Practical Workbook

MY-101: Introduction to Metallurgical Engineering

Name___________________________

Roll No_________________________

Batch__________________________

Year ___________________________

Department of Metallurgical Engineering

NED University of Engineering and Technology

Karachi-75270, Pakistan

<u>Practical Workbook</u>

MY-101: Introduction to Metallurgical Engineering

Prepared by

Dr. Zubia Anwer & Prof. Dr. Ali Dad Chandio

(Assistant Professor & Chairman MYD)

This is to certify that this practical book contains __________ pages.

Approved by

Prof. Dr. Ali Dad Chandio

Chairman, MYD

Department of Metallurgical Engineering

NED University of Engineering and Technology

Karachi-75270, Pakistan

CERTIFICATE

It is certified that Mr. / Ms. ____student of class _____Batch_____, bearing Roll No. MY _____ has completed his / her coursework in **Introduction to Metallurgical Engineering (MY-101)** as prescribed and approved by the Board of Review of the Metallurgical Engineering Department.

His/her performance is reflected by the performance rubrics of his/her practical workbook. The student's overall performance will address the assigned learning attribute.

____

Course Teacher

TABLE OF CONTENTS

MY-101: INTRODUCTION TO METALLURGICAL ENGINEERING

Experiment No. 1

Aim of the Experiment

Safety in Laboratories.

Safety Precautions

1. Keep the work area clean. Wipe up oil and grease spills immediately to prevent injuries caused by slipping and falling. Keep paths to exits clear.
2. Wear a lab coat at all times while in the sample preparation lab.
3. Wear safety glasses and gloves during grinding and polishing, and during etching.
4. Etching can only be done under supervision.
5. Do not wear gloves in the microscope room.
6. Always carry out etching in a fume cupboard.
7. While etching, always use tongs to handle the specimen.
8. Etchant splashes on the skin or eyes must be washed with copious amounts of water.
9. Mount specimen in vices, anvils, and clamps securely in abrasive cutter equipment
10. Use proper tools. Always use the proper-sized tools and equipment for the job.
11. Obtain the instructor's permission. Use equipment only with the instructor’s permission. The instructor must be aware of all laboratory activities and will know if the equipment is in safe working order.
12. Wear proper clothing. Wear clothing that is not loose or bulky and wear hard-toed shoes with non-skid soles.
13. Restrain long hair. Restrain excessively long hair with a band or cap to keep hair from getting entangled in machines.
14. Know emergency procedures. In the event of an emergency, all students involved in or observing the emergency should call for help immediately as well as assist in correcting the situation. You should know the location of fire extinguishers and fire blankets and how to use them. You should also know the approved procedure for exiting the laboratory.
15. Report all injuries or accidents to the instructor immediately, no matter how slight. The instructor will secure medical help.
16. Avoid horseplay and loud talk. Loud talking as well as pushing, running, and scuffling that can cause serious accidents. Keep your mind on your work.
17. Turn off all equipment before leaving the work area. Before leaving the laboratory or workstation, make certain the equipment is properly shut off.

Questions

1. What safety practices are used in the material testing lab to promote general safety?

2. What personal safety protection devices or clothing must you wear while working in the shop?

3. List the importance of safety in the industry.

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NED University of Engineering & Technology
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date	

Experiment No. 2

Aim of the Experiment

To recognize various crystal structures along with their lattice parameters and coordination numbers by ball-stick and space-filling models using CrystalMaker software.

Theory

The crystal structure is one of the most important aspects of materials science and engineering, as many properties of materials depend on their crystal structure. The solids are either crystalline or non-crystalline. The majority of engineering materials, such as ceramics and most minerals, some plastics and all metals are crystalline in structure.

Ideal Crystal
(Considers ***both*** Geometrical Entity AND Physical Property/)

↓

Crystal
(Here we consider ***either*** geometrical entity OR physical property)

↓

Crystal
(Consider ***either*** the Orientational OR the Positional Order)

↓

'Real Crystal'
(Presence of Crystalline defects & Free Surface & Thermal Vibration)

↓

~Microconstituents
(Put in Multiple Crystals *(Phases)* giving rise to interfacial defects)

↓

Microstructure
(Put in multiple ~microconstituents and add additional residual stress†)

↓

Material
(Put in many microstructures)

↓

Component
(Put in material/s and/or material treatment i.e. temperature/pressure)

Crystal Structure

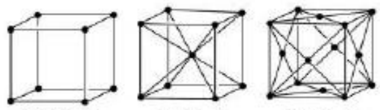
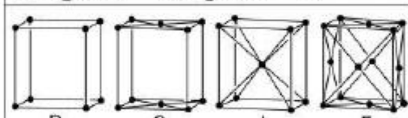
A regular and repetitious pattern in which an atom or group of atoms of crystalline materials are well arranged themselves is known as crystal structure. All crystalline solids may be classified into 7- 7-crystal systems or 14-crystal structures based on symmetry.

Symmetry

Symmetry refers to a certain pattern or arrangement. A body is symmetrical when it is reproduced by certain operations. Symmetry operations are as follows:

- ➢ Translation
- ➢ Rotation
- ➢ Reflection
- ➢ Inversion

Table 1: The 14 Bravais Lattice

Bravais lattice cells	Axes and interaxial angles	Examples
 Cubic P, Cubic I, Cubic F	Three axes at right angles; all equal: $a = b = c$; $\alpha = \beta = \gamma = 90°$	Copper (Cu), silver (Ag), sodium chloride (NaCl)
 Tetragonal P, Tetragonal I	Three axes at right angles; two equal: $a = b \neq c$; $\alpha = \beta = \gamma = 90°$	White tin (Sn), rutile (TiO_2), β-spodumene ($LiAlSi_2O_6$)
 P, C, I, F Orthorhombic	Three axes at right angles; all unequal: $a \neq b \neq c$; $\alpha = \beta = \gamma = 90°$	Gallium (Ga), perovskite ($CaTiO_3$)
 Monoclinic P, Monoclinic C	Three axes, one pair not at right angles, of any lengths: $a \neq b \neq c$; $\alpha = \gamma = 90° \neq \beta$	Gypsum ($CaSO_4 \cdot 2H_2O$)
 Triclinic P	Three axes not at right angles, of any lengths: $a \neq b \neq c$; $\alpha \neq \beta \neq \gamma \neq 90°$	Potassium chromate (K_2CrO_7)
 Trigonal R (rhombohedral)	Rhombohedral: three axes equally inclined, not at right angles; all equal: $a = b = c$; $\alpha = \beta = \gamma \neq 90°$	Calcite ($CaCO_3$), arsenic (As), bismuth (Bi)
 Trigonal and hexagonal C (or P)	Hexagonal: three equal axes coplanar at 120°, fourth axis at right angles to these: $a_1 = a_2 = a_3 \neq c$; $\alpha = \beta = 90°$, $\gamma = 120°$	Zinc (Zn), cadmium (Cd), quartz (SiO_2) [P]

Coordination number

The coordination number may also be defined as the nearest neighbour to an atom in a crystal.

