INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

MANUFACTURING PRACTICE								
I Semester: CSE (AI & ML) / IT / ECE / EEE **II Semester:** CSE / CSE (DS) / CSE (CS)								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
AMED02	**Foundation**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		-	1	2	2	40	60	100
Contact Classes: Nil	**Tutorial Classes: 15**	**Practical Classes:30**				**Total Classes:45**		
Prerequisite: There is no prerequisite for this course.								

I. COURSE OVERVIEW:
This course provides the opportunity to become confident with new tools, equipment, and techniques for creating physical objects and mechanisms with a variety of materials. The students will learn the concepts of 3D printing, laser cutting, circuit board soldering, wood carving and CNC machining. Skills learned in the course enable the students about the design process in digital manufacturing used in various industrial applications.

II. COURSES OBJECTIVES:
The students will try to learn

I. The digital and additive manufacturing techniques used in various industrial applications in the current era to develop prototype models.
II. The unconventional machining processes and their selective applications as an alternative to traditional manufacturing methods.
III. The standard electrical wiring practices for domestic and industrial appliances.
IV. The soldering and de-soldering components on a circuit board safely and correctly.

III. COURSE OUTCOMES:
At the end of the course students should be able to:

CO 1 Practice the various types of manufacturing methods for preparing the given material to desired shape by using traditional and unconventional manufacturing practices.

CO 2 Execute the additive manufacturing technology for learning about the 3D printing processes and techniques.

CO 3 Select computer numerical control laser techniques for preparing the required geometrical profiles on non-metallic materials.

CO 4 Demonstrate the assembly and disassembly of electrical equipment's and controls for safe domestic applications.

CO 5 Make use of computer numerical technologies to create products using wood carving techniques.

CO 6 Apply the plumbing skills to work with fittings and pipes made of PVC and galvanized steel.

IV. COURSE CONTENT:

EXERCISES ON MANUFACTURING PRACTICES

Note: Students are encouraged to bring their own laptops for laboratory practice sessions.

All dimensions are in mm in experiments.

Safety

Safety is a vital issue in all workplaces. Before using any equipment and machines or attempt practical work in a workshop everyone must understand basic safety rules. These rules will help keep all safe in the workshop.

Safety Rules

1. Always listen carefully to the teacher and follow instructions.
2. When learning how to use a machine, listen very carefully to all the instructions given by the faculty / instructor. Ask questions, especially if you do not fully understand.
3. Always wear an apron as it will protect your clothes and holds lose clothing such as ties in place.
4. Wear good strong shoes.
5. Bags should not be brought into a workshop as people can trip over them.
6. Do not use a machine if you have not been shown how to operate it safely by the faculty / instructors
7. Know where the emergency stop buttons are positioned in the workshop. If you see an accident at the other side of the workshop you can use the emergency stop button to turn off all electrical power to machines.
8. Wherever required, wear protective equipment, such as goggles, safety glasses, masks, gloves, hair nets, etc.
9. Always be patient, never rush in the workshop.
10. Always use a guard when working on a machine.
11. Keep hands away from moving/rotating machinery.
12. Use hand tools carefully, keeping both hands behind the cutting edge.
13. Report any UNSAFE condition or acts to instructor.
14. Report any damage to machines/equipment as this could cause an accident.
15. Keep your work area clean.

1. Getting Started Exercises

1.1 Principles of 3D printing and additive manufacturing techniques

3D printing or additive manufacturing enables to produce geometrically complex objects, shapes and textures. It often uses less material than traditional manufacturing methods and allows the production of prototypes / products that are not possible to produce economically with conventional manufacturing.

i) Familiarization of 3D printing machine and its principle of operation.
ii) Standard use of Computer Aided Design (CAD) drawings .dwg format and Interface with CURA / Simplify 3D software as .stl file.
iii) Selection of Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) materials and their specifications.

1.2 Preparation of stepped pulley with PLA material as shown in Figure 1.1

- Slicing of stepped pulley using. stl format
- Laying of stepped pulley using 3D printing

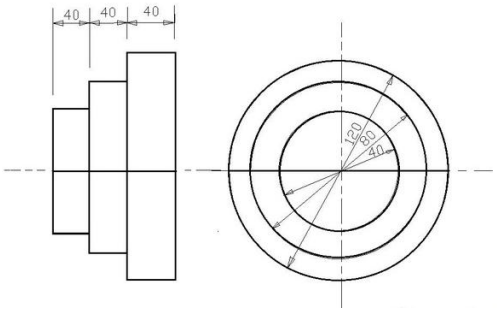

Figure 1.1 Stepped pulley

Try

1. Preparation of spur gear with ABS material as shown in the Figure 1.2
   - Slicing of spur gear using .stl format
   - Laying of spur gear using 3D printing.

