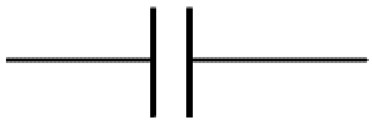
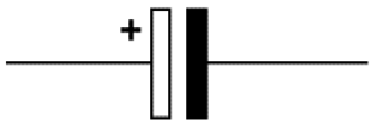
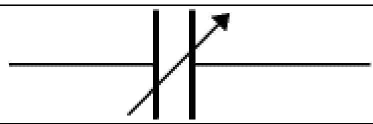
			isolate both the live and neutral connections.
6.	REVERSING SWITCH(DPDT)		DPDT = Double Pole, Double Throw. This switch can be wired up as a reversing switch for a motor. Some DPDT switches have a central off position.
7.	RELAY		An electrically operated switch, for example a 9V battery circuit connected to the coil can switch a 230V AC mains circuit. NO = Normally Open, COM = Common, NC = Normally Closed.

RESISTORS

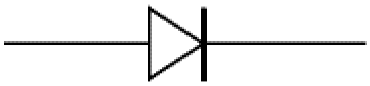
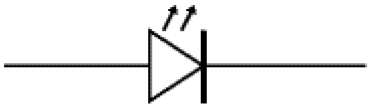
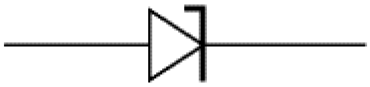
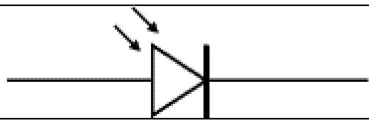
S.NO	COMPONENT NAME	CIRCUIT SYMBOL	FUNCTION
1.	RESISTOR	 **Or** 	A resistor restricts the flow of current, for example to limit the current passing through an LED. A resistor is used with a capacitor in a timing circuit.
2.	VARIABLE RESISTOR(RHEOSTAT)		This type of variable resistor with 2 contacts (a rheostat) is usually used to control current. Examples include: adjusting lamp brightness, adjusting motor speed, and adjusting the rate of flow of charge into a capacitor in a timing circuit.
3.	VARIABLE RESISTOR(POTENTIOMETER)		This type of variable resistor with 3 contacts (a potentiometer) is usually used to control voltage. It can be used like this as a transducer converting position (angle of the control spindle) to an electrical signal

4.	VARIABLE RESISTER(PRESET)		This type of variable resistor (a preset) is operated with a small screwdriver or similar tool. It is designed to be set when the circuit is made and then left without further adjustment. Presets are cheaper than normal variable resistors so they are often used in projects to reduce the cost

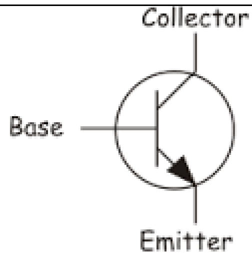
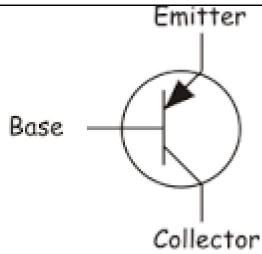
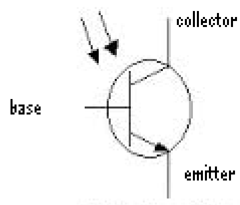
CAPACITORS

S.NO	NAME OF THE COMPONENT	CIRCUIT SYMBOL	FUNCTION OF THE COMPONENT
1.	CAPACITOR		A capacitor stores electric charge. A capacitor is used with a resistor in a timing circuit. It can also be used as a filter, to block DC signals but pass AC signals.
2.	CAPACITOR POLARISED		A capacitor stores electric charge. This type must be connected the correct way round. A capacitor is used with a resistor in a timing circuit. It can also be used as a filter, to block DC signals but pass AC signals.
3.	VARIABLE CAPACITOR		A variable capacitor is used in a radio tuner.
3.	TRIMMER CAPACITOR		This type of variable capacitor (a trimmer) is operated with a small screwdriver or similar tool. It is designed to be set when the circuit is made and then left without further adjustment

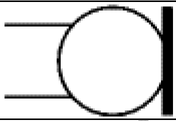
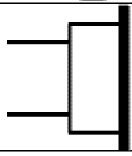
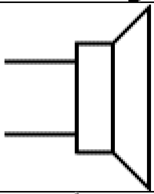
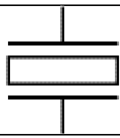
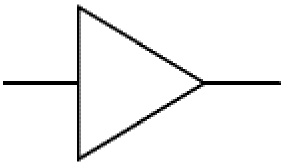
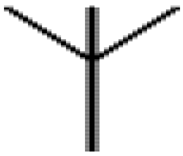
DIODES

S.NO	NAME OF THE COMPONENT	CIRCUIT SYMBOL	FUNCTION OF THE COMPONENT
1.	DIODE		A device which only allows current to flow in one direction
2.	LED(LIGHT EMITTING DIODE)		A transducer which converts electrical energy to light.
3.	ZENER DIODE		A special diode which is used to maintain a fixed voltage across its terminals
4.	Photodiode		A light-sensitive diode.

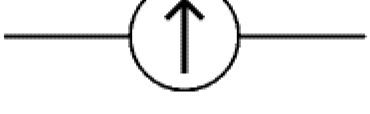
TRANSISTORS

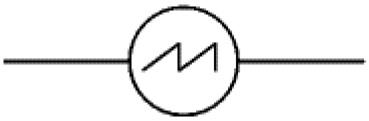
S.NO	NAME OF THE COMPONENT	CIRCUIT SYMBOL	FUNCTION OF THE COMPONENT
5.	TRANSISTOR NPN		A transistor amplifies current. It can be used with other components to make an amplifier or switching circuit.
6.	TRANSISTOR PNP		A transistor amplifies current. It can be used with other components to make an amplifier or switching circuit.
7.	PHOTO TRANSISTOR		A light-sensitive transistor.

AUDIO AND RADIO DEVICES

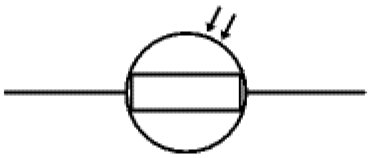
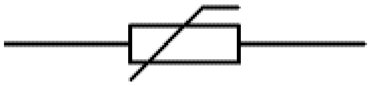
S.NO	NAME OF THE COMPONENT	CIRCUIT SYMBOL	FUNCTION OF THE COMPONENT
1.	MICROPHONE		A transducer which converts sound to electrical energy.
2.	EARPHONE		A transducer which converts electrical energy to sound.
3.	LOUD SPEAKER		A transducer which converts electrical energy to sound.
4.	PIEZO TRANSDUCER		A transducer which converts electrical energy to sound.
5.	AMPLIFIER(GENERAL SYMBOL)		An amplifier circuit with one input. Really it is a block diagram symbol because it represents a circuit rather than just one component.
6.	ARIEL (ANTENNA)		A device which is designed to receive or transmit radio signals. It is also known as an antenna

Meters and Oscilloscope

S.NO	NAME OF THE COMPONENT	CIRCUIT SYMBOL	FUNCTION OF THE COMPONENT
1.	VOLTMETER		A voltmeter is used to measure voltage. The Proper name for voltage is 'potential difference', but most people prefer to say voltage.
2.	AMMETTER		An ammeter is used to measure current
3.	GALVANOMETER		A galvanometer is a very sensitive meter which is used to measure tiny currents, usually 1mA or

			less
4.	OHEMMETER		An ohmmeter is used to measure resistance. Most multimeters have an ohmmeter setting.
5.	OSCILLOSCOPE		An oscilloscope is used to display the shape of electrical signals and it can be used to measure their voltage and time period.

Sensors (input devices)

S.NO	NAME OF THE COMPONENT	CIRCUIT SYMBOL	FUNCTION OF THE COMPONENT
1.	LDR		A transducer which converts brightness (light) to resistance (an electrical property). LDR = Light Dependent Resistor
2.	THERMISTOR		A transducer which converts temperature (heat) to resistance (an electrical property).

3. STUDY OF CRO

An oscilloscope is a test instrument which allows us to look at the 'shape' of electrical signals by displaying a graph of voltage against time on its screen. It is like a voltmeter with the valuable extra function of showing how the voltage varies with time. A graticule with a 1cm grid enables us to take measurements of voltage and time from the screen.

The graph, usually called the trace, is drawn by a beam of electrons striking the phosphor coating of the screen making it emit light, usually green or blue. This is similar to the way a television picture is produced.

Oscilloscopes contain a vacuum tube with a cathode (negative electrode) at one end to emit electrons and an anode (positive electrode) to accelerate them so they move rapidly down the tube to the screen. This arrangement is called an electron gun. The tube also contains electrodes to deflect the electron beam up/down and left/right.

The electrons are called cathode rays because they are emitted by the cathode and this gives the oscilloscope its full name of cathode ray oscilloscope or CRO.

A dual trace oscilloscope can display two traces on the screen, allowing us to easily compare the input and output of an amplifier for example. It is well worth paying the modest extra cost to have this facility.

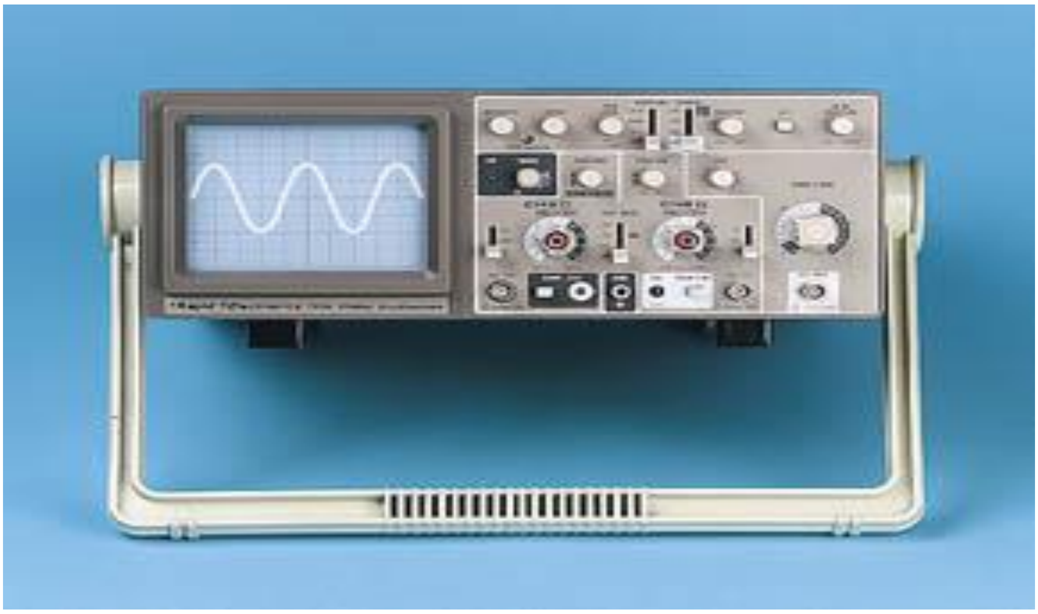


Figure1: Front Panel of CRO

- **BASIC OPERATION:**

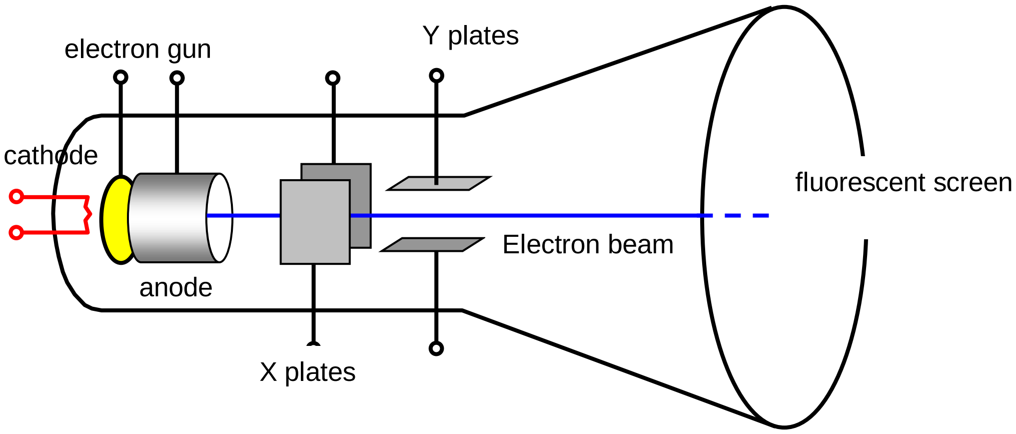


Figure2: Internal Blocks of CRO

Setting up an oscilloscope:

Oscilloscopes are complex instruments with many controls and they require some care to set up and use successfully. It is quite easy to 'lose' the trace off the screen if controls are set wrongly.

There is some variation in the arrangement and labeling of the many controls so the following instructions may need to be adapted for this instrument.

1. Switch on the oscilloscope to warm up (it takes a minute or two).
2. Do not connect the input lead at this stage.
3. Set the AC/GND/DC switch (by the Y INPUT) to DC.
4. Set the SWP/X-Y switch to SWP (sweep).
5. Set Trigger Level to AUTO.
6. Set Trigger Source to INT (internal, the y input).
7. Set the Y AMPLIFIER to 5V/cm (a moderate value).
8. Set the TIMEBASE to 10ms/cm (a moderate speed).
9. Turn the time base VARIABLE control to 1 or CAL.
10. Adjust Y SHIFT (up/down) and X SHIFT (left/right) to give a trace across the middle of the screen, like the picture.
11. Adjust INTENSITY (brightness) and FOCUS to give a bright, sharp trace.

The following type of trace is observed on CRO after setting up, when there is no input signal connected.

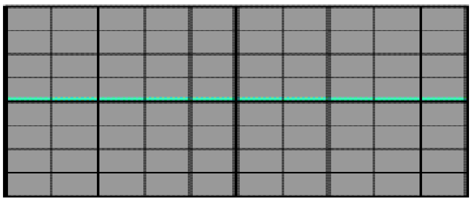


Figure 3: Absence of input signal

Connecting an oscilloscope:

The Y INPUT lead to an oscilloscope should be a co-axial lead and the figure 4 shows its construction. The central wire carries the signal and the screen is connected to earth (0V) to shield the signal from electrical interference (usually called noise).

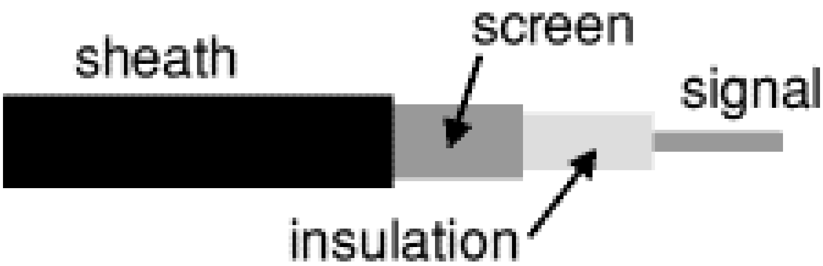


Figure4: Construction of a co-axial lead

Most oscilloscopes have a BNC socket for the y input and the lead is connected with a push and twist action, to disconnect we need to twist and pull. Professionals use a specially designed lead and probes kit for best results with high frequency signals and when testing high resistance circuits, but this is not essential for simpler work at audio frequencies (up to 20 kHz).

Figure 5: Oscilloscope lead and probes kit

Obtaining a clear and stable trace:

Once if we connect the oscilloscope to the circuit, it is necessary to adjust the controls to obtain a clear and stable trace on the screen in order to test it.

- The Y AMPLIFIER (VOLTS/CM) control determines the height of the trace. Choose a setting so the trace occupies at least half the screen height, but does not disappear off the screen.
- The TIMEBASE (TIME/CM) control determines the rate at which the dot sweeps across the screen. Choose a setting so the trace shows at least one cycle of the signal across the screen. Note that a steady DC input signal gives a horizontal line trace for which the time base setting is not critical.
- The TRIGGER control is usually best left set to AUTO.

The trace of an AC signal with the oscilloscope controls correctly set is as shown in Figure 6.

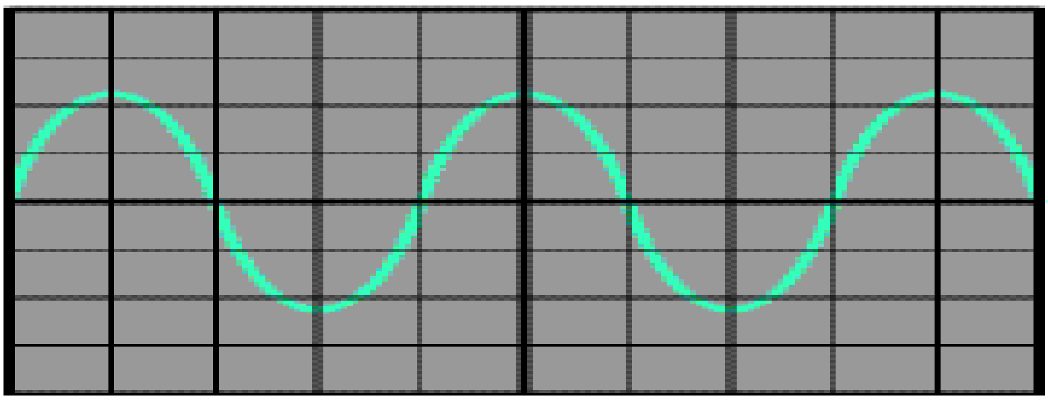


Figure 6 : Stable waveform

Measuring voltage and time period

The trace on an oscilloscope screen is a graph of voltage against time. The shape of this graph is determined by the nature of the input signal. In addition to the properties labeled on the graph, there is frequency which is the number of cycles per second. The diagram shows a sine wave but these properties apply to any signal with a constant shape

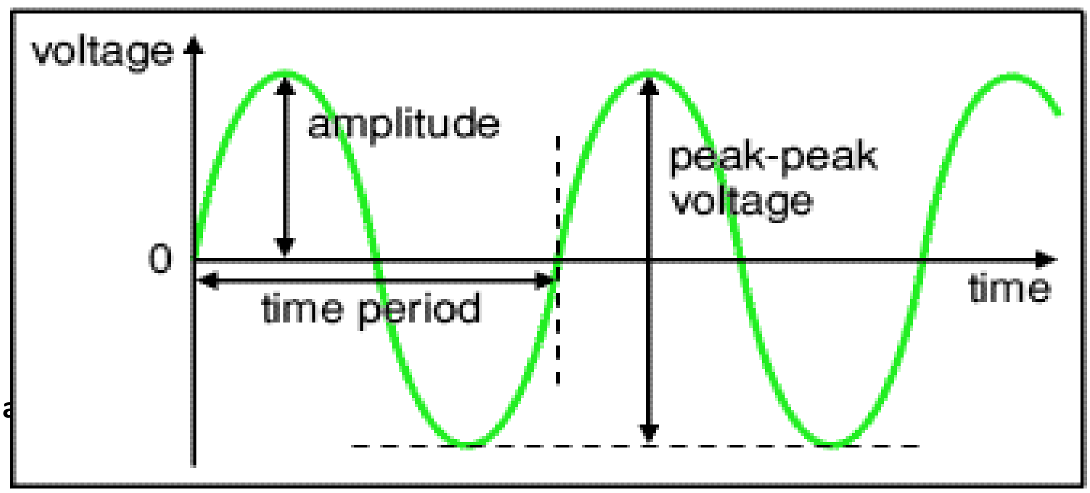


Figure7: Properties of trace

- **Amplitude** is the maximum voltage reached by the signal. It is measured in volts.
- **Peak voltage** is another name for amplitude.
- **Peak-peak voltage** is twice the peak voltage (amplitude). When reading an oscilloscope trace it is usual to measure peak-peak voltage.
- **Time period** is the time taken for the signal to complete one cycle.
  It is measured in seconds (s), but time periods tend to be short so milliseconds (ms) and microseconds (µs) are often used. 1ms = 0.001s and 1µs = 0.000001s.
- **Frequency** is the number of cycles per second. It is measured in hertz (Hz), but frequencies tend to be high so kilohertz (kHz) and megahertz (MHz) are often used. 1kHz = 1000Hz and 1MHz = 1000000Hz.

$$\text{Frequency} = \frac{1}{\text{Time period}}$$

$$\text{Time period} = \frac{1}{\text{Frequency}}$$

A) **Voltage:** Voltage is shown on the vertical y-axis and the scale is determined by the Y AMPLIFIER (VOLTS/CM) control. Usually peak-peak voltage is measured because it can be read correctly even if the position of 0V is not known. The amplitude is half the peak-peak voltage.

Voltage = distance in cm × volts/cm

B) Time period: Time is shown on the horizontal x-axis and the scale is determined by the TIMEBASE (TIME/CM) control. The time period (often just called period) is the time for one cycle of the signal. The frequency is the number of cycles per second, frequency = 1/time period.

Time = distance in cm × time/cm

4. STUDY OF FUNCTION GENERATOR

A function generator is a device that can produce various patterns of voltage at a variety of frequencies and amplitudes. It is used to test the response of circuits to common input signals. The electrical leads from the device are attached to the ground and signal input terminals of the device under test.

Figure 1: A typical low-cost function generator.

➢ Features and controls :

Most function generators allow the user to choose the shape of the output from a small number of options.

- Square wave - The signal goes directly from high to low voltage.

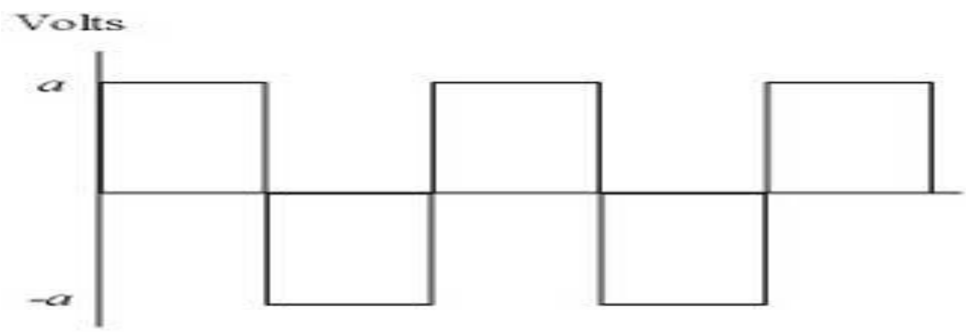


Figure 2: Square wave

The duty cycle of a signal refers to the ratio of high voltage to low voltage time in a square wave signal.

- Sine wave - The signal curves like a sinusoid from high to low voltage.

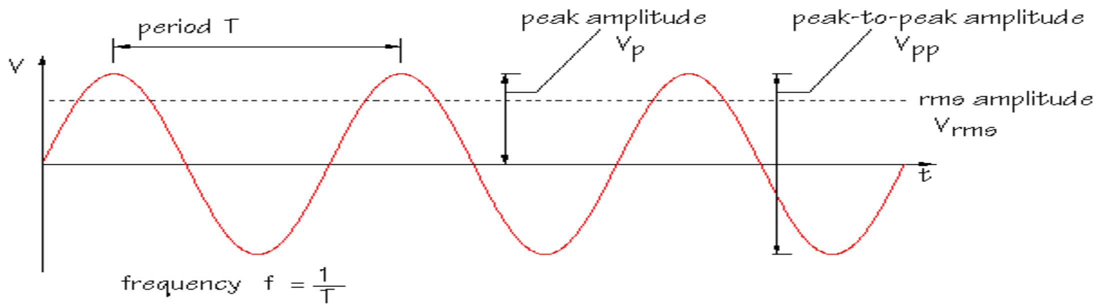


Figure3: Sine Wave

- Triangle wave - The signal goes from high to low voltage at a fixed rate.

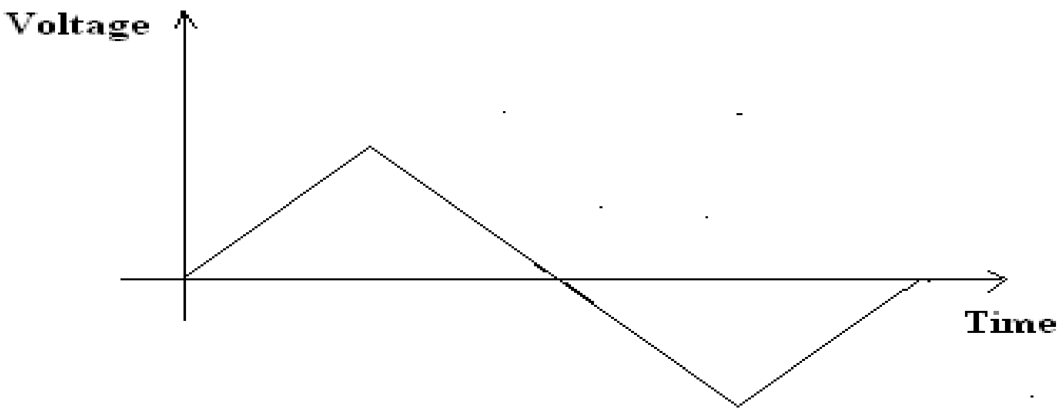


Figure4: Triangular Wave

The amplitude control on a function generator varies the voltage difference between the high and low voltage of the output signal. The direct current (DC) offset control on a function generator varies the average voltage of a signal relative to the ground. The frequency control of a function generator controls the rate at which output signal oscillates. On some function generators, the frequency control is a combination of different controls. One set of controls chooses the broad frequency range (order of magnitude) and the other selects the precise frequency. This allows the function generator to handle the enormous variation in frequency scale needed for signals.

➢ How to use a function generator

After powering on the function generator, the output signal needs to be configured to the desired shape. Typically, this means connecting the signal and ground leads to an oscilloscope to check the controls. Adjust the function generator until the output signal is correct, then attach the signal and ground leads from the function generator to the input and ground of the device under test. For some applications, the negative lead of the function generator should attach to a negative input of the device, but usually attaching to ground is sufficient.

5. STUDY OF REGULATED POWER SUPPLY

There are many types of power supply. Most are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices. A power supply can by broken down into a series of blocks, each of which performs a particular function. For example a 5V regulated supply:

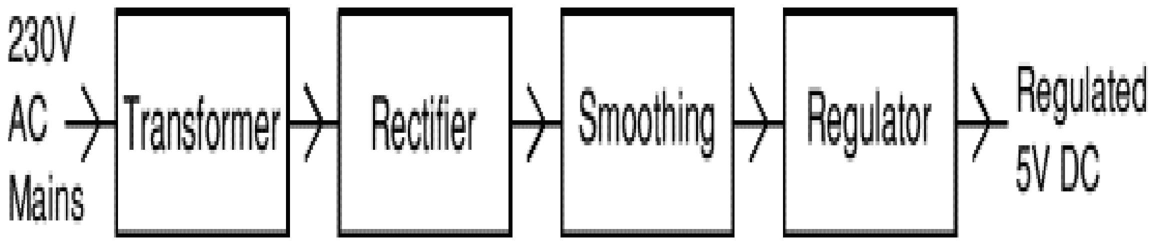


Figure1: Block Diagram of Regulated power supply

Each of the blocks is described in more detail below:

- Transformer: Steps down high voltage AC mains to low voltage AC.
- Rectifier: Converts AC to DC, but the DC output is varying.
- Smoothing: Smooths the DC from varying greatly to a small ripple.
- Regulator: Eliminates ripple by setting DC output to a fixed voltage.

➢ **Dual Supplies:** Some electronic circuits require a power supply with positive and negative outputs as well as zero volts (0V). This is called a 'dual supply' because it is like two ordinary supplies connected together as shown in the diagram. Dual supplies have three outputs, for example a ±9V supply has +9V, 0V and -9V outputs.

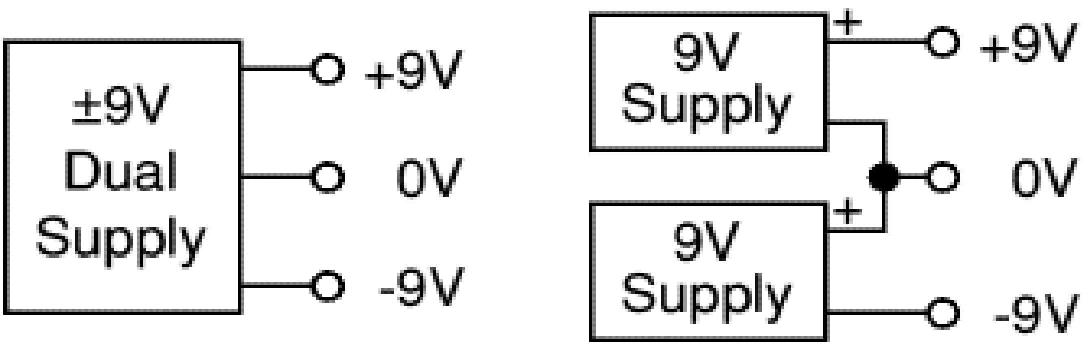


Figure 2: Dual Supply

6. TYPES OF CIRCUIT BOARD

- **Breadboard:** This is a way of making a temporary circuit, for testing purposes or to try out an idea. No soldering is required and all the components can be re-used afterwards. It is easy to change connections and replace components. Almost all the Electronics Club projects started life on a breadboard to check that the circuit worked as intended. The following figure depicts the appearance of Bread board in which the holes in top and bottom stribes are connected horizontally that are used for power supply and ground connection conventionally and holes on middle stribes connected vertically. And that are used for circuit connections conventionally**.**

Figure 1: Bread board

- **Strip board:**

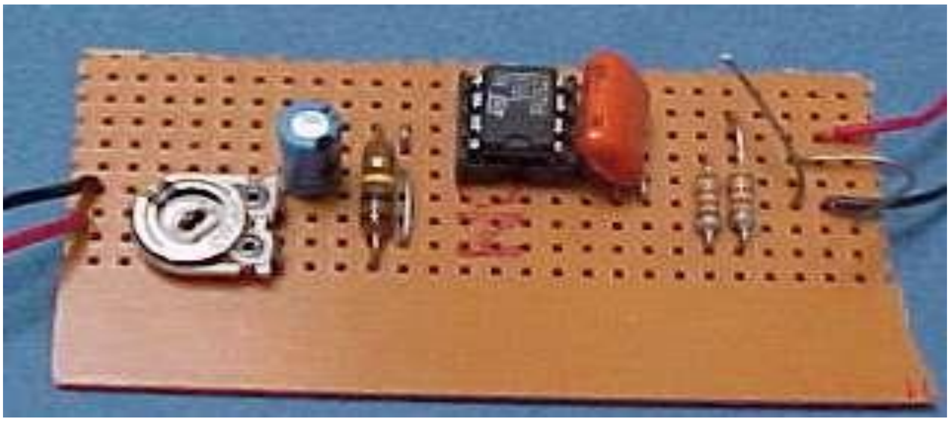


Figure 2: Strip board

Strip board has parallel strips of copper track on one side. The strips are 0.1" (2.54mm) apart and there are holes every 0.1" (2.54mm). Strip board requires no special preparation other than cutting to size. It can be cut with a junior hacksaw, or simply snap it along the lines of holes by putting it over the edge of a bench or table and pushing hard.