Observations

Solids	Crystal Structure	Lattice parameters	Coordination number
Aluminum			
Chromium			
Iron			
Zinc			
Copper			

Questions

1. Define the relationship between symmetry and crystal structure.

____
____
____
____
____
____

2. How many atoms are present in unit cell of BCC, FCC, HCP and Diamond Cubic?

____
____
____

3. What is the significance of this experiment? How is it related to your course of study?

4. Define the Atomic packing factor.

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Experiment No. 3

Aim of the Experiment

To recognize various engineering materials based on density and physical appearance.

Apparatus

Weight balance, Vernier Caliper, Assorted Specimen

Theory

The density of a material is defined as the mass per unit volume of the material.
The density can be expressed as follows:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Its unit is grams per centimetre cube (g/cm^3). Metals, as a category, have higher density than plastic however; some metals are denser than others. Therefore, materials can be categorised based on density.

Procedure

First, we take the mass of the specimen by using a weight balance. Measure the dimension of the specimen by using an vernier calliper. Using the measured values, determine the volume of the specimen by using the given formulas:

Volume of cylinder = $\pi r^2 h$

Volume rectangular Cone = Length * Width * HeightVolume

= $1/3 \pi r^2$ * height

Volume sphere = $4/3 \pi r$

1. **Compare the observed density of each specimen with the standard density.**

Table 1: Density of Materials

Material	**Density (gm/cm^3)**
Aluminum	2.7
Copper	8.8
Steel	7.85
Polymers (Elastomers)	0.98
Ceramics (Concrete)	2.4
Composite Material (Wood)	0.46-0.50

Table 2: Standard Density for Various Engineering Materials at 20 ^{0}C

No.	Materials	(gm/cm^3)
01.	Aluminum Alloys	2.6 to 2.9
02	Copper alloys	7.5 to 9.o
03	Lead alloys	8.9 to 11.3
04	Magnesium alloys	1.9
05	Nickel alloys	7.8 to 9.2
06	Titanium alloys	4.3 to 5.1
07	Zinc alloys	5.2 to 7.2
08	Carbon & low alloy Steels	7.8
09	High alloy Steels	7.8 to 8.1
10	Engineering Ceramics	2.2 to 3.9
11	Glasses	2 to 3
12	Thermoplastics	0.9 to 1.6
13	Polymer Foams	0.04 to 0.7
14	Engineering Composites	1.4 to 2
15	Concrete	2.4 to 2.5
16	Wood	0.4 to 1.8
17	Polyester (Thermoset)	1.04 to 1.46

2. Now identify the materials based on appearance

Materials may also be identified by appearance to some extent when in pure form

Table 3: Color Identification

Materials	Color
Aluminum	White
Copper	Reddish
Iron	Grey
Zinc	Bluish
Tin	Silvery

Calculation

Volume specimen 1 =

Volume specimen 2 =

Volume specimen 3 =

Density of specimen 1 =

Density of specimen 2 =

Density of specimen 3 =

Observation

No.	Specimen	Mass	Volume	Density	Color
1					
2					
3					

Result

Specimen 1 has been identified as ________

Specimen 2 has been identified as ________

Specimen 3 has been identified as _________

Questions

1. The theoretical density of a metal can also be calculated using the properties of the _________________
2. The unit of density in S.I system ___________, C.G.S system________, F.P.Ssystem _________________.
3. Enlist some physical properties of metals.

____
____
____
____
____
____
____
____

4. Enlist some physical properties of non-metals.

____
____
____
____
____
____
____
____

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Experiment No. 4

Aim of the Experiment

To perceive the cutting of a given specimen by using the abrasive cut-off machine.

Apparatus

Abrasive cut-off machine, Samples, Coolant, eye protection goggles, gloves.

Theory

The first step in preparing a specimen for metallographic or microstructural analysis is to locate the area of interest. Most metallographic samples need to be cut to the area of interest and for easy handling Sectioning or cutting is the most common technique for obtaining this area of interest. One of the most important aspects of sectioning is to not alter the microstructure or damage fracture features when cutting a specimen.

Sectioning can be categorized into two areas: Abrasive Cutting and Precision Wafer Cutting. In metallographic sample preparation, mostly abrasive cut-off machines are used for sectioning of workpieces for microscopic examination and other material investigations. This technique uses low-speed cut-off wheels in cases where the heat created by standard abrasive cutters must be avoided. Optimum cooling is just as important for the sectioning result as precise movement. It is important to keep the sample cool with lubricant or coolant. The damage to the specimen during sectioning depends on the material being sectioned, the nature of the cutting device, the cutting speed, the feed rate, and the amount and type of coolant used. Common cooling media consist of a mixture of a boric and amino acid-free corrosion protection agent with water. An appropriate concentrate is diluted with water in a ratio of e.g. 1:3. A cut-off wheel consists of abrasive grains (such as Aluminum Oxide or Silicon Carbide), bonded together with rubber or other materials in the form of a thin wheel. Abrasive cutting is primarily used for ductile materials. Examples include metals, plastics, polymer matrix composites, metal matrix composites, etc. Proper blade selection is required to minimize burning and heat generation during cutting which degrades both the specimen surface as well as the blade cutting efficiency. Lubrication during abrasive cutting is required to minimize damage and remove the cutting debris. It should have a relatively high flash point because of the sparks produced during abrasive sectioning.

Proper sectioning is required to minimize damage, which may alter the microstructure and produce false metallographic characterization. Proper cutting requires the correct selection of abrasive type, bonding and size, as well as proper cutting speed, load and coolant.

Procedure

- Select the appropriate abrasive blade.
- Secure specimen - improper clamping may result in blade and specimen damage
- Check coolant level and replace when low or excessively dirty.
- Since abrasive blades break down or wear out during cutting, they produce a significant amount of debris.
- Allow the blade to reach its operating speed before starting the cutting. A steady force or light pulsing action will produce the best cuts and minimize blade wear characteristics as well as maintain sample integrity (no burning).

Result

The metallic sample is successfully sectioned to the area of interest.

Questions

1. The purpose of cutting is to____

   ____

   ____

2. Different types of cutting methods are ____

   ____

   ____

3. The coolant used in the experiment is____

   ____

   ____

4. The composition of the cutting blade used in the experiment is_______________________

   ____

   ____

5. Safety required during sectioning is ____

   ____

   ____

6. The material used in the experiment is ____

   ____

   ____

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Experiment No. 5

Aim of the Experiment
To perceive the hot mounting of given specimens using a Mounting Press Machine.

Apparatus
Mounting press specimen, Bakelite, funnel, measuring spoon, and mold release wax.