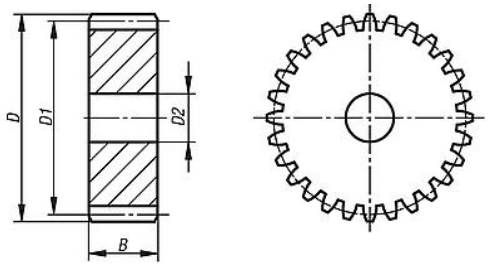

Figure 1.2 Spur gear

Dimensions:

D = 40mm

D1 = 44mm Module, m= 2mm

D2= 20mm B= 10mm

Hint: Set the appropriate nozzle and temperature for ABS material, compare with PLA material.

2. Introduction to computerized numerical control (CNC) laser engraving

CNC Engraving machine is the process of gradually removing a small amount of material from a surface along a defined path. The process leaves a visible marking on the surface of the substrate (workpiece) with high accuracy and precision control.

i) Familiarization of CNC engraving machine with action control.

ii) Create a visualization of the engraving pattern on CAD software. The student must have a solid grip on CAD to be able to create complex patterns in a quick and accurate manner.

iii) Computer Aided Manufacturing (CAM) software is a special software that is used to generate programs for the CNC engraving machine.

2.1 Preparation of acrylic gears using CNC laser engraving / cutting machine as shown in Figure 2.1

i) The parts file is divided into two pages. The file is a pdf. As different laser cutters use different file formats I leave it to you to convert it to a format suitable for your machine.

ii) All the parts apart for the dowel pieces cut out and ready to go. The blue piece is the clear acrylic front with its protective film still attached. Having cut out all the parts follow the instructions below to assemble the gear display.

iii) Glue together the two eighteen teeth gears. Make sure that they are aligned precisely.

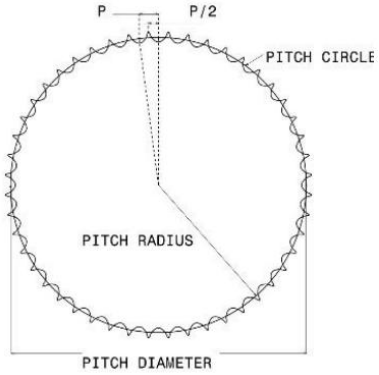

Figure 2.1 Acrylic gear

Try

1. Preparation of artistic components IARE logo using CNC laser engraving as shown in the Figure 2.2
   - Open your program and create new file (OPEN-NEW FILE), use the TEXT tool and write the word you want to engrave.
   - Shows how to transform this word into an objects, each letter will become an individual shape.
   - When using the laser technology, you have to make sure the file is one whole object, not a group of objects.

Figure 2.2 IARE logo

Hint: Set the appropriate parameters to perform operation on the balsaw wood material.

3. Introduction to computerized numerical control wood carving machines

CNC wood carving is the process of gradually removing a small amount of material from a surface along a defined path. The process leaves a visible marking on the surface of the substrate (workpiece) with high accuracy and precision control.

i) Familiarization of CNC machine with action control.
ii) Create a visualization of the engraving pattern on CAD software. The student must have a solid grip on CAD to be able to create complex patterns in a quick and accurate manner.
iii) Computer Aided Manufacturing (CAM) software is a special software that is used to generate programs for the CNC engraving machine.

3.1 Preparation of wooden wheel using computerized wood carving machine as shown in the Figure 3.1

- Preparation of CAD .dwg file
- Importing the file into wood carving machine for generating the profile using CAM software.

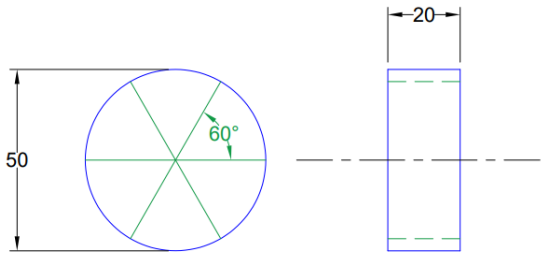

Figure 3.1 Wooden wheel

Try

1. Preparation of IARE lettering using CNC wood carving as shown in the Figure 3.2.

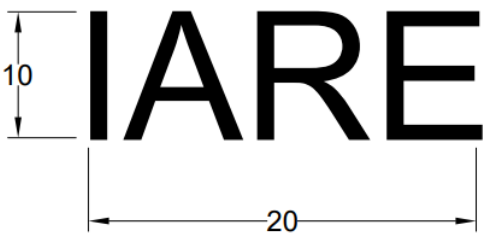

Figure 3.2 IARE lettering

Hint: Set the appropriate parameters to perform operation on the medium density fibreboard (MDF) wood material.