Printed Circuit Board: A printed circuit board, or PCB, is used to mechanically support and electrically connect electronic components using conductive pathways, tracks or traces etched from copper sheets laminated onto a non-conductive substrate. It is also referred to as printed wiring board (PWB) or etched wiring board. A PCB populated with electronic components is a printed circuit assembly (PCA), also known as a printed circuit board assembly (PCBA).

Printed circuit boards have copper tracks connecting the holes where the components are placed. They are designed specially for each circuit and make construction very easy. However, producing the PCB requires special equipment so this method is not recommended if you are a beginner unless the PCB is provided for you.

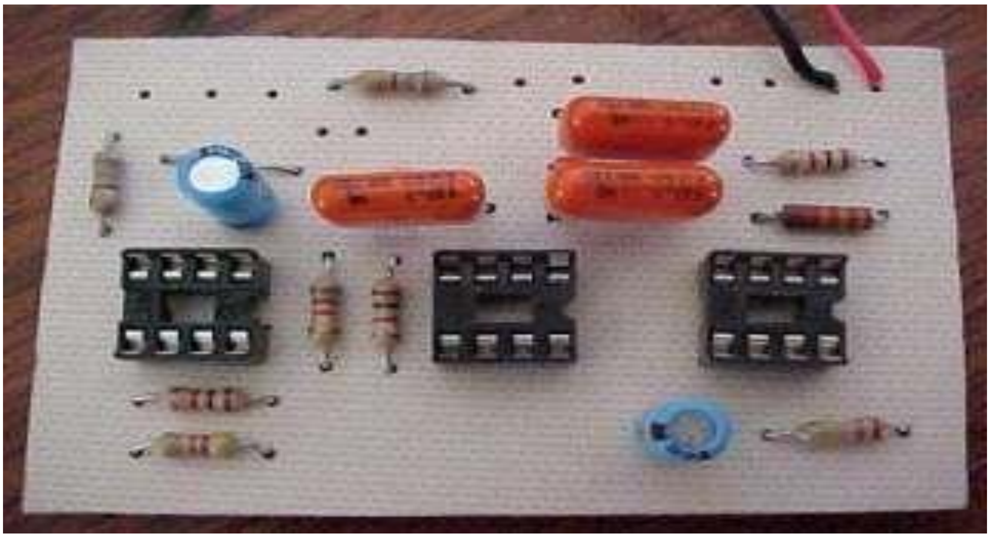


Figure 3: Printed circuit board

PCBs are inexpensive, and can be highly reliable. They require much more layout effort and higher initial cost than either wire-wrapped or point-to-point constructed circuits, but are much cheaper and faster for high-volume production. Much of the electronics industry's PCB design, assembly, and quality control needs are set by standards that are published by the IPC organization.

SECTION-B

1. P-N JUNCTION DIODE CHARACTERISTICS

AIM: 1. To observe and draw the Forward and Reverse bias V-I Characteristics of a P-N Junction diode.
2. To calculate static and dynamic resistance in both forward and Reverse Bias Conditions.

APPARATUS:

1. P-N Diode IN4007 - 1No.
2. Regulated Power supply (0-30V) - 1No.
3. Resistor 1KΩ - 1No.
4. Ammeter (0-20 mA) - 1No
5. Ammeter (0-200µA) - 1No.
6. Voltmeter (0-20V) - 2No.
7. Bread board
8. Connecting wires

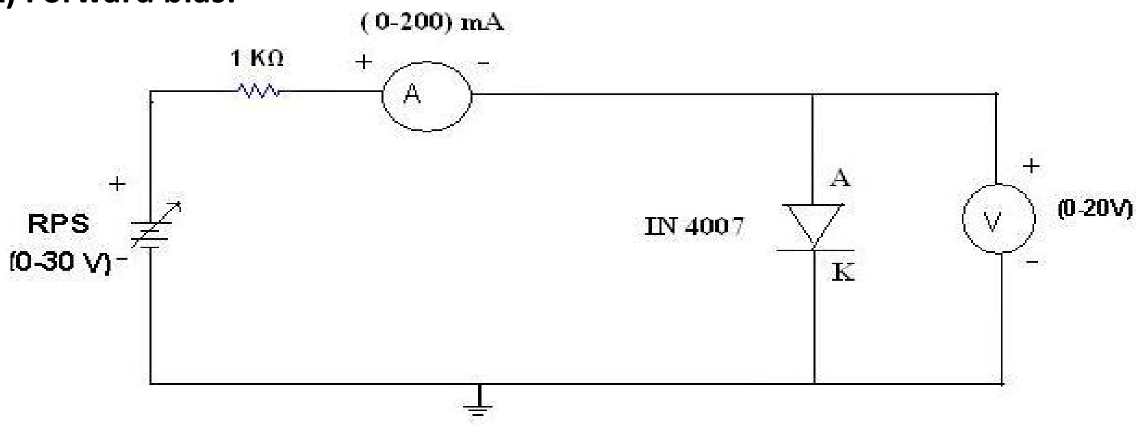
THEORY:

A P-N junction diode conducts only in one direction. The V-I characteristics of the diode are curve between voltage across the diode and current flowing through the diode. When external voltage is zero, circuit is open and the potential barrier does not allow the current to flow. Therefore, the circuit current is zero. When P-type (Anode) is connected to +ve terminal and n- type (cathode) is connected to –ve terminal of the supply voltage is known as forward bias. The potential barrier is reduced when diode is in the forward biased condition. At some forward voltage, the potential barrier altogether eliminated and current starts flowing through the diode and also in the circuit. Then diode is said to be in ON state. The current increases with increasing forward voltage.

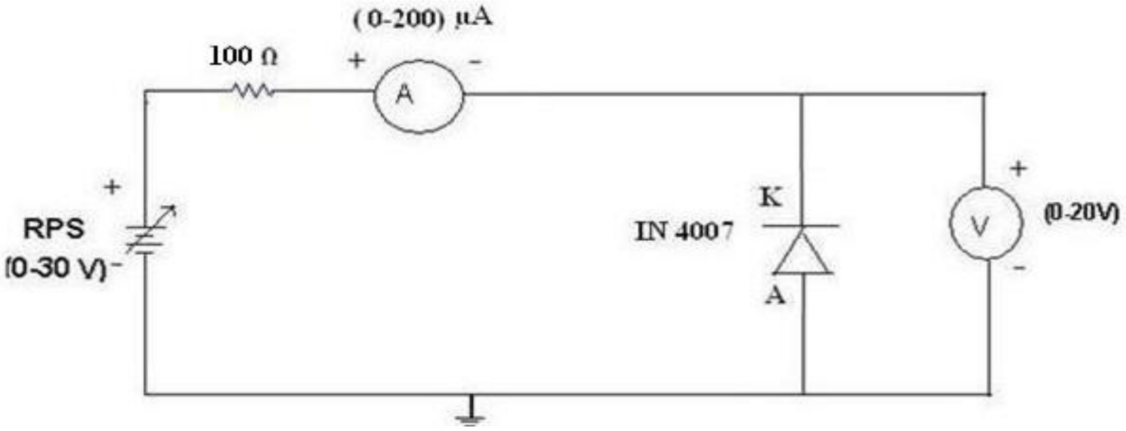
When N-type (cathode) is connected to +ve terminal and P-type (Anode) is connected –ve terminal of the supply voltage is known as reverse bias and the potential barrier across the junction increases. Therefore, the junction resistance becomes very high and a very small current (reverse saturation current) flows in the circuit. Then diode is said to be in OFF state. The reverse bias current is due to minority charge carriers.

CIRCUIT DIAGRAM:

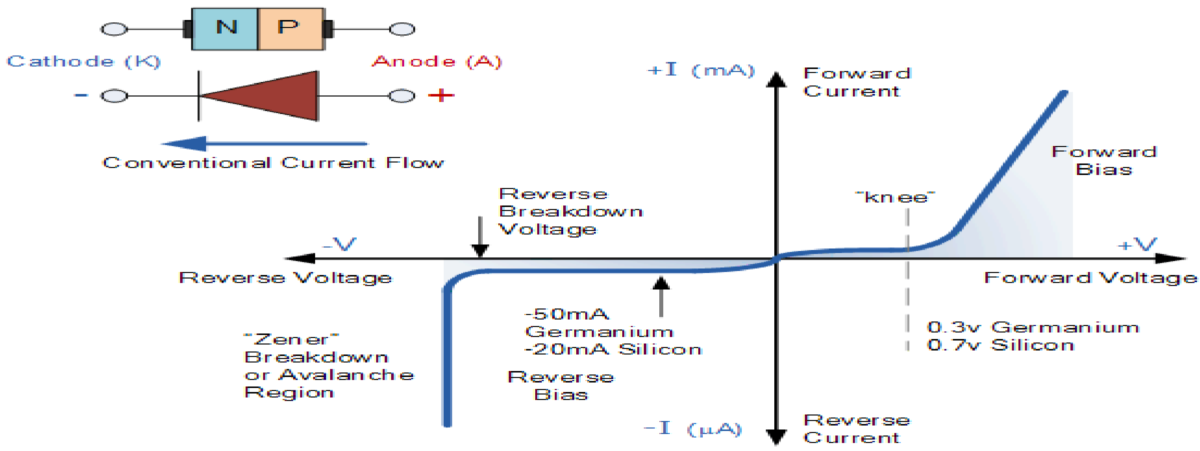
A) Forward bias:



B) Reverse Bias:



MODEL GRAPH:



OBSERVATIONS:

A) FORWARD BIAS:

S.NO	Applied Voltage(V)	Forward Voltage(V_f)	Forward Current(I_f(mA))

B) REVERSE BIAS:

S.NO	Applied Voltage(V)	Reverse Voltage(V_R)	Reverse Current(I_R(μA))

Calculations:

Calculation of Static and Dynamic Resistance for a given diode.

In forward bias condition:

Static Resistance , $R_s = Vf/I_f =$
Dynamic Resistance, $R_D = \Delta V_f / \Delta I_f =$

In Reverse bias condition:

Static Resistance , $R_s = V_R/I_R =$
Dynamic Resistance, $RD = \Delta V_R / \Delta I_R =$

PROCEDURE:

A) FORWARD BIAS:

1. Connections are made as per the circuit diagram.
2. For forward bias, the RPS +ve is connected to the anode of the diode and RPS –ve is connected to the cathode of the diode
3. Switch on the power supply and increases the input voltage (supply voltage) in Steps of 0.1V
4. Note down the corresponding current flowing through the diode and voltage across the diode for each and every step of the input voltage.
5. The reading of voltage and current are tabulated.
6. Graph is plotted between voltage (V_f) on X-axis and current (I_f) on Y-axis.

B) REVERSE BIAS:

1. Connections are made as per the circuit diagram
2. for reverse bias, the RPS +ve is connected to the cathode of the diode and RPS –ve is connected to the anode of the diode.
3. Switch on the power supply and increase the input voltage (supply voltage) in Steps of 1V.

4. Note down the corresponding current flowing through the diode voltage across the diode for each and every step of the input voltage.
5. The readings of voltage and current are tabulated
6. Graph is plotted between voltage (V_R) on X-axis and current (I_R) on Y-axis.

PRECAUTIONS:

1. All the connections should be correct.
2. Parallax error should be avoided while taking the readings from the Analog meters.

RESULT:

EXERCISE QUESTIONS:

1. The reverse saturation current of a silicon p – n function diode at an operating temperature of 270C is 50 nA. Compute the dynamic forward and reverse resistances of the diode for applied voltages of 0.8 V and -0.4 V respectively
2. Find the value of D.C. resistance and A.C resistance of a Germanium junction diode at 250 C with reverse saturation current, Io = 25μA and at an applied voltage of 0.2V across the diode

VIVA QUESTIONS:

1. Define depletion region of a diode?
2. What is meant by transition & space charge capacitance of a diode?
3. Is the V-I relationship of a diode Linear or Exponential?
4. Define cut-in voltage of a diode and specify the values for Si and Ge diodes?
5. What are the applications of a p-n diode?
6. Draw the ideal characteristics of P-N junction diode?
7. What is the diode equation?
8. What is PIV?
9. What is the break down voltage?
10. What is the effect of temperature on PN junction diodes?

2. ZENER DIODE CHARACTERISTICS AND ZENER AS VOLTAGE REGULATOR

AIM:

a) To observe and draw the static characteristics of a zener diode
b) To find the voltage regulation of a given zener diode

APPARATUS:

1. Zener diode - 1No.
2. Regulated Power Supply (0-30v) - 1No.
3. Voltmeter (0-20v) - 1No.
4. Ammeter (0-20mA) - 1No.
5. Resistor (1K ohm)
6. Bread Board
7. Connecting wires

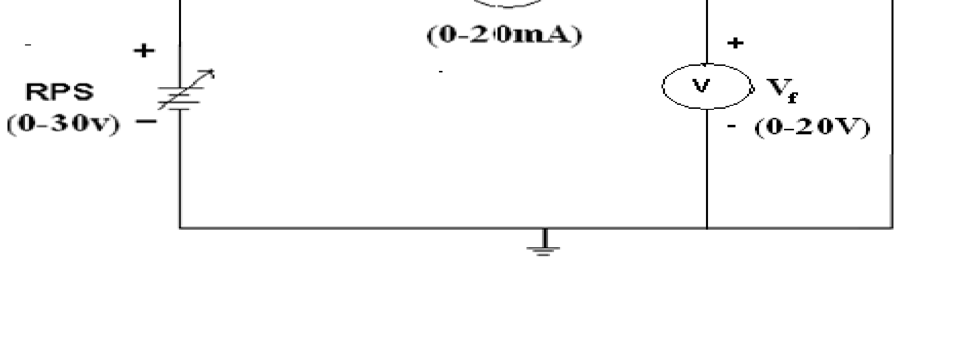
THEORY:

A zener diode is heavily doped p-n junction diode, specially made to operate in the break down region. A p-n junction diode normally does not conduct when reverse biased. But if the reverse bias is increased, at a particular voltage it starts conducting heavily. This voltage is called Break down Voltage. High current through the diode can permanently damage the device

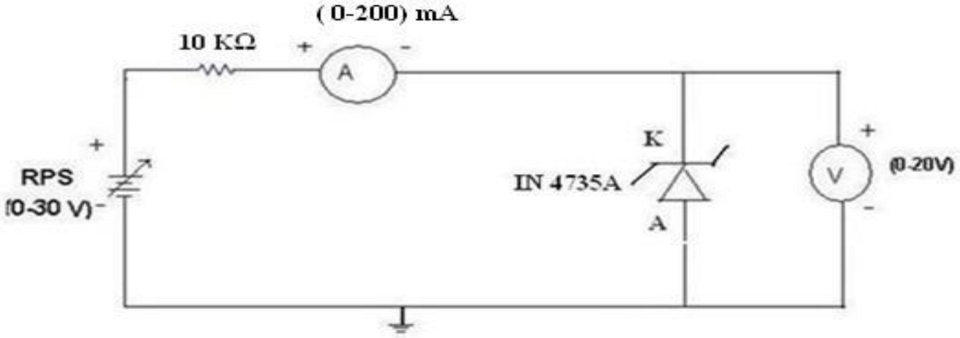
To avoid high current, we connect a resistor in series with zener diode. Once the diode starts conducting it maintains almost constant voltage across the terminals whatever may be the current through it, i.e., it has very low dynamic resistance. It is used in voltage regulators.

CIRCUIT DIAGRAM

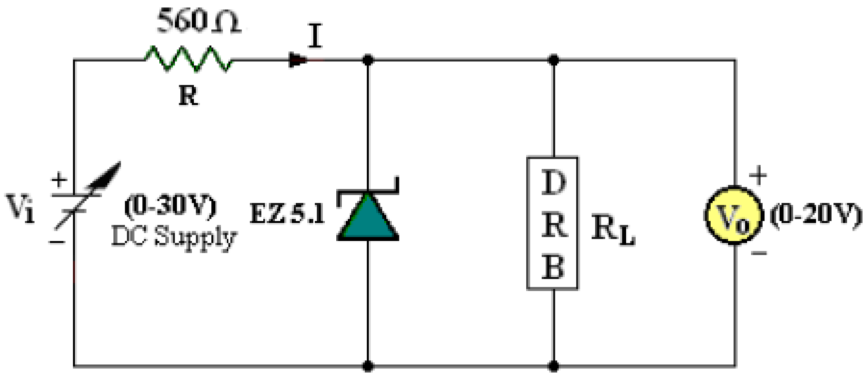
A) STATIC CHARACTERISTICS :



b) REVERSE BIAS CHARACTERISTICS:



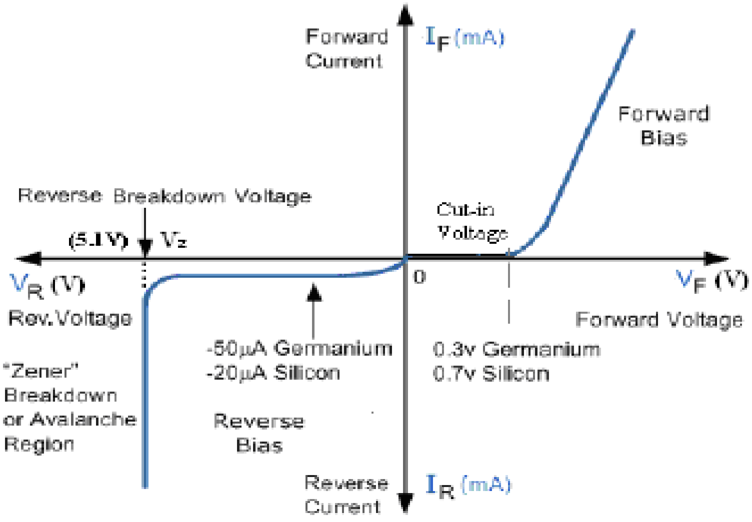
VOLTAGE REGULATION:



Zener Diode Voltage Regulation

MODEL GRAPHS:

ZENER DIODE CHARACTERISTICS:



V-I Characteristics of Zener Diode

OBSERVATIONS:

A) FORWARD BIAS characteristics:

S.NO	Applied Voltage(V)	Forward Voltage(V_f)	Forward Current(I_f(mA))

B) REVERSE BIAS Characteristics:

S.NO	Applied Voltage(V)	Reverse Voltage(V_R)	Reverse Current(I_R(mA))

PROCEDURE:

A) Static characteristics:

1. Connections are made as per the circuit diagram.
2. The Regulated power supply voltage is increased in steps.
3. The Forward current (I_f), and the forward voltage (V_f.) are observed and then noted in the tabular form.
4. A graph is plotted between Forward current (I_f) on X-axis and the forward voltage (V_f) on Y-axis.

B) Regulation characteristics:

LOAD REGULATION CHARACTERISTICS:

1. Connect the Circuit as per the Circuit Diagram on the bread board.
2. By changing the load Resistance, kept constant I/P Voltage at 5V, 10 V, 15 V as Per table given below. Take the readings of O/P Voltmeter (Vo=Vz).
3. Now by changing the I/P Voltage, kept constant load Resistance at 1K, 2K, 3K as per table given below. Take the readings of O/P Voltmeter (Vo=Vz).

LOAD REGULATION

S.No	R_L (Ω)	V_{i1}= 5V V_O (V)	V_{i2}= 10V V_O (V)	V_{i3}=15V V_O (V)
1	100			
2	300			
3	500			
4	700			
5	900			
6	1K			
7	3K			
8	5K			
9	7K			
10	10K			

LINE REGULATION

Vi (V)	R_{L1}=1KΩ V_O (V)	R_{L2}=2KΩ V_O (V)	R_{L3}=3KΩ V_O (V)
0			
1			
3			
5			
7			
9			
11			
13			
15			
20			

PRECAUTIONS:

1. The terminals of the zener diode should be properly identified
2. While determined the load regulation, load should not be immediately shorted.
3. Should be ensured that the applied voltages & currents do not exceed the ratings of the diode.

RESULT:

EXERCISE QUESTIONS:

1. A Zener voltage regulator circuit is to maintain constant voltage at 60 V, over a current range from 5 to 50 mA. The input supply voltage is 200 V. Determine the value of resistance R to be connected in the circuit, for voltage regulation from load current I_L = 0 mA to I_L max, the maximum possible value of I_L. What is the value I_L max?

VIVAQUESTIONS:

1. What type of temp coefficient does the zener diode have?
2. If the impurity concentration is increased, how the depletion width effected?
3. Does the dynamic impendence of a zener diode vary?
4. Explain briefly about avalanche and zener breakdowns?
5. Draw the zener equivalent circuit?
6. Differentiate between line regulation & load regulation?
7. In which region zener diode can be used as a regulator?
8. How the breakdown voltage of a particular diode can be controlled?
9. What type of temperature coefficient does the Avalanche breakdown has?
10. By what type of charge carriers the current flows in zener and avalanche breakdown diodes?

3. HALF -WAVE RECTIFIER WITH AND WITHOUT FILTER

AIM: To examine the input and output waveforms of half wave Rectifier and also calculate its load regulation and ripple factor.

1. with Filter
2. without Filter

APPARATUS:

Digital multimetersMultimeter - 1No.
Transformer (6V-0-6V) - 1No.
Diode, 1N4007 - 1No.
Capacitor 100µf/470 µf - 1No.
Decade Resistance Box - 1No.
Breadboard
CRO and CRO probes
Connecting wires

THEORY:

In Half Wave Rectification, When AC supply is applied at the input, only Positive Half Cycle appears across the load whereas, the negative Half Cycle is suppressed. How this can be explained as follows:

During positive half-cycle of the input voltage, the diode D1 is in forward bias and conducts through the load resistor R_L. Hence the current produces an output voltage across the load resistor R_L, which has the same shape as the +ve half cycle of the input voltage.

During the negative half-cycle of the input voltage, the diode is reverse biased and there is no current through the circuit. i.e., the voltage across R_L is zero. The net result is that only the +ve half cycle of the input voltage appears across the load. The average value of the half wave rectified o/p voltage is the value measured on dc voltmeter.

For practical circuits, transformer coupling is usually provided for two reasons.

1. The voltage can be stepped-up or stepped-down, as needed.
2. The ac source is electrically isolated from the rectifier. Thus preventing shock hazards in the secondary circuit.

The efficiency of the Half Wave Rectifier is 40.6%

Theoretical calculations for Ripple factor:

Without Filter:

Vrms=Vm/2

Vm=2Vrms

Vdc=Vm/Π

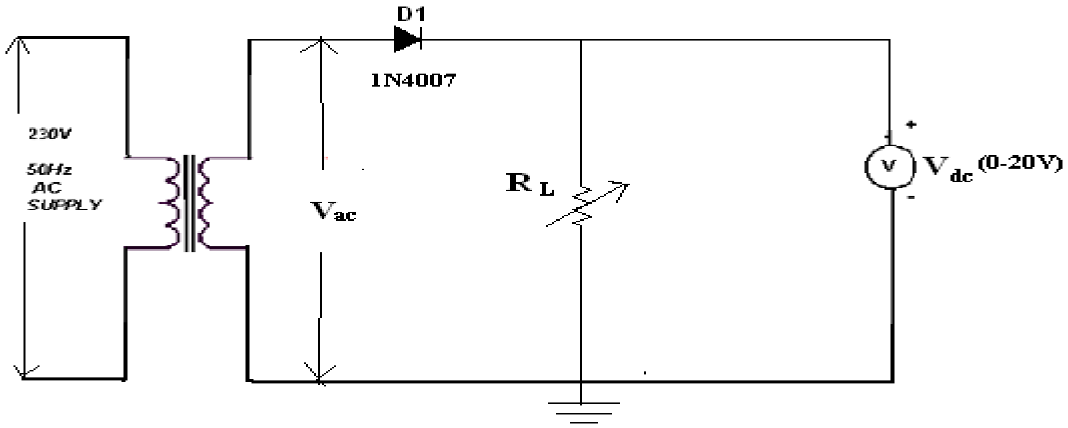
Ripple factor r=√ (Vrms/ Vdc)^2 -1 =1.21

With Filter:

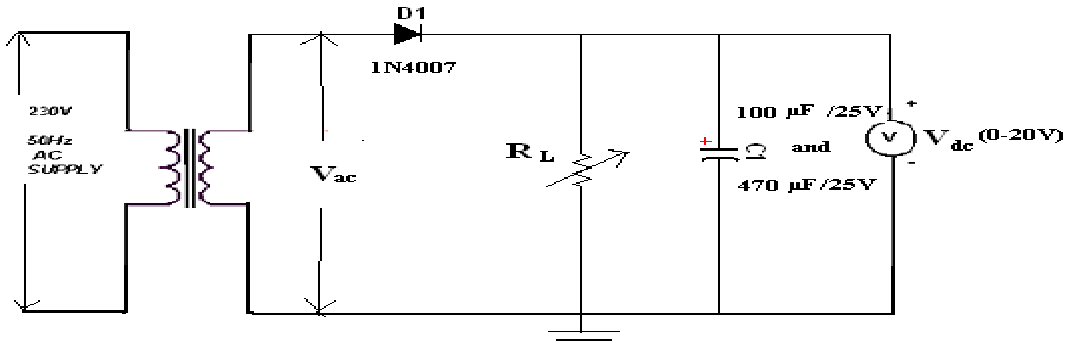
Ripple factor, r=1/ (2√3 f C R)

CIRCUIT DIAGRAM:

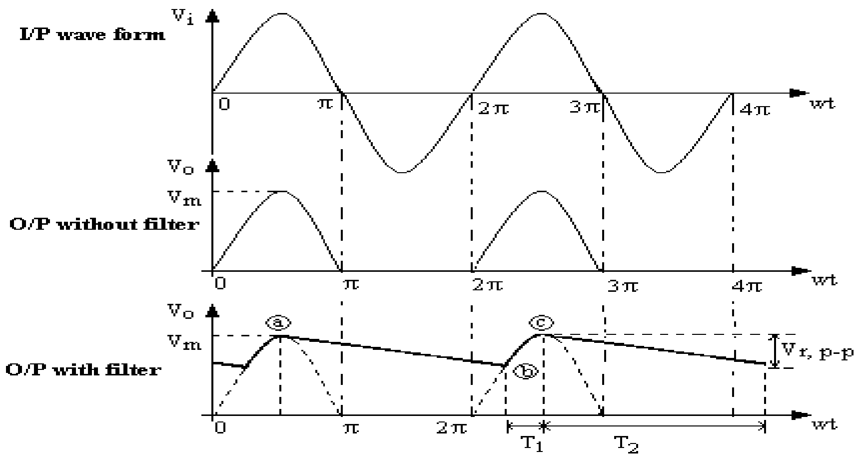
A) Half wave Rectifier without filter:



B) Half wave Rectifier with filter



MODEL WAVEFORMS:



Half-wave Rectifier with capacitor filter wave form

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect the primary side of the transformer to ac mains and the secondary side to the rectifier input.
3. By the multimeter, measure the ac input voltage of the rectifier and, ac and dc voltage at the output of the rectifier.
4. Find the theoretical of dc voltage by using the formula,

   Vdc=Vm/Π

   Where, Vm=2Vrms, (Vrms=output ac voltage.)
5. The Ripple factor is calculated by using the formula

   r = ac output voltage/dc output voltage.

WITHOUT FILTER:

V no load Voltage (Vdc) = V

S.No	Load Resistance R_L kilo-ohms	O/P Voltage (Vo) V_{ac} (V)	O/P Voltage (Vo) V_{dc} (V)	Ripple factor $\left(\gamma = \frac{V_{ac}}{V_{dc}}\right)$	% of Regulation $\left(\frac{V_{NL} - V_{FL}}{V_{NL}} * 100\%\right)$
1	1				
2	2				
3	3				
4	4				
5	5				
6	6				
7	7				
8	8				
	.				

WITH CAPACITOR FILTER:

V no load Voltage (Vdc) = V

S.No	Load Resistance R_L kilo-ohms	O/P Voltage (Vo)		Ripple factor $\left(\gamma = \frac{V_{ac}}{V_{dc}}\right)$	% of Regulation $\left(\frac{V_{NL} - V_{FL}}{V_{NL}} * 100\%\right)$
		V_{ac} (V)	V_{dc} (V)		
1	1				
2	2				
3	3				
4	4				
5	5				
6	6				
7	7				
8	8				

REGULATION CHARACTERSTICS:

1. Connections are made as per the circuit diagram.
2. By increasing the value of the rheostat, the voltage across the load and current flowing through the load are measured.
3. The reading is tabulated.
4. From the value of no-load voltages, the %regulation is calculated using the formula,

%Regulation = $[(V_{NL}-V_{FL}) / V_{FL}]*100$

PRECAUTIONS:

1. The primary and secondary side of the transformer should be carefully identified
2. The polarities of all the diodes should be carefully identified.
3. While determining the % regulation, first Full load should be applied and then it should be decremented in steps.

RESULT:

EXERCISE QUESTIONS:

1. A half wave rectifier having a resistor load of 1000 ohms rectifier an alternating of 325V peak value and the diode has a forward resistance of 100 ohms calculate a) peak ,average and RMS value of current) dc power output c) A.C input power and d) efficiency of the rectifier

VIVA QUESTIONS:

1. What is the PIV of Half wave rectifier?
2. What is the efficiency of half wave rectifier?
3. What is the rectifier?
4. What is the difference between the half wave rectifier and full wave Rectifier?
5. What is the o/p frequency of Bridge Rectifier?
6. What are the ripples?
7. What is the function of the filters?
8. What is TUF?
9. What is the average value of o/p voltage for HWR?
10. What is the peak factor?