Theory
The mounting press machine is an Automatic Mounting Press shown in Fig. 1. The primary purpose of mounting is for convenience in handling specimens of difficult shapesor sizes during the subsequent steps of preparation and examination. A secondary purpose is to protect and preserve extreme edges of surface defects during preparation. The thicknessof the mount should be sufficient to enable the operator to hold the mount firmly during grinding and polishing thereby to prevent a rocking motion and to maintain a flat surface.Circular mounts are commonly 1 to 2 in. in diameter and are the most easily handled. Different types of mounting methods are available e.g. clamp mounting, compression mounting, cold mounting etc. we use the compression mounting method in an experiment using an automatic hydraulic mounting press.

Compression mounting, the most common mounting method involves molding aroundthe specimen by heat pressure. Molding materials used are bakelite, aniline formaldehydecompound resins, acrylic, and Lucite resins. Bakelite and aniline formaldehyde compound resins are thermosetting, and acrylic and Lucite resins are thermoplastic. For making transparent mold we may use Lucite. Both thermosetting and thermoplasticmaterials require head and pressure during the molding cycle, but after curing, mounts made of thermosetting materials may be ejected from the mold at maximum temperature. Thermoplastic materials remain molten at the molding temperature and must cold under pressure before ejection. Mounting presses quipped with molding tools and a heater is necessary for compression mounting. The cylinder is nearly filled with molding material in powder form, and the plunger is inserted into open end of the cylinder. A cylinder heater is placed around the mold assembly, which has been exerted and maintained on the plunger to compress the molding material until it and the mold assembly have been heated to the proper temperature, the finished mount may be ejected from the mold by forcing the plunger entirely through the mold cylinder.

Procedure

1. The inner ram pressure I supplied by hydraulic pressure. To activate the ram, the “Ram Up” and “Ram Down” buttons on the control panel are used.

2. Raise the ram until the top below the edge of mold assembly.

3. Apply mold release inside the mold chamber. When using either spray ofliquid silicone mold release.

4. Raise the ram from flush with the top of the assembly.

5. Place the specimen onto the lower ram and lower is using the ram downbutton until

fully down.

6. Apply enough mounting material to cover the mount, as well extra material ontop, so the top ram does not make contact with the part.

7. If using the duple Xing spacer to produce two mounts in one cycle, place the spacer on top of the mounting material covering the first sample.

8. Swing the top ram/die over the mold chamber. The ram is spring-loaded for ease of removal when unloading the chamber. Push down on the bayonet handles and turn it clockwise to lock the lid until stops hard against the bayonet.

9. Press the button “RUN” on the menu screen, select the menu and press “Run” again to begin the cycle.

10. During the cycle, an illuminated LED on the display panel will indicate the operation of a cycle (Cycle On), and whichever cycle is operating: Pre-Heat, Heat or Cool.

11. When the cycle is complete, an alarm will sound as a series of beeps. The mold will lower automatically enough to loosen and rotate the bayonet open. Loosenthe bayonet by turning the top handle, counterclockwise, until it is unlocked. Itmight be necessary to lower the ram a little more to loosen the bayonet, whichcan be done by pressing the “Ram Down” button.

12. List the top ram up and swing it away around to the rear where it may rest on the heat sink until it is ready to be used again. The sample may be removed at this time.

Figure 1: Mounting Press Machine

Result

A small specimen is successfully mounted in thermosetting plastic and bakelite.

Questions

1. The purpose of mounting is to ____

   ____

   ____

2. Different types of mounting methods are ____________________________________

   ____

   ____
   .

3. Mounting press used in the experiment is ____________________________________

   ____

4. Mounting material used in the experiment is __________________________________

   ____

   ____

5. The mounting temperature for thermosetting plastic is __________________________

6. For making transparent mounts we use _____________________as mounting material.

7. The diameter of the mount made in the experiment is __________________________.

8. Mounting temperature used in the experiment is ______________________________.

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Remarks	
Instructor's Signature with Date	

Experiment No. 6

Aim of the Experiment

To perceive cold mounting of the given specimen.

Apparatus

Weigh Machine, Hardener, Resin, Mixing Cup and Sample.

Theory

After sectioning, material samples are usually mounted. They are typically embedded in synthetic material. This procedure ensures that the sample is held securely for subsequent mechanical preparation. The primary purpose of mounting is for convenience is handling specimens of difficult shapesor sizes during the following steps of preparation and examination. A secondary purposeis to protect and preserve extreme edges of surface defects during preparation. The thicknessof the mount should be sufficient to enable the operator to hold the mount firmly during grinding and polishing thereby to prevent a rocking motion and to maintain a flat surface.Circular mounts are commonly 1 to 2 in. in diameter and are the most easily handled.

During the cold mounting process, the mounting resin is mixed with a hardener. Subsequently, the mixture is poured into an embedding mold containing the sample. Then, polymerization takes place. Different types of resins, such as epoxy resin, polyester acrylic resin, etc., are used for cold mounting. Epoxy resins are suitable for mounting all types of materials and are especially recommended for vacuum impregnation. Epoxies have the lowest shrinkage of all cold-mounting resins. The curing time is relatively long, but adhesion to most materials is excellent.They polymerize through a chemical reaction after being mixed in the correct proportions. The hardened epoxy is duroplastic, and not affected by moderate heat or chemicals. Epoxysystems consist of two components: a resin and a curing agent/hardener. Properties such as low vapor pressure, transparency, good adhesion, low viscosity, and no shrinkage are all specific to epoxies.

Procedure:

The specimen must be cleaned prior to mounting in order to improve the adhesion of the mounting medium to the specimen. Use acetone or at least alcohol. Cleaning in an ultrasonic bath may be necessary.

Dry the specimen well. Clean specimens should be handled with either gloves or tweezers.

Weigh and mix components in a single cup (do not use wax-lined or paper cups)

Mix thoroughly by scraping both sides and bottom of mixing cup for approximately 2-3 minutes until mixture appears homogeneous. Pour the mixture into a mounting cup over the sample and allow curing / hardening.

Result

A small specimen is successfully mounted by using epoxy resin and hardener.

Questions

1. The purpose of mounting is to____

2. Different types of resins are ____

3. The ratio of resin and hardener used in the experiment is ___________________________

   ____

4. Mounting material used in the experiment is ___________________________________

5. The mounting temperature for thermosetting plastic is ____________________________

6. The diameter of the mount made in the experiment is ____________________________

7. Is there any pressure required for Cold Mounting?

____

____

____

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Experiment No. 7

Aim of the Experiment

To observe the grinding and polishing of a given metallographic specimen.

Apparatus

Grinding Machine, Polishing Machine, Grinding Papers, Polishing Papers, Polishing Suspension and Sample.

Theory

The purpose of the coarse grinding stage is to generate the initial flat surface necessary for the subsequent grinding and polishing steps. As a result of sectioning and grinding, the material may get cold worked to a considerable depth with a resultant transition zone of deformed material between the surface and the undistorted metal. Coarse grinding can be accomplished using 60 to 180-grit electrically powered disks, but care must be taken to avoid significant heating of the sample. The final objective is to obtain a flat surface free from all previous tool marks and cold working due to specimen cutting. An important factor throughout the coarse grinding and fine grinding stages is that the scratches be uniform in size and parallel to each other in any one grinding stage. Proper grinding involves rotation of the sample by 90° between stages while the grinding angle must be held constant during the grinding at any one stage.

