

Curriculum of Diploma Programme in Mechanical Engineering



**Department of Science,
Technology and Technical Education (DSTTE),
Govt. of Bihar**

**State Board of Technical Education
(SBTE), Bihar**

Semester – IV

Teaching & Learning Scheme

Course Codes	Category of course	Course Titles	Teaching & Learning Scheme(Hours/Week)					
			Classroom Instruction(CI)		Lab Instruction (LI)	Notional Hours (TW+SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
			L	T				
2425401	PCC	Engineering Metrology and Instrumentation	03	-	04	02	09	06
2425402	PCC	Fluid Mechanics & Hydraulic Machinery	03	-	04	02	09	06
2425403	PCC	Applied Thermodynamics and HVAC	03	-	04	02	09	06
2425404	PCC	Theory of Machines (ME, ME (Auto))	02	01	04	02	09	06
2425505	PCC	Advance Manufacturing Engineering and Cost Estimation	03	-	04	02	09	06
Total			14	1	20	10	45	30

Note: Prefix will be added to course code if applicable (T for Theory Paper, P for Practical Paper and S for Term Work)

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, work shop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits= (1x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note : TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

Semester - IV Assessment Scheme

Course Codes	Category of course	Course Titles	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term work &Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2425401	PCC	Engineering Metrology and Instrumentation	30	70	20	30	20	30	200
2425402	PCC	Fluid Mechanics & HydraulicMachinery	30	70	20	30	20	30	200
2425403	PCC	Applied Thermodynamicsand HVAC	30	70	20	30	20	30	200
2425404	PCC	Theory of Machines (ME, ME (Auto))	30	70	20	30	20	30	200
2425505	PCC	Advance Manufacturing Engineering and Cost Estimation	30	70	20	30	20	30	200
Total			150	350	100	150	100	150	1000

Note: Prefix will be added to course code if applicable (T for Theory Paper, P for Practical Paper and S for Term Work)

Legend:

- PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)
- PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)
- TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

- A) **Course Code** : 2425401 (T2425401/P2425401/S2425401)
- B) **Course Title** : Engineering Metrology & Instrumentation
- C) **Pre-requisite Course(s)** :
- D) **Rationale** :

In today's high-tech world dimensional control of products has become very important to ensure the quality and reliability of the products being manufactured. Unless the manufactured parts are accurately measured, assurance of quality cannot be given. In this context, the course deals with the basic principles of dimensional measuring instruments and precision measurement techniques. The Mechanical Engineering Diploma holder should understand, select and use various measuring instruments as he often comes across measuring different parameters of machined components and the appropriate fitment of interchangeable components in the assemblies. The course also aims at making a Mechanical Engineering student familiar with the principles of measurements of mechanical parameters like temperature, pressure, flow, speed, force and strain.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/laboratory/workshop/field/ industry.

After completion of the course, the students will be able to-

- CO-1** Use appropriate instrument(s) for linear measurements.
- CO-2** Use relevant instruments for angular measurements.
- CO-3** Use relevant geometric tolerance and surface roughness instruments for dimensional applications.
- CO-4** Use relevant instruments for screw thread measurements and gear measurements.
- CO-5** Use relevant instruments for Displacement, Speed, Temperature, Flow, Pressure, Strain, Force, Torque and other quantities.

- F) **Suggested Course Articulation Matrix (CAM):**

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2
CO-1	3	2	-	2	-	1	1		
CO-2	3	2	-	2	-	1	1		
CO-3	3	2	-	2	-	1	1		
CO-4	3	2	-	2	-	1	1		
CO-5	3	2	-	2	-	1	1		
CO-6	3	2	-	-	-	3	1		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2425401	Engineering Metrology & Instrumentation	03	-	04	02	09	06

Legend:

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LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2425401	Engineering Metrology & Instrumentation	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2425401

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 1a.</i> Explain the importance of metrology as a means for achieving quality. <i>TSO 1b.</i> Explain the given terminology of Metrology. <i>TSO 1c.</i> Explain the given type of error in the measurement. <i>TSO 1d.</i> List the linear and angular direct/indirect measuring instrument(s). <i>TSO 1e.</i> Explain the procedure of using linear direct/indirect measuring instrument for the given measurement with justification. <i>TSO 1f.</i> Explain the procedure of using dial gauge for checking linear features of the given component with justification. <i>TSO 1g.</i> Explain the procedure of using slip gauges for measuring the given job. <i>TSO 1h.</i> Explain the procedure of using angular direct/indirect measuring instrument for the given situation with justification. <i>TSO 1i.</i> Select suitable linear and angular direct/indirect measuring instrument(s) for the given situation with justification.	Unit-1.0 Linear and Angular Measurements 1.1 Metrology: Correlation of inspection and metrology, definition of metrology and its importance in industrial inspection, meaning of specification, Interchangeability and selective assembly, 1.2 Terms applicable to measuring instruments: Precision and Accuracy, Sensitivity and Repeatability, Range, Threshold, Hysteresis, Calibration; 1.3 Errors in Measurements: Classification of errors, Systematic and Random error. Linear Measurement: 1.4 Classification of linear measurement instruments: • Direct measuring instruments: Vernier caliper; Micrometer – outside, inside and depth; Vernier height gauge. • Indirect measuring instruments: Telescopic gauges, small hole gauges –their construction, working, specifications, applications, precautions and errors. 1.5 Dial Gauge: classification as per IS: 2092-1962, schematic diagram, function of parts, working principle, accuracy, applications and precautions. 1.6 Slip gauge – Classification as per IS: 2984-1966, their accuracy, applications, selection of gauge blocks, wringing, handling and precautions. Angle measurement 1.7 Direct angle measurement: • Optical Bevel Protractor • Universal Bevel protractor 1.8 Indirect angle measurement: • Angle gauges – sets, , handling, method of combining, selection of angle gauge blocks for a given angle • Sine bar –types as per IS:5979-1970, specifications, handling, measuring known and unknown angles • Spirit level • Autocollimator • Angle Dekkar	CO1, CO2

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	1.9 Working principle, construction, handling, applications of all above devices.	
<i>TSO 2a.</i> Explain the given limits, fits and tolerance. <i>TSO 2b.</i> Explain the given Geometric tolerance. <i>TSO 2c.</i> Explain the use of the given Plug and Ring gauge. <i>TSO 1j.</i> Explain the procedure of using device(s) to measure the given Geometric tolerance. <i>TSO 2d.</i> Select instrument(s) to measure the given Geometric tolerance (Straightness, Flatness, Squareness and Roundness) of the given job/situation with justification. <i>TSO 2e.</i> Explain the various terms associated with assessment of surface roughness. <i>TSO 2f.</i> Explain the given surface roughness unit. <i>TSO 2g.</i> Select the surface roughness instruments for the given job with justification. <i>TSO 2h.</i> Identify the conditions of surface for the given surface roughness value/symbol for different machining processes recommended by IS:3073	Unit-2.0 Limits, Fits, Tolerance, Measurements of Geometric Tolerances and Surface Roughness 2.1 Concept of Limits, Fits, and Tolerances; Selective Assembly; Interchangeability; Hole and Shaft Basis System. 2.2 Taylor's Principle; Design of Plug; Ring Gauges; IS 919- 1993 (Limits, Fits & Tolerances, Gauges) Geometric Tolerances 2.3 Concept of straightness, flatness, squareness and roundness, importance of their measurement. 2.4 Measurement of Straightness: Straight edge method (Light gap and feeler gauge method), and Autocollimator method. 2.5 Measurement of flatness: High spot method, Precision level method, Autocollimator method. 2.6 Measurement of Squareness: Indicator method, Engineer's square tester, Autocollimator method. 2.7 Measurement of Roundness: V block and Dial indicator method, 2.8 Working principle, instruments required for each of above methods, precautions, limitations, applicability. Measurements of Surface Roughness 2.9 Assessment of surface roughness: Terminology associated with assessment of surface roughness (as per IS: 3073 – 1967) – Surface roughness, primary texture (roughness), secondary texture (waviness), real surface, geometrical surface, effective surface, real profile, geometrical profile, effective profile, reference line, lay, traversing length, sampling length, spacing of irregularities, mean line of profile, centre line of profile. 2.10 'M' and 'E' system of assessment of surface roughness, their merits and demerits, reasons for adoption of 'M' system, 2.11 Basic units of indicating surface roughness – C.L.A. value, R.M.S. value, ten point height of irregularity, their graphical and mathematical interpretation 2.12 Measurement of surface roughness: Stylus based instrument: Tomlinson surface meter, Taylor- Hobson Talysurf, Profilometer. 2.13 Relationship of Machining processes and surface texture and their representation	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 3a.</i> Identify the various elements of the given screw thread. <i>TSO 3b.</i> Explain the procedure of measurement of external or internal screw thread element using the given instrument. <i>TSO 3c.</i> Select measuring instrument/method for measuring the given external or internal screw thread element(s) with justification. <i>TSO 3d.</i> Identify various elements of the given gear. <i>TSO 3e.</i> Explain the procedure of measurement of gear element(s) element using the given instrument. <i>TSO 3f.</i> Select suitable measuring instrument/ method for measuring given gear element with justification.	Unit-3.0 Screw Thread and Gear Measurements 3.1 Thread nomenclature, Various types of threads, Errors in screw threads: Error in Pitch (Progressive and periodic), effective diameter, major diameter, minor diameter and angle or form. 3.2 Methods of measuring external screw thread elements: • Pitch – Thread pitch gauge, microscope method, Pitch measuring machine • Effective diameter – Thread micrometer, two and three wire method • Minor diameter – Micrometer with two V – shaped hard steel pieces • Major diameter – Micrometer • Angle or Form – Tool room projection 3.3 Methods of internal thread measurement: Procedure of each method, precautions to be taken, advantages and limitations. • Core diameter –Wedge parallel and micrometer • Effective diameter - Optical comparator • Thread Form – Thread cast method 3.4 Gear Measurement: Terminology associated with gear measurements, Spur gear nomenclature, Gear elements requiring measurement – gear tooth form, gear tooth thickness, pitch and eccentricity. 3.5 Measurement of gear elements: • Gear tooth form – Tool room microscope, David Brown gear tooth form testing machine. • Gear tooth thickness –Chordal thickness and Constant Chord, Use of Gear tooth vernier caliper. • Pitch –of Parkson gear tester. 3.6 Procedure of all above methods, advantages and limitations.	CO4
<i>TSO 4a.</i> List the various displacement/speed measuring instruments. <i>TSO 4b.</i> Explain the procedure to measure displacement/speed using the given instrument. <i>TSO 4c.</i> Select the relevant displacement/speed measuring instrument for the given situation with justification <i>TSO 4d.</i> List the various Temperature measuring instruments.	Unit-4.0 Displacement, Speed and Temperature Measurements Displacement and Speed measurement 4.1 Working principle & use of Potentiometer, Differential transformer (LVDT & RVDT), capacitive element & Optical encoders. 4.2 Mechanical tachometer, Electrical Tachometer, incremental optical encoder, Eddy current drag cup tachometer.	CO5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 4e.</i> Explain the procedure to measure temperature using the given instrument. <i>TSO 4f.</i> Select the relevant Temperature measuring instrument for the given situation with justification	4.3 Magnetic pickup tachometer, Stroboscopic tachometer, Photoelectric tachometer, non contacting electrical tachometer (inductive pick up & capacitive pick up) 4.4 Functions, working principles, sketches, applications and limitations of above measuring devices. Temperature measurement 4.5 Principles of temperature measuring devices – change in physical state, expansion, electrical resistance, thermoelectric emf, intensity of radiation, change in chemical state. Construction, working, measuring range, accuracy, applications, limitations of devices operating on above principles (Bimetal thermometer, Pressure Spring thermometer, Electrical resistance thermometer, Thermister, Thermocouple, Pyrometer).	
<i>TSO 5a.</i> List the various Flow/Pressure/Force/Torque measuring instruments. <i>TSO 5b.</i> Explain the procedure to measure Flow/Pressure/Force/Torque using the given instrument. <i>TSO 5c.</i> Select the relevant Flow/Pressure/Force/Torque measuring instrument for the given situation with justification <i>TSO 5d.</i> List the various Transducer used to measure different quantities <i>TSO 5e.</i> Explain the procedure to use the given Transducer to measure the given quantity. <i>TSO 5f.</i> Explain the procedure to use the Strain gauge to measure the strain in the given situation.	Unit-5.0 Transducers, Strain Gauges, Pressure, Flow, Force and Torque Measurements Flow measurement 5.1 Classify flow measuring devices as Volumetric or Primary or Quantity meters and Rate of flow or Velocity or Secondary meters, their function and examples. 5.2 Volumetric or Primary meters - Bellow type meter, Rotating impeller type meter. 5.3 Positive displacement meter, Rotating lobe meter, Nutating disc meter 5.4 Rate of flow or Secondary meters – Obstruction meters • Orifice • Venturimeter • Flow nozzles • Variable area meter • Pitot tube Velocity probes • Total pressure probes • Static pressure probes • Direction sensing probes • Special meters • Turbine meter • Hot wire anemometer, Magnetic flow meter Functions, working principles, sketches, applications and limitations of above measuring devices	CO5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	Pressure Measurement: 5.5 Classify pressure measuring devices • Manometer • Elastic gauges • Diaphragm • Pressure capsules • Bellows • Pressure springs 5.6 Electronic pressure sensors/Transducers - Resistance, Inductance and Capacitive type; Functions, working principles, sketches, applications and limitations of above pressure measuring devices. 5.7 Low pressure gauges- McLeod Gauge, Pirani gauge. Measurement of Force and Torque: 5.8 Force measurement: Spring Balance, Proving ring, Load cell. 5.9 Torque measurement: Prony brake, Eddy current, Hydraulic dynamometer. Transducers and Strain Gauges: 5.10 Introduction of Transducers, Characteristics, classification of transducers, two coil self-inductance transducer, Piezoelectric transducer. 5.11 Strain gauges & Measurements: Strain gauge, Classification, mounting of strain gauges, Strain gauge rosettes-two and three elements.	