4. Introduction to pipe fitting and threading

Threaded fittings are used in non-critical applications and when service fluid is at ambient temperatures such was instrument air, plant air, cooling water, potable water etc. As they do not require welding, they are used at places where welding is not permitted.

i) Preparation of Polyvinyl Chloride (PVC) material for pipe fitting
ii) Making threads on PVC pipe using thread die sets
iii) Fitting the threaded PVC pipe for T-shape using Tee joint

4.1 Preparation of PVC material for pipe threading and fitting as shown in the figure 4.1

i) Start by cutting the two pipes to the required length, making sure that they are the same size and the ends line up properly.
ii) Make the threads using die sets to one end of the pipes, then place it on top of the pipe where you want to join.
iii) Then start rotating to get bonded together.

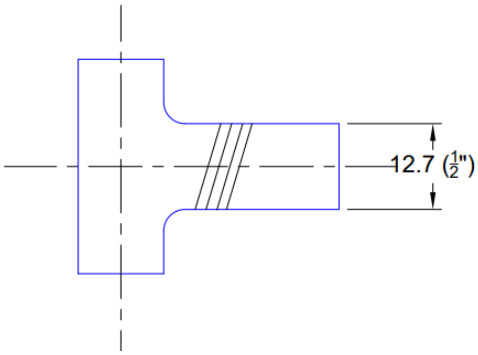

Figure 4.1 T Joint

Try

1. Preparation of galvanized steel I joint as shown in the Figure 4.2.
   i) Start by cutting the two pipes to the required length, making sure that they are the same size and the ends line up properly.
   ii) Make the threads using die sets to one end of the pipes, then place it on top of the pipe where you want to join.
   iii) Then start rotating to get bonded together.

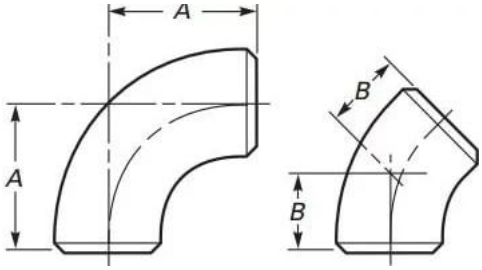

Figure 4.2. GI Elbow Joint

Dimensions:

A = 40mm

B = 30mm

Hint: Set the appropriate die sets in order to get perfect threading in pipe fittings.

5. Introduction to computer numerical control (CNC) lathe machines

A lathe is a machine tool that rotates a workpiece about an axis of rotation to perform various operations such as cutting, sanding, knurling, drilling, deformation, facing, and turning, with tools that are applied to the workpiece to create an object with symmetry about that axis.

i) Operate with Computer Numerical Control (CNC) systems and provided with precise design instructions.
ii) CNC Lathes are machine tools where the material or part is clamped and rotated by the main spindle, while the cutting tool that work on the material, is mounted and moved in various axis.

5.1 Preparation of Mild Steel (MS) material for step turning with grooving operation as shown in the Figure 5.1

- Inspect the mild steel raw material using Vernier calipers. The work piece is held in the chuck by placing it properly and tightening it using the chuck key.
- Now single point cutting tool is placed in the tool post and properly arranged to the centre of the work piece.
- Work piece is rotated by switching on the motor.
- Perform the facing operations on both sides and maintain the given dimensions.
- First the plain turning operation is carried out by placing the tool at 1 mm feed to the lathe axis.
- After that step turning operation is performed till the desired diameter is obtained.

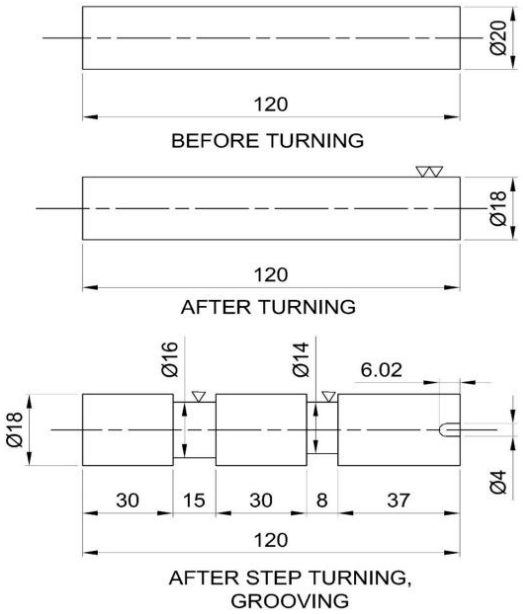

Figure 5.1. Step turning with grooving operation

Try

1. Preparation of Mild Steel (MS) material for step turning with tapper operation as shown in the Figure 5.2.
   - Select a tool bit to the desired size and shape of the groove required.
   - Lay out the location of the groove.
   - Set the lathe to half the speed for turning.
   - Mount the workpiece in the lathe and set the tool bit to centre height.