Medium and fine grinding of metallurgical samples is closely allied with the coarse grinding which precedes them. In general, successive steps are 240, 320, 400 and 600 grit SiC and the grinding rate should steadily decrease from one stage to the next. Proper grinding involves the rotation of the sample between stages while the grinding angle must be held constant during the grinding at any stage. The sample must be washed thoroughly before proceeding from one grinding operation to the next.

Wet grinding is generally applied in medium and fine grinding to avoid possible side effects due to heating such as tempering, transformation, aging, incipient melting, etc. Wet grinding also provides a flushing action for loose particles and keeps the sharp edges of the grinding medium exposed at all times.

Figure 1: Grinding Machine

Mechanical Polishing

Polishing involves the use of abrasives, suspended in a water solution, on a cloth-covered electrically powered wheel. Diamond abrasives provide the best, and most expensive, compounds utilized in polishing; standard sized aluminum oxide powders are applied for general use purposes. Following the final 600-grit fine-grinding stage, the sample must be washed and carefully dried before proceeding to the first polishing stage! At the polishing stages, even hard dust particles in the air which settle on the polishing cloth can cause unwanted scratching of the specimen! Careful washing of the specimen and the operator's hands must be carried out before each stage of polishing! Beginning with 5-micron suspended aluminium oxide particles (suspended in water) on a nylon cloth, the final fine-grinding surface layer resulting from the previous grinding procedure should be completely removed with a rotation rate of 150-200 rpm. The specimen is initially held at one position on the wheel, without rotation, until most of the previous grinding marks are removed. It can be rotated slowly, counter to the wheel rotation, until only scratches from the 5- micron aluminium oxide are visible. The final polishing stage with 1-micron suspended aluminium oxide particles should be carried out on a separate polishing wheel following "Careful washing of the specimen and operator's hands" at a slower speed of 100 - 150 rpm using a napped cloth. After 1 or 2 minutes a properly polished specimen should have a mirror-like surface free of scratches! During final polishing, minimal pressure should be applied and time should be kept to a minimum since the napped material will conform to the specimen shape under pressure. The wetness of the cloth used for final polishing has a great influence on the result. If the cloth is too wet the sample will show pits; if too dry, buffing and/or smearing will result. To determine the proper wetness, the sample should be removed from the wheel and the time required for the polishing film to dry (five to eight seconds) should be checked.

Figure 2: Polishing Machine

Result

The mounted specimen is successfully ground and polished.

Questions

1. The purpose of grinding is ____

2. The grit papers used in the grinding process are ______________________________

3. The purpose of water as a medium is_______________________________________

4. Proper grinding involves rotation of sample by________________________________

5. The purpose of polishing is ____

6. The medium used for polishing the sample is _________________________________

7. The samples after polishing have a surface like ______________________________

F/OBEM 01/03/00

NED University of Engineering & Technology

Department of ____________________ Engineering

Course Code and Title: ____

Laboratory Session No. _____________ Date: ___________________

Psychomotor Domain Assessment Rubric-Level P1					
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	0	1	2	3	4
Equipment Identification Sensory skill to ***identify*** equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify the equipment as well as its components.
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Equipment Handling ***Equipment care*** during the use.	Doesn't handle equipment with required care	Rarely handles equipment with required care	Occasionally handles equipment with the required care	Often handles equipment with the required care	Handles equipment with required care
Group Work ***Contributes*** in a group-based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date	

Experiment No. 8

Aim of the Experiment

To observe the etching practice for given ferrous and non-ferrous alloys.

Apparatus

Chemicals, Samples, Beaker, and Tong, gloves, goggles.

Theory

Etching is used to highlight, and sometimes identify, microstructural features or phases present. Metallographic etching encompasses all processes used to reveal particular structural characteristics of metal that are not evident in the as-polished condition. Examination of a properly polished specimen before etching may reveal structural aspects such as porosity, cracks, and nonmetallic inclusions.

Metallographic etching is done by immersion or by swabbing (or electrolytically) with a suitable chemical solution that essentially produces selective corrosion. Swabbing is preferred for those metals and alloys that form a tenacious oxide surface layer with atmospheric exposure such as stainless steels, aluminum, nickel, niobium, and titanium and their alloys. It is best to use surgical grade cotton that will not scratch the polished surface. Etching time may be different depending on type of alloy. In general, for high magnification examination the etch depth should be shallow; while for low magnification examination a deeper etch yields better image contrast. Some etchants produce selective results in that only one phase will be attacked or colored. Different types of etchants techniques have been utilized such as tint etching, macro etching and selective etching.

Tint etching may color the grains according to their crystallographic orientation. With the development of color image, one can now be used quite effectively to provide accurate grain size measurements and phase identification.

Selective etching: This has been commonly applied to stainless steels for detection, identification and measurement of delta ferrite, ferrite in dual phase grades, and sigma phase. Selective etching techniques are not limited to iron-based alloys, although these have more thoroughly developed than for any other alloy system. Selective etching of the beta phase in alpha-beta copper alloys has been a popular subject.

Macro etching is the selective attack of the surface with the object of revealing the features developed during processing, solidification such as voids, porosity, flakes, inclusions, and cracks etc.

Table 1: List of etchants for ferrous and non-ferrous alloys.

S.No	Etchant	Composition	Conc.	Conditions	Alloys
1.	Kroll's Reagent	Distilled water Nitric acid Hydrofluoric acid	92 ml 6 ml 2 ml	Swab the specimen up to 20 seconds	Titanium and its alloys.
2.	Nital	Ethanol Nitric acid	100 ml 1-10 ml	Immersion up to a few minutes.	Pure iron, carbon steel, low-alloy steel, and grey cast iron. General etchant for steel, in particular, structures of ferritic phases.
3.	Picral	Ethanol Picric acid	100 ml 2-4 grams	Seconds to minutes Do not let etchant crystallize or dry –explosive	Pure iron, carbon steel, low-alloy steel, and cast iron.
4.	Marbel's reagent	Copper sulphate HCL	4gm 20ml		Stainless steels
5.	Keller's reagent	Hydro fluoric acid Nitric acid and Glycerin	20ml 10ml 30ml	immerse 8–15 s, and wash in water; do not remove etchant products from the surface	Aluminum & its alloys
6.	Ferric Chloride	$FeCl_3$ HCl Ethyl alcohol	5gms 2ml 96gms	Immerse 3–12 s.	Common etchant for copper alloys; also, applicable to cold-rolled tempers of copper-beryllium alloys C17500 and C17510 to show grain structure.

Result

The polished specimen is successfully etched to examine microscopically.