4. FULL-WAVE RECTIFIER WITH AND WITHOUT FILTER

AIM: To Examine the input and output waveforms of Full Wave Rectifier and also calculate its load regulation and ripple factor.

1. with Filter
2. without Filter

APPARATUS:

Digital multimetersMultimeter - 1No.

Transformer (6V-0-6V) - 1No.
Diode, 1N4007 - 2No.
Capacitor 100µf/470 µf - 1No.
Decade Resistance Box - 1No.
Breadboard
CRO and CRO probes
Connecting wires

THEORY:

The circuit of a center-tapped full wave rectifier uses two diodes D1&D2. During positive half cycle of secondary voltage (input voltage), the diode D1 is forward biased and D2is reverse biased. So the diode D1 conducts and current flows through load resistor R_L.

During negative half cycle, diode D2 becomes forward biased and D1 reverse biased. Now, D2 conducts and current flows through the load resistor R_L in the same direction. There is a continuous current flow through the load resistor R_L, during both the half cycles and will get unidirectional current as show in the model graph. The difference between full wave and half wave rectification is that a full wave rectifier allows unidirectional (one way) current to the load during the entire 360 degrees of the input signal and half-wave rectifier allows this only during one half cycle (180 degree).

THEORITICAL CALCULATIONS:

$V_{rms} = V_m/ \sqrt{2}$
$V_m = V_{rms}\sqrt{2}$
$V_{dc} = 2V_m/\Pi$

(i)Without filter:

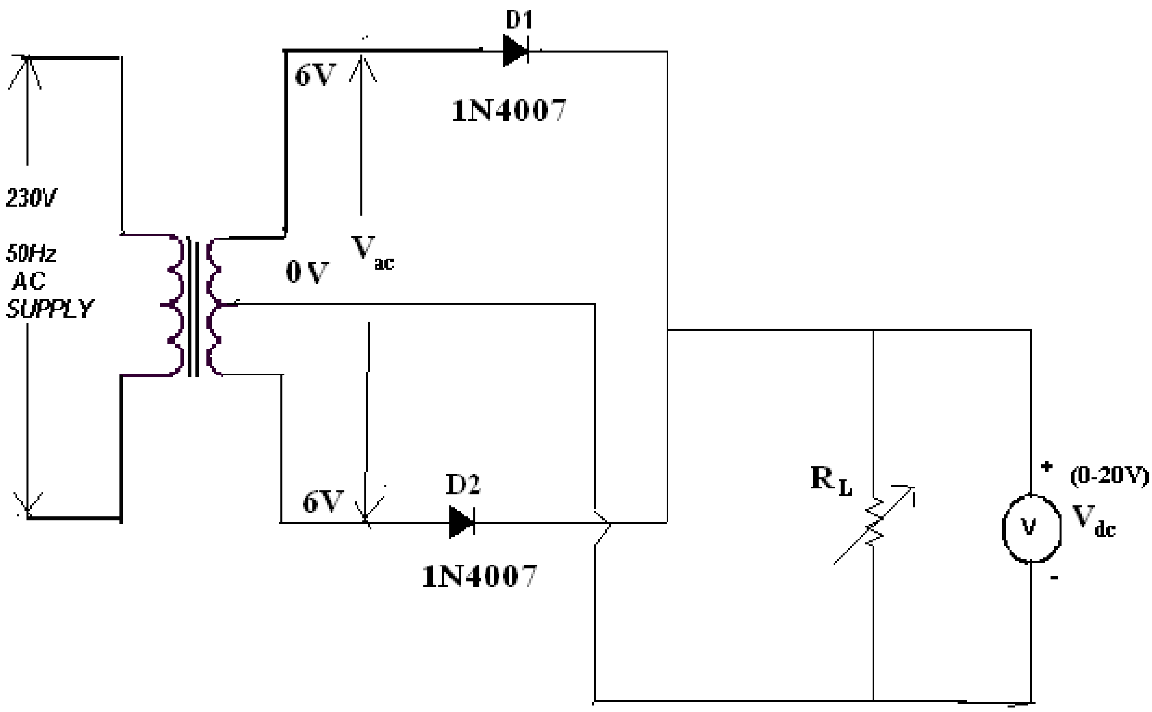
Ripple factor, $r = \sqrt{(V_{rms}/ V_{dc})^2 - 1} = 0.812$

(ii)With filter:

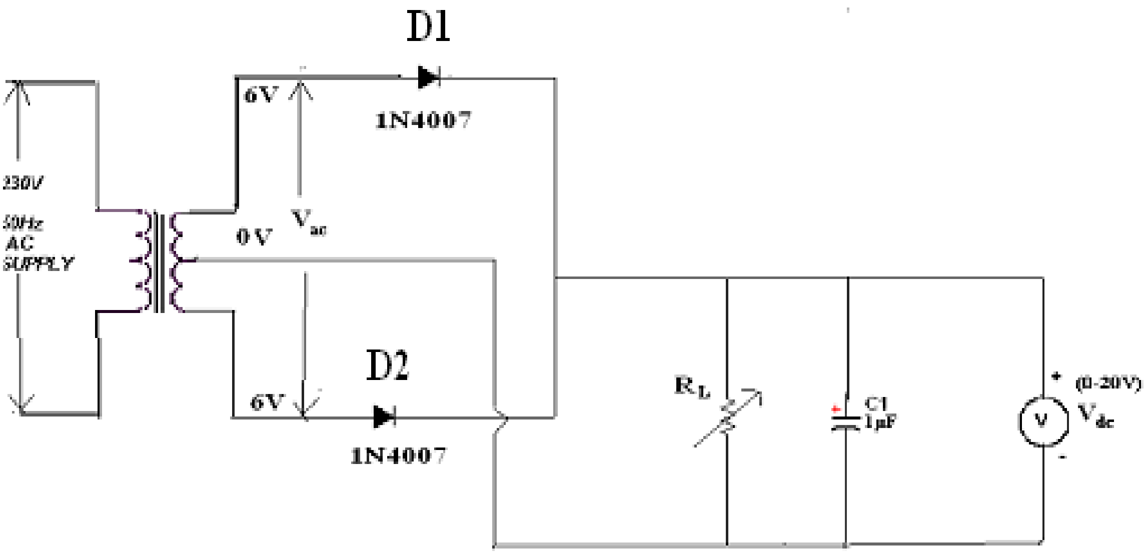
Ripple factor, $r = 1/ (4\sqrt{3}\, f\, C\, R_L)$

CIRCUIT DIAGRAM:

A) FULL WAVE RECTIFIER WITHOUT FILTER:

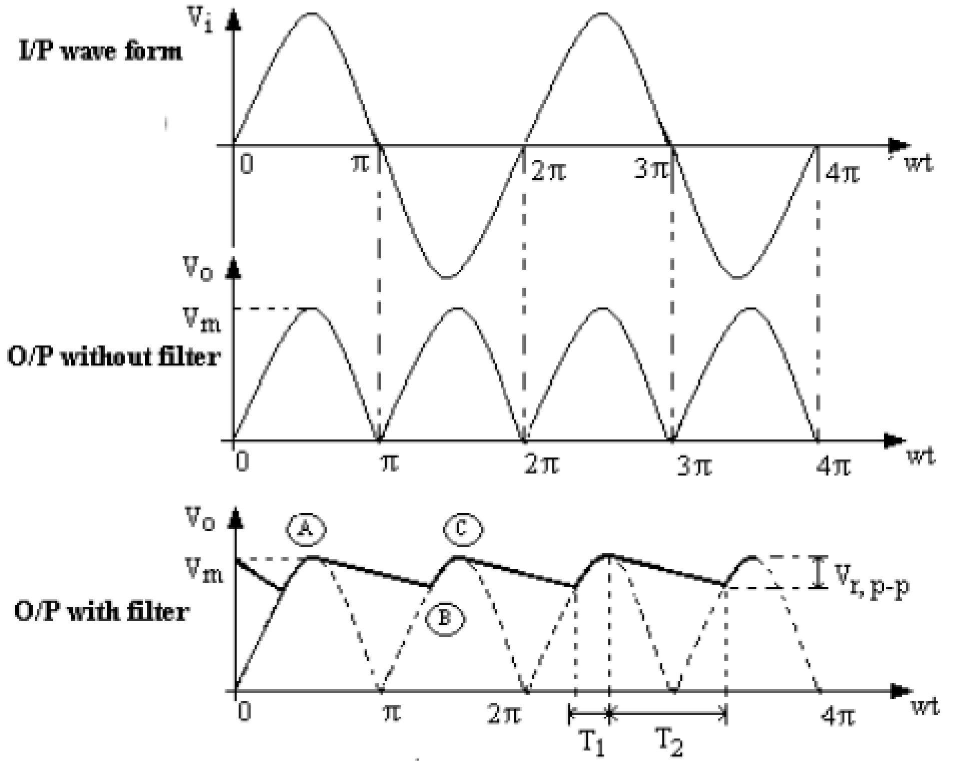


B) FULL WAVE RECTIFIER WITH FILTER:



MODEL WAVEFORMS:

A) WAVEFORMS:



Full-wave Rectifier with capacitor filter wave form

WITHOUT FILTER:

V no load Voltage (Vdc) = V

S.No	Load Resistance R_L kilo-ohms	O/P Voltage (Vo)		Ripple factor $\left(\gamma = \frac{V_{ac}}{V_{dc}}\right)$	% of Regulation $\left(\frac{V_{NL} - V_{FL}}{V_{NL}} * 100\%\right)$
		V_{ac} (V)	V_{dc} (V)		
1	1				
2	2				
3	3				
4	4				
5	5				
6	6				
7	7				
8	8				

WITH CAPACITOR FILTER:

V no load Voltage (Vdc) = V

S.No	Load Resistance R_L kilo-ohms	O/P Voltage (Vo)		Ripple factor $\left(\gamma = \frac{V_{ac}}{V_{dc}}\right)$	% of Regulation $\left(\frac{V_{NL}-V_{FL}}{V_{NL}}*100\%\right)$
		V_{ac} (V)	V_{dc} (V)		
1	1				
2	2				
3	3				
4	4				
5	5				
6	6				
7	7				
8	8				

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect the ac mains to the primary side of the transformer and the secondary side to the rectifier.
3. Measure the ac voltage at the input side of the rectifier.
4. Measure both ac and dc voltages at the output side the rectifier.
5. Find the theoretical value of the dc voltage by using the formula Vdc=2Vm/Π
6. Connect the filter capacitor across the load resistor and measure the values of Vac and Vdc at the output.
7. The theoretical values of Ripple factors with and without capacitor are calculated.
8. From the values of Vac and Vdc practical values of Ripple factors are calculated. The practical values are compared with theoretical values.

PRECAUTIONS:

1. The primary and secondary side of the transformer should be carefully identified.
2. The polarities of all the diodes should be carefully identified.

RESULT:

EXERCISE QUESTIONS:

1. A Full wave single phase rectifier makes use of 2 diodes, the internal forward resistance of each is considered to be constant and equal to 30Ω. The load resistance is 1KΩ. The transformer secondary voltage is 200-0-200V (rms).Calculate V_{DC}, I_{DC}, and Ripple factor efficiency.

VIVA QUESTIONS:

1. Define regulation of the full wave rectifier?
2. Define peak inverse voltage (PIV)? And write its value for Full-wave rectifier?
3. If one of the diode is changed in its polarities what wave form would you get?
4. Does the process of rectification alter the frequency of the waveform?
5. What is ripple factor of the Full-wave rectifier?
6. What is the necessity of the transformer in the rectifier circuit?
7. What are the applications of a rectifier?
8. What is meant by ripple and define Ripple factor?
9. Explain how capacitor helps to improve the ripple factor?
10. Can a rectifier made in INDIA (V=230v, f=50Hz) be used in USA (V=110v, f=60Hz)?

5. INPUT AND OUTPUT CHARACTERISTICS OF TRANSISTOR CB CONFIGURATION

AIM: 1.To observe and draw the input and output characteristics of a transistor connected in common base configuration.

2. To find α of the given transistor and also its input and output Resistances.

APPARATUS:

Transistor, BC107	-1No.
Regulated power supply (0-30V)	-1No.
Voltmeter (0-20V)	- 2No.
Ammeters (0-10mA)	-2No.
Resistor, 1KΩ	-2No
Bread board	
Connecting wires	

THEORY:

A transistor is a three terminal active device. The terminals are emitter, base, collector. In CB configuration, the base is common to both input (emitter) and output (collector). For normal operation, the E-B junction is forward biased and C-B junction is reverse biased. In CB configuration, I_E is +ve, I_C is –ve and I_B is –ve. So,

$$\mathbf{V_{EB} = F1\ (V_{CB},\ I_E)\ and}$$

$$\mathbf{I_C = F_2\ (V_{EB}, I_B)}$$

With an increasing the reverse collector voltage, the space-charge width at the output junction increases and the effective base width 'W' decreases. This phenomenon is known as "Early effect". Then, there will be less chance for recombination within the base region. With increase of charge gradient with in the base region, the current of minority carriers injected across the emitter junction increases.

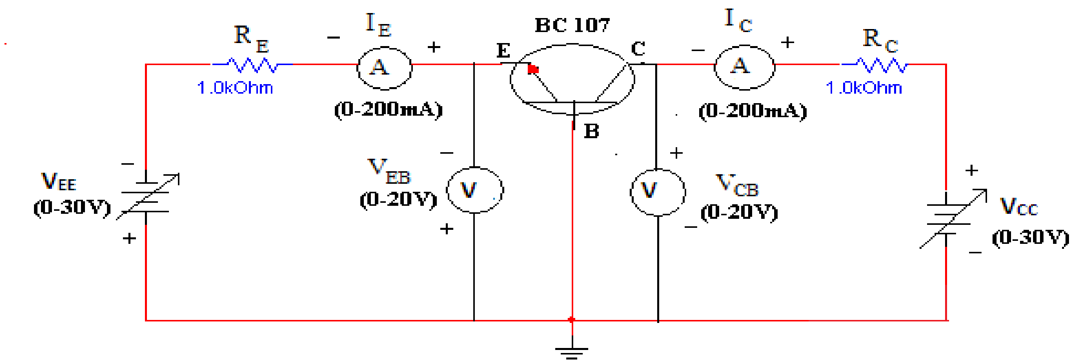
The current amplification factor of CB configuration is given by,

$$\boldsymbol{\alpha = \Delta I_C / \Delta I_E}$$

Input Resistance, r_i = $\mathbf{\Delta V_{BE} / \Delta I_E}$ at Constant V_{CB}

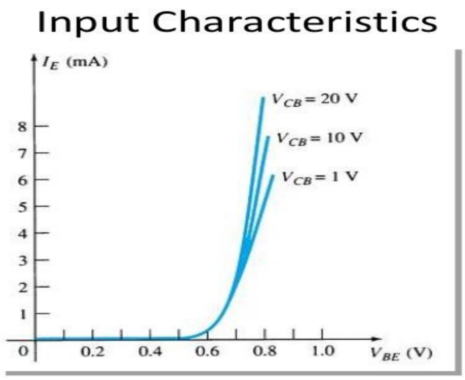
Output Résistance, r_o = $\mathbf{\Delta V_{CB} / \Delta I_C}$ at Constant I_E

CIRCUIT:

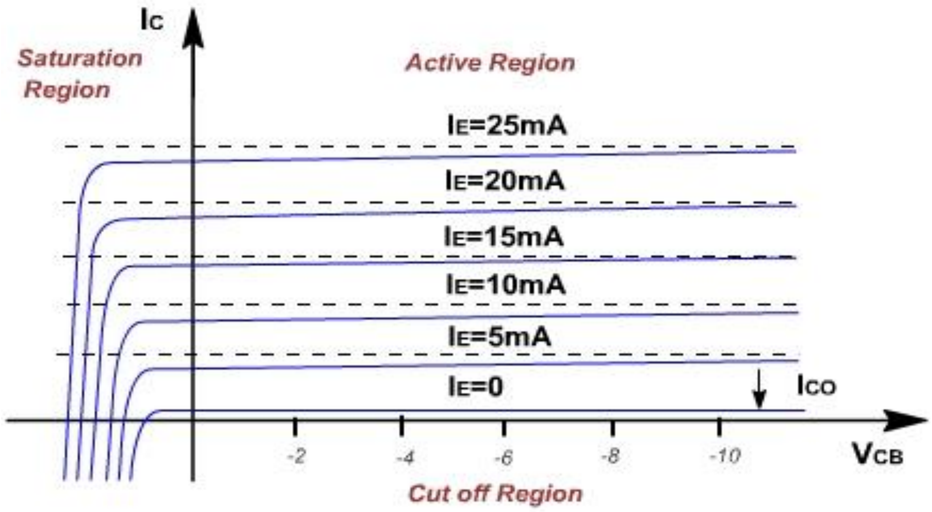


MODEL GRAPHS:

A) INPUT CHARACTERISTICS



B) OUTPUTCHARACTERISTICS



OBSERVATIONS:

A) INPUT CHARACTERISTICS:

V_{EE}(V)	$V_{CB=}$1V		$V_{CB=}$ = 2V		$V_{CB=}$ 4V	
	V_{EB}(V)	I_E(mA)	V_{EB}(V)	$I_{E(}$mA)	V_{EB}(V)	$I_{E(}$mA)

B) OUTPUT CHARACTERISTICS:

V_{cc}(V)	$I_{E=}$10mA		$I_{E=}$20mA		I_E=30mA	
	V_{CB}(V)	$I_{C(}$mA)	V_{CB}(V)	$I_{C(}$mA)	V_{CB}(V)	$I_{C(}$mA)

PROCEDURE:

A) INPUT CHARACTERISTICS:

1. Connections are made as per the circuit diagram.
2. For plotting the input characteristics, the output voltage V_{CE} is kept constant at 0V and for different values of V_{EE} ,note down the values of I_E and V_{BE}
3. Repeat the above step keeping V_{CB} at 2V, 4V, and 6V and all the readings are tabulated.
4. A graph is drawn between V_{EB} and I_E for constant $V_{CB.}$

B) OUTPUT CHARACTERISTICS:

1. Connections are made as per the circuit diagram.
2. For plotting the output characteristics, the input I_E is kept constant at 0.5mA and for different values of V_{CC}, note down the values of I_C and V_{CB}.
3. Repeat the above step for the values of I_E at 1mA, 5mA and all the readings are tabulated.
4. A graph is drawn between V_{CB} and Ic for constant I_E

PRECAUTIONS:

1. The supply voltages should not exceed the rating of the transistor.
2. Meters should be connected properly according to their polarities.

RESULT:

EXERCISE QUESTIONS:

1. Calculate the collector current and emitter current for a transistor with $\alpha_{D.C.}$ = 0.99 and I_{CBO} = 20 µA when the base current is 50µ A.

VIVA QUESTIONS:

1. What is the range of α for the transistor?
2. Draw the input and output characteristics of the transistor in CB configuration?
3. Identify various regions in output characteristics?
4. What is the relation between α and β?
5. What are the applications of CB configuration?
6. What are the input and output impedances of CB configuration?
7. Define α (alpha)?
8. What is early effect?
9. Draw Circuit diagram of CB configuration for PNP transistor?
10. What is the power gain of CB configuration?

6. INPUT AND OUTPUT CHARACTERISTICS OF TRASISTOR CE CONFIGURATION

AIM:

1. To draw the input and output characteristics of transistor connected in CE configuration
2. To find β of the given transistor and also its input and output Resistances

APPARATUS:

Transistor, BC107	-1No.
Regulated power supply (0-30V)	-1No.
Voltmeter (0-20V)	-2No.
Ammeters (0-20mA)	-1No.
Ammeters (0-200µA)	-1No.
Resistor, 100Ω	-1No
Resistor, 1KΩ	-1No.
Bread board	
Connecting wires	

THEORY:

In common emitter configuration, input voltage is applied between base and emitter terminals and out put is taken across the collector and emitter terminals. Therefore the emitter terminal is common to both input and output.

The input characteristics resemble that of a forward biased diode curve. This is expected since the Base-Emitter junction of the transistor is forward biased. As compared to CB arrangement I_B increases less rapidly with $V_{BE.}$ Therefore input resistance of CE circuit is higher than that of CB circuit.

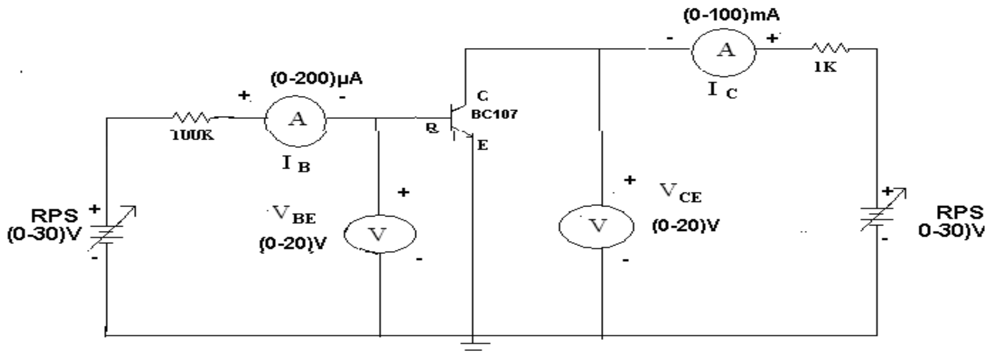
The output characteristics are drawn between I_c and V_{CE} at constant $I_{B.}$ the collector current varies with V_{CE} upto few volts only. After this the collector current becomes almost constant, and independent of $V_{CE.}$ The value of V_{CE} up to which the collector current changes with V_{CE} is known as Knee voltage. The transistor always operated in the region above Knee voltage, I_C is always constant and is approximately equal to $I_{B.}$The current amplification factor of CE configuration is given by

$$\beta = \Delta I_C/\Delta I_B$$

Input Resistance, r_i = $\mathbf{\Delta V_{BE} / \Delta I_B}$ (µA) at Constant V_{CE}

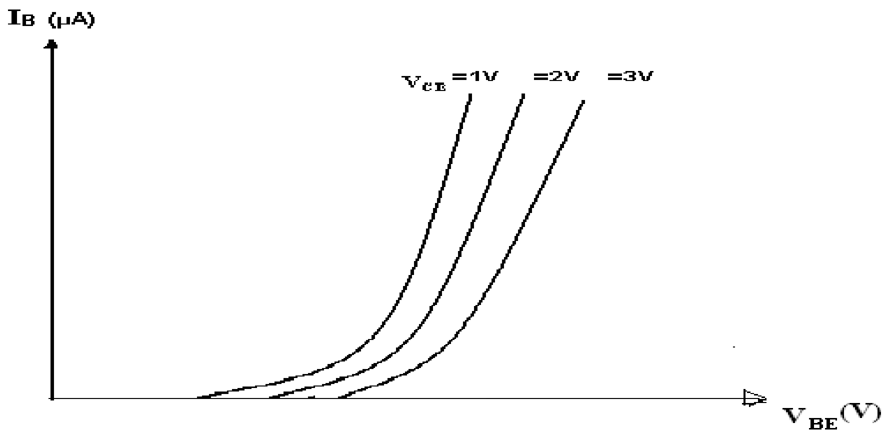
Output Résistance, r_o = $\mathbf{\Delta V_{CE} / \Delta I_C}$ at Constant I_B (µA)

CIRCUIT DIAGRAM:

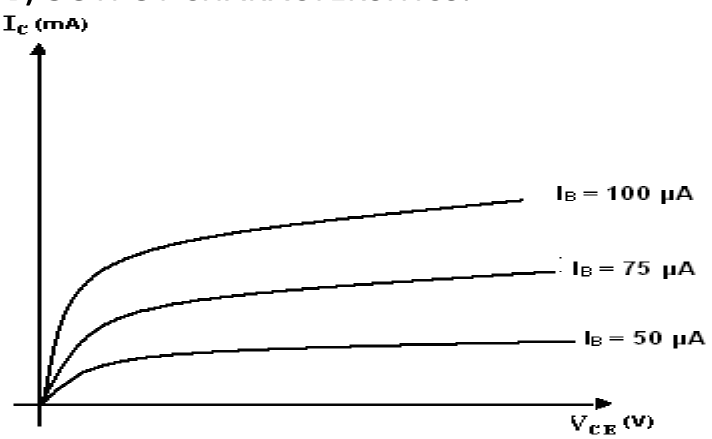


MODEL GRAPHS:

A) INPUT CHARACTERISTICS:



B) OUTPUT CHARACTERSITICS:



OBSERVATIONS:

A) INPUT CHARACTERISTICS:

V_{BB}	V_{CE} = 1V		V_{CE} = 2V		V_{CE} = 4V	
	V_{BE}(V)	I_B(μA)	V_{BE}(V)	I_B(μA)	V_{BE}(V)	I_B(μA)

B) OUTPUT CHAREACTARISTICS:

S.NO	I_B = 50 μA		I_B = 75 μA		I_B = 100 μA	
	V_{CE}(V)	I_C(mA)	V_{CE}(V)	I_C(mA)	V_{CE}(V)	I_C(mA)

PROCEDURE:

INPUT CHARECTERSTICS:

1. Connect the circuit as per the circuit diagram.
2. For plotting the input characteristics the output voltage V_{CE} is kept constant at 1V and for different values of V_{BB} , note down the values of I_B and V_{BE}
3. Repeat the above step by keeping V_{CE} at 2V and 4V and tabulate all the readings.
4. plot the graph between V_{BE} and I_B for constant V_{CE}

OUTPUT CHARACTERSTICS:

1. Connect the circuit as per the circuit diagram
2. For plotting the output characteristics the input current I_B is kept constant at 50μA and for different values of V_{CC} note down the values of I_C and V_{CE}

3. Repeat the above step by keeping I_B at 75 µA and 100 µA and tabulate the all the readings
4. Plot the graph between V_{CE} and I_C for constant I_B

PRECAUTIONS:

1. The supply voltage should not exceed the rating of the transistor
2. Meters should be connected properly according to their polarities

RESULT:

EXERCISE QUESTIONS:

1. For an NPN transistor with α_N= 0.98, I_{CO}= 2µA and I_{EO}= 1.6µA connected in Common Emitter Configuration, calculate the minimum base current for which the transistor enters into saturation region. V_{CC} and load resistance are given as 12 V and 4.0 KΩ respectively.

2. Calculate the values of I_E, α_{dc} and β_{dc} for a transistor with I_B=13µA, I_C=200mA, I_{CBO}=6µA. Also determine the new level of I_C which will result from reducing I_B to 100 mA.

VIVA QUESTIONS:

1. What is the range of β for the transistor?
2. What are the input and output impedances of CE configuration?
3. Identify various regions in the output characteristics?
4. What is the relation between α and β?
5. Define current gain in CE configuration?
6. Why CE configuration is preferred for amplification?
7. What is the phase relation between input and output?
8. Draw diagram of CE configuration for PNP transistor?
9. What is the power gain of CE configuration?
10. What are the applications of CE configuration?

MATERIAL SCIENCE AND STRENGTH OF MATERIALS LAB

LABORATORY MANUAL

B.TECH
(II YEAR – I SEM)

(2018-19)

Department of Mechanical Engineering

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

Recognized under 2(f) and 12 (B) of UGC ACT 1956

Affiliated to JNTUH, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2015 Certified)

PART I

MATERIAL SCIENCE LAB

LIST OF EXPERIMENTS

S.No.	Name of the Experiment
1	Specimen preparation for metallographic examination and study of metallurgical microscope
2	Microstructures of Plain carbon steels
3	Study of microstructures of Plain carbon steels (heat treated)
4	Study of microstructure of Alloy steels
5	Study of microstructures of Cast Irons
6	Study of microstructures of Non ferrous metals
7	Study of structures of some Non ferrous alloys
8	Jominy end quench test
9	Hardening of steels
10	Age Hardening

Exercise-1

SPECIMEN PREPARATION FOR METALLOGRAPHIC EXAMINATION AND STUDY OF METALLURGICAL MICROSCOPE

a. AIM:

a. To prepare the given specimen for metallographic examination.

b. To Study the constructional details of Metallurgical Microscope and observe the micro structure of the prepared specimen.

b. APPARATUS AND MATERIALS REQUIRED:

Metallurgical microscope, emery belt 1/0, 2/0, 3/0, 4/0 emery papers, lapping cloth, alumina powder, etchants, sample of metal.

c. THEORY:

The microstructure of metal decides its properties. An optical microscope is used to study the microstructure. A mirror polished surface of the metal is required for metallographic study.

d. PROCEDURE OF SPECIMEN PREPARATION:

a. Cut the specimen to the required size (small cylindrical pieces of 10 to 15mm diameter with 15mm height or 10mm cubes)

b. The opposite surfaces (circular faces in case of cylindrical pieces) are made flat with grinding or filing. A small chamfer should be ground on each edge for better handling(if the sample is small it should be mounted).

c. **Belt grinding:-** One of the faces of the specimen is pressed against the emery belt of the belt grinder so that all the scratches on the specimen are unidirectional.

d. **Intermediate:-** The sample is to be polished on 1/0, 2/0, 3/0, 4/0 numbered emery papers with increasing fineness of the paper. While changing the polish paper, the sample is to be turned by 90^0 so that new scratches shall be exactly perpendicular to previous scratches.

e. **Disc polishing (fine polishing):-** After polishing on 4/0 paper the specimen is to be polished on disc polishing machine (Buffing machine). In this disc-polishing machine a disc is rotated by a vertical shaft. The disc is covered with velvet cloth. Alumina solution is used as abrasive. Alumina solution is sprinkled continuously over the disc and the specimen is gently pressed against it. In case of Non-ferrous metals such as Brass, Brass is used instead of Alumina and water. The polishing should be continued till a mirror polished surface is obtained.

f. The sample is then washed with water and dried.

g. **Etching**: the sample is then etched with a suitable etching reagent, detailed in article 5.
h. After etching the specimen should be washed in running water and then with alcohol and then finally dried.
i. The sample is now ready for studying its microstructure under the microscope.

e. ETCHING:

Except for few cases a polished metallic surface can't reveal the various constituents (phases). Hence specimen should be etched to reveal the details of the microstructure i.e. a chemical reagent should be applied on the polished surface for a definite period of time. This reagent preferentially attacks the grain boundaries revealing them as this lines. Thus under the microscope the grain structure of the metal becomes visible after etching i.e. grain boundary area appears dark and grains appear bright. The rate of etching not only depends on the solution employed and composition of the material but also on the uniformity of the material. A few etching reagents, their composition and their application are given below.