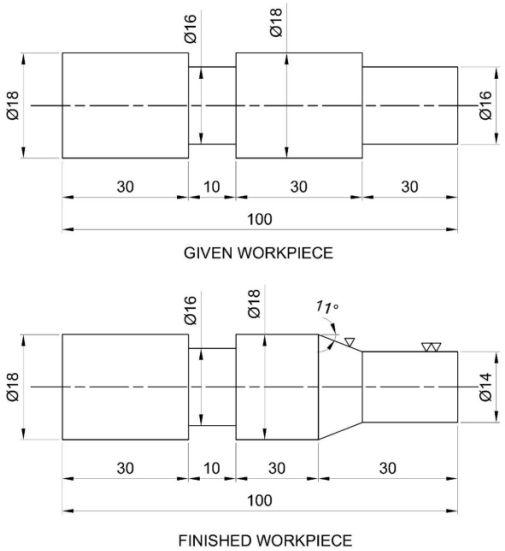

Figure 5.2. Step turning with tapper operation

6. Introduction to conventional lathe machines

The conventional lathe machine is a standard lathe that is used for holding and turning various types of materials such as metal, wood, plastic etc. against a cutting tool in order to produce a cylindrical object. Besides this it can even perform many other functions like grinding, boring, threading, polishing, reaming, drilling etc.

i) Operate with conventional lathe provides with manual design instructions.
ii) Lathes are machine tools where the material or part is clamped and rotated by the main spindle, while the cutting tool that work on the material, is mounted and moved in various axis.

6.1 Preparation of mild steel (MS) material for thread cutting and knurling operation as shown in the Figure 6.1

- Fix the job on the machine by using chuck key. Turn the job to the required diameter by fixing the single point cutting tool.
- Chamfer the edge and make an under cut at the other end.
- Engage the bed screw and perform the threading operation.
- Stop when the pitch is measured by the pitch gauge.
- Reverse the job and hold it carefully so that the threads are not damaged. Disengage the back gear and lead screw
- Hold the knurling tool against the rotating job.

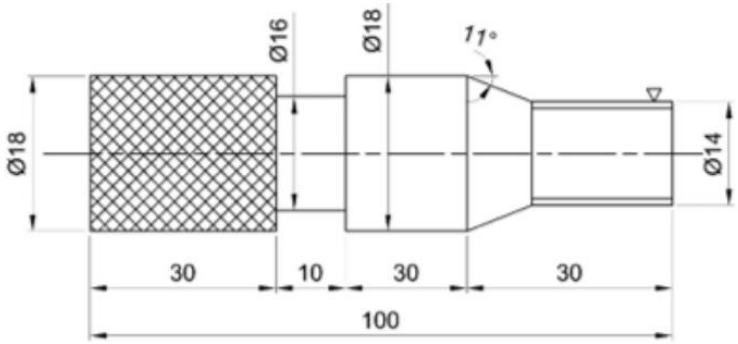

Figure 6.1. Thread cutting and knurling operation

Try

1. Preparation of aluminum material for step turning with tapper operation as shown in the Figure 6.2.
   - Select a tool bit to the desired size and shape of the groove required.
   - Lay out the location of the groove.
   - Set the lathe to half the speed for turning.
   - Mount the workpiece in the lathe and set the tool bit to centre height.

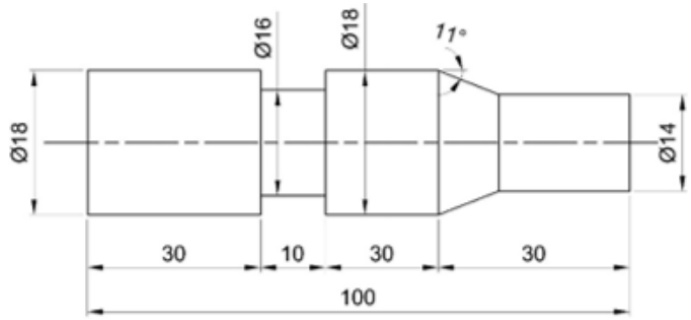

Figure 6.2. Step turning with tapper operation

7. Introduction to milling machines

Milling is the process of machining using rotary cutters to remove material by advancing a cutter into a workpiece. This may be done by varying directions on one or several axes, cutter head speed, and pressure. Milling covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most used processes for machining custom parts to precise tolerances.

i) Milling machine employed in the metal removing operation in which the work is rigidly clamped on the table of the machine and the revolving cutter which has multiple teeth is mounted on the arbor.

ii) The cutter revolves at high speed and the work is fed slowly past the cutter.

iii) The work can be fed in a vertical, longitudinal, or cross direction depending upon the type of milling machine being used.

iv) As the work proceeds, the cutter-teeth removes the metal from the surface of the job(workpiece) to produce the desired shape.

7.1 Preparation of slotting operation as shown in Figure 7.1

- Keep the work piece on the working table in req. position with the help of holding device.
- Keep the cutting tool in the spindle and move the working table upward to give touch the surface of the work piece.
- Then give the power supply and move the work table forward and backward with the help of lever.
- Repeat the same procedure by changing the feed rate in upward and cross direction to get the req. dimension of slot on the work piece.