Questions

1. The purpose of etching is to
____

____

2. The chemicals used in etching process are
____.

3. The purpose of selective etching is
____

____

4. The purpose of Tint etching is____

____

____

5. Enlist some common etchants for aluminium alloys.
____

____

6. How does etchant chemically react to reveal microstructure?
____

____

____

F/OBEM 01/03/00

NED University of Engineering & Technology

Department of ____________________ Engineering

Course Code and Title: ____

Laboratory Session No. ______________ Date: ____________________

Psychomotor Domain Assessment Rubric-Level P1					
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<u>Equipment</u> <u>Handling</u> ***Equipment care*** during the use.	Doesn't handle equipment with required care	Rarely handles equipment with required care	Occasionally handles equipment with the required care	Often handles equipment with the required care	Handles equipment with required care
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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date	

Experiment No. 9

Aim of the Experiment

To observe the working operation of an optical microscope.

Apparatus
Optical Microscope

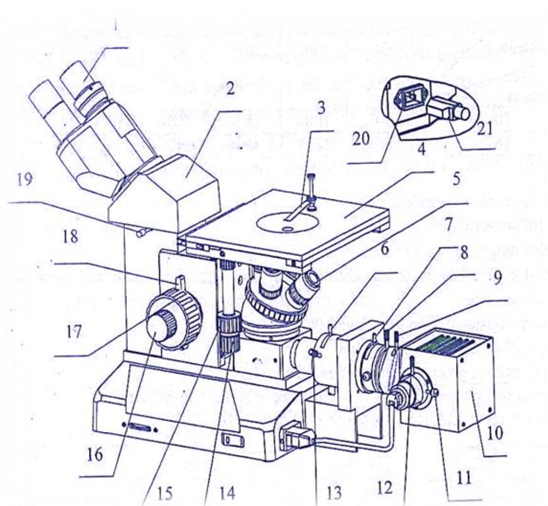
Theory
Optical microscopes as shown in Fig.1 are used for identification and analysis of thestructures of different metals and alloys. They are important instruments for the research of metallurgy. They can be used for quality research of foundry, smelt and heat treatment, for testing of raw and processed materials or analysis of heat treatment materials. They are ideal instrument for scientific research, teaching, factories and so on.

Principle of Metallurgical Microscope
In an Optical Microscope, a horizontal beam of light from some light source is reflected, by means of a plane-glass reflector, downward through the microscope objective onto the surface of the specimen. Some of this incident light reflected from the specimen surface will be magnified in passing through the lower lens system, the objective, and will continue upward through the plane glass reflectorand be magnified again by the upper lens system, the eyepiece. The initial magnifying power of the objective and the eyepiece is usually engraved on the lens mount. When a particular combination of objective and eyepiece is used at the proper tube length, the total magnification is equal to the product of the magnifications of the objective and the eyepiece.

The maximum magnification obtained with the optical microscope is about 2OOOX

Principle Limitation
The principal limitation is the wavelength of visible light, which limits the resolution of fine detail in the metallographic specimen. The magnification may be extended somewhat by the use of shorter-wavelength radiation, such as ultraviolet radiation, but the sample preparation technique is more involved.

Figure 1: Optical Microscope



1. Eye Piece	10. Lamp Box
2. Binoculars	11. Lamp Holder Lock Screw
3. Stretchy Clip	12. Lamp Adjustment Pole
4. Mechanical stage	13. Field Diaphragm Adjustment Screw
5. Objective	14. Cross Movement Knob
6. Field Diaphragm	15. Lengthways Movement Knobs
7.Stage Adjustment Pole	16. Fine Focusing Knob
8. Aperture Diaphragm Adjustment Pole	17. Coarse Focusing Knob
9. Filter	18. Limit Knob
10. Condenser Adjustment Pole	19. Tube Holding Screw
20. Electrical Outlet	21. Power Supply

Figure 2: Various parts of the optical microscope

Question

1. In an Optical Microscope a horizontal beam of ___________________________________ passes through a plane glass reflector.

2. The total magnification is equal to the product of the magnification of the objectiveand the ____.

3. The maximum magnification obtained with the Optical Microscope is about ____.

4. An Optical Microscope helps determine ____________________________ _________and ____.

5. In Optical Microscope illumination beam is ______________________________________.

F/OBEM 01/03/00

NED University of Engineering & Technology

Department of ____________________ Engineering

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EXPERIMENT No. 10

Aim of the Experiment

To observe the working principle of the Brinell hardness tester.

Apparatus

Brinell hardness tester.

Theory

Hardness may be defined as resistance to plastic deformation (usually) by indentation. However, the term may also refer to stiffness, temper or resistance to scratching, abrasion, or cutting. Indentation hardness may be measured by various hardness tests such as Brinell, Rockwell, etc. In the Brinell hardness method, the indenter size and the load to be applied are determined from the scales provided for the type of material to be tested.

The hardness is calculated by the following formula.

$$BHN = \frac{2P}{\pi D\ (D - \sqrt{D^2 - d^2})}$$

Where,

P= Major Load
D= Diameter of the ball
d=Indentation diameter

An indenter (A hard metal ball with diameter D) is forced into the surface of a test pieceand the diameter of the indentation d left in the surface after removal of the force F is measured.

The brinell hardness is proportional to the quotient obtained by dividing the test force by the curved surface area of the indentation. The indentation is assumed to be spherical with a radius corresponding to half of the diameter of the ball.

The brinell number which normally rises from HB50 to HB750 for metals, will increase as the sample gets harder.

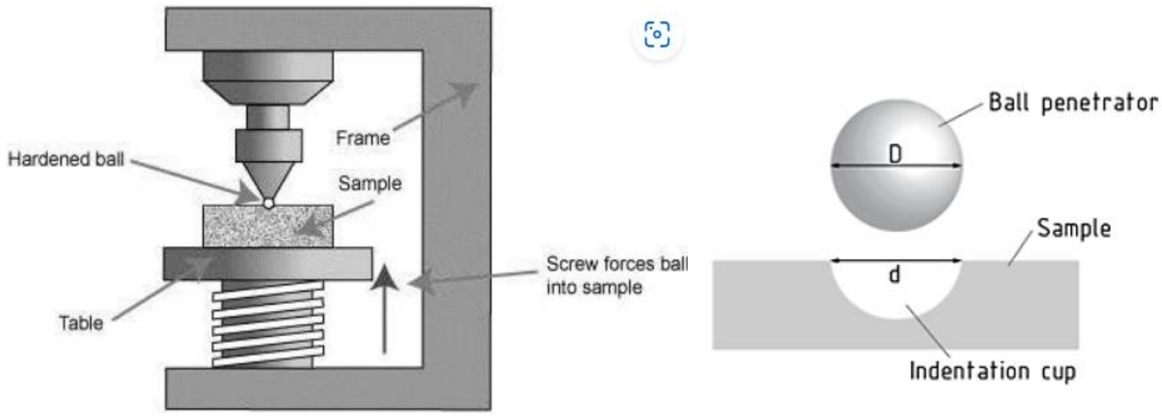

Figure 1: Brinell Hardness Tester

Procedure

Explain yourself about this practical.