S.No.	Name of Etchant	Composition	Application
1.	Nital		General structure of Iron and steel
	a)5% Nital	Nitric acid(5ml)and	
		Abs. Methyl alcohol(95ml)	
	b)2% Nital	Nitric acid(2ml) and	General structure of Iron and steel
		Abs, Methyl alcohol (98ml)	
2.	Picral	Picric acid(4gm) and	General structure of Iron and steel
		Abs ethyl alcohol(96ml)	
3.	Marbel's reagent	Copper sulphate (4gm),	Stainless steels
		Hydrochloric acid(20ml) and	
		Water (20ml)	
4.	Murakami's reagent	Potassium ferry cyanide,	

		(10grms), KOH(10grms) and	
		Water(100ml)	Stainless steels
5.	Sodium hydroxide	Sodium hydroxide(10gm) and	
		Water (90ml)	Aluminum & its alloys
6.	Keller's reagent	Hydro fluoric acid(20ml)	
		Nitric acid(10ml) and	
		Glycerin (30ml)	Aluminum & its alloys
7.	Keller's reagent	Hydro fluoric acid(1ml)	
		Hydrochloric acid(1.5ml)	
		Nitric acid(2.5ml) and Water(95 ml)	Duralumin
8.	Ammonium phosphate solution	Ammonium persulphate solution(10gms) and water (90ml)	Copper and copper alloys
9.	Fecl3 solution	FeCl3 (5gms), HCl acid(2ml) and Ethyl alcohol (96gms)	brass

METALLURGICAL MICROSCOPE:

Metallurgical microscope is used for micro and macro examination of metals. Micro examinations of specimens yield valuable metallurgical information of the metal. The absolute necessity for examination arises from the fact that many microscopically observed structural characteristics of a metal such as grain size ,segregation, distribution of different phases and mode of occurrence of component phases and non metallic inclusions such as slag, sulfides etc., and other heterogeneous condition(different phases)expert a powerful influence or mechanical properties of the metal. It is possible to predict as to how metal will behave under a specific stress. Microstructure of metals at magnifications ranging from 50x to 2000x is carried out with the aid of metallurgical microscope.

a) PRINCIPLE:

A Metallurgical microscope is shown in fig.1.1.Metallurgical microscope differs with a biological microscope in a manner by which specimen of interest is illuminated .As metals are opaque their structural constituents Are studied under a reflected light. Is shown fig.1.2. a horizontal beam of light from appropriate source is directed by means of plane glass reflects downwards and through the microscope objective on to the specimen surface. A certain amount of this light will be reflected from the specimen surface and that reflected light, which again passes through the objective, will form an enlarged image of the illuminated area.

A microscope objective consists of a number of separate lens elements which are compound group behave as positive and converging type of lens system of an illuminated object. Specimen is placed just outside the equivalent front focus point of objective. A primary real image of grater dimension than those of object field will be formed at some distance beyond the real lens element. Objective size of primary image w.r.t. object field will depend on focal length of objective and front focus point of objective. By appropriately positioning primary image w.r.t. a second optical system, primary image be further enlarged by an amount related, to magnifying power of eyepiece. As separation between objective and eye piece is fixed at same distance equivalent to mechanical tube length of microscope, primary image may be properly positioned w.r.t eye piece. By merely focusing microscope i.e. increase or decrease or the distance between object plane and front lens of objective the image is formed by objective in conjunction with field of eyepiece and microscope is so focused that primary image is located at focal point. Such precise positioning of primary image is essential in order that final image can be formed and rendered visible to observe when looking into eyepiece. If now entrance pupil of eye is made to coincide with exit pupil eyepiece. Eyepiece lens in conjunction with cornea lens will form a second real image on retina. This retrieval image will be erect, un reversed owing to the manner of response of human brain to excitation of retina. The image since it has no real existence, known as virtual image and appears to be inverted and reversed with respect to object field.

f. a) MAGNIFICATION:

The total magnification is the power of objective multiplied by power of eyepiece

$$\frac{\text{(Power of eye piece) (distance from eye piece to object)}}{\text{Focal length of object}}$$

The magnification is marked on the side objective

b) construction:

The micro scope consists of a body tube (refer fig 1.1), which carries an objective below, and an eyepiece above with plane glass vertical illuminator above the objective. Incident light from a source strikes illuminator at 45^0, part of which is reflected on to the specimen, Rays after reflection pass through the eye again, working table is secured on heavy base. The microscope has compound slide to give longitudinal and lateral movements by accurate screws having scale and verniers. Vertical movement of specimen platform is made by a screw for proper focusing. For getting perfect focusing fine adjustment of focusing can be made use of.

Light Filters:These are used in metallurgical microscope and essentially of three types

a) Gelatin sheets connected between two planes
b) Solid glass filters
c) Liquid dye solution

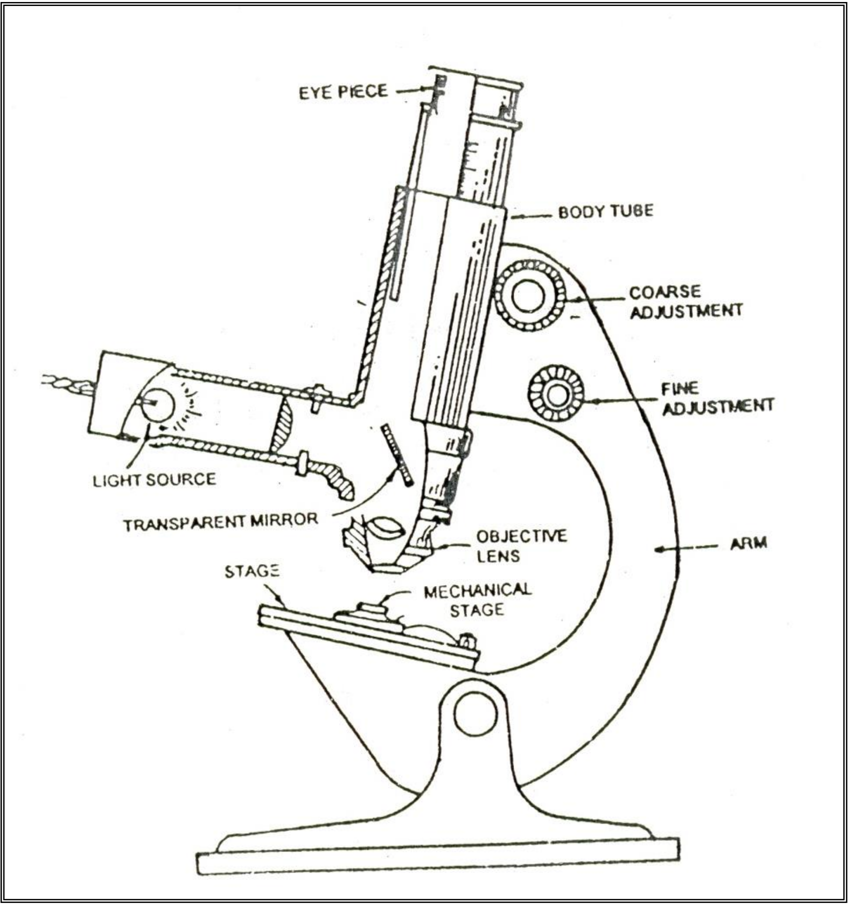
Solid glass filters are more preferable as they are more durable. Usually light filters are used principally to render a quality of illumination. Hence filters improve degree of resolution.
A METZ-57 model microscope is used in the laboratory.
6.2.1 Optical compilation
Eye pieces and objectives of different magnifications are available.
Huygens eyepieces: 5x, 10x
Achromatic objectives 5x, 10x, 45x

PRECAUTIONS:

a. Ensure mirror polished surface of specimen before etching.
b. Fine focusing should be done only after correct focusing has been done.
c. The glass lens should not be touched with fingers.

REVIEW QUESTIONS:

i. What is the use of micro structural study?
ii. What is the difference among 1/0, 2/0, 3/0 and 4/0 emery papers?
iii. What is lapping?
iv. Why the specimen has to be etched before in lapping?
v. What are the different abrasives used in lapping?
vi. Why the specimen has to be etched before micro structural study?
vii. What is the etchant used for mild steel?
viii. In a microstructure how the grain boundary area appears?
ix. Why specimen is to be rotated through 90(between. Polishing on 1/0 and 2/0 emery papers?
x. What is etching reagent used for duralumin?
xi. Why should a specimen be prepared following the set procedure before its observation under a microscope?
xii. Is the specimen preparation necessary at all? If not why not?
xiii. What is the difference between Metallurgical microscope and Biological microscope?
xiv. What is the magnification of the microscope?
xv. What are the different magnifications available in the microscope of our laboratory?
xvi. What are the precautions to be observed while studying microstructure under microscope?
xvii. What is the used of light filters?
xviii. How do you calculate the magnifying power of a microscope



Metallurgical Microscope

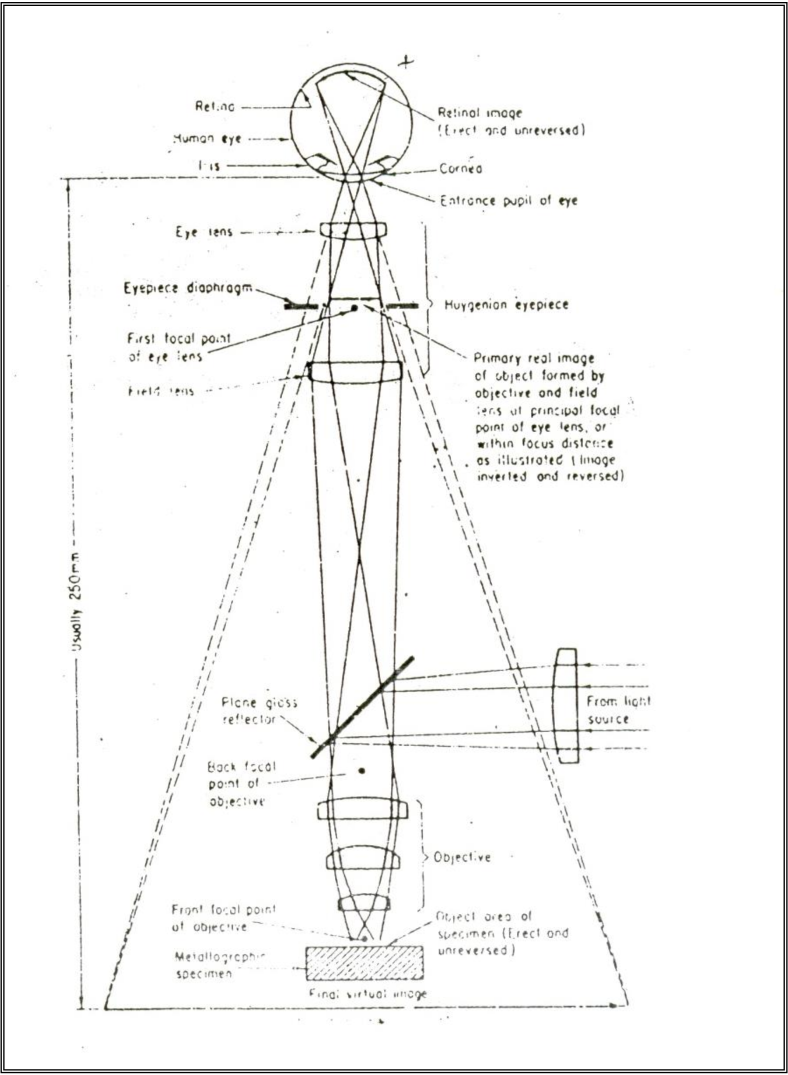


Illustration of Principle of Metallurgical Microscope

Exercise-2

MICROSTRUCTURES OF PLAIN CARBON STEELS

1. AIM

To identity the different phases and to draw the microstructures of Plain Carbon Steels.

2. APPARATUS AND SPECIMENS:

Metallurgical Microscope, specimens of Plain carbon steel of different composition (untreated)

3. THEORY

3.1. Alloy:

Combination of two or more metals is called alloy. The substances that make the alloy are called its components. The metals are mixed together in required proportion when they are in molten form and then they are allowed to solidity together. After solidification the components of alloy may be in the form of solid solution, chemical compound, mechanical mixture.

If the constituents of the alloy completely soluble in both liquid and solid state a solid solution is formed. If constituents of the alloy are completely soluble in liquid state and completely insoluble in solid state a mechanical mixture is formed.

3.1.1 Phases

A homogeneous, Physically distinct and Mechanically separable part of the system under study is known as phase.

3.2.Cooling Curve:

For a molten metal that is cooled from state to room temperature the graph drawn between time on x-axis and temperature on Y-axis is known as cooling curve. A pure metal solidifies at constant temperature.

3.2a. Cooling Curve of Pure metal:

Cooling Curve of pure metal is show in fig.2.1. at 'A' metal is in liquid state. As metal is cooled the solidification starts at "B". As metal is further the temperature of metal remains constant but metal is converted from liquid state to solid state. Solidification is completed at point 'C'. From 'C' to 'D' there is no change in the solidified metal(except fall in temperature).

3.2b. Cooling curve of a solid solution:

If the components of the alloy are completely soluble in both liquid and solid state a solid solution is formed. Cooling curve of solid solution is shown in fig 'A' to 'B' the alloy is in liquid state. Solidification starts at 'B' and solidification ends at 'C'. From 'C' to 'D' there is no change in solid state of alloy. From 3.2 it can be observed that a solid solution alloy is solidified over a range of temperature.

3.2c. Cooling curve of an eutectic alloy:

Cooling curve of a binary eutectic alloy is shown in fig.2.3. from 'A' to 'B' the alloy is in liquid state. As alloy is further cooled from 'B' the temperature of alloy remains constant, and two solids S_1, S_2 start separating out from the liquid separaterly. The alloy gets completely solidified at 'C' and gives a mixture of S1 and S2 (eutectic mixture). From 'C' to 'D' there is no change in the solidified alloy.

3.3 Cooling curve of pure Iron

Cooling curve of pure Iron is shown in fig.2.4 Depending on the temperature Iron exists in separate crystalline forms (α, γ, and δ). Above1539^{0}C Iron is in further cooled to 1400^{0}C Iron is in the form of δ – Iron and at1400^{0}c ALL δ-Iron is converted to γ-Iron. As the iron is still cooled from 1400^{0}C to 910^{0}C Iron is in the form of γ-Iron and at 910^{0}C all γ –Iron is converted to nonmagnetic α-Iron. If the further cooled from 910 at 7680C non magnetic α – Iron is converted to Magnetic α –Iron. If the Iron is further cooled to room temperature Iron exists as magnetic α - Iron only.

4Iron-Iron Carbide equilibrium diagram:

Iron-Iron Carbide equilibrium diagram is shown in fig.2.5

Iron carbon alloys contain less than 2% carbon are called steels and Iron carbon alloy that contains >2 % Carbon alloys cast irons. Steels having <0.8% Carbon, 0.8% carbon and >0.8 carbon are called Hypo eutectoid steels, eutectoid steels and Hyper eutectoid steels respectively.

3.4.1 Curie temperature (768^{0}C):

At curie temperature on cooling Non- magnetic α-iron becomes magnetic.

ABCD is the liquids line and AHJECF the solidus line of the system.(i.e. the alloy will be completely in liquid state at all temperatures above liquids line and will be under solid state at all temperatures below solidus line).

3.4.2 Critical points:

The temperature at which the transformation in solid state occurs are called critical points. In hypo eutectoid steels GS (A3 line) represents upper and lower critical points. In hyper eutectoid steels the line SE(Acm) and SK(A13) and SK(A13) represents upper and lower critical temperatures respectively.

3.4.3 Different phases that appear in Fe-Fe_3C diagram:

a. Ferrite(α): It is an interstitial solid solution of carbon in α-iron, maximum solubility of carbon in α-iron is 0.025% at 723^{0}C

b. Austenite (γ): It is an interstitial solid solution of carbon in γ -iron, maximum solubility of carbon in γ -iron is 0.2% at1130^{0}C

c. Cementite(Fe_3C): It is a chemical compound of Iron and carbon that contains 6.67%carbon by weight.

d. Pearlite: The eutectoid mixture of Ferrite and cementite is called Pearlite.

e. Ledeburite: The eutectic mixture of austenite and cementite is called Lideburite

the three horizontal lines in the diagram (HJB,ECF and PSK) indicate three isothermal reactions at fixed composition and temperature.

3.5Slow Cooling of Hypo Eutectoid steel(0.18% Carbon):

In fig 2.5 alloy 1 represents 0.18% carbon steel. Initially at X, the alloy is in completely liquid state as shown in fig 3.0a. As it is cooled when it crosses 'AB' line δ-iron neucli start forming in liquid Iron. The Micro structure of the alloy at X_2 is shown in fig 2.6b. as alloy is further cooled

cooled. When it crosses' BJ line at J liquid Iron and δ-Iron are combined together at constant temperature to form δ-iron. This reaction is known as peritectic reaction.

L	+	δ Cooling →	γ
(Liquid)	+	(δ-Iron)	(Austenite)

If the alloy is further cooled at X3 the microstructure of the alloy consists of homogeneous solid solution of - γ Iron as shown in fig.2.6c.
Upon slow cooling of alloy from X_3 nothing happens until 'A3' line is crossed. As alloy is cooled below' A3' line ferrite begins to form at austenite grain boundaries. The micro structure of alloy at X4 is shown if fig. 2.6d. As cooling progresses amount of ferrite increases and remaining and remaining austenite becomes richer in Carbon

On further cooling of alloy from X4 it crosses A1 line(lower critical temperature line)at X6. The microstructure of alloy 1 at X5(just above A1 line) is shown in fig 2.6e. the microstructure shows austenite (around 22%) and proeutectoid ferrite (77%).

At X6 the Austenite gets converted into ferrite and cementite(a Mechanical mixture) at constant temperature. This is known as eutectoid reaction.
Austenite δ Cooling → (Ferrite + Cementite) (pearlite)

The eutectoid mixture of ferrite and cementite is known as pearlite. At temperature just below X6 the micro structure shows pearlite and proeutectoid ferrite as shown in fig.2.6f.

On further cooling of the alloy to room temperature no more phase changes are observed. Hence at room temperature micro structure shows pearlite and proeutectoid ferrite.

3.6 Cooling of Eutectoid steel(0.8% Carbon):
In fig 2.5 alloy 2 represents 0.8% Carbon steel. Initially at X1 the alloy is completely in liquid state as shown on in fig.2.7a. On slow cooling once it crosses 'BC' line (liquids line) - γ-iron dendrites start forming in the liquid Iron. At X2 alloy consists of uniform solid solution of γ-iron as shown in fig.2.7c. On further cooling cooling of alloy from X3 no change is observed unit it crosses 'PSK' line (lower critical temperature (7230C) and gets converted into pearlite (mechanical mixture of ferrite and cementite).

Austenite → Cooling (Ferrite + Cementite) (pearlite)

Just below the eutectoid temperature ('PSK') at X4 the alloy consists of 100% pearlite as shown in fig. 2.7d. There is no change in microstructure on cooling of the alloy from X4, to room temperature.

3.7 Cooling of Hyper eutectoid steel (1% Carbon):

In fig 2.5 alloy 3 represents 1% carbon steel, initially at X1 the alloy is completely in liquid state as shown in fig.2.8a. on a slow cooling from observed till 'BC' line (liquid line) is crossed. Once 'BC' line is crossed on further cooling of alloy to X2 austenite crystals start neucleating from liquid iron as shown in fig.2.8b. as cooling is continued more and more amount of austenite is formed. By the time it crosses the line 'JE' all liquid iron is converted to austenite. At X3 the alloy consists of uniform solid solution of austenite as shown in fig.2.8c. On show cooling of alloy from X3 nothing happens until 'Acm' line is crossed at X4. Above X4 austenite is an unsaturated solid solution. At X4 austenite is saturated with carbon. As the temperature is decreased, carbon content of austenite (maximum amount of carbon that be disolved in austenite) decreases along grain boundaries. The micro structure of alloy at X5 in shown in fig.2.8d. On further cooling of alloy, once temperature of alloy crosses lower critical temperature line ('PSK' line) at X7 the austenite present in the alloy undergoes eutectiod reaction and gets converted into pearlite. Just below A3.1, line ('SK' line) at microstructure of alloy shows around 96% pearlite and continuous network of cementite (around 4%) as shown fig 2.8e.

3.8 Plain Carbon Steels:

The usual composition of plan carbon steel is as follows

Carbon 0.08 to 1.7%; Mn 0.3 to 1.0%; silicon 0.05 to 0.3%; Sulphur 0.05(max); Phosphorus 0.05 %(max)

In plain carbon steels, carbon percentage plays a vital role in deciding the properties of steels. Depending on the carbon percentage plain carbon steels are divided into three types.

a.Low carbon steel(Mild steel) b. Medium carbon steel c. High Carbon steel

The microstructure of low carbon steel (Mild Steel) consists of single phase ferrite, (equi axial grains) i.e., it doesn't respond much to the heat treatment. The properties don't vary to any treatment given to the mild steel. It remains mild.

4The following specimens are to be studied for their Microstructures in this exercise

a. Mild Steel

Specimen	:	Mild Steel
Composition	:	Very low carbon(0.05%), remaining iron
Heat treatment	:	Nil
Etchant	:	Nital
Etching time	:	10 seconds

The structure is single phase equiaxed grains of ferrite.

Application: nuts, bolts, rivets, shafts etc.

b. Hypo eutectoid steel:

Specimen	:	Hypo eutectoid steel
Composition	:	0.5% carbon, remaining iron
Heat treatment		: Nil
Etchant	:	Nital
Etching time	:	10 Seconds

The microstructure shows ferrite and pearlite.

c. Eutectoid steel:

Specimen	:	Eutectoid steel
Composition	:	0.8% carbon, remaining iron
Heat treatment	:	: Nil
Etchant	:	Natal
Etching time	:	10 Seconds

The microstructure of eutectoid steel consists of 100% pearlite

d. Hyper eutectoid steel

Specimen	:	Hyper eutectoid steel(High carbon steel)
Composition	:	1% carbon, remaining iron
Heat treatment	:	Nil
Etchant	:	Natal
Etching time	:	10 Seconds

The microstructure shows continuous network of cementite along the grain boundaries of coarse pearlite.

5.REVIEW QUESTIONS:

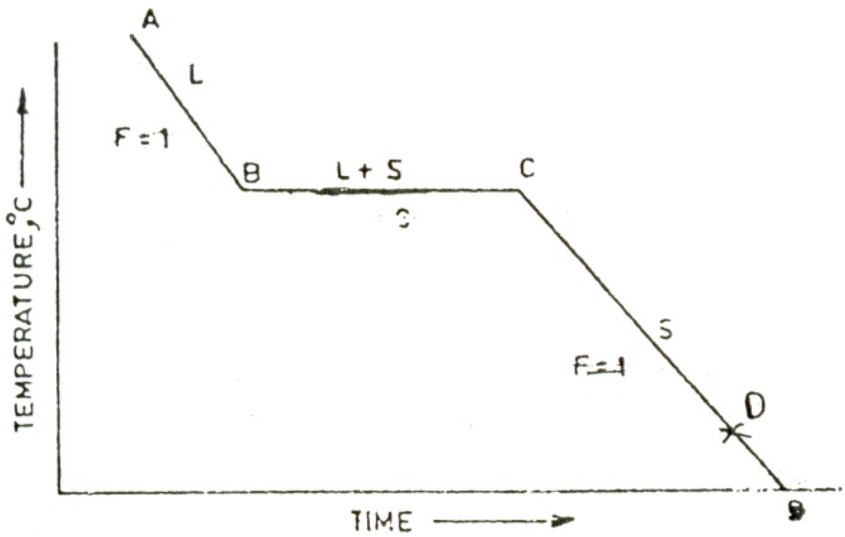
i. What is a cooling curve?
ii. What is the use of equilibrium diagram?
iii. What is curie temperature?
iv. What is the percentage of carbon in cementite?
v. What are the different phases in Fe-Fe3C equilibrium diagram?
vi. How Cast iron and steel are distinguished with respect to carbon percentage?
vii. What is eutectoid reaction?
viii. What is eutectoid reaction?
ix. What is peritectic reaction?
x. What is peritectoid reaction?
xi. Draw the microstructure of eutectoid steel?
xii. Draw the microstructure of Hypo eutectoid steel?
xiii. Draw the microstructure of Hyper eutectoid steel?
xiv. What is the maximum solubility of carbon in ferrite?
xv. What is the maximum solubility of carbon in Austenite?

xvi. What are the properties & applications of mild Steel?

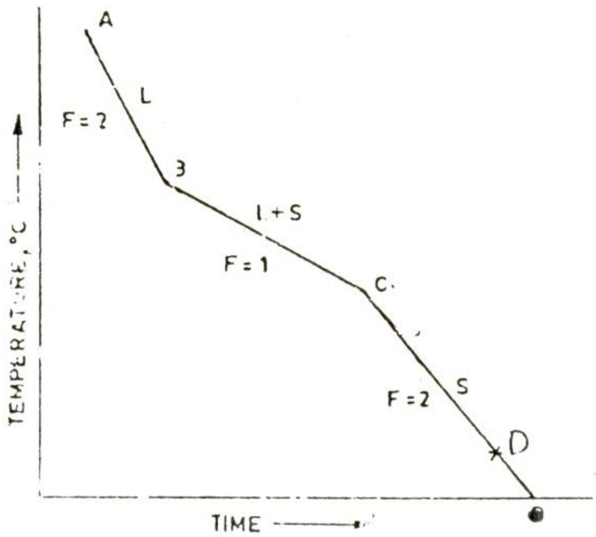
xvii. What are the properties & applications of medium carbon steel(hypo eutectoid steel)?

xviii. What are the properties & applications of Eutectoid steel?

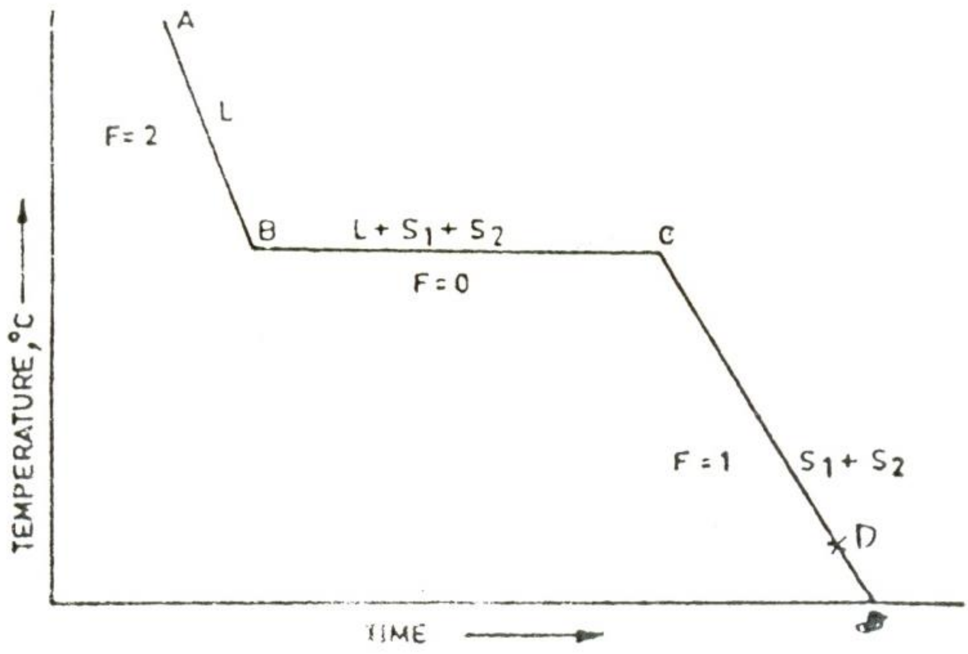
xix. What are the properties & applications of Hyper eutectoid steel?



Cooling curve of a pure metal.



Cooling curve of a solid solution alloy.



Cooling curve of an eutectic alloy.

Figure 1 Cooling curve of a pure metal

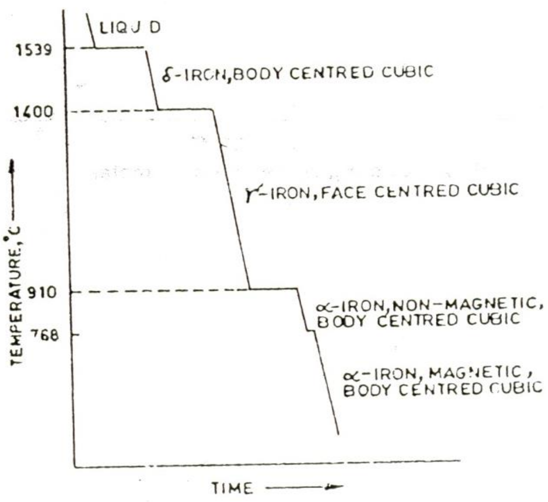


Fig. 2.4 Cooling curve of pure iron

Figure 2Cooling curve of pure Iron

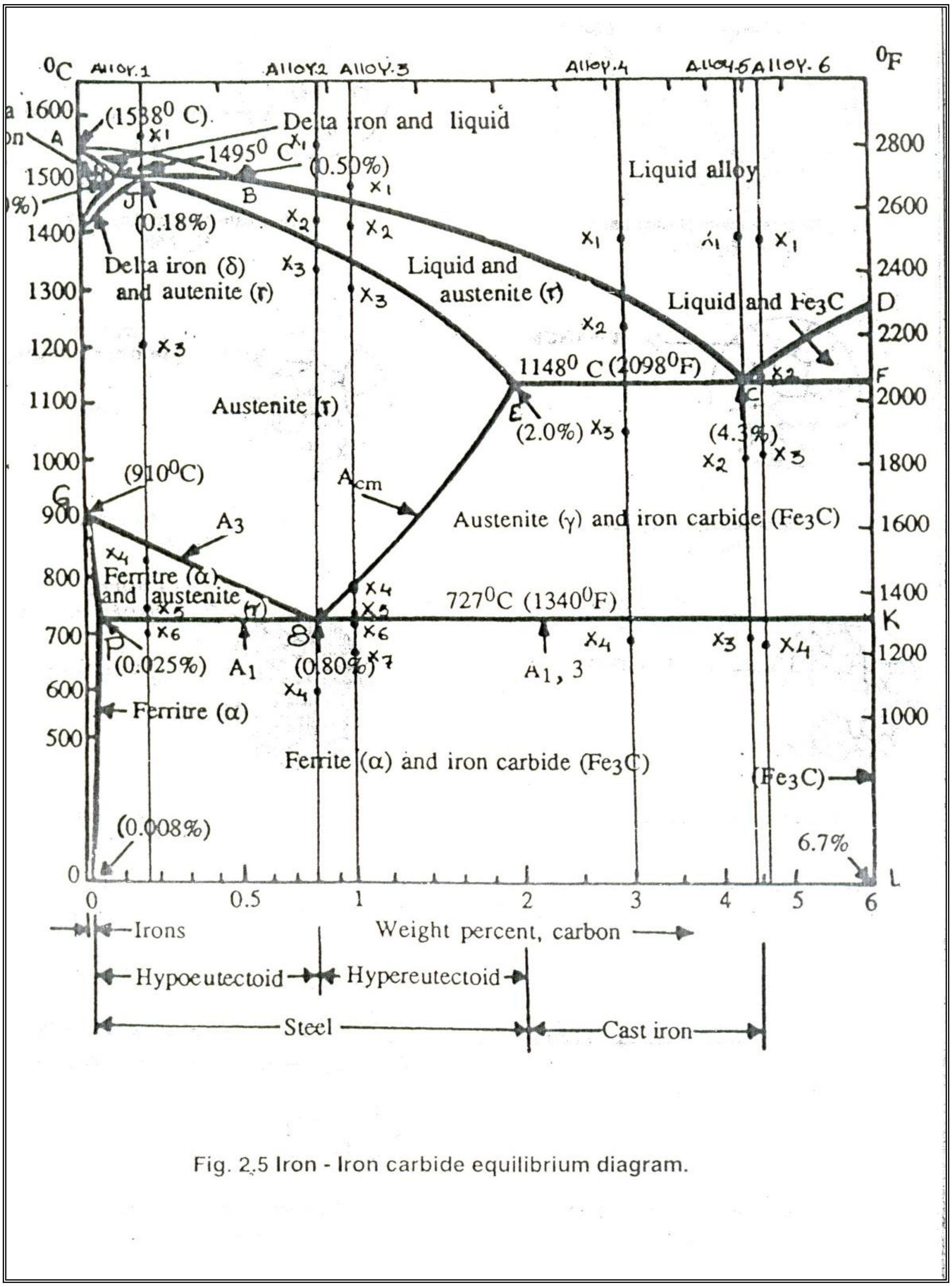
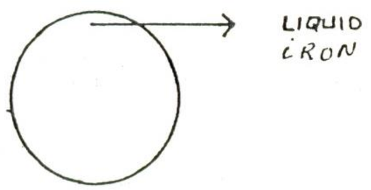
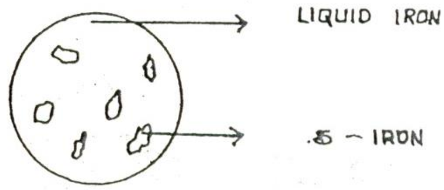


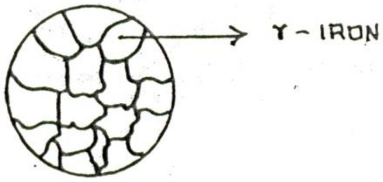
Figure 3Iron-Iron carbide equilibrium diagram



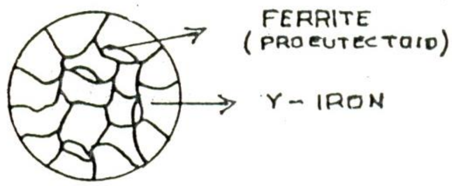
Miscrostructure of alloy 1 at X_1
Fig. 2.6a.



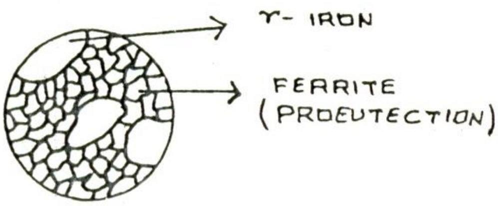
Miscrostructure of alloy 1 at X_2
Fig. 2.6b.



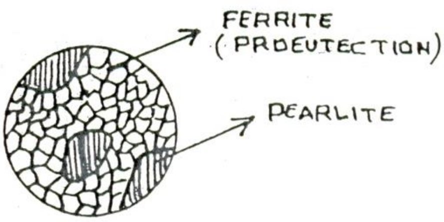
Miscrostructure of alloy 1 at X_3
Fig. 2.6c.



Miscrostructure of alloy 1 at X_4
Fig. 2.6d.

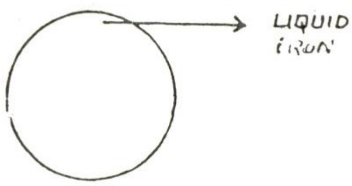


Miscrostructure of alloy 1 at X_5
Fig. 2.6e.

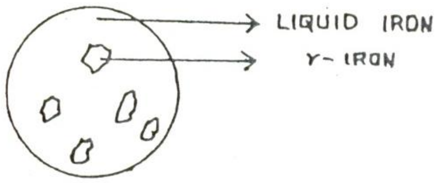


Miscrostructure of alloy 1 at X_6
Fig. 2.6f.

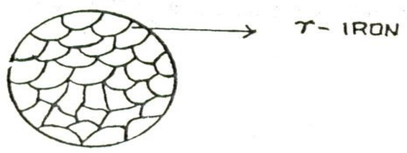
Fig. 2.6 Microstructures of alloy 1 with % of carbon is 0.18 (slowly cooled from liquid state to room temperatu at different temperature levels.



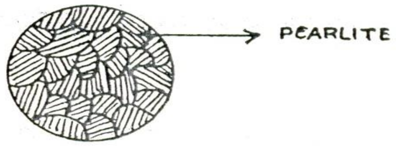
Miscrostructure of alloy 2 at X_1
Fig. 2.7a.



Miscrostructure of alloy 2 at X_2
Fig. 2.7b.

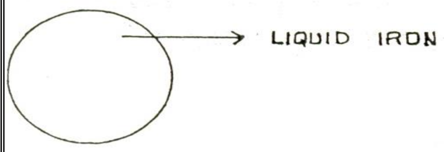


Miscrostructure of alloy 2 at X_3
Fig. 2.7c.

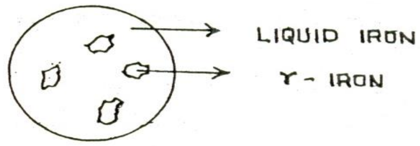


Miscrostructure of alloy 2 at X_4
Fig. 2.7d.

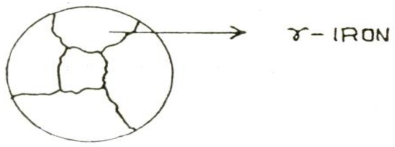
Fig. 2.7 Microstructures of alloy 2 with % of carbon is 0.8 (slowly cooled from liquid state to room temperature) at different temperature levels



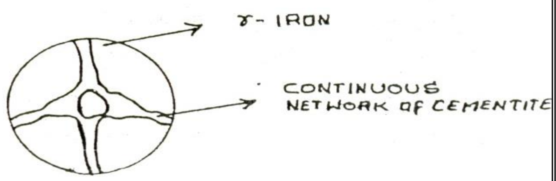
Miscrostructure of alloy 3 at X_1
Fig. 2.8a.



Miscrostructure of alloy 3 at X_2
Fig. 2.8b.



Miscrostructure of alloy 3 at X_3
Fig. 2.8c.



Miscrostructure of alloy 3 at X_5
Fig. 2.8d.

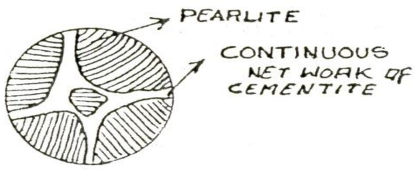


Fig. 2.8e. (Miscrostructure of alloy 3 at X_7)

g. 2.8 Microstructures of alloy 3 with % of carbon is 1.0 (slowly cooled from liquid state to room temperature) at different temperatures

Exercise-3

STUDY OF MICROSTRUCTURES OF PLAIN CARBON STEELS (HEAT TREATED)

1.AIM:

To identify the different phases and to draw the microstructures Heat treated plain carbon steel.

2. Apparatus and specimens required:

Metallurgical microscope, specimen of high carbon steel subjected to annealing, normalizing, hardening and Hardening & tempering.

3.Theory:

3.1 Heat Treatment: It involves heating the metal to a suitable temperature within the solid state, maintaining the sample at that temperature for a specified period of time and cooling it ti room temperature in a controlled manner.

The purpose of heat treatment may be

- To relieve internal stresses and soften the metal for further deformation.
- To refine the grain size improve mechanical properties.
- To alter the surface condition
- To increase corrosion and wear resistance.

3.1.1 Different Heat treatment processes are:

a. Annealing b. Normalizing C. Hardening d. Tempering e. Surface hardening treatments

3.2 Time Temperature and Transformation Diagram(TTT diagram):

The TTT Diagram super imposed with different cooling austenitising temperature to room temperature is shown in fig.3.1

In fig. 3.1 V_1 represents annealing (with slow cooling in the furnace)

V_2 represents normalizing (a little faster cooling i.e. in air)

V_c represents Critical cooling rate (more faster cooling in a bath of a mixture)

V_5 represents Hardening (very fast cooling-dipping the specimen in oil or water)

3.3 Annealing:

The main purpose of annealing is stress relieving so that ductility of the steel can be improved to a greater extent. The annealing temperature range of steel is shown in fig.3.2

Annealing process cycle on Time-temperature diagram is show in fig.3.4 Annealing process consists of

a. Heating the specimen of steel to a temperature (above A_3 line in case of Hypo eutectoid steels and above A_3, line case of Hyper eutectoid steels)

b. Holding specimen at that temperature for a specified period of time(depending on the section thickness)

c. Then cooling the steel specimen to the room temperature in the furnace itself. The annealed structure of Hypo eutectoid steel consists of Ferrite and coarse pearlite.

3.4 Normalising: the purpose of Normalizing is to

a. Relieve the internal stresses

b. Refine the structure and improve the machinability. Normalising temperature range of steels is shown in fig.3.2 Normalizing process cycle Time-Temperature diagram is shown in fig. Normalizing process consists of

a. Heating the specimen of steel to a temperature (30 to 500C above A3 line in case of hypereutectoid steels and above Acm line in case of hyper eutectoid steels.)

b. Holding the specimen at this temperature for a specified period of Time.

c. Then cooling the specimen to the room temperature in air. Normalized Hypo eutectoid steel consists of Ferrite and fine Pearlite.

3.5 Hardening:Main purpose of hardening is to improve the hardness & wear resistance of steels. Temperature range of hardening of steels is shown in fig.3.3

Hardening process cycle on Time-Temperature diagram is shown in fig. 3.6. Hardening process consists of

a. Heating the steel specimen to a temperature (500C higher than A3 line in case of hypo eutectoid steel and around 500C higher than A3 line in case of hyper eutectoid steel)

b. Holding at that temperature for sufficient period of time.

c. Quenching in water or oil to cool the specimen of steel to room temperature. The microstructure of hardened hyper eutectoid steel consists of fine martensite embedded with carbon network.

3.6 Tempering: Main purpose of tempering are

a. To reduce the thermal stresses.

b. To stabilized the structure of metal.

c. To reduce the hardness and brittleness.

d. To increase ductility and toughness of hardened steel specimens. Tempering process cycle on Tim-Temperature diagram is shown in fig.3.7 Tempering process consists of heating the specimen to a temperature below lower critical temperature for sufficient period of time and then slowly cooling to room temperature.

Microstructure of hardened and tempered steel consists of Ferrite and finely divided cementite.

3.7 Case hardening: For certain application hard ware resistant case and tough core is required. To get hard case and tougher core steels must be subjected to Case hardening treatment.

3.8 Case hardening methods:

Case hardening methods are broadly divided into two types.

a. Methods of case hardening by altering the surface chemical composition of the components. examples of this type are (i) carburizing (ii) Nitriding (iii) Carbonitriding.

b. Methods of case hardening without altering the surface chemical composition of the components. Examples of this type are (1) Flame hardening (2) induction hardening.

3.9 Methods of case hardening by altering surface chemical composition of the components

3.9.1 Carburizing: the method of increasing the carbon content on the surface of a steel is called carburizing. The process of carburizing consists of heating the steel in austenite region in contact with a carburizing medium, holding at his temperature for a sufficient period and cooling to room temperature.
Depending on the medium used for carburizing it is classified into three types (i) Pack carburizing (ii) Gas carburizing (iii) Liquid carburizing.
3.9.1 a) Pack carburizing : The components to be carburized are packed with a carbonaceous medium 9carbonaceous medium consists of hard wood charcoal, coke and energizer(barium carbonat0 in a box and sealed with clay. The box is heated to austenitic region and then cooled to room temperature.
3.9.1 b) Gas Carburizing: Here the components are heated in austenetic region in the presence of a carbonaceous gas such as methane, ethane with a carrier gas such as flue gas. These gases decompose and the carbon diffuses into steel.
3.9.1 c) Liquid Carburizing: in this method carburizing id done by immersing the steel components in a carbonaceous fused salt bath medium (bath is composed of 10% sodium cyanide, sodium carbonate and sodium chloride) at a temperatures in the austenite region for sufficient time and then cooling to room temperature.
3.9.2 Nitriding: Nitriding is accomplished by heating steel in contact with a source of atomic nitrogen (ammonia gas) at a temperature of around 550^0C for sufficient time and they cooling to room temperature. The atomic Nitrogen diffuses into steel and cambiues with iron and carbon alloying elements present in steel and form respective nitrides. These nitrides increase hardness and wear resistance of steels.
3.9.3 CarboNitriding: The components to be carbonnitrided are heated in a fused salt bath or in a gaseous medium (gaseous medium contains carbunizing gases like CH_4, C_2H_6 with 5 to 10% Ammonia) to a temperature between A_1 and A_3 temperatures of steel for sufficient period of time and are then cooled to room temperature. In this process both carbon and Nitrogen are diffused into the surface of steel.
3.10 Methods of case hardening without altering the surface chemical composition of components.
3.10.1 Flame hardening: This process consists of heating the surface layer of the component to above its upper critical temperature by means of oxyacetylene flame followed by water spray quenching or immersion quenching to transform austenite to martensite.
3.10.2 Induction Hardening: This process also increases surface hardness by heating and quenching a thin surface layer of components. Here heating is done by means of an induction coil.

4.The Micro structures of following specimens are studied in this exercise.

a. High carbon steel.

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Annealing
Etchant	:	Nital
Etching time	:	10 seconds

The annealed structure of high carbon steel consists of continuous network of cements and pearlite.

b. High carbon steel.

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Normalized
Etchant	:	Nital
Etching time	:	10 seconds

The normalizing continuous network cementite is broken. The microstructure shows cementite and pearlite.

c. High carbon steel.

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Hardened
Etchant	:	Nital
Etching time	:	10 seconds

The microstructure consists of martensite and carbon network.

d. High Carbon steel

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Hardened & Tempered
Etchant	:	Nital
Etching time	:	10 seconds

The microstructure consists of tempered martensite and epsilon carbide.

4. REVIEW QUESTIONS

i. What is the Annealing temperature range of Hypo eutectoid steels?
ii. What is the hardening temperature range of Hyper eutectoid steels?
iii. Why hardened steel specimens are subjected to tempering?
iv. What is the normalizing temperature range of hyper eutectoid steels?
v. How the soaking time in furnace is decided ? Mention the times required for 1 cm thickness, 5cm thickness, 10cm thickness etc.

vi. Explain the properties of Hypereutectoid, eutectoid, Hyper eutectoid steels, before and after heat treatments?
vii. Show Time Temperature diagram for different types of plain carbon steels?

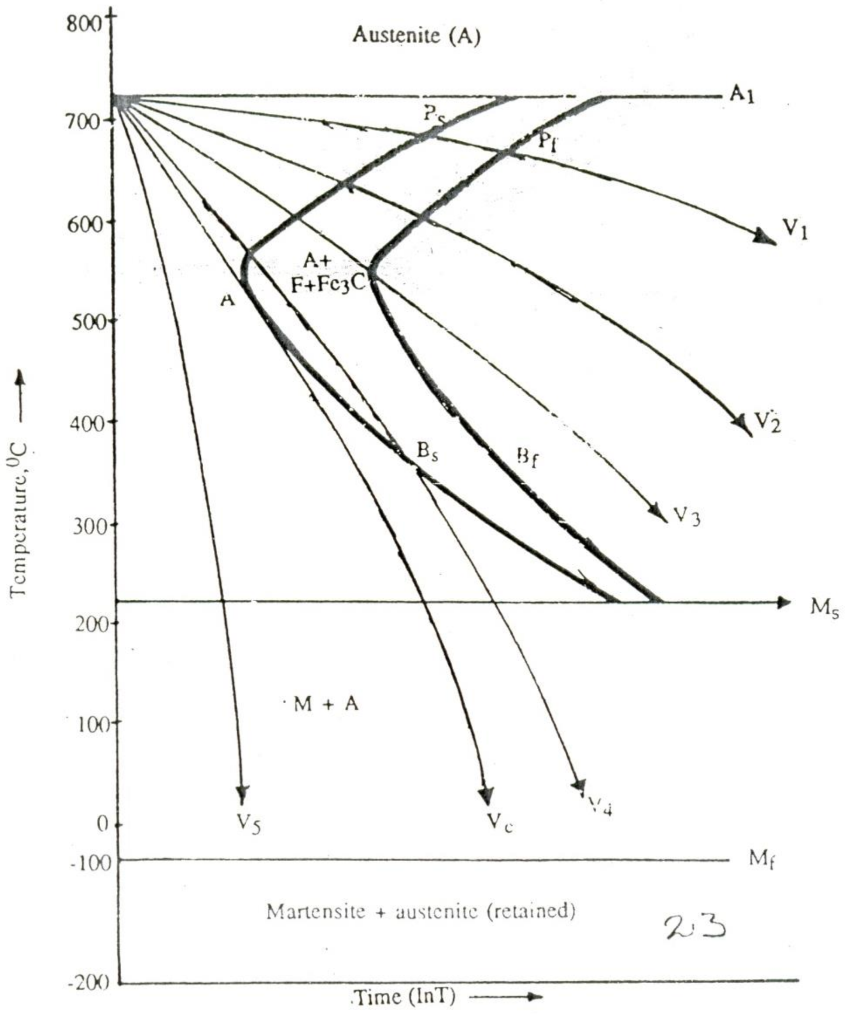


Fig. 3.1 TTT diagram (super imposed with different cooling rates)

TTT diagram(super imposed with different cooling rates)

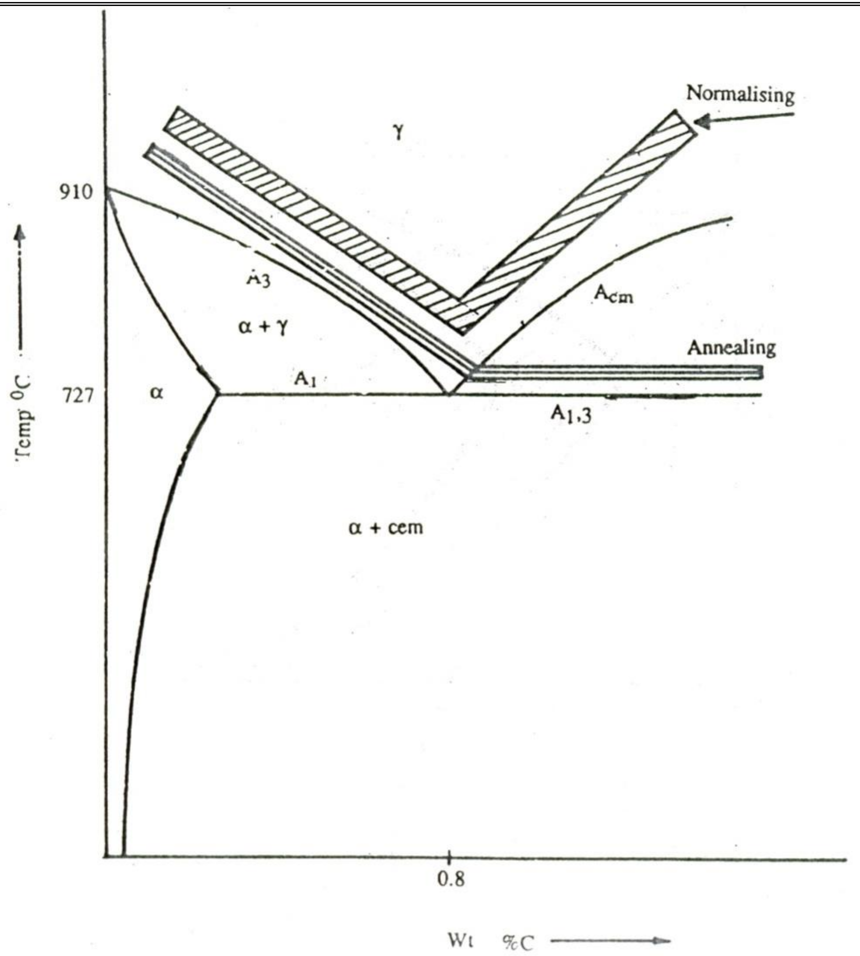


Fig. 3.2 Annealing and Normalising temperature ranges of steels

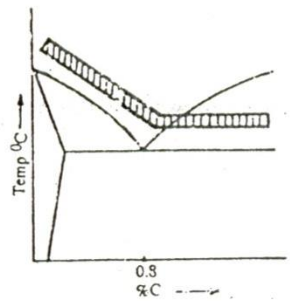


Fig. 3.3 Hardening temperature range of steels

Figure 4 Hardening temperature range of steels

Figure 5 Annealing and Normalising temperature ranges of steels

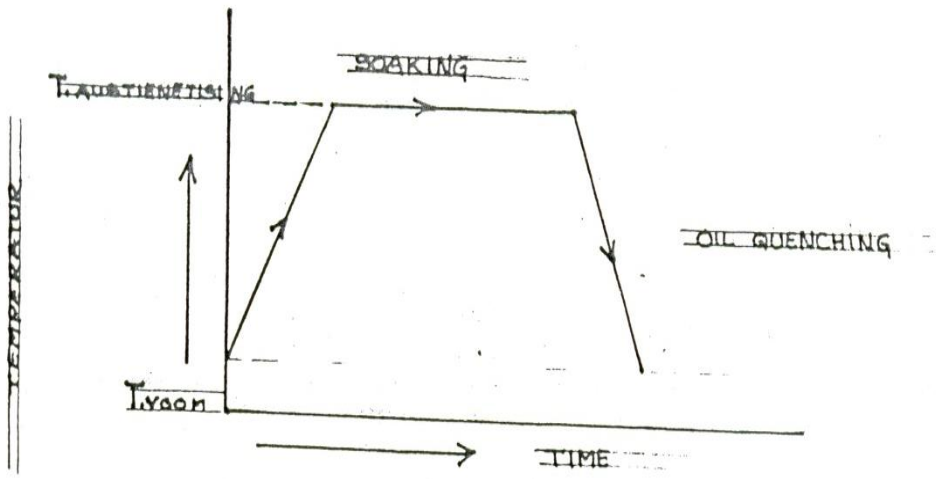


Fig. 3.6 Heat treatment cycle for Hardening on Time - Temperature diagrams for different types of steels

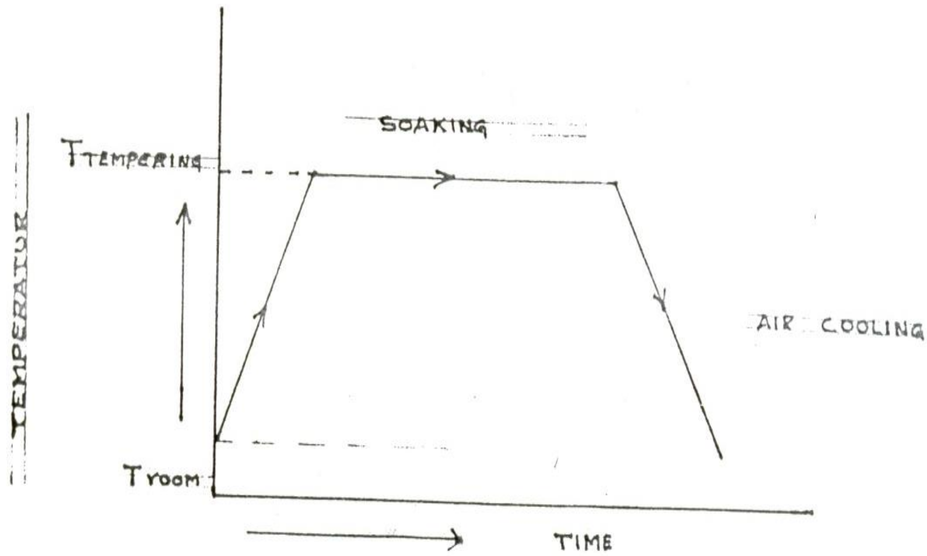


Fig. 3.7 Heat treatment cycle for tempering on Time - Temperature diagrams for different types of steels

Exercise-4

STUDY OF MICROSTRUCTURE OF ALLOY STEELS

1. **AIM**:To identify the different phases and to draw the microstructure of alloy steels.

2. **APPARATUS AND SPECIMEN REQUIRED:**

   Metallurgical microscope, specimens of different Alloy Steels.

3. **THEORY:**

   Steels are to be alloyed for improving their mechanical properties. Common alloying are Al, Ni, Mn, Cr,, etc., However, the properties of alloy steels are not so much superior to plain carbon steels in untreated Cr, etc., However the properties of alloy steels are not so much supervisor to plain carbon steels in untreated condition. Different heat treatments are given to alloy steels to fully exploit their properties.

   a. **Effect of Alloying Elements:** Alloying elements may have one or more of the following effects.

      i. **Solid solution strengthening/Hardening:** Most of the alloying elements are soluble in ferrite to some extent and form solid solutions are harder and stronger than the pure metals and hence these elements increase strength and hardness of steels.

         Examples: Mn, Cr, W, Mo, V, Ti, Si, Al, Zr........

      ii. **Formation of carbides:** Some of the alloying elements combine with carbon in steel and form respective carbides. These alloy carbides are hard and increase wear and abrasion resistance of steels.

         Examples: Mn, Cr, W, Mo, V, Ti, Si, Zr and Nb........

         These phases increase the brittleness of steel and hence their presence in undesirable

      iii. **Formation of Intermediate Compounds:** Some of the elements from intermediate compounds with iron e.g. Fe, Cr(sigma phase in high chromium alloys) and Fe3W2 (in tool Steels).

         Examples: W, V, Ni, Si, Al, Zr, Cr, and Ti....

      iv. **Formation of inclusions**: They may combine with oxygen and form oxides when added to steel.

         Examples: Si, Al, Mn, Cr, V, and Ti...

      v. Shifting of critical temperature and eutectoid carbon: The alloying element may lower or raise the transformation temperature of steel. Elements, which are austenite stabilizers like Ni and Mn, lower the eutectoid temperature (A) while the elements, which are austenite stabilizers like Ni and Mn, lower the eutectoid temperature (A) while the elements, which are ferrite stabilizers, raise the above temperature.

Most of the alloying elements shift the eutectoid carbon to lower values e.g. the carbon content of eutectoid in a 12% Cr steel is less than 0.4% as against to 0.8% in plain carbon steels.

vi. Lowering of critical cooling rate: Most of the alloying elements (except Co) shift the T.T.T diagram to the right side, thus decreasing the critical cooling rate. This effect is very useful for increasing the hardenability of steel. Elements such as Mn, Mo, Cr and Ni are more effective in increasing the hardenability.

vii. Changes in volume during transformation: Elements may be chosen in proper proportion so as to reduce in volume change to reduce distortions and the risk of quench cracking during hardening.

Other effects:

i. The transformation may become sluggish

ii. The corrosion and oxidation resistance may increase e.g. chromium increases corrosion resistance by forming a thin of chromium oxide on the surface. This is found in stainless steels.

iii. Creep strength may get increased due to the presence and dispersion of fine carbides.

iv. Fatigue strength may also get increased.

b. Classification of Alloying Elements:

With respect relation with Carbon, alloying elements can be classified into 3 groups.

a. Carbide forming elements: They form carbides when added to steels or cast irons.

Examples: Ti, Zr, V, nb, W, Mo, Cr, Mn.....

b. Neutral Elements: Cobalt is the only element in this category, which neither forms carbides nor causes graphitization.

c. Graphitizing elements: They try to decompose the carbides into graphite, in cast irons.

Examples: Ni, Si, Cu, Al

With respect to their effect on the temperatures intervals in which allotropic forms of iron exists alloying elements can be classified into 2 groups.

a. Austenite stabilizers: The elements from this group raise A_4, temperature and lower A_3, temperature, thus increasing the range of stability of austenite.

Example: Mn, Ni, Cu, C, N....

b. **Ferrite Stabilizers:** These elements lower A4 temperature and raised A3 temperature, thus increasing the range of stability of ferrite.

Examples: Cr, W, Mo, V, Ti, Ni, Si, Al, Zr, B ,Nb, P............

c. **Uses of Alloying Elements:**

a. **Sulphur:** Sulphur combines with iron and forms iron sulphide and induces brittleness phase.
b. **Phosphorus:** Phosphorus dissolves in ferrite and increases its tensile strength and hardness.
c. **Silicon:** It is ferrite solid solution strengthener. It dissolves in ferrite increasing strength, hardness and toughness without loss of ductility. It is a strong graphitizer in cast irons.
d. **Manganese:** It dissolves in ferrite and increases yield strength tensile strength, toughness and hardness. It combines with sulphur and forms MnS reducing the detrimetal effect of FeS
e. **Nickel:** It is ferrite solid solution strengthener. It dissolves in ferrite and increases hardness, tensile strength and toughness without decreasing ductility. It increases impact resistances of steels at low temperatures i.e., it reduces ductile-brittle transition temperature.
f. **Chromium:**
Chromium has several functions as given below:
   i. It forms carbides hardenability of steels.
   ii. It forms carbides and increases hardness and wear resistance of steels.
   iii. It increases corrosion and resistance when added in substantial amount.

   Chromium has following disadvantages
   i. It makes the steel susceptible to temper embrittlement.
   ii. These steels are liable to form surface markings, generally referred to as chrome line.
g. **Tungsten:**
It has following functions:
   i. It increases harndenability.
   ii. It forms carbides and increases wear and abrasion resistance.
   iii. It refines the gain size and the carbides inhibit the grain coarsening.
   iv. It reduces the tendency of decarburization.

h. **Molybdenum:**

Molybdenum has similar functions as Tungsten. However, its resistance to grain coarsening and decarburization is less as compared to Tungsten.

i. **Vanadium:**

The Properties of vanadium containing steels are on similar lines as tungsten or/ and molybdenum containing steels. However, vanadium containing steels have improved distinct properties below:

i. The resistance to grain coarsening is excellent.
ii. The carbides of vanadium are extremely hard and hence, vanadium promotes secondary hardening during tempering.
iii. It effectively improves the fatigue and creep resistance.
iv. It is strong deoxidizer.

j. **Titanium:** It is strong carbide former it effectively inhibits grain coarsening and also acts as a grain refiner.
k. **Cobalt**: It is neither carbide former nor a graphitizer. It is the only element, which reduces hardenability of steels.
l. **Aluminum**: It is a powerful deoxidizer and hence is used for killing of steels. It is a grain refiner and also inhibitor.
m. **Boron**: small additions of boron (0.001 – 0.003%) sharply increase hardenability of medium carbon steels.

4. **The Microstructure of following Alloy steels are studied in this exercise.**

a. High Speed Tool Steel: The Important characteristics of Tool Steels are

i. High hardness at elevated temperatures ii) High wear resistance iii) High Hardenability iv) Good toughness

The steels maintain high hardness up to a temperature about 550^{0}C. These are designated by T-series.

Specimen : High speed steel
Composition Treatment : 0.7%C, 18% W, 4% Cr, 1%V
Heat treatment : Heated to a temperature of 1250-1300^{0}C, soaked this temperature for every short period of time. The steel is then quenched in oil to room temperature. The steel is then multiple tempered at 550^{0}C at which it shows secondary hardening.
Etchant : Nital
Etching time : 20 Seconds

The microstructure consists of tempered martensite, alloy carbides and low carbon retained austenite.

Application time : Cutting tools

b. Stainless steel: These steels have high corrosion resistance

Specimen : Stainless(Austenitic)
Composition : <0.15%C, 18% Cr, 10% Ni

Etchant : Nital
Etching time : 20 seconds

The microstructure consists of Austenite grains. The dark regions are due to alloy carbide precipitation.

Applications: Utensils, Chemical plant equipment, Medical equipment Blades etc.,

c. **High Carbon high Chromium steel**: These steels have very high hardenability and very less distortion during hardening.

Specimen	:	High carbon high chromium steel
Composition	:	1.5%C, 12% Cr, 1% Mo
Heat treatment	:	Hardened and tempered
Etchant	:	Nital
Etching Time	:	20 seconds

The microstructure consists of tempered martensite. The dark areas are alloy carbides.

Applications: Drawing dies, Blanking dies etc

d. **En36:**

Specimen	:	En36
Composition	:	0.15%, 0.6%Mn, 3.35%Ni, 1.1%Cr, 0.35% Si
Heat treatment	:	Case Carburizing
Etching	:	Nital
Etching time	:	10 Seconds

The microstructures shows a while compound layer of few microns thick at the surface and Ferrite and pearlite at the core.

Applications: These are used where a hard case and a tough core is required. Boring bits etc.

5.REVIEW QUESTIONS:

i. Why alloying elements are added to steels?
ii. How negative effects of sulphur in steels will be neutralized?
iii. What is the composition of stain less steel?
iv. What are the important characteristic of Tool steels?
v. What is the composition of H.S.S?
vi. What makes High Carbon high chromium steel suitable for making dies>
vii. Show the heat treatment cycles, n Time-Temperature diagrams for different types of Steels?
viii. Compare the properties of alloy steels with and without heat treatment?

Exercise-5

STUDY OF MICROSTRUCTURES OF CAST IRONS

1. **AIM:**
   To Identify the different phases and to draw the microstructures of different cast Irons.
2. **APPARATUS AND SPECIMENS REQUIRED:**
   Metallurgical microscope, specimen of different cast irons
3. **THEORY**
4. Cast irons are Iron carbon alloys in which carbon content varies from 2 to 6.67%. cast-iron that contain carbon percentage between 2 to 4.3% are called Hypo eutectic cast irons. If carbon content of cast-iron is 4.3% it is called Eutectic cast iron. If the carbon content is above 4.3% it is called Hyper eutectic cast iron.

3.1 Cooling of a Hypo eutectic cast iron (3% carbon):

Alloy in fig.2.5(Iron-Iron carbide equilibrium diagram) represents Hypo eutectic cast iron with 3% carbon. Initially at point X_1, the alloy is in completely liquid state as shown in fig.5.1a. as it is slowly cooled no change is observed until it crosses 'BC' line (liquid line). After crossing 'BC' line austenite dendrites start forming from liquid iron. At X_2 the microstructure of alloy shows dendrites of protectoid austenite in liquid iron as showing in fig.5.1b. on further cooling of alloy when it crosses 'ECF' line(eutectic temperature line) liquid of alloy undergoes eutectic reaction at constant temperature (1130^0C) and transforms into lideburite (eutectic mixture of austenite and cementite)

Liquid eutectic cast Iron (Lideburite) $\xrightarrow{\text{Cooling}}$ (Austenite + Cementite)

The microstructure of alloy at X3 consists of dendrites of primary austenite, eutectic austenite and cementite as shown in fig.5.1c. on further cooling of alloy there is no considerable change in microstructure except increase of cementite (This cementite is separated from austenite because of decrease of solubility of carbon n austenite as temperature is reduces).

On further cooling of alloy when 'PSK' line (eutectoid temperature line) is crossed the austenite (primary as well as eutectic) undergoes eutectoid reaction at constant temperature (723^0C) and is converted to pearlite. At X_4 the microstructure of alloy consists of dendritic areas of transformed austenite (i.e. pearlite) in the matrix of transformed lideburite (pearlite + cemetite0 as shown in fig.5.1d

3.2 Cooling of Eutectic cast iron (4.3% carbon):

Alloy 5 in fig.2.5 represents eutectic cast iron with 4.3 % carbon. Initially at X1 the alloy is completely in liquid state as shown in fig.5.2a. on further cooling of the alloy no change is observed until it crosses 'ECF' (eutectic temperature line) at C. At 'C' liquid iron undergoes eutectic reaction at constant temperature (113^0C) and transforms into lideburite. At X2 the

alloy consists of completely lideburite (Austenite + Cementite) as shown in fig. 5.2b. On further cooling of alloy no change is observed till it crosses 'PSK' line. When alloy crosses eutectoid temperature line('PSK') eutectic austenite undergoes eutectic reaction at 723^{0}C and transforms into pearlite. The microstructure of alloy at X3(Just below 'PSK' line) consists of transformed austenite
(pearlite and cementite as shown in fig.5.2c. On further cooling of alloy to room temperature there is no change in the microstructure.

3.3 Cooling of hyper eutectic cast Iron(4.5% Carbon)

Alloy 6 in fig.2.5 represents Hyper eutectic cast-iron with 4.5% carbon. Initially at X1 the alloy consists of only liquid iron as shown in fig.5.3(a). On cooling of alloy no change is observed till it crosses 'CD' line. After crossing 'CD' line cementite starts nucleating from liquid iron. The microstructure of alloy at X2 consists of proeutectic cementite dendrites in liquid iron shown in. .3b. on further cooling of alloy no change is observed till it crosses 'ECF' line (eutectic temperature line). When 'ECF' line is crossed liquid of the alloy undergoes eutectic reaction at constant temperature (1130^{0}C) and is transformed into lideburite (eutectic mixture of austenite and cementite). The microstructure of alloy at X3(just below 'ECF' line) consists of eutectic austenite, cementite and proeutectic cementite as shown in fig.5.3c. On further cooling of alloy no change is observed till it crosses 'PSK' line (eutectic temperature line). When it crosses 'PSK' line the austenite of alloy undergoes eutectoid reaction at constant temperature(723^{0}C) and transforms into pearlite. At X4(just below 'PSK' line) the microstructure consists of cementite and pearlite as shown in fig.5.3d. the alloy is further cooled to room temperature there is no change in the microstructure.

3.4 The useful properties of cast iron are
i) Good fluidity (ability to fill narrow cavities in casting in liquid steel ii) Low melting point iii) Good machinability iv) Less dimensional changes during solidification.

Cast irons are brittle and have low tensile strength than most of the steels. Specially in the case of Grey cast iron, the graphite present will act line cracks and reduce tensile strength, toughness etc.,

3.5a Types of cast irons:

Depending on the form of carbon, cast irons are divided into
a) White cast iron b) Gray cast iron c) Malleable cast iron d) Spheroidal cast iron e) Chilled cast iron

3.5a White cast iron:
In white cast iron most of the carbon is present in combined form as cementite. This is obtained by rapidly cooling the cast iron from its molten state. These are hard and wear resistant. These are used only for hard and wear resistance applications and also used as raw material to produce malleable iron. At room temperature microstructure of Hypo eutectic C.I

consists of dendritic areas of transformed austenite in a matrix of transformed lideburite. At room temperature microstructure of eutectic cast iron consists of cementite and pearlite. At room temperature microstructure Hyper eutectic C.I consists of dendrites of primary cementite in the matrix of transformed lederburite.

3.5b Grey cast iron:

In Grey cast iron carbon in present as free graphite flakes. They contain more carbon and silicon content than white cast irons. It is a low melting alloy having good cast ability and good damping capacity. The tendency of carbon to form graphite flakes is due to increase in carbon and silicon content and decreasing cooling rate. Grey cast iron receive its name from the color of a freshly made fracture. At room temperature the microstructure of Grey cast iron consists of graphite flakes and pearlite.

3.5.c Malleable cast iron:

Malleable cast iron is produced by heating white cast iron to 90 to 1000^{0}C for about 50 hours followed by slow cooling to room temperature. On heating white cast iron, cementite structure tend to decompose into ferrite and tempered carbon. The lubrication action of graphite imparts high machineability to malleable cast iron. Malleable castings are tough, strong and shock resistant. These are used for wide range of applications such as automobile parts, railroad equipment, manhole covers etc., At room temperature the microstructure of Malleable cast iron consists of rosettes of tempered carbon graphite in the matrix of pearlite.

3.5.d Spheroidal graphite cast iron (Nodular cast iron or Ductile cast iron):

Spheroidal graphite cast iron is an iron carbon alloy having a structure composed of nodules (spheroids) of graphite formed directly during the process of solidification and embedded in matrix of steel. The formation of spherical graphite is due to addition of Magnesium for hypo eutectic cast iron and cerium for hyper eutectic cast iron. This is used for hydraulic cylinder, valves cylinder heads for compressor and diesel engine etc., Due to spherodization tensile strength, ductility and toughness are improved. This cast iron combines the advantages of cast iron and steel. The graphite in spherical shape reduces stress concentration effect and hence higher strength and toughness results.

3.5e Chilled cast iron:

Chilled cast iron is produced by adjusting the composition of white cast iron and then cooling it rapidly to room temperature. Rapid cooling promotes hard, thin layer on the surface of a soft iron casting. It is used where surface hardness is important. It finds applications in making dies and rolls for crushing.

The Micro structures of following cast irons are studied in this exercise

4.a Grey cast iron:

Specimen : Grey cast iron

Composition : 3.5% carbon 2%silicon 0.5% manganese 0.4% phosphorous 0.09% Sulphur

Heat treatment : Nil
Etchant : Nital
Etching time : 20 seconds
The micro structure shows uniformly distributed and randomly oriented graphite flakes in the matrix of ferrite and pearlite.

Applications: These are widely used for machine bases, engine frames, cylinders and pistons of I.C engines etc.,

B.White cast Iron:

Specimen : White cast iron
Composition : 4% carbon 0.5% silicon 0.4% manganese 0.05% phosphorous0.3% sulphur
Heat treatment : Nil
Etchant : Nital
Etching time : 20 seconds
The micro structure shows dendrites of transformed austenite(pearlite) in the matrix of transformed Ledeberite(i.e. pearlite and cementite). Majority of these cast irons are Hypo eutectic cast irons.

Applications: Used for wearing plates, pump liners, dies, etc., and also for production of Malleable castings.

C. Malleable cast iron:

Specimen : Malleable
Composition : 4%carbon 0.5% silicon 0.4% manganese 0.1% phosphorus 0.1% sulphur
Heat treatment : Nil
Etchant : Nital
Etching time : 20 seconds

The micro structure shows irregular nodules of tempered carbon (graphite) in the matrix of white ferrite phase, (if cooling rate is low) or pearlite phase(if cooling rate is high).
Applications: Cam shafts, crank shafts, Axles, etc.,

d. Spheroidal graphite cast iron (Nodular cast iron or Ductile cast iron):

Specimen : Ductile cast iron/Nodular/Spheroidal cast iron
Composition : 3.3% carbon, 2.4 silicon 0.05% manganese, small amount of Mn, Phosphorous & sulphur
Heat treatment : Nil
Etchant : Nital
Etching Time : 20 Seconds

Time micro structure shows a typical structure. It contains nodules (spheroids) of graphite surrounded by ferrite in the matrix of pearlite.
Applications: Used for gears, punches, dies, metal working rolls, furnace doors, etc.,

5.REVIEW QUESTIONS:

i. What are the different types of cast irons?
ii. What is the difference between white cast cast iron and Grey cast iron?
iii. What are the important properties of Grey cast iron?
iv. Why white cast iron has limited applications?
v. What is the structure of Malleable cast irons? Explain the heat treatment cycles used for black heart and white heart malleable iron?
vi. What is the additional metal added for spherodisation for Hypo and Hyper eutectic cast irons? How they act?
vii. What is chilled cat iron?
viii. What is the difference between Ferrite malleable, pearlitic malleable and Pearlitic-ferrite malleable cast irons?
ix. Why Gray cast irons has got that name?
x. Why Gray cast iron is o brittle?
xi. Explain important properties of different types of cast irons?

Exercise-6

STUDY OF MICROSTRUCTURES OF NON FERROUS METALS

1.AIM: To determine the present and to draw the microstructures of copper, Aluminum & Magnesium.

2.APPARATUS AND SPECIMENS REQUIRED:

Metallurgical microscope, specimens of Aluminium ,copper and Magnesium.

3.THEORY:

3.INTRODUCTION TO NON METALS

Non ferrous metals don't contain as base . A wide range of Non metals are employed for various engineering applications. Most Non ferrous metals posses good corrosion resistance, formability, castablity and special electrical and magnetic properties. Important Non –ferrous metals their melting points and crystal structures are tabulated here under.

S.NO	Name	Melting point degrees C	crystal structure
1.	Aluminum(Al)	660	FCC
2.	Antimony(Sb)	630	Rhombohydral
3.	Bismuth(Bi)	271	Rhombohydral
4.	Cadmium(Cd)	321	CPH
5.	Chromium(Cr)	1900	BCC
6.	Copper(Cr)	1083	FCC
7.	Gold(Au)	1064	FCC
8.	Lead(Po)	327	FCC
9.	Magnesium(Mg)	650	CPH
10.	manganese(Mn)	1250	Complexcube
11.	Nickle(Ni)	1453	FCC
12.	Silver(Ag)	961	FCC
13.	Tin(Sn)	232	Body centered tetragonal
14.	Zinc(Zn)	419	CPH

4.The microstructures of following specimens are in this experiment

a. Copper:

Specimen : Pure Copper
Heat treatment : Nil
Etchant : Ferric chloride solution
Etching time : 100 seconds

The micro structure shows equi axed grains of copper

b.Aluminium:

Specimen : Pure Aluminum
Heat treatment : Nil

Etchant : Ferric chloride solution
Etching time : 60 seconds

The microstructure shows grains of Aluminum

c. Magnesium

specimen : Pure Aluminum
Heat treatment : Nil
Etchant : Ferric chloride solution
Etching time : 60 seconds

The microprocessor shows grains of magnesium.

5.REVIEW QUESTIONS :

i. What are the important properties of Non-Ferrous metals and alloys?

ii. List out some important Non-Ferrous metals?

iii. What is melting point temperature of Aluminum?

iv. What is the crystal structure of Magnesium?

v. FCC metals are usually ductile and have high strain hardening tendency. Explain why?

Exercise-7

STUDY OF STRUCTURES OF SOME NON FERROUS ALLOYS

1.AIM: To determine the phases present and to draw the microstructures of some Non ferrous alloys.

2.APPARATUS AND SPECIMENS REUIRED:

Metallurgical microscope, specimens of alpha brass, alpha beta brass, Gunmetal and Tin based babbit.

3.THEORY:

3.1 Brasses: Brasses are the alloys of Copper and Zinc equilibrium diagram shown in fig observe that the region solid solution is quite extending from 0 to 38% of Zinc. If Zn percentage is more than 38% a second solid solution is formed. With zinc content more than 50% another solid solution called gamma is found .Useful Cu-Zn alloys are those that contain less 40% Zn.

Different brasses are Cap copper(contains 2 to 5% zinc),Gilding metals (contains 50% to 15% zinc)Cartridge brass(70% copper,30% zinc) Admiralty brass(69% copper ,30% zinc,1%tin), Muntz metal(605 copper,40% zinc),Naval brass(60% copper,39% zinc, 1% tin).

3.2 Copper-Tin Alloys:-

Alloys containing principally copper and tin are called Bronzes. Bronzes posses desirable properties of strength resistance and salt water corrosion resistance. From Copper-Tin equilibrium diagram shown in fig 7.2 one can observe that the solubility of Tin in Copper is 13.5% at 798% c, and it increases to 15.8% at 586c, and remains constant up to 520c,decreases to 11% at 350c and to about 1% at room temperature, With larger properties of Tin the hard compounds like Cu3Sn,epsilon phase, may appear in the structure .Useful engineering alloys in this system are those less than 20% Tin.

General range of composition of bronzes with respect to Copper and content may be divided into four groups as follows.

a. alloys containing up to 8% Tin which are used to sheets and wires.
b. Alloys containing Tin percentage between 8 to 12,which are used for gears and other machine parts.
c. Alloys containing between 12 and 20% Tin which are used for bearings.
d. Alloys containing between 20 and 25% Tin which are used for bells.

4.The microstructures of following specimens are observed in this exercise.

a. Cartridge Brass (Brass):

specimen	:	Cartridge brass
composition	:	70% Cu,30% Zn
Heat treatment	:	nil
Etchant	:	Ferric Chloride
Etching time	:	60 seconds

The micro structure shows single phase solid solution of zinc in copper ,grain of phase are polygonal and grain size is mixed. Application: Used cartridge cases, radiator fins, rivets etc.

b.Muntzmetal(α-β Brass):

specimen	:	Muntz metal
Composition	:	60% Cu ,40% Zn
Heat treatment	:	Nil

Etchant : Ferric Chloride
Etching time : 60 seconds

The micro structures two phases. White α-Phases (α- solid solution of Zn in copper) is present in the matrix of dark β- phase (β- solid solution of Zinc in Copper)

Applications : Utensils, shafts, nuts, bolts and condenser tubes.

C. Gun metal:

specimen : Gun metal Bronze
Composition : 10% Sn, 2%, Balance is Copper
Etchant : Ferric Chloride
Etching time : 40 seconds

The micro structures shows heavily cored dendrites of and islands of (**α-δ**)eutectoid.

Applications: It is widely used for gun barrels, marine parts, valve bodies, bearing bushes etc.

d. White metal alloys(Babbits):

Babbits are either Lead based or Tin alloys. Both the types contain Antimony. These are mainly used as bearing materials. The microstructures of Babbits consist of hard cuboids of(sn-sb)in a soft matrix of eutectoid. In addition to above cuboids the microstructure may consists of hard needles of CuSn and hard star shaped crystals of Cu_3Sn.

Specimen : Tin Base Babbit
Composition : 84% Sn,7%Cu,9%Sb
Heat treatment : Nil
Etchant : Ferric chloride solution
Etching Time : 20 seconds

The microstructure shows star shaped Cu-Sn compound. Rectangular crystals of sn-sb compound are observed in ductile in matrix of Cu-Sn ternary eutectic.

Applications: Bearings

5.REVIEW QUESTIONS

i. What are the important alloys of Copper & Zinc?

ii. What is Composition of Muntz metal?

iii. What is the composition of Cartridge Brass?

Exercise-8

JOMINY END QUENCH TEST

1.AIM: To determine the harden ability of a given steel
2.APPARATUS: Jominy test apparatus, furnace, Rockwell hardness tester and a grinder.

3.THEORY:Jominy end quench test is used to determine harden ability of steels .The process of increasing the hardness of steel is known as Hardening .Specific specimen with standard dimensions, used for the test is given in fig.8.1.The hardness of hardened bar is measured along its length.

3.1. Harden ability: The depth up to which steel can be hardened is defined as harden ability. A steel having high hardness need not have high harden ability. Harden ability may be defined as susceptibility to hardening by quenching. A material that has high harden ability is said to be hardened more uniformly throughout the section than one that has lower harden ability.

M.A Gross man devised a method to decide harden ability.

3.1.1.Critical diameter: The size of the bar in which the zone of 50% martensite occurs at center is taken as critical diameter. This is a measure of harden ability of steel for a particular quenching medium employed.

3.1.2.Severity of Quench:

The severity of quench is indicated by heat transfer equivalent

H=f/k f = Heat transfer factor of quenching medium and the turbulence of the bath.
K=Thermal conductivity of bar material.

The most rapid cooling is possible with severity of as infinity

3.1.3.Ideal Critical Diameter:

The harden ability of steel can be expressed as the diameter of bar that will form structure composed of 50% marten site at the center when quenched with H=infinity. This diameter is defined as critical diameter.

4.Description of Apparatus:

Jominy end quench apparatus is shown in fig 8.2.

The apparatus consists of a cylindrical drum. At the top of the drum provision is made for fixing the test specimen. A pipe line is connected for water flow, which can be controlled by means of a stop cock.

5.PROCEDURE:

Out of the given steel bar, the standard sample is to be prepared as per the dimensions shown in the fig 8.1

a. The austenitising temperature and time for the given steel is to be determined depending on its chemical composition .
b. The furnace is setup on the required temperature and sample is kept in the furnace.
c. The sample is to be kept in the furnace for a predetermined time(based on chemical composition of steel) then it is taken out of the furnace and is kept fixed in the test apparatus.
d. The water flow is directed onto the bottom end of the sample. The water flow is adjusted such that it obtains shape of umbrella over bottom of sample.
e. The quenching is to be continued for approximately 15 minutes.
f. A flat near about 0.4 mm deep is grounded on the specimen.
g. The hardness of the sample can be determined at various points starting from the quenched end and the results are tabulated.
h. The graph is plotted with hardness versus distance from quenched end. From the results and graph plotted the depth of hardening of the given steel sample can be determined.

The harden ability of the specimen is foundry by observing the structure under the microscope. As detailed above the diameter at which the percentage of martensite is 50 indicates harden ability of material. More this diameter high will be the harden ability. Now the important factor is the relationship between size are diameter of a steel bar quenched in an ideal quenching medium which has the same cooling rate at it centre as a given position along the fact that if position on the jominy bar where the structures is 50% martensite is known then the shown fig 8.4 makes it possible to determined ideal critical diameter.

6.TABLE

S.NO.	Distance from quenched end	Hardness

7. RESULTS:

8. CONCLUSION:

9. PRECAUTION: The specimen is to be handled carefully while transferring furnace to test apparatus

1. Proper water flow (at high pressure) over the bottom end of specimen is to be ensured.

10.REVIEW QUESTIONS:

1. What is the difference between Hardness & Harden ability?
2. What is severity of Quench?
3. What is critical diameter ?
4. What is the ideal critical diameter?
5. What is the quenching medium employed in the test?
6. What is the important precautions to be observed in the test?
7. why a flat is to be ground on the test specimen?
8. What is the equipment used to measure the hardness of specimen in the experiment?

<u>Exercise -9</u>

HARDENING OF STEELS

1. **AIM:**To harden the given steel specimen.
2. **APPARATUS:**Muffle furnace quenching medium(oil).
3. **THEORY:**

The purpose of hardening is to increase the hardness and wear resistance of steel .Steel specimens when heated to hardening temperature the structure will be transformed to austenite. When thin steel is cooled to room temperature at a cooling rate greater than the critical cooling rate. Austenite will undergo diffusion less transformation and gets converted in to Martensite. Is the hardest phase .Hence the hardness of steel specimen will be increased during hardening treatment. The improvement in hardness during hardening treatment depends on carbon content of austenite and also on type and amount of alloying elements present in the steel.

4. **PROCEDURE:**
   i. Determine the hardness of given steel specimens
   ii. Heat the steel specimens to hardening temperature and soak it for sufficient period of time.
   iii. Quench the specimens in oil.
   iv. Determine the hardness of the hardened specimens.
5. **TABLE:**

S.NO	MATERIAL	HARDNESS	HARDENING TEMPERATUR	SOPKING TIME	Hardness after hardening

6. RESUL TS & DISCUSSION

7. CONCLUSION:

8. **PRECAUTIONS:**

i. The hot specimen is to be handled carefully
ii. The furnace should be carefully set to appropriate temperature.

9. REVIEW QUESTIONS:

i. Why specimen has to tempered after hardening?

ii. what is low temperature tempering?

iii. What is medium temperature tempering?

iv. what is high temperature tempering?

v. what is the micro structure of a hardened and tempered steel?

vi. What are the important precautions observed in the test?

vii. what is the type of furnace used and mention its specifications?

viii. What is the cooling medium employed during hardening &during tempering?

Exercise – 10

AGE HARDENING

1. **AIM:**To Age harden the A1-4.5% Cu alloy.
2. **APPARATUS:**Furnace, Quenching medium, Rock well hardness tester,clock,A1-4.5% Cu alloy**.**
3. **THEORY:**

Some of alloys show increase in hardness with time at room temperature or after heating to slightly higher temperature. This type of hardening is called Age or Precipitation hardening. Age hardening is observed in alloys such as
A1-4.5% Cu,
A1-6%Zn, 2.5% Mg,
Cu-2% Be,
T1-6% A1-4%v, etc.
Important applications of A1-4.5%Cu alloy(LM11) are aircraft castings and other highly stressed parts. The strength to weight ratio of LM11 is higher than steel.

3.1.1 The conditions for an alloy to undergo precipitation hardening are

i. The solubility in the solvent must decrease with decrease in temperature
ii. The precipitate that separates out from the matrix should be coherent.

Since the solute atoms are the different size from the solvent atoms, large amount of elastic distortion is observed around the precipitate particle. The coherent precipitate particles are powerful obstacles to the motion of dislocations. Hence dislocations will be piled up and material hardness will be increased.
The microstructures at different stages of a precipitation harden able alloy are shown fig 10.1

3.2.1 **A1- Cu Equilibrium Diagram:**

By observing A1- Cu equilibrium diagram showing in fig 10.2 it can be seen that solubility of Cu in A1 decreases from 5.65% at 48c to less than 0.25 % at room temperature An eutectic is formed at 33% copper .Useful A1 –Cu alloys are those which contain less than 10% Cu. The mechanical properties of A1-4.5%Cu) alloy can be improved by precipitation of phase(CuSl2) from solid solution .

3.3 **Steps in precipitation Hardening :** The general steps involved in precipitation hardening of an alloy (Al-C 4.5%%) are explained below

a. **Heating(Solutionising);** The alloy is heated to a temperature between the eutectic and a solves temperature, so that it forms a single phase solid solution i.e. ,$\alpha+\theta \rightarrow \alpha$. The alloy is kept at this temperature sufficient period of time for complete homogenization.
b. **Quenching:** The alloy is rapidly cooled to room temperature to obtain a super saturated solution α phase
c. **Now** the alloy is in solution treated condition. It's hardness is relatively low (but higher than annealed condition).

d. **Aging:**

i. **Natural Aging:** Some of the alloys show increase in hardness with time at room temperature. This is known as Natural Aging.

ii. **Artificial Aging:** For some alloys increase in hardness with time at room temperature is not appreciable. In such case they will be aged at a higher temperature(the temperature is roughly between 15 to 25% of the temperature difference of room temperature and solutionising temperature) to increase the kinetics of precipitation, this is known as Artificial aging. A decrease of aging temperature considerably increases aging time.

Note: Over aging decreases the hardness. Hence aging should be stopped as soon as the optimum hardness is obtained. In Al-4.5% Cu alloy precipitation hardening process Cu Al2 is precipitated.

During the aging the hardness of the specimen should be measured at different lengths of time and a graph is to be drawn between hardness and time.

4. PROCEDURE:

a. An (Al-4.5% Cu) alloy specimen is taken and cleaned.

b. Hardness of the specimen is determined.

c. The specimen should be treated to a temperature (600^{0}C).

d. The specimen is kept at that temperature for sufficient period of time.

e. The specimen is quenched to room temperature.

f. The specimen is again heated to a temperature (100^{0}C), and maintained at that temperature.

g. The hardness of the specimen is noted at different lengths of time.

h. Results are tabulated and graph is drawn between hardness and time.

5. TABLE

S.No	Time	Hardness

6. RESULTS & DISCUSSIONS:

7. CONCLUSIONS:

8. REVIEW QUESTIONS:

i. What is Age hardening?
ii. What is difference between Natural aging and Artificial aging?
iii. What is the maximum solubility of Copper in Aluminum at room temperature?
iv. What is the name of (- phase observed in the age hardening of Aluminum Copper alloy?
v. What are the precautions to be observed in the experiment?
vi. What is the composition of age harden able Aluminum Copper alloy?
vii. Name different alloy that can be Age hardened?
viii. What is the problem with over aging?

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PART –II

STRENGTH OF MATERIALS LAB

LIST OF EXPERIMENTS

Objectives:

- Student able to know about different loads.
- Student able to learn about different stresses and strains.

S. No.	Name of the Experiment
1	To Study the various component parts of the Universal Testing Machine (U.T.M.) & test procedures of various practical's to be performed.
2	To study the Universal testing machine and perform the tensile test.
3	To study the Rockwell hardness testing machine & perform the Rockwell hardness test.
4	To study the Brinnel hardness testing machine & perform the Brinnel hardness test.
5	To perform compression & bending tests on UTM.
6	To perform shear test on UTM
7	To determine the stiffness of the spring and modulus of rigidity of the spring wire
8	To determine Bending test on UTM
9	IZOD Impact Test
10	Torsion Test

OUTCOMES:

- The student shall be able utilize the mechanics of solids in day –to -day life for design
- simple structures and for other limited applications

Note:

1. At least ten experiments are to be performed in the semester.
2. At least FOUR experiments should be performed from the above list. Remaining two experiments may either be performed from the above list or designed & set by the concerned institute as per the scope of the syllabus.

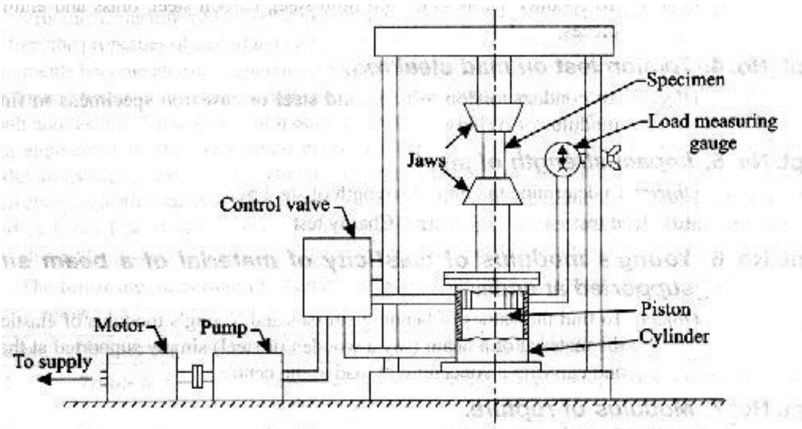
EXPERIMENT NO.: 01

AIM: Study of Universal Testing Machine (U.T.M.)

OBJECT: To Study the various component parts of the Universal Testing Machine (U.T.M.) & test procedures of various practical's to be performed.

APPARATUS: Universal Testing Machine with all attachment i.e. shears test attachment, bending attachment, tension grips, compression test attachment etc.

DIAGRAM:



• Fig. 1. Tenstile testing machine.

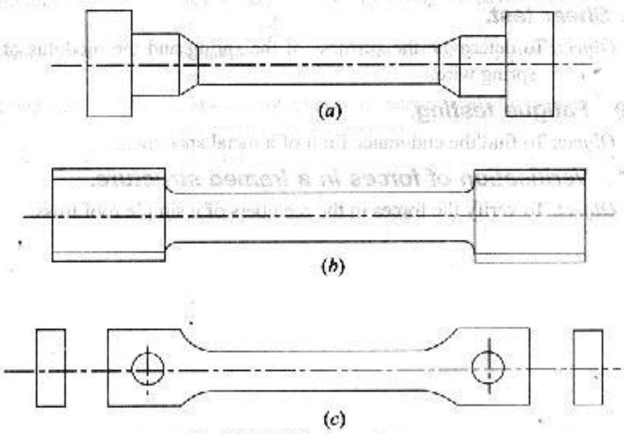


Fig. 2. Mild steel specimens.

THEORY: The Universal Testing Machine consists of two units. 1) Loading unit, 2) Control panel.

LOADING UNIT: It consists of main hydraulic cylinder with robust base inside. The piston which moves up and down. The chain driven by electric motor which is fitted on left hand side. The screw column maintained in the base can be rotated using above arrangement of chain. Each column passes through the main nut which is fitted in the lower cross head. The lower table connected to main piston through a ball & the ball seat is joined to ensure axial loading. There is a connection between lower table and upper head assembly that moves up and down with main piston. The measurement of this assembly is carried out by number of bearings which slides over the columns. The test specimen each fixed in the job is known as 'Jack Job'. To fix up the specimen tightly, the movement of jack job is achieved helically by handle.

CONTROL PANEL: It consists of oil tank having a hydraulic oil level sight glass for checking the oil level. The pump is displacement type piston pump having free plungers those ensure for continuation of high pressure. The pump is fixed to the tank from bottom. The suction & delivery valve are fitted to the pump near tank Electric motor driven the pump is mounted on four studs which is fitted on the right side of the tank. There is an arrangement for loosing or tightening of the valve. The four valves on control panel control the oil stroke in the hydraulic system. The loading system works as described below. The return valve is close, oil delivered by the pump through the flow control valves to the cylinder & the piston goes up. Pressure starts developing & either the specimen breaks or the load having maximum value is controlled with the base dynameters consisting in a cylinder in which the piston reciprocates. The switches have upper and lower push at the control panel for the downward & upward movement of the movable head. The on & off switch provided on the control panel & the pilot lamp shows the transmission of main supply.

METHOD OF TESTING: **Initial Adjustment: -** before testing adjust the pendulum with respect to capacity of the test i.e. 8 Tones; 10 Tones; 20 Tones; 40 Tones etc. For ex: - A specimen of 6 tones capacity gives more accurate result of 10 Tones capacity range instead of 20 Tones capacity range. These ranges of capacity are adjusted on the dial with the help of range selector knob. The control weights of the pendulum are adjusted correctly. The ink should be inserted in pen holder of recording paper around the drum & the testing process is started depending upon the types of test as mentioned below.

TENSION TEST: Select the proper job and complete upper and lower check adjustment. Apply some Greece to the tapered surface of specimen or groove. Then operate the upper cross head grip operation handle & grip the upper end of test specimen fully in to the groove. Keep the lower left valve in fully close position. Open the right valve & close it after lower table is slightly lifted. Adjust the lower points to zero with the help of adjusting knob. This is necessary to remove the dead weight of the lower table. Then lock the jobs in this position by operating job working handle. Then open the left control valve. The printer on dial gauge at which the specimen breaks slightly return back & corresponding load is known as breaking load & maximum load is known as the ultimate load.

COMPRESSION TEST: Fix upper and lower pressure plates to the upper stationary head & lower table respectively. Place the specimen on the lower plate in order to grip. Then adjust zero by lifting the lower table. Then perform the test in the same manner as described in tension test.

FLEXURAL OR BENDING TEST: Keep the bending table on the lower table in such a way that the central position of the bending table is fixed in the central location value of the lower table. The bending supports are adjusted to required distance. Stuffers at the back of the bending table at different positions. Then place the specimen on bending table & apply the load by bending attachment at the upper stationary head. Then perform the test in the same manner as described in tension test.

BRINELL HARDNESS TEST: Place the specimen on the lower table & lift it up slightly. Adjust the zero fixed value at the bottom side of the lower cross head. Increase the load slowly ultimate load value is obtained. Then release the load slowly with left control valve. Get the impression of a suitable value of five to ten millimeter on the specimen & measure the diameter of the impression correctly by microscope & calculate Brinell hardness.

SHEAR TEST: Place the shear test attachment on the lower table, this attachment consists of cutter. The specimen is inserted in roles of shear test attachment & lift the lower table so that the zero is adjusted, then apply the load such that the specimen breaks in two or three pieces. If the specimen breaks in two pieces then it will be in angle shear, & if it breaks in three pieces then it will be in double shear.

STUDY OF EXTENSOMETER: This instrument is an attachment to Universal / Tensile Testing Machines. This measures the elongation of a test place on load for the set gauge length. The least count of measurement being 0.01 mm, and maximum elongation measurement up to 3 mm. This elongation measurement helps in finding out the proof stress at the required percentage elongation.

WORKING OF THE INSTRUMENT: The required gauge length (between 30 to 120) is set by adjusting the upper knife edges (3) A scale (2) is provided for this purpose. Hold the specimen in the upper and lower jaws of Tensile / Universal Testing Machine. Position the extensometer on the specimen. Position upper clamp (4) To press upper knife edges on the specimen. The extensometer will be now fixed to the specimen by spring pressure. Set zero on both the dial gauges by zero adjusts screws (7). Start loading the specimen and take the reading of load on the machine at required elongation or the elongation at required load. Force setter accuracies mean of both the dial gauge (8) readings should be taken as elongation. It is very important to note & follow the practice of removing the extensometer from the specimen before the specimen breaks otherwise the instrument will be totally damaged. As a safety, while testing the instrument may be kept hanging from a fixed support by a slightly loose thread.

TECHNICAL DATA:

Measuring Range: 0 – 3 mm.

Least Count: 0. 01 mm.

Gauge Length adjustable from: 30 – 120 mm

Specimen Size: 1 to 20mm Round or Flats up to 20 x 20 mm.

A) STRESS-STRAIN GRAPH OF MILD STEEL

Stress-strain Relationships

When a load is applied to a material, deformation will occur. The relationships between load and deformation of materials are usually determined by testing, in which the load and deformation are expressed in terms of stress and strain. Stress is the internal force per unit area experienced by the material while strain is the unit change in deformation of the material. The stress-strain relationships can then be used to establish the compressive or tensile yielding strength, the modulus of elasticity and the ultimate strength.

Figure 3 presents a typical stress-strain curve for a structural mild steel specimen subjected to tensile test under normal conditions. The specimen elongation is plotted along the horizontal axis and the corresponding stresses are indicated by the ordinates of the curve 0ABCD. This diagram will be used to explain some of the following nomenclature.

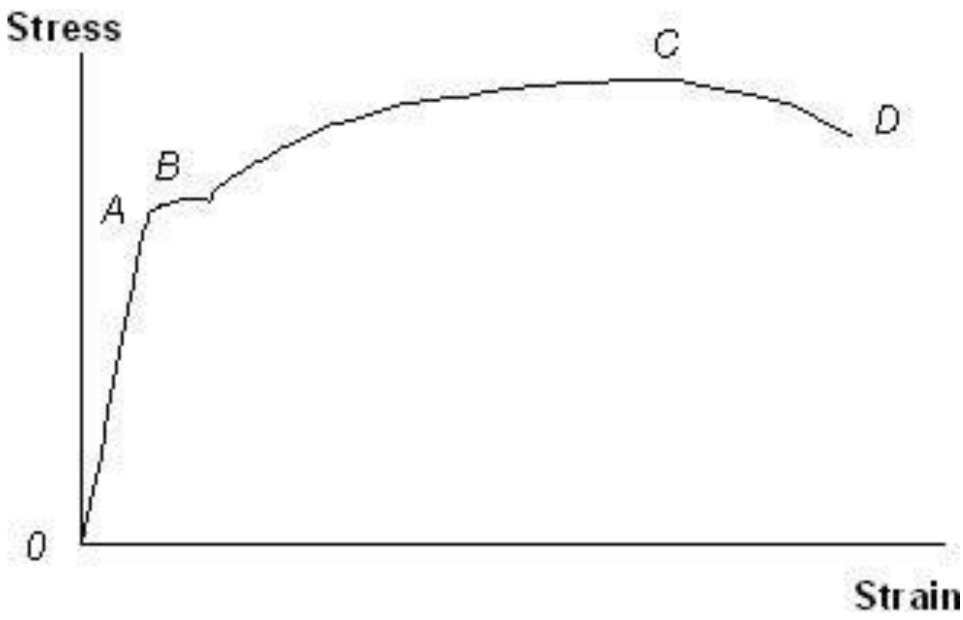


Figure 3. Stress –Strain graph of Mild Steel

Proportional Limit: In the region 0A, in Figure 3, the stress and the strain are proportional and the stress at *A* is the proportional limit. If upon removal of the stress (load), the strain in the specimen returns to zero as the stress goes to zero, the material is said to remain perfectly elastic.

Modulus of Elastic: The constant of proportionality in the straight-line region 0A is called the modulus of elastic or Young's modulus. Geometrically, it is equal to the slope of the stress-strain relationship in the region 0A.

Yield Strength: Upon loading beyond the proportional limit, the elongation increases more rapidly and the diagram becomes curved. At point *B,* a sudden elongation of the specimen takes place without significant increase in the applied load and the material has yielded. The value of stress at point *B* is called yield stress or yield strength. The deformation of the material prior to reaching the yield point creates only elastic strains, which are fully recovered if the applied load is removed. However, once the stress in the material exceeds the yield stress, permanent (plastic) deformation begins to occur. The strains associated with this permanent deformation are called plastic strains.

Ultimate Strength: When the material has passed through the yielding point, stress continues to increase with strain, but at a slower rate than in the elastic range, until a maximum value is reached which is termed the ultimate strength (point *C* in Figure 1). The increase in stress upon yield stress is due to material strain hardening. Beyond point *C,* the stress decreases until the specimen ruptures at point *D.*

B) Stress-strain graphs of different materials.

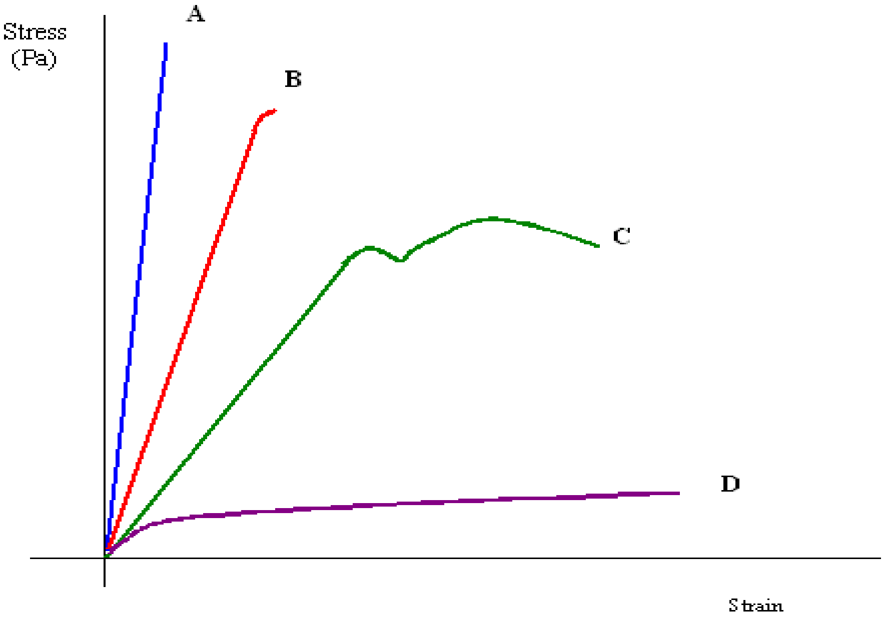


Figure 4: Stress-strain graphs of different materials

- Curve **A** shows a **brittle** material. This material is also strong because there is little strain for a high stress. The fracture of a brittle material is sudden and catastrophic, with little or no plastic deformation. Brittle materials crack under tension and the stress increases around the cracks. Cracks propagate less under compression.
- Curve **B** is a **strong** material which is not ductile. Steel wires stretch very little, and break suddenly. There can be a lot of elastic strain energy in a steel wire under tension and it will "whiplash" if it breaks. The ends are razor sharp and such a failure is very dangerous indeed.
- Curve **C** is a **ductile** material
- Curve **D** is a **plastic** material. Notice a very large strain for a small stress. The material will not go back to its original length.

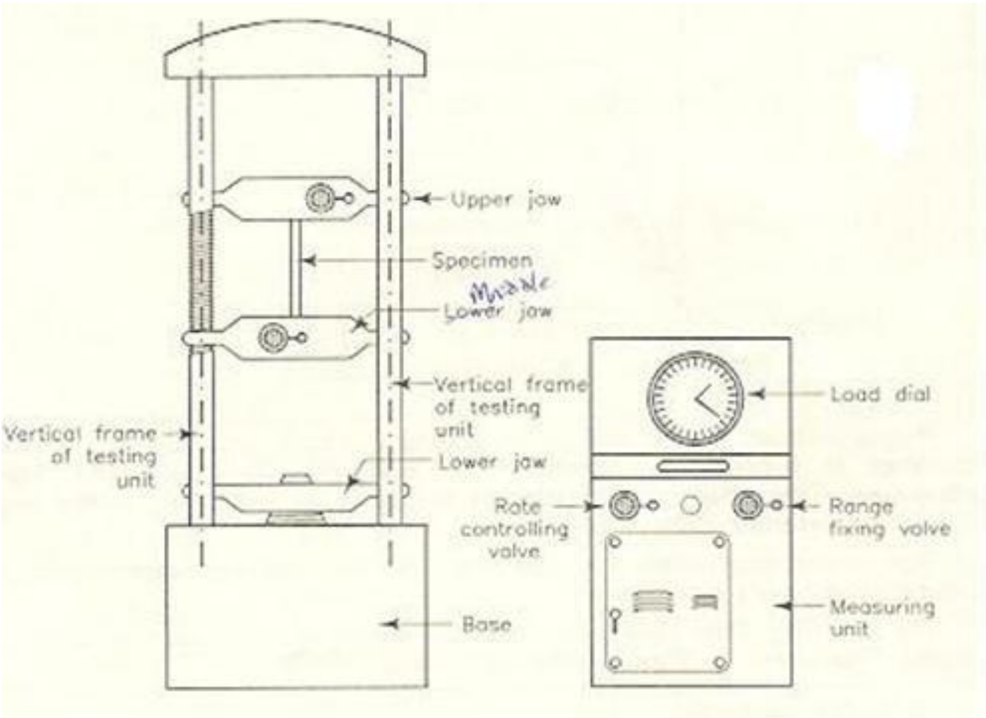
EXPERIMENT NO.: 02

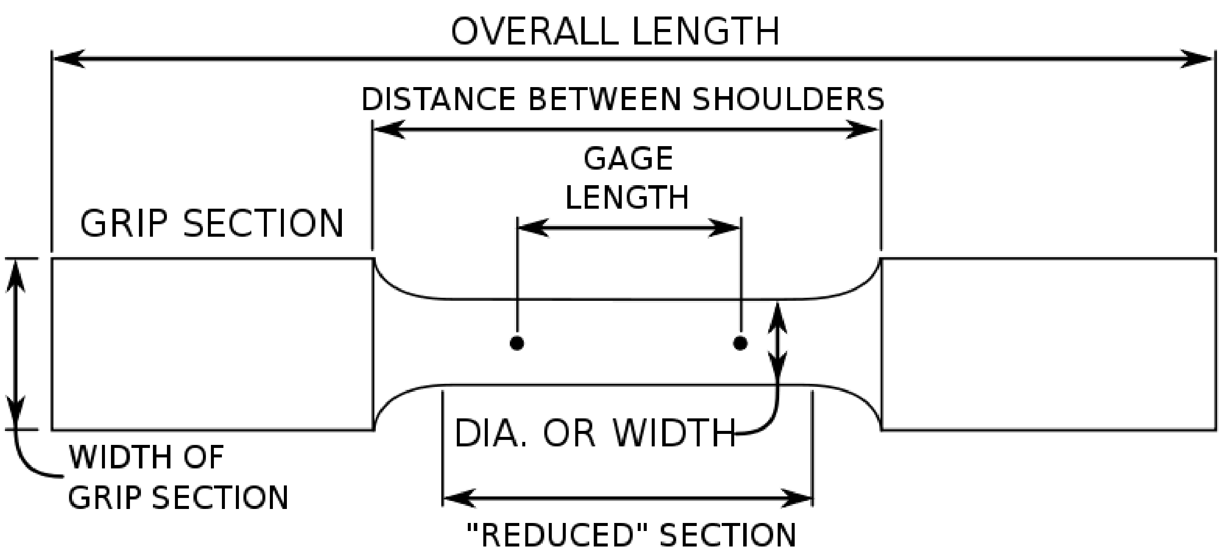
AIM: Determine tensile Strength of a given specimen using UTM.

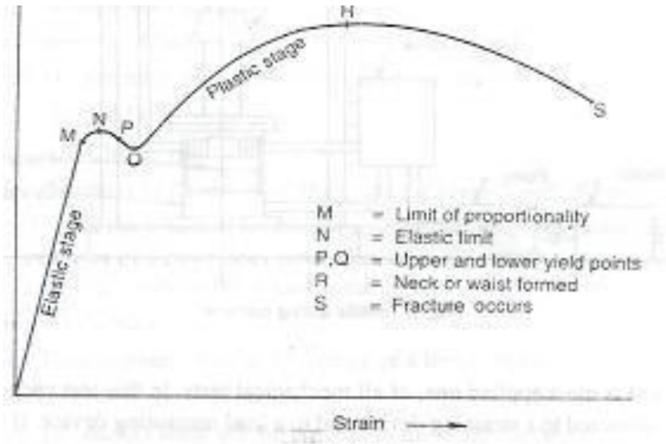
OBJECT: To conduct a tensile test on a mild steel specimen and determine the following:
(i) Limit of proportionality (ii) Elastic limit (iii) Yield strength (iv) Ultimate strength
(v) Young's modulus of elasticity (vi) Percentage elongation (vii) Percentage reduction in area.

APPARATUS: (i) Universal Testing Machine (UTM) (ii) Mild steel specimens
(iii) Graph paper (iv) Scale (v) Vernier Caliper

DIAGRAM:-







THEORY:

The tensile test is most applied one, of all mechanical tests. In this test ends of test piece are fixed into grips connected to a straining device and to a load measuring device. If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original from as soon as load is removed. However, if the load is too large, the material can be deformed permanently. The initial part of the tension curve which is recoverable immediately after unloading is termed. As elastic and the rest of the curve which represents the manner in which solid undergoes plastic deformation is termed plastic. The stress below which the deformations essentially entirely elastic is known as the yield strength of material. In some material the onset of plastic deformation is denoted by a sudden drop in load indicating both an upper and a lower yield point. However, some materials do not exhibit a sharp yield point. During plastic deformation, at larger extensions strain hardening cannot compensate for the decrease in section and thus the load passes through a maximum and then begins to decrease. This stage the "ultimate strength"' which is defined as the ratio of the load on the specimen to original cross-sectional area, reaches a maximum value. Further loading will eventually cause 'neck' formation and rupture.

ABOUT OF UTM & ITS SPECIFICATIONS:

The tensile test is conducted on UTM. It is hydraulically operates a pump, oil in oil sump, load dial indicator and central buttons. The left has upper, middle and lower cross heads i.e; specimen grips (or jaws). Idle cross head can be moved up and down for adjustment. The pipes connecting the lift and right parts are oil pipes through which the pumped oil under pressure flows on left parts to more the cross-heads.

SPECIFICATIONS:

1. Load capacity = 0-40 Tones.
2. Least count = 8 kgf.
3. Overall dimn. =
4. Power supply = 440 V

PROCEDURE:

1) Measure the original length and diameter of the specimen. The length may either be length of gauge section which is marked on the specimen with a preset punch or the total length of the specimen.
2. Insert the specimen into grips of the test machine and attach strain-measuring device to it
3. Begin the load application and record load versus elongation data.
4. Take readings more frequently as yield point is approached.

5. Measure elongation values with the help of dividers and a ruler.
6. Continue the test till Fracture occurs.
7. By joining the two broken halves of the specimen together, measure the final length and diameter of specimen.

OBSEVATION:

(a) Initial diameter of specimen d_1 =
(b) Initial gauge length of specimen L_1 =
(c) Initial cross-section area of specimen A_1 =
(d) Load of yield point Ft. =
(e) Ultimate load after specimen breaking F =
(f) Final length after specimen breaking L_2 =
(g) Diameter of specimen at breaking place d_2 =
(h) Cross section area at breaking place A_2 =

OBESERVATION TABLE:

S.No	Load (N)	Original Gauge Length	Extension (mm)	Stress = (N/mm^2)	Strain =
1					
2					
3					
4					
5					

CALCULATION:

(i) Ultimate tensile strength = = ___________N/mm^2

(ii) Elastic Limit = $\frac{\text{Load at elastic limt}}{\text{Original area of cross section}}$ = ____________N/mm^2

(iii) Modulus of Elasticity (E) = $\frac{\text{Stree below Proportionality Limit}}{\text{Corresponding Strain}}$ = _____N/mm^2

(iv) Yield Strength= $\frac{\text{Yield Load}}{\text{Original area of cross section}}$ = ____________N/mm^2

(v) % Reduction in Area = $\frac{\text{Orignal Area} - \text{Area at fracture}}{\text{Original area}}$

(vi) Percentage Elongation % = $\frac{\text{Final Length (at fracture)} - \text{Original Length}}{\text{Original Length}}$

(vii) Limit of Propagation = $\frac{\text{Load at limit of proportionality}}{\text{Original area of cross section}}$

PRECAUTIONS:

1. The specimen should be prepared in proper dimensions.
2. The specimen should be properly to get between the jaws.
3. Take reading carefully.
4. After breaking specimen stop to m/c.

RESULT: (i) Average Breaking Stress =
(ii) Ultimate Stress =
(iii) Average % Elongation =

ADVANTAGES

1. The main advantage of investing in a universal testing machine is that the device can be used to test the strength, durability, and suitability for most any material.
2. A universal testing machine has the capability to pull, compress, bend, or stretch material to its breaking point. It is primarily used by laboratories that manufacture and or mould different types of plastics.

VIVA-QUESTIONS

1. Which steel have you tested? What is its carbon content?
2. What general information are obtained from tensile test regarding the properties of a material?
3. Which stress have you calculated: nominal stress or true stress?
4. What kind of fracture has occurred in the tensile specimen and why?
5. Which is the most ductile metal? How much is its elongation?

EXPERIMENT No.:03

AIM: Determine hardness of given specimen in Rockwell scale

OBJECT: To determine the hardness of the given Specimen using Rockwell hardness test.

APPARATUS: Rockwell hardness testing machine, soft and hard mild steel specimens, brass, aluminum etc., Black diamond cone indenter..

DIAGRAM:

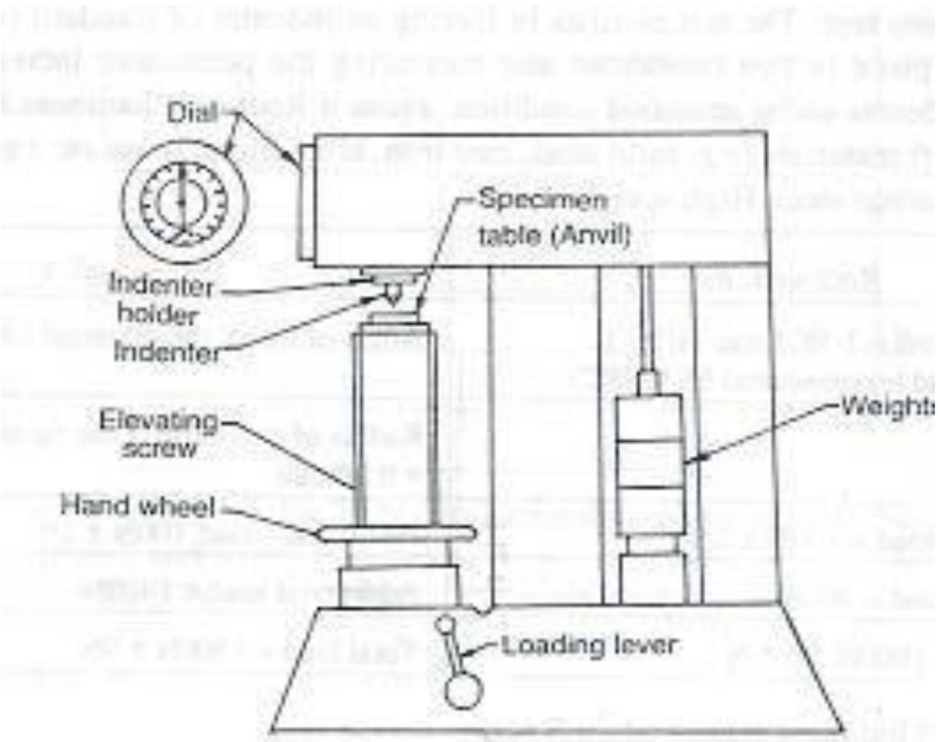


Figure 1: Rockwell hardness test equipment

THEORY:

Rockwell test is developed by the Wilson instrument co U.S.A in 1920. This test is an indentation test used for smaller specimens and harder materials. The test is subject of IS: 1586. The hardness of a material is resistance to penetration under a localized pressure or resistance to abrasion. Hardness tests provide an accurate, rapid and economical way of determining the resistance of materials to deformation. There are three general types of hardness measurements depending upon the manner in which the test is conducted:

a. Scratch hardness measurement,

b. Rebound hardness measurement

c. Indention hardness measurement.

In scratch hardness method the material are rated on their ability to scratch one another and it is usually used by mineralogists only. In rebound hardness measurement, a standard body is usually dropped on to the material surface and the hardness is measured in terms of the height of its rebound .The general means of judging the hardness is measuring the resistance of a material to indentation. The indenters usually a ball cone or pyramid of a material much harder than that being used. Hardened steel, sintered tungsten carbide or diamond indenters are generally used in indentation tests. The hardness of the material depends on the resistance which it exerts during a small amount of yielding or plastic. The resistance depends on friction, elasticity, viscosity and the intensity and distribution of plastic strain produced by a given tool during indentation In this test indenter is forced into the surface of a test piece in two operations, measuring the permanent increase in depth of an indentation from the depth increased from the depth reached under a datum load due to an additional load. Rockwell hardness tester presents direct reading of hardness number on a dial provided with the m/c. principally this testing is similar to Brinnel hardness testing. It differs only in diameter and material of the indenter and the applied force.

Although there are many scales having different combinations of load and size of indenter but commonly 'C' scale is used and hardness is presented as HRC. Here the indenter has a diamond cone at the tip and applied force is of 150 kgf. Soft materials are often tested in 'B' scale with a 1.6 mm diameter Steel indenter at 60kgf. Measurement of indentation is made after removing the additional load. Indenter used is the cone having an angle of 120 degrees made of black diamond.

PRECAUTIONS:

1. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.
2. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such case distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
3. Rapid rate of applying load should be avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.

Various scales in Rockwell hardness test are given below

Scale	Type of indenter (Dimension)	Initial load (kgf)	Major load (kgf)	Pointer Position on dial	Kind of material
A	Cone, 120°	10	50	0	Much harder such as carburized steel, cemented carbides
B	Ball, 1.58 mm	10	90	30	Soft steels, copper, aluminum, brass, grey cast iron.
C	Cone, 120°	**10**	**140**	**0**	Hard steels, Ti, W, Va, etc

PROCEDURE:

1. Examine hardness testing machine (fig.1).
2. Place the specimen on platform of a machine. Using the elevating screw raise the platform and bring the specimen just in contact with the ball. Apply an initial load until the small pointer shows red mark.
3. Release the operating valve to apply additional load. Immediately after the additional load applied, bring back operating valve to its position.
4. Read the position of the pointer on the C scale, which gives the hardness number.

5. Repeat the procedure five times on the specimen selecting different points for indentation.

OBESERVATION TABLE:

S.No.	Specimens	Reading (HRC/)			Mean
		1	2	3	
1	Mild Steel				HRB =
2	High Carbon steel				HRC =
3	Brass				HRB =
4	Aluminum				HRB =

OBSERVATION:

1. The specimen should be clean properly
2. Take reading more carefully and
3. Take average of five values of indentation of each specimen. Obtain the hardness number from the dial of a machine.
4. Compare Brinnel and Rockwell hardness tests obtained.

RESULT

Rockwell hardness of given specimen is =

ADVANTAGES:

1. Rockwell is the only one that allows direct reading of the hardness value without need of optical reading as per Vickers and Brinell methods. Therefore, it is the most rapid method and the only one that can be fully automated.
2 .The main limitations are due to the fact that between maximum and minimum load there is only a 10:1 ratio. In hardness testing, the most required loads by foundries and workshops are included in the range between 1 and 3000 kgf.

VIVA-QUESTIONS:

1. What is Hardness
2. What is toughness
3. What is the difference between Brinnel and Rockwell hardness tests
4. How many types of indentor are there
5. What is material for ball indentor

EXPERIMENT No.: 04

AIM: Determine hardness of given specimen in Brinnel scale.

OBJECT: To determine the hardness of the given specimen using Brinnel hardness test.

APPARATUS: Brinnel hardness testing machine, Aluminum specimen, Ball indenter.

DIAGRAM:

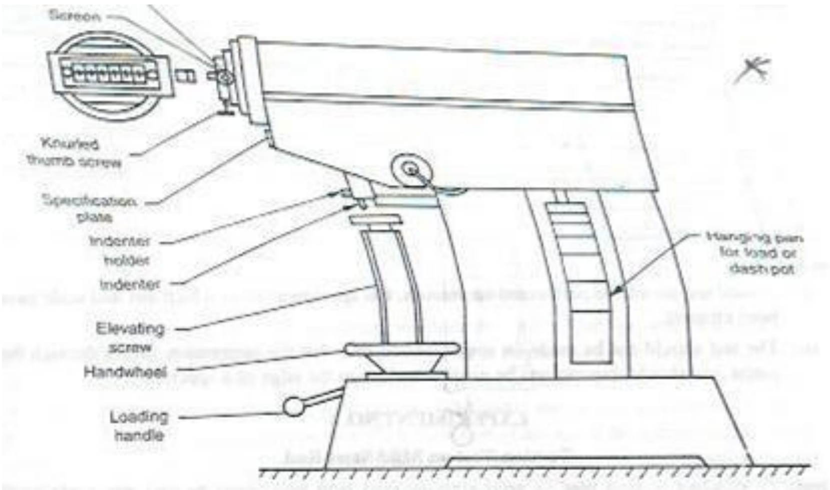


Figure: Brinnel hardness tester

THEORY:

Hardness of a material is generally defined as Resistance to the permanent indentation under static and dynamic load. When a material is required to use under direct static or dynamic loads, only indentation hardness test will be useful to find out resistance to indentation. In Brinnel hardness test, a steel ball of diameter (D) is forced under a load (F) on to a surface of test specimen. Mean diameter (d) of indentation is measured after the removal of the load (F). Hardness represents the resistance of material surface to abrasion, scratching and cutting, hardness after gives clear identification of strength. In all hardness testes, a define force is mechanically applied on the test piece for about 15 seconds. The indenter, which transmits the load to the test piece, varies in size and shape for different tests. Common indenters are made of hardened steel or diamond. In Brinnel hardness testing, steel balls are used as indenter. Diameter of the indenter and the applied force depend upon the thickness of the test specimen, because for accurate results, depth of indentation should be less than 1/8th of the thickness of the test pieces. According to the thickness of the test piece increase, the diameter of the indenter and force are changed.

SPECIFICATIONS: A hardness test can be conducted on Brinnel testing machine, Rockwell hardness machine or Vickers testing m/c. the specimen may be a cylinder, cube, think or thin metallic sheet. A Brinnel- cum-Rockwell hardness testing mmachine along with the specimen is shown in figure.

Its specification is as follows:

1. Ability to determine hardnessup to 500BHN.
2. Diameter of ball (as indenter) used D = 2.5mm, 5mm, 10mm.
3. Maximum application load = 3000kgf.
4. Method of load application = Lever type
5. Capability of testing the lower hardness range = 1 BHN on application of 0.5D2 load.

PROCEDURE:

1. Load to be applied for hardness test should be selected according to the expected hardness of the material. However test load shall be kept equal to 30 times the square of the diameter of the ball (diameter in mm)

$F=30.D^2$

Where ball diameter, generally taken as 10 mm.

For guidelines hardness range for standard loads given below

Ball diameter	Load (kg)	Range of Brinnel hardness
10	3000	96 to 600
	1500	48 to 300
	500	16 to 100

2. Apply the load for a minimum of 15 seconds to 30 seconds. [if ferrous metals are to be tested time applied will be 15 seconds and for softer metal 30 seconds]

3. Remove the load and measure the diameter of indentation nearest to 0.02 mm using microscope (projected image)

4. Calculate Brinnel hardness number (HB). As per IS: 1500.

5. Brinnel hardness number = 2F/ (π D [D-√D2-d2])

Where D is the diameter of ball indenter and d is the diameter of indentation. Hardness numbers normally obtained for different materials are given below (under 3000 kg and 10 mm diameter ball used)

Ordinary steels medium carbon	100 to 500
Structural steel	130 to 160
Very hard steel	800 to 900

Note: Brinnel test is not recommended for then materials having HB over 630. It is necessary to mention ball size and load with the hardness test when standard size of ball and load are not used. Because indentation done by different size of ball and load on different materials are not geometrically similar. Ball also undergoes deformation when load is applied. Material response to the load is not same all the time.

6. Brinnel hardness numbers can be obtained from tables 1 to 5 given in IS: 1500, knowing diameter of indentation, diameter of the ball and load applied.

OBSERVATIONS AND CALCULATIONS:

Following observation are recorded f r o m a test on steel specimen using a hardened steel ball as indenter. Test piece material = ---------------

S.No.	Ball Diameter 'D' in mm.	Load applied F in kgf.	Diameter of Indentation 'd' (mm)	P/D^2	BHN
1					
2					
3					
4					

BHN = Load Applied (kgf.)/ Spherical surface area indentation (in mm.) = $2GP/\pi D(D-\sqrt{D^2 - d^2})$

PRECAUTIONS:

1. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.
2. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such case distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
3. Rapid rate of applying load should be avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.
4. Surface of the specimen is well polished, free from oxide scale and any foreign material.

OBSERVATION:

1. The specimen should be clean properly.
2. Take reading more carefully and accurately.
3. Place the specimen properly.
4. Jack adjustment wheel move slowly.
5. Take average of five values of indentation of each specimen. Obtain the hardness number from equation.
6. Compare Brinnel and Rockwell hardness tests obtained.

RESULT:

The Brinnel hardness number of the specimen is

ADVANTAGES:

1. Takes heavy loads for testing
2. Easy to operate the testing equipment
3. Indentation made during the test can be observed under microscope or eyepiece
4. Not sensitive to deflection and so easy to test
5. easy to calculate tensile strength also from hardness value by multiplying with constant values based on the material on which testing is done

DISADVANTAGES:

1. Developing of residual stress because of indentation
2. Parallel ax error during operation
3. Accurate surfaces required for testing
4. Only flat surfaces can be tested

VIVA-QUESTIONS:

1. What is the limitation of Brinnel hardness test and why?
2. Which is the harness material and why?
3. Can we predict the tensile strength of a material if its hardness is known?
4. What is the unit of B.H.N?
5. Which ball size is recommended for Brinnel test?

EXPERIMENT No.: 05

AIM: Find out the Compressive strength of a given specimen using UTM

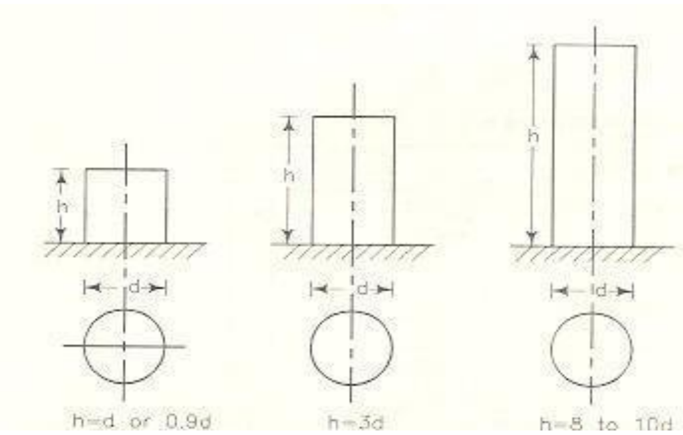
OBJECT: To Perform compression test on UTM.

APPARATUS:

A UTM or A compression testing machine, cylindrical or cube shaped specimen of cast iron, Aluminum or mild steel, vernier caliper, liner scale, dial gauge (or compressometer).

THEORY:

Several machine and structure components such as columns and struts are subjected to compressive load in applications. These components are made of high compressive strength materials. Not all the materials are strong in compression. Several materials, which are good in tension, are poor in compression. Contrary to this, many materials poor in tension but very strong in compression. Cast iron is one such example. That is why determine of ultimate compressive strength is essential before using a material. This strength is determined by conduct of a compression test. Compression test is just opposite in nature to tensile test. Nature of deformation and fracture is quite different from that in tensile test. Compressive load tends to squeeze the specimen. Brittle materials are generally weak in tension but strong in compression. Hence this test is normally performed on cast iron, cement concrete etc. But ductile materials like aluminum and mild steel which are strong in tension, are also tested in compression.



PROCEDURE:

1. Place the specimen in position between the compression pads.
2. Switch on the UTM
3. Bring the drag indicator in contact with the main indicator.
4. Select the suitable range of loads and space the corresponding weight in the pendulum and balance it if necessary with the help of small balancing weights
5. Operate (push) the button for driving the motor to drive the pump.
6. Gradually move the head control ever in left hand direction till the specimen fails.
7. Note down the load at which the specimen shears
8. Stop the machine and remove the specimen.
9. Repeat the experiment with other specimens.

OBSERVATION:

1. Cross sectional area of the specimen perpendicular to the load=A=......mm^2
2. Load taken by the specimen at the time of failure, W=. ...... (N)
3. Strength of the pin against shearing (s) = [W/A] N/mm 2
4. Initial length or height of specimen h =———–– mm.
5. Initial diameter of specimen do =————–– mm.

S.No.	Applied load (P) in Newton	Recorded change in length (mm)
1		
2		
3		
4		
5		

CALCULATIONS:

1. Original cross-section area A_o = -----
2. Final cross-section area A_f = --------
3. Stress = -------
4. Strain = -------

For compression test, we can

1. Draw stress-strain (σ-ε) curve in compression,
2. Determine Young's modulus in compression,
3. Determine ultimate (max.) compressive strength, and
4. Determine percentage reduction in length (or height) to the specimen.

PRECAUTIONS:

1. The specimen should be prepared in proper dimensions.
2. The specimen should be properly to get between the compression plates.
3. Take reading carefully.
4. After failed specimen stop to machine.

RESULT: The compressive strength of given specimen =————–- N/mm^2

ADVANTAGES

Universal testing machines are also capable of shear and compression testing. In a shear test, a metal blade is brought into the material at a constant rate until a piece of the sample is sheared off. In a compression test, a sample is pressed down between the machine's plates until it loses form or breaks. This test is commonly used to measure plastic foam strength or determine just how easily plastic bottles lose their shape. Current models of universal testing machines feature digital controls and software that eliminate the need for a specialised recorder, which was first used to log test information meant to be read and interpreted by a specialist.

VIVA-QUESTIONS:

1. Compression tests are generally performed on brittles materials-why?
2. Which will have a higher strength: a small specimen or a full size member made of the same material?
3. What is column action? How does the h/d ratio of specimen affect the test result?
4. How do ductile and brittle materials in their behavior in compression test?
5. What are bi-modulus materials? Give examples.

EXPERIMENT No.: 06

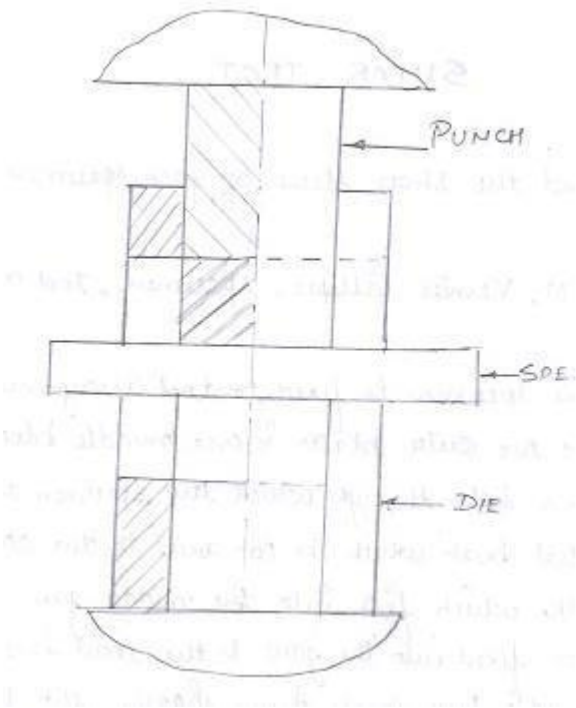
AIM: - Find out the Shear strength of a given specimen using UTM**.**

OBJECT: To find the shear strength of given specimen on UTM.

APPARATUS USED: A UTM, Specimen, shearing attachment, vernier caliper etc.

THEORY: A type of force which causes or tends to cause two contiguous parts of the body to slide relative to each other in a direction parallel to their plane of contact is called the shear force. The stress required to produce fracture in the plane of cross-section, acted on by the shear force is called shear strength.

DIAGRAM:



PROCEDURE:

1. Insert the specimen in position and grip one end of the attachment in the upper portion and one end in the lower position
2. Switch on the UTM
3. Bring the drag indicator in contact with the main indicator.
4. Select the suitable range of loads and space the corresponding weight in the pendulum and balance it if necessary with the help of small balancing weights
5. Operate (push) the button for driving the motor to drive the pump.
6. Gradually move the head control ever in left hand direction till the specimen shears.
7. Note down the load at which the specimen shears.
8. Stop the machine and remove the specimen.
9. Repeat the experiment with other specimens.

PRECAUTIONS:

1. The measuring range should not be changed at any stage during the test.
1. The inner diameter of the hole in the shear stress attachment should be slightly greater than the specimen.
2. Measure the diameter of the specimen accurately.
3. The method for determining the shear strength consists of subjecting a suitable length of steel specimen in full cross-section to double shear, using a suitable test rig, in a testing m/c under a compressive load or tensile pull and recording the maximum load 'F' to fracture.

OBSERVATION:

1. Applied compressive force (F) = ---------kgf.
2. Diameter of specimen = -------- mm.

Cross sectional area of the pin (in double shear) = $2 \times \pi/4 \times d^2$ = ... mm^2

Load taken by the specimen at the time of failure, W = ... (N)

Strength of the pin against shearing (τ) = $4W/2\pi d^2$————————N/mm^2

RESULT

Shear strength of specimen = --------

ADVANTAGES

TestResources designs, develops, manufactures, markets, and services universal testing machines including software, and accessories used to evaluate the mechanical properties of materials and components. Our testing products are used in research and development, and quality control applications to test the strength, elasticity, durability and properties of materials including metals, adhesives, plastics, wood, textiles, composites, ceramics and rubber.

VIVA-QUESTIONS:-

1. Does the shear failure in wood occur along the 45° shear plane?
2. What is buldging? Why does it occur?
3. What is single & double shear?
4. What is finding in shear test?
5. What is unit of shear strength?

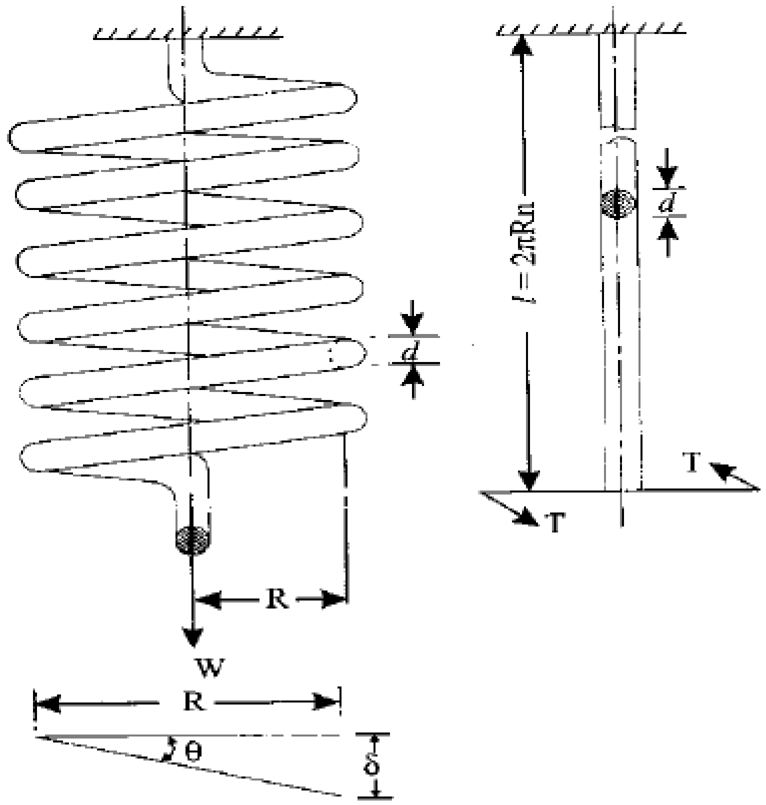
EXPERIMENT No: 07

AIM: Determine the stiffness of the spring and modulus of rigidity of the spring wire

OBJECT: To determine the stiffness of the spring and modulus of rigidity of the spring wire

APPARATUS: - i) Spring testing machine. ii) A spring iii) Vernier caliper, Scale.
iv) Micrometer.

DIAGRAM:-



Close-coiled helical spring.

THEORY:

Springs are elastic member which distort under load and regain their original shape when load is removed. They are used in railway carriages, motor cars, scooters, motorcycles, rickshaws, governors etc. According to their uses the springs perform the following Functions:
1) To absorb shock or impact loading as in carriage springs.
2) To store energy as in clock springs.
3) To apply forces to and to control motions as in brakes and clutches.
4) To measure forces as in spring balances.
5) To change the variations characteristic of a member as in flexible mounting of motors.
The spring is usually made of either high carbon steel (0.7 to 1.0%) or medium carbon alloy steels. Phosphor bronze, brass, 18/8 stainless steel and Monel and other metal alloys are used for

corrosion resistance spring. Several types of spring are available for different application. Springs may classified as helical springs, leaf springs and flat spring depending upon their shape. They are fabricated of high shear strength materials such as high carbon alloy steels spring form elements of not only mechanical system but also structural system. In several cases it is essential to idealize complex structural systems by suitable spring.

PROCEDURE:

1) Measure the diameter of the wire of the spring by using the micrometer.
2) Measure the diameter of spring coils by using the vernier caliper
3) Count the number of turns.
4) Insert the spring in the spring testing machine and load the spring by a suitable weight and note the corresponding axial deflection in tension or compression.
5) Increase the load and take the corresponding axial deflection readings.
6) Plot a curve between load and deflection. The shape of the curve gives the stiffness of the spring.

OBESERVATION

Least count of micrometer = ……mm
Diameter of the spring wire, d =………mm (Mean of three readings)
Least count of vernier caliper = ……mm
Diameter of the spring coil, D = ……mm (Mean of three readings)
Mean coil diameter, Dm = D - d……mm
Number of turns, n =

OBESERVATION TABLE:

S.No.	Load, W (N)	Deflection, (δ) (mm)	Stiffness K = W / δ, N	Modulus of Rigidity (C) N/mm^2
1				
2				
3				
4				
5				

Mean k = ……
Modulus of rigidity $C = 8W D^3 n / \delta D_m^4$
Spring Index = Dm/D

PRECAUTION:

1) The dimension of spring was measured accurately.
2) Deflection obtained in spring was measured accurately

RESULT: The value of spring constant k of closely coiled helical spring is found to be_ ________N/ mm

ADVANTAGES:

1. To apply forces and to control motions as in brakes and clutches.
2. To store energy as in clock springs.
3. This test is conducted to find the material properties of the spring like modulus of rigidity. This can be obtained by observing the values of deflections of the spring with the application of different amounts of the load applied along the axis of the spring. The observed Values of deflections are compared with the theoretical value for the deflection of the spring under the load and shear modulus is to be obtained.
4. To reduce the effect of shock or impact loading as in carriage springs

VIVA QUESTIONS:

1. What is meant by stiffness
2. Define deflection
3. What are different types of springs
4. Define helical spring
5. What is the strain energy stored in the springs

EXPERIMENT No. 08

AIM: Determine the deflection and bending stress of simply supported subjected to concentrated load at the center .

OBJECT: To find the values of bending stresses and young's modulus of the material of a beam (say a wooden or steel) simply supported at the ends and carrying a concentrated load at the center.

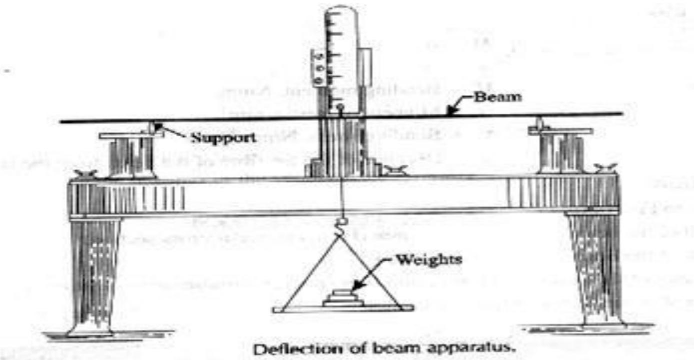
APPARATUS USED:

UTM or Beam apparatus, Bending fixture, vernier caliper, meter rod, test piece & dial gauge.

THEORY:

Bending test is performing on beam by using the three point loading system. The bending fixture is supported on the platform of hydraulic cylinder of the UTM. The loading is held in the middle cross head. At a particular load the deflection at the center of the beam is determined by using a dial gauge. The deflection at the beam center is given by: $\delta = WL^3 / 48EI$

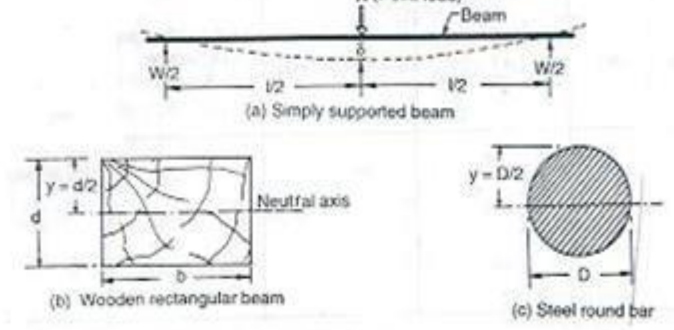
DIAGRAM:



Deflection of beam apparatus.

PROCEDURE:

1. Measure the length, width and thickness of test piece, by vernier caliper.
2. Place the bending fixture on the lower cross head of the testing machine.
3. Place the test piece on the rollers of the bending fixture.
4. By loading the dial gauge in a stand, make its spindle knob the test piece.
5. Start the m/c and note down the load and dial gauge readings.
6. Plot the graph between load and deflection.



$$\delta = \frac{wl^3}{48\,EI}$$

OBSERVATIONS:

1. Least count of vernier caliper = -----
2. Length of beam (L) = ------
3. Width of beam (b) = ------
4. Thickness of beam (t) = ------

S.No.	Load 'W' in Newton	Deflection 'δ' in mm.	Young's Modulus 'E' N/mm^2
1			
2			
3			
4			
5			

PRECAUTIONS:

1. Make sure that the beam and load is placed at the proper position.
2. Cross section of the beam should be large
3. Note down the readings of the vernier scale carefully.

CALCULATIONS:

1. $I = bt^3 / 12$
2. $\delta = WL^3 / 48EI$

RESULT:

The Bending strength of given specimen =------- N/mm^2

VIVA QUESTIONS

1. Types of beams.
2. What is deflection
3. Write the equation for the Slope for a cantilever beam with point load
4. Write the deflection equation for thesimply supported beam with point load at the center
5. How many types of bending are there?
6. Define plane bending?
7. Define distributed load?
8. Define Maxwell's reciprocal theorem?

EXPERIMENT No. 09

AIM: To perform the izod impact test on materials.

APPARATUS USED:

Izod impact test machine, test specimen, vernier calipers, steel rule

IMPACT STRENGTH: The resistance of a material to fracture under sudden load application.

MATERIALS: Two types of test pieces are used for this test as given.

1) Square cross-section
2) Round cross-section.

.

THEORY:

The type of test specimen used for this test is a Square Cross-section. The specimen may have single, two or three notches. The testing machine should have the following specifications.The angle between top face of grips and face holding the specimen vertical=90^0 The angle of tip of hammer =$75^0 \pm 1^0$ The angle between normal to the specimen and underside face of the hammer at striking point=$10^0 \pm 1^0$ Speed of hammer at impact=3.99m/sec Striking energy=168N-m or Joules Angle of drop of pendulum =90^0 Effective weight of pendulum=21.79kg
Minimum value of scale graduation=2 Joules.
Permissible total friction loss of corresponding energy=0.50%

Distance from the axis of rotation of distance between the base of specimen notch and the point of specimen hit by the hammer=22mm±0.5mm

The longitudinal axes of the test piece shall lie in the plane of swing of the center of gravity of the hammer. The notch shall be positioned so that its in the plane of the hammer .the notch shall be positioned its plane of symmetry coincides with the top face of the grips .for setting the specimen the notch impact strength I is calculated according to the following relation.

Where I= impact strength in joules/m^2

PROCEDURE:

1. For conducting Izod test, a proper striker is to be fitted firmly to the bottom of the hammer with the help of the clamming piece.
2. The latching take for izod test is to be firmly fitted to the bearing housing at the side of the columns.
3. The frictional loss of the machine can be determined by free fall test, raise the hammer by hands and latch in release the hammer by operating lever the pointer will then indicate the energy

loss due to friction. From this reading confirm that the friction loss is not exceeding 0.5% of the initial potential energy. Otherwise frictional loss has to be added to the final reading.

4. The specimen for izod test is firmly fitted in the specimen support with the help of clamping screw and élan key. Care should be taken that the notch on the specimen should face to pendulum striker.

5. After ascertaining that there is no person in the range of swinging pendulum, release the pendulum to smash the specimen.
6. Carefully operate the pendulum brake when returning after one swing to stop the oscillations.
7. Read-off position of reading pointer on dial and note indicated value.
8. Remove the broken specimen by loosening the clamping screw.

The notch impact strength depends largely on the shape of the specimen and the notch. the values determined with other specimens therefore may not be compared with each other.

OBSERVATION TABLE:

S .No	A(Area of cross section of specimen)	K Impact energy observed	I Impact Strength

RESULT:

The Impact strength of the given specimen is----------------- J/mm^2

VIVA QUESTIONS:-

1. In what way the values of impact energy will be influenced if the impact tests are conducted on two specimens, one having smooth surface and the other having scratches on the surface
2. What is the effect of temp. on the values of rupture energy and notch impact strength ?
3. What is resilience? How is it different from proof resilience and toughness?
4. What is the necessity of making a notch in impact test specimen ?
5. If the sharpness of V-notch is more in one specimen than the other, what will be its effect on the test result ?

EXPERIMENT No. 10

AIM: To conduct torsion test on mild steel or cast iron specimen to find modulus of rigidity or to find angle of twist of the materials which are subjected to torsion?

APPARATUS:

1. A torsion test machine along with angle of twist measuring attachment.
2. Standard specimen of mild steel or cast iron.
3. Steel rule.
4. Vernnier caliper or a micrometer.

THEORY:

For transmitting power through a rotating shaft it is necessary to apply a turning force. The force is applied tangentially and in the plane of transverse cross section. The torque or twisting moment may be calculated by multiplying two opposite turning moments. It is said to be in pure torsion and it will exhibit the tendency of shearing off at every cross section which is perpendicular to the longitudinal axis.

Torsion equation:

Torsion equation is given by below

$$T / I_P = C\theta/L = \tau/R$$

T= maximum twisting torque (Nmm) I_P = polar moment of inertia (mm^4) τ =shear stress (N/mm^2)
C=modulus of rigidity (N/mm^2)
θ=angle of twist in radians
L=length of shaft under torsion (mm)

Assumptions made for getting torsion equation

1. The material of the shaft is uniform throughout.
2. The shaft, circular in section remain circular after loading.
3. Plane sections of shaft normal to its axis before loading remain plane after the torque have been applied.
4. The twist along the length of the shaft is uniform throughout.
5. The distance between any two normal-sections remains the same after the application of torque.
6. Maximum shear stress induced in the shaft due to application of torque does not exceed its elastic limit.

PROCEDURE:

1. Select the suitable grips to suit the size of the specimen and clamp it in the machine by adjusting sliding jaw.
2. Measure the diameter at about the three places and take average value.
3. Choose the appropriate loading range depending upon specimen.
4. Set the maximum load pointer to zero
5. Carry out straining by rotating the hand wheel or by switching on the motor.
6. Load the members in suitable increments, observe and record strain reading.
7. Continue till failure of the specimen.
8. Calculate the modulus of rigidity C by using the torsion equation.
9. Plot the torque –twist graph (T Vs θ)

OBSERVATIONS:

Gauge length **L** =

Polar moment of inertia **IP** =

Modulus of rigidity **$C=TL/I_P\theta$** =

S.No	Twisting Moment Kgf-m	Twisting Moment N-mm	Angle of Twist (Degrees)	Twist (Radians)	Modulus of rigidity (C)	Average C N/mm^2

RESULT:

The modulus of rigidity of the given test specimen material is

VIVA-QUESTIONS:-

1. What is torque?
2. What is torsion equation?
3. What is flexural rigidity?
4. Define Section modulus.
5. What is modulus of rigidity