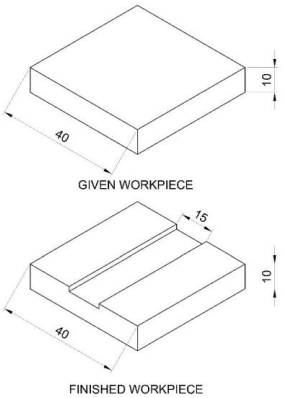

Figure 7.1 Slotting operation

Try

1. Perform the boring and reaming operation on a rectangular work piece to obtain the required dimensions using vertical milling machine as shown in Figure 7.2.

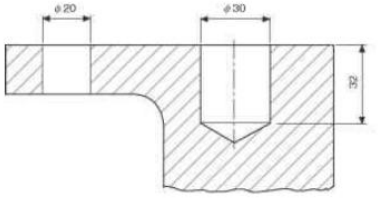

Figure 7.2. Boring and reaming operation

8. Introduction to shaping machines

A shaping machine is a mechanical device used to shape and form metal workpieces. It operates by removing material through a reciprocating cutting motion, resulting in the desired shape or contour. Shaping machines are commonly used in metalworking industries for various applications, including creating flat surfaces, slots, and grooves.

i) A rigid table on the machine supports the workpiece. Over the workpiece, the ram moves back and forth as shown in the animation above. A vertical tool slide is adjusted to either side of the vertical plane along the stroke axis, which is located at the front of the ram.

ii) The geometry of the linkage causes the ram to travel more quickly on the return stroke than the forward stroke (cutting stroke). As the shaper works on the quick return mechanism, the sliding action of the slider is aided by the rotating link.

iii) One of the four mechanisms i.e. crank and slotted, whitworth quick return, hydraulic, and automatic table feed mechanism, is responsible for the quick return mechanism and reciprocating movement of the ram. The automatic table feed is commonly used today which employs a pawl and ratchet mechanism in a shaping machine.

8.1 Preparation of V-groove operation as shown in Figure 8.1

- The job is fixed on a vice and the tool is fixed on tool post.
- The stroke of ram is adjusted to required length and machine is switched on.
- Always during machining, the job should be properly fixed with the half of try Square and vice to get a right-angle surface after machining.
- After completion of work, the job should be filled help of file before fixing the job, V block dimensions are marked on the job with the help of dot punch.
- The tool head should be rotated at 450 to make the V- groove.

- The feed is given such that the tool moves gradually on either side of the middle line.

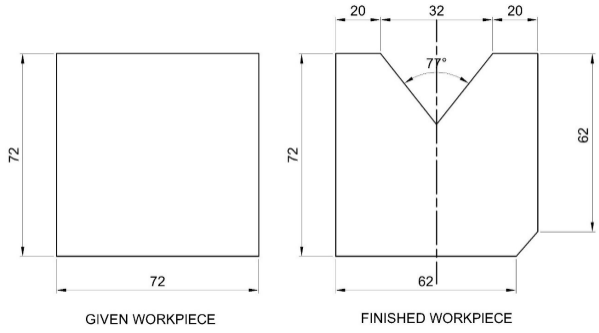

Figure 8.1 V-groove operation

Try

1. Perform the key ways on a cylindrical work piece to obtain the required dimensions using shaping machine as shown in Figure 8.2

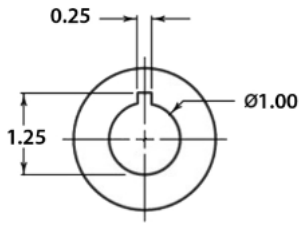

Figure 8.2 Key ways on a cylindrical work piece

9. Introduction to electrical wiring practices for domestic appliances

The Electrical Wiring Systems are mostly standardized with several rules, regulations, and laws. Electrical Wiring must be installed correctly and safely in accordance with electrical regulations and standards. If the electrical wiring is carried out incorrectly or without confirming to any standard, then it may lead to incidents like short circuits, electric shocks, damage the device / appliance or leads to the malfunctioning of device which further causes for the reduction of device life.

i) Before starting any installation work, the first and foremost thing is the concern of safety of the personnel. Electricity is dangerous and direct or indirect contact of electrical equipment or wires with the power turned ON can result in serious injuries or sometimes even causes death. Follow the below steps to maintain the safety at the workplace.

ii) Several factors must be considered before the actual installation work to be done for residential, commercial, or industrial wiring. These factors include type of building construction, type of ceiling, wall, and floor construction, wiring methods, installation requirements, etc.