Question

1. The unit for measuring Brinell's hardness is

a) HRB
b) Hardness number
c) Grams /mm
d) None of the above

2. Diamond indenter is used in

a) Brinell Hardness test
b) Rockwell Hardness test
c) Both of the above

3. A Brinell's Hardness test was done on the following materials and the results were tabulated as follows

a) Materials A,	HB=200
b) Materials B,	HB=100
c) Materials C,	HB=50

4 Which material is the hardest?

Answer ___________________________

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NED University of Engineering & Technology

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Laboratory Session No. _____________ Date: ___________________

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date	

Experiment No. 11

Aim of the Experiment

To **observe** the working principle of the lathe machine and various lathe operations.

Theory

A lathe is a machine, that removes the metal from a piece of work to the required shape and size. The lathe is one of the most important machine tools in the metalworking industry. A lathe operates on the principle of a rotating workpiece and a fixed cutting tool. The cutting tool is fed into the workpiece, which rotates about its axis causing the workpiece to be formed to the desired shape. Lathe machine is also known as "the mother/father of the entire tool family".

Function of lathe

The lathe is to remove excess material in the form of chips by rotating the workpiece against a stationary cutting tool. The Lathe Machine is also known as the "**Centre Lathe**" because it has two centres between which the job can be held and rotated.
The main parts of the centre lathe are:

- ➢ Bed,
- ➢ Headstock,
- ➢ Tail stock,
- ➢ Carriage, etc.

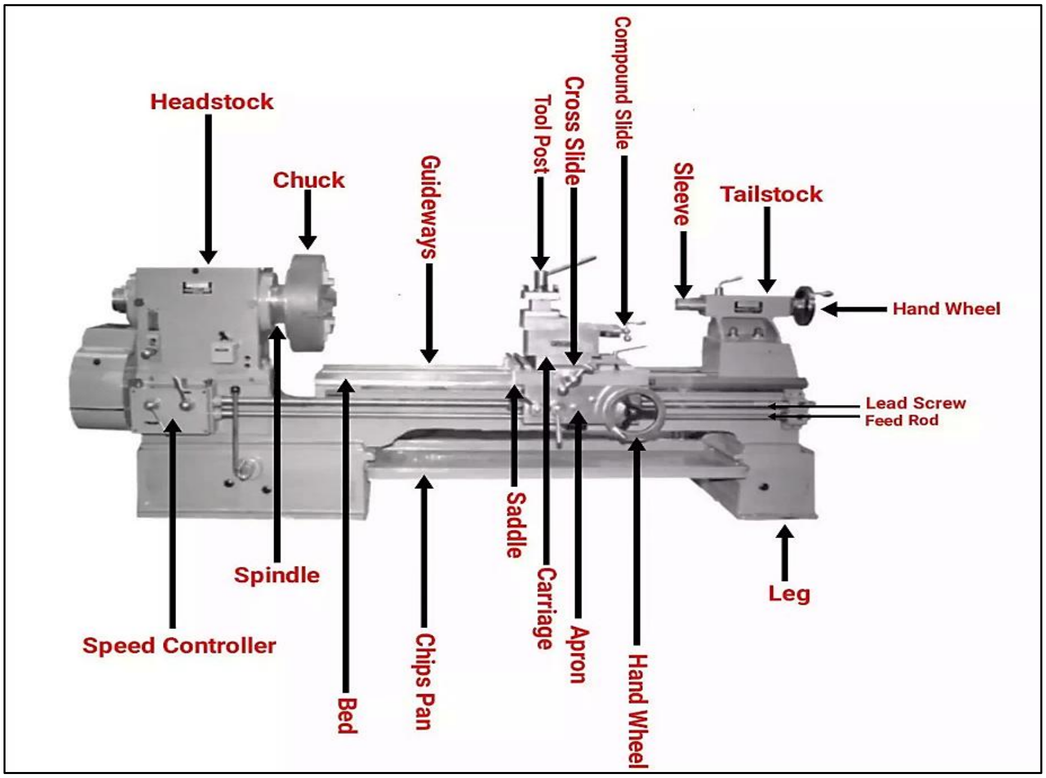


Figure 1: The figure shows various parts of the lathe machine.

The working principle of lathe

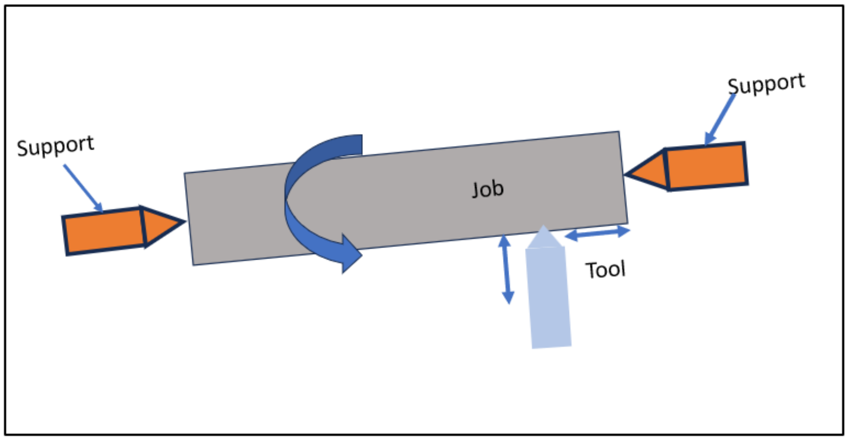
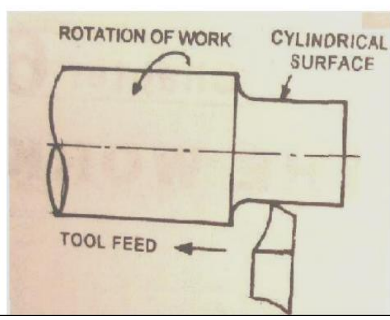


Figure 2: The working principle of the lathe machine.

If the tool moves parallel to workpiece cylindrical surface is formed.



If the tool moves inclined to the axis it produces a taper surface and is called taper turning.

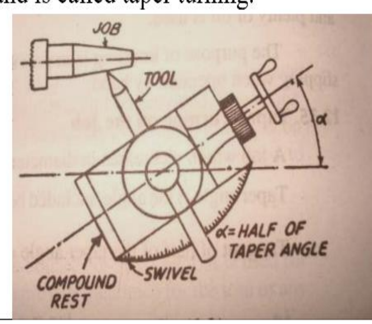


Figure 3: The lathe operations i.e., straight turning (left), and taper turning (right).