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425401

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 1.1.</i> Interpret the measuring elements of the given component drawing. <i>LSO 1.2.</i> Identify type of linear and measuring device required for the given dimension(s)	1*	Identify the type of linear and/or angular measurement device(s) required to measure the different dimensions of the given industrial component/Production drawing.	CO1, CO2
<i>LSO 2.1.</i> Calculate the least count of the given Vernier Caliper. <i>LSO 2.2.</i> Use the suitable part/jaws of the given Vernier Caliper for measurement of the given dimensions.	2*	Measure the linear dimensions (length, diameter – outside & inside) of the given job using Vernier caliper.	CO1, CO2
<i>LSO 3.1.</i> Calculate the least count of the given Micrometer. <i>LSO 3.2.</i> Use the given Micrometer for measurement of the given dimensions.	3*	Measure the outside & inside diameters of a given job using Micrometer.	CO1, CO2
<i>LSO 4.1.</i> Calculate/Read the least count of the given Vernier height gauge.	4.	Measure the height of the given object using Vernier height gauge.	CO1, CO2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 4.2.</i> Use the given Vernier height gauge for measurement of the given dimensions.			
<i>LSO 5.1.</i> Calculate/Read the least count of the given Depth gauge. <i>LSO 5.2.</i> Use the given Depth gauge for measurement of the given dimensions.	5*.	Measure the depth of a given object using Depth gauge.	CO1, CO2
<i>LSO 6.1.</i> Identify different slip gauges available and their measuring values. <i>LSO 6.2.</i> Select the suitable set of Slip gauges to measure the given dimension. <i>LSO 6.3.</i> Perform wringing and un-wringing the Slip gauges to make/detach the stake. <i>LSO 6.4.</i> Measure the given dimension using given slip gauges.	6*.	Measure the thickness of ground MS plates using Slip gauges.	CO1, CO2
<i>LSO 7.1.</i> Identify different slip gauges available and their measuring values. <i>LSO 7.2.</i> Select the suitable Sine bar and other accessories for the angle to be measured. <i>LSO 7.3.</i> Measure the given dimension using given Slip gauges and Sine bar.	7*.	Measure the angle of the machined surface using Sine bar with Slip gauges.	CO1, CO2
<i>LSO 8.1.</i> Set the given Optical Bevel protractor/ Universal Bevel protractor for the angle to be measured. <i>LSO 8.2.</i> Measure the given angle using given Optical Bevel protractor/ Universal Bevel protractor.	8*.	Measure given angle of a component using Optical Bevel protractor and Universal Bevel protractor.	CO1, CO2
<i>LSO 9.1.</i> Set the given Angle Dekkar for the angle to be measured. <i>LSO 9.2.</i> Measure the given angle using given Angle Dekkar. <i>LSO 9.3.</i> Compared the measured values with Optical Bevel protractor/ Universal Bevel protractor.	9*.	Measure the angle of a given component with Angle Dekkar.	CO1, CO2
<i>LSO 10.1.</i> Set the given Precision level/Autocollimator for the measuring Straightness of the given surface/edge. <i>LSO 10.2.</i> Measure the straightness of the given job using Precision level/ Autocollimator.	10* .	Check the straightness of the given job using Precision level and Autocollimator.	CO3
<i>LSO 