9.1 Preparation of wiring for a stair case arrangement using a two-way switch as shown in Figure 9.1

- Mark switch and bulb location points and draw lines for wiring on the wooden Board.
- Place wires along the lines and fix them with the help of clips.
- Fix the two-way switches and bulb holder in the marked position on the wooden Board.
- Complete the wiring as per the wiring diagram.
- Test the working of the bulbs by giving electric supply to the circuit

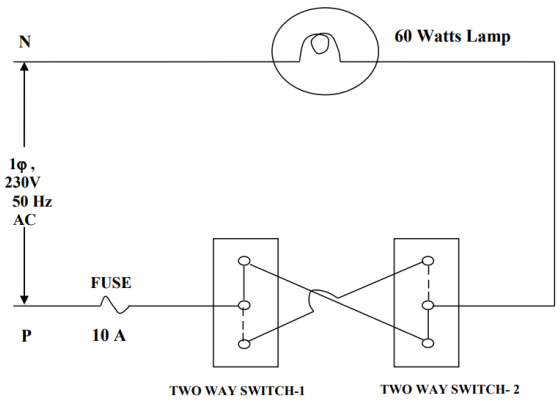

Figure 9.1 Circuit diagram-staircase wiring

Try

1. Prepare wiring for a tube light with switch control as shown in Figure 9.2.
   - Mark the switch and tube light location points and draw lines for wiring on the wooden board.
   - Place wires along the lines and fix them with the help of clips.
   - Fix the switch and tube light fitting in the marked positions.
   - Complete the wiring as per the wiring diagram.
   - Test the working of the tube light by giving electric supply to the Circuit.

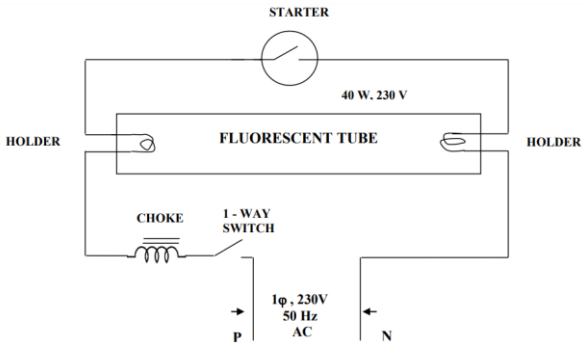

Figure 9.2 Circuit diagram-tube light

10. Introduction to soldering and desoldering practice

Soldering is defined as "the joining of metals by a fusion of alloys, which have relatively low melting points". In other words, you use a metal that has a low melting point to adhere the surfaces to be soldered together. Soldering is more like gluing with molten metal than anything else. Soldering is also a must have skill for all sorts of electrical and electronics work. It is also a skill that can only be developed with practice.

i) Soldering requires two main things: a soldering iron and solder. Soldering irons are the heat source used to melt solder. Irons of the 15W to 30W range are good for most electronics/printed circuit board work.

ii) Using anything higher in wattage and you risk damaging either the component or the board. Note that you should not use so-called soldering guns. These are very high wattage and generate most of their heat by passing an electrical current through a wire. Because of this, the wire carries a stray voltage that could damage circuits and components. The choice of solder is also important.

iii) One of the things to remember is to never use acid core solder. Acid core solder will corrode component leads, board traces and form conductive paths between components.

10.1 Preparation of soldering from a circuit board as shown in Figure 10.1

- All parts must be clean and free from dirt and grease.
- Try to secure the work firmly.
- "Tin" the iron tip with a small amount of solder. Do this immediately, with new tips being used for the first time.
- Clean the tip of the hot soldering iron on a damp sponge.
- Many people then add a tiny amount of fresh solder to the cleansed tip.
- Heat all parts of the joint with the iron for under a second or so.
- Continue heating, then apply sufficient solder only, to form an adequate joint.
- Remove and return the iron safely to its stand.
- It only takes two or three seconds at most, to solder the average printed circuit board (PCB). joint.
- Do not move parts until the solder has cooled.

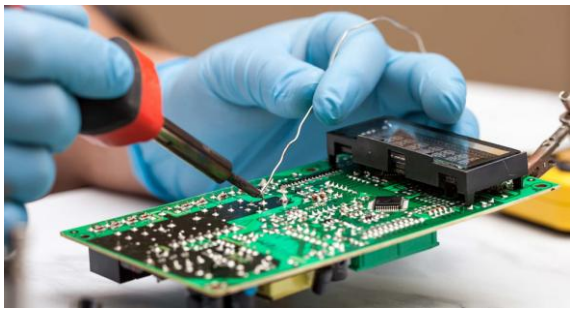

Figure 10.1 Soldering operation

Try

1. Perform desoldering operation from a circuit board as shown in Figure 10.2.
   - Heat up the solder with the iron.
   - Slide the iron up the pins to bring most of the solder away from the joint.
   - Using pliers, gently pull at the components to remove their pins from the pin holes while they are still hot. It's a good idea to pull by their leads as opposed to on the components themselves to maintain the quality of the component.

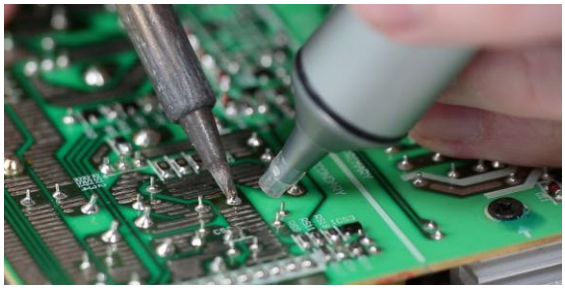

Figure 10.2 De-Soldering operation

11. Introduction to troubleshooting the ceiling fan and mixer grinder

In generally most ceiling fan and table fan have a capacitor start permanent capacitor motors which a difference from usual motor that it central position (Rotor/ Armature) remains fixed, while the outer portion rotates blades are mounted on the outer shaft when the motor is energized the blade cause

to rotate and to circulate the surroundings are depends on the speed of fan. A regulator is connected in series with fan at different tapings hence the speed of the fan consist of a number of parts are connected together as a shaft to avoid loose fittings the parts are located bolts, split, pins and bearing lock.

i) Usually, a ceiling fan and table fan consist of a capacitor start and run motor. Capacitor are always connected in the circuit the advantages of leaving the capacitor permanently in circuit.

ii) It has one starting winding in series with one capacitor and running winding since the capacitor remains in the circuit permanently. This motor is often referred to as permanent. Split capacitor runs motor and behaves practically like an unbalanced 2phase motor.

11.1 Perform the maintenance of ceiling fan and ending the trouble shoot problems as shown in Figure 11.1

- The rapid spinning and vibrations your fan's components are subjected to can cause them to work loose and wear out. Inspecting the fan every two or three months you use it helps keep the fan working efficiently and extends its lifespan.
- One of the most common problems is a loose mount, which can cause your fan to wobble. A wobbling fan is unlikely to fall, but it can cause the light fixture to fall, so it's not something to ignore.
- Blades that are misaligned or out of balance can also cause wobbling. Over time, one or more blades can become warped, bent or otherwise damaged. Even a minor difference can disrupt the fan's normal performance, so check each blade closely.

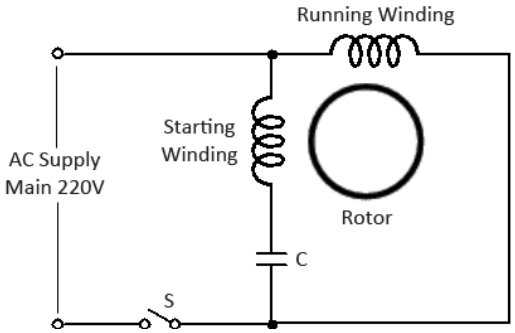

Figure 11.1 Celling fan circuit diagram

Try;

1. Perform the maintenance for mixer grinder from a circuit board as shown in Figure 11.2.
   - Universal Series Motor
   - Three Position Speed Control Rotary Switch
   - Thermal Overload Relay or overload switch
   - Indicator Light
   - Power Switch

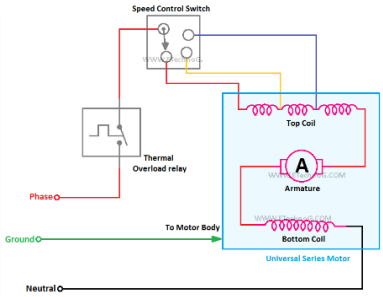

Figure 11.2. Mixer grinder circuit diagram

12. Introduction to 6 axis articulated robotic arm

ARISTO is six axis articulated robotic arm of industrial for training and research and is manufactured to industrial standards. The robot is capable of lifting up to 2.5kg of pay load. The robot can be used with pneumatic or electrical grippers. ARISTO has simulation software that allows the user to learn robot functions, application & programming.

- The evolution of the performance of robots and programming software provides new machining solutions. For complex parts, six axes robots offer more accessibility than a machining center CNC 5 axis and allow the integration of additional axes to extend the workspace.
- Robots have seen in recent years an expansion of their field of use with new requirements related to the increasing use of composites. The robots are then considered for machining operations (polishing, cutting, drilling etc.) that require high performance in terms of position, orientation, followed by trajectory precision and stiffness.

12.1 Preparation of articulated robot for lifting load as shown in Figure 12.1

- A load lifting robot is a type of industrial robot that is used for handling and placing products on a production line.
- They are typically used in high-volume manufacturing settings, where they can quickly and accurately place products onto conveyor belts or other production equipment

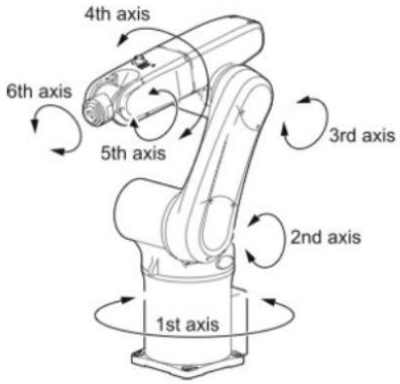

Figure 12.1 Six Axis Aristo Robot

Try

1. Perform the pick and place operation for the articulated robot as shown in Figure 12.2
   - A pick-and-place robot is a type of industrial robot that is used for handling and placing products on a production line.
   - They are typically used in high-volume manufacturing settings, where they can quickly and accurately place products onto conveyor belts or other production equipment.

Figure 12.2. Pick and place operation

13. Introduction to FANUC simulator

The FANUC CNC Simulator brings the world's most popular control right into your workplace training room, providing hands-on training for FANUC CNC operation without the need for a full machine. Add Machining Simulation Software to the CNC Simulator for advanced machine simulation capability.

- This PC-based platform is perfect for training and designing part programming. The CNC Machining Simulation software provides a digital twin of the machine tool producing the real-world cutting process. This provides you with the most realistic simulation of the actual machining on your floor. To prepare the industry for more complex machining knowhow, a 5-axis machining training option is now available.
- For companies needing a more tailored training offering, FANUC America's CNC Hardware Simulators are fully functional CNCs that include the panel and operating system. More robust than our CNC Simulators, our CNC Hardware Simulators are complete control simulators customized to address your specific workplace training needs. Operations needing a particular CNC model for their shopfloor training will benefit from these simulators.

13.1 Preparation of milling and lathe system switchable on one simulator as shown in Figure 13.1

- Switchable mill and lathe (turning) system in one simulator
- 3-axis milling / 2-axis turning system plus one spindle
- Manual Guide is installed for conversational program creation and 3D simulation
- Imperial / metric switchable
- 512KB part-program storage, with 400 registered programs
- 32 tool offset pairs
- Workpiece coordinates G52 – G59 plus 48 additional on mill

Figure 13.1 FANUC Simulator

Try

1. Perform the combination of CNC Simulator with CNC machining simulation software as shown in Figure 13.2.
   - The CNC Machining Simulator carries all the same features as the standard simulator with the addition of an internal PC, which will provide a virtual mill or lathe with real kinematics, allowing the user to view the live machine movement, tooling and part machining.
   - Tool and workpiece setup is required and colored back plot, collision detection and sound bring the machine operating experience to life.

Figure 13.2 CNC Simulator with CNC machining simulation

14. Demonstration to cylindrical grinding machine

Most commonly, cylindrical grinding is used for grinding pieces with a central axis of rotation, like rods and cylinders. This process involves using a cylindrical grinder, which is a type of machinery categorized by rotation style and wheel device.

- A grinding machine uses an abrasive product usually a rotating wheel to shape and finish a workpiece by removing metal and generating a surface within a given tolerance. A grinding wheel is made with abrasive grains bonded together. Each grain acts as a cutting tool, removing tiny chips from the workpiece.

14.1 Demonstration on industry standard grinding as shown in Figure 14.1

- The ECO-200 Micromatic industry standard universal cylindrical grinding machine is used for grinding of components up to an accuracy of 5m and used for projects.

Figure 14.1 Cylindrical griding

Try

1. Demonstration grinding methods and machines
   - Grinding, or abrasive machining, once performed on conventional milling machines, lathes and shapers, is now performed on various types of grinding machines.
   - Grinding machines have advanced in design, construction, rigidity and application far more in the last decade than any other standard machine tool in the manufacturing industry. Grinding machines fall into five categories: surface grinders, cylindrical grinders, centerless grinders, internal grinders and specials.

V. TEXT BOOKS:

1. Hajra Choudhury S.K., Hajra Choudhury A.K. and NirjharRoy S.K., *Elements of Workshop Technology*, Media promoters and publishers private limited, Mumbai, 2020.
2. Kalpakjian S, Steven S. Schmid, *Manufacturing Engineering and Technology*, Pearson Education India Edition, 7th Edition, 2019.

VI. REFERENCE BOOKS:

1. Gowri P. Hariharan, A. Suresh Babu, *Manufacturing Technology – I*, Pearson Education, 2018.
2. Roy A. Lindberg, *Processes and Materials of Manufacture*, Prentice Hall India, 4th Edition, 2017.
3. P.N., *Manufacturing Technology*, Vol. I and Vol. II, Tata McGraw-Hill House, 2017.
4. Rupinder Singh, J. Paulo Davim, *Additive Manufacturing: Applications and Innovations*, CRC Press, 2nd Edition, August, 2021.
5. Jeyaprakash Natarajan, Muralimohan Cheepu, Che-Hua Yang, *Advances in Additive Manufacturing Processes*, Bentham Books, 4th Edition, September, 2021.

VII. ELECTRONICS RESOURCES:

1. https://elearn.nptel.ac.in/shop/iit-workshops/ongoing/additive-manufacturing-technologies-for-practicing-engineers/.
2. https://akanksha.iare.ac.in/index?route=course/details&course_id=94.

VIII. MATERIALS ONLINE:

1. Course Template
2. Lab manual