Operating Conditions

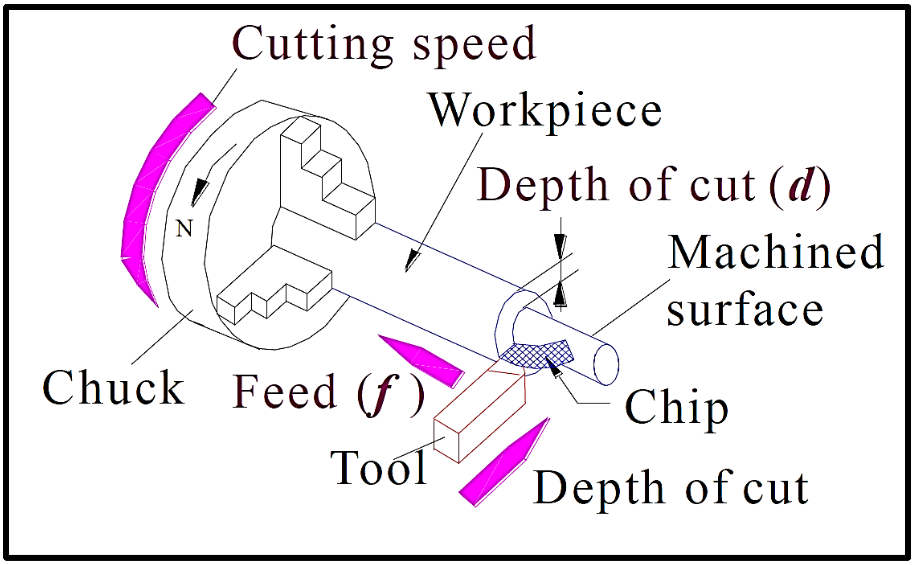


Figure 4: The operating condition of the lathe.

Lathe Operations

- **Turning:** to remove material from the outside diameter of a workpiece to obtain a finished surface**.**
- **Facing:** to produce a flat surface at the end of the workpiece or for making face grooves
- **Boring:** to enlarge a hole or cylindrical cavity made by a previous process or to produce circular internal grooves.
- **Drilling:** to produce a hole in the workpiece.
- **Reaming**: to finish the drilled hole.
- **Threading:** to produce external or internal threads on the workpiece.
- **Knurling:** to produce a regularly shaped roughness on the workpiece.

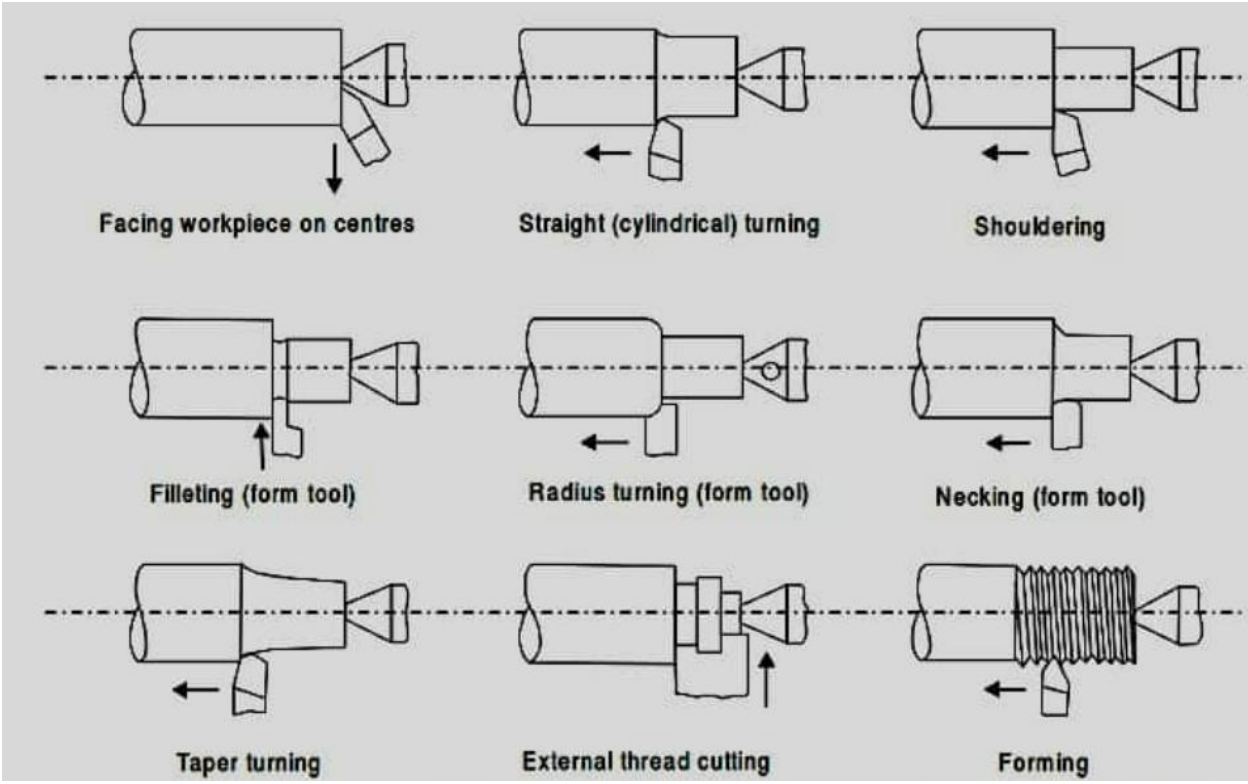


Figure 5: The lathe Operations.

Question

1. Explain the Knurling operation on the lathe machine

2. Discuss the term "undercutting".

3. Discuss the steps adopted for turning operation on a cylindrical workpiece.

4. Discuss the limitations of the Lathe machine.

5. Discuss various types of lathe machine tools.

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date	

Experiment No. 12

Aim of the Experiment

To **perceive** various types of milling machines and milling cutters.

Theory

Milling is a machining process in which metal is removed by a rotating multiple-tooth cutter against a fixed work piece, each tooth removing a small amount of metal with each revolution of the spindle. In this operation, the cutter rotates at high speeds, and metal removal is very fast. Milling machines are employed for machining flat surfaces, contoured surfaces, external and internal teeth on gear blanks, and helical surfaces.

Classification of Milling Machine:

1. **Column and knee type**
   a) Plain or Horizontal milling Machine
   b) Universal milling machine
   c) Vertical milling machine
2. **Fixed bed type**
   a) Simplex milling machine
   b) Duplex milling machine
   c) Triplex milling machine

3. **Planer type**
4. **Special type.**
   a) Rotary fable milling machine
   b) Drum milling machine
   c) Planetary milling machine.
   d) Profile tracer milling machine

Spindle orientation is one of the means of classifying milling machines. Horizontal milling machines have horizontal spindles and are most commonly used. Vertical milling machines have their spindle in the vertical direction. Special milling machines have horizontal, vertical, and angular spindles, which operate either one after the other or all at the same time.

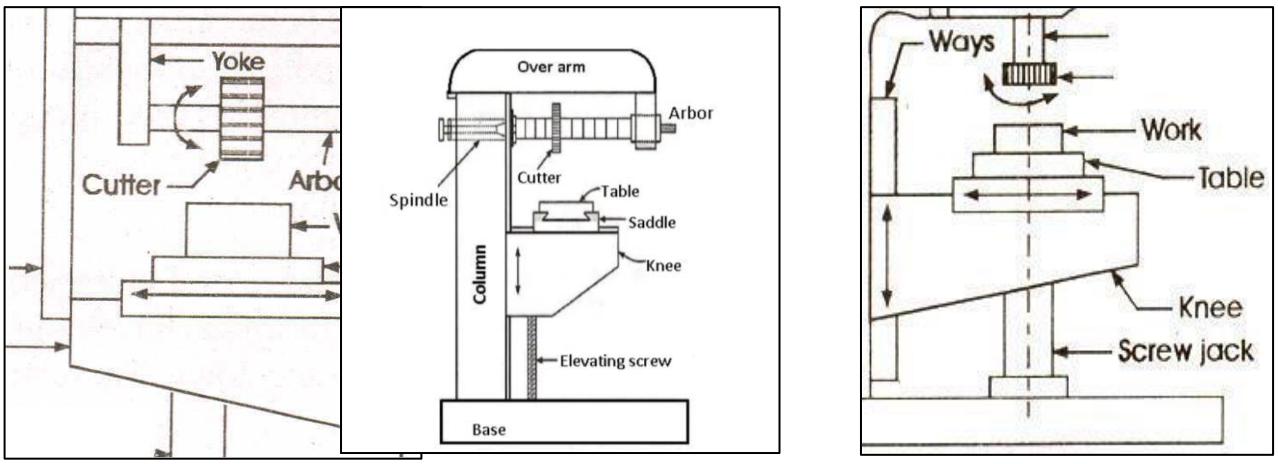
Column and Knee type Milling Machines:

These are so named because of two of their main structural elements, a column-shaped main frame and knee-shaped projection. The six principal parts of these machines are:

a) The base, on which the milling machine structure is built.
b) The column, which contains the spindle and its driving mechanism.
c) The overarm mounted on the column, which supports the other end of the arbour.
d) The knee, which is a structural member attached to the column and which moves vertically on the column.
e) The saddle, which is mounted on the knee and moves horizontally.
f) The table mounted on the saddle, which moves at right angles to the saddle.

g) Work is clamped on the table. The column and knee-type milling machines can have manual or power control for all movements. By the use of stops & other control devices, the machine can be adapted for Automatic cycles.

Horizontal Milling Machine:
Horizontal knee-type milling machines are classified as plain or universal depending upon whether or not the table can be swivelled in a horizontal plane. The table on the universal machine can be swiveled up to 459 to the right or left, making possible angular and helical milling. These machines can also be converted into vertical type if they have vertical spindle heads. The feature of a horizontal or plain milling machine is illustrated in the figures below.



(a) **(b)** **(c)**

Figure 1 (a): Horizontal Milling Machine, (b) Column and Knee type Milling Machine and (c) Vertical Milling Machine

Parts:
Base, Column, Table. Saddle (upper and lower), Knee, arbor, adjustable bearing block.

Vertical Milling Machine:
Vertical knee-type milling machines have a vertical spindle. They may be either the fixed head, sliding head, or swivel head type or they may be a combination of the multiple cutting teeth of similar shape equally spaced on the circumference of the cutter. These teeth intermittently engage with the workpiece and cause cutting action upon continuous feeding. Milling cutters may be made of High-Speed Steel, cast alloys, or cemented carbide tips. Generally, HSS, tools are used for regular operations. The different types of milling cutters, classified based on their constructional features and the type of operation performed, are as follows:

1) **Plain Milling Cutters**
    a) Straight teeth cutter
    b) Helical teeth cutter

2) **Milling cutters**
    a) Plain teeth
    b) Staggered teeth
    c) Half side teeth

3) **Metal slitting Saw**
    a) Plain teeth
    b) Staggered teeth

4) **Angle Milling cutters**
    a) Single-angle type
    b) Double-angle type

5) **End Milling Cutters**
    a) Straight shank
    b) Taper shank
    c) Shell end

6) **Slot Milling Cutters**
7) **Fly cutters.**
8) **Formed cutters**
9) **Tip and Reamer cutters**

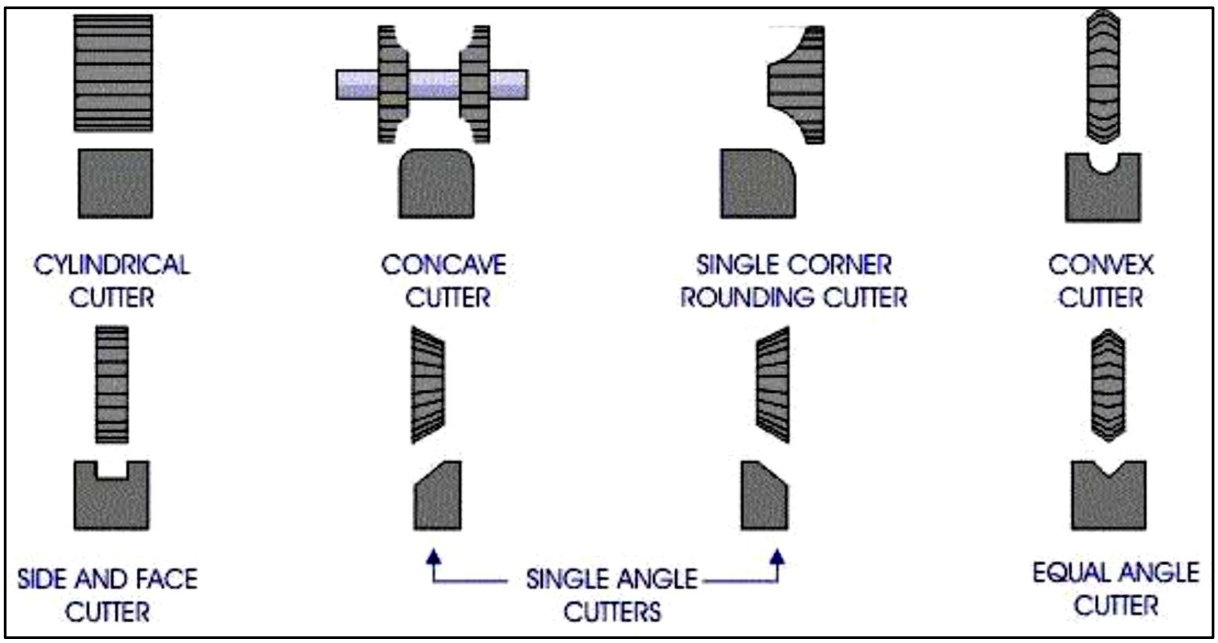


Figure 2: Different types of milling cutters

Question

1) Discuss various types of milling operations.

2) Demonstrate the milling operations performed on CNC milling machine.

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Safety Adherence Adherence to ***safety*** procedures.	Doesn’t adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
Equipment Handling ***Equipment care*** during the use.	Doesn’t handle equipment with required care	Rarely handles equipment with required care	Occasionally handles equipment with the required care	Often handles equipment with the required care	Handles equipment with required care
Group Work ***Contributes*** in a group-based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor’s Signature with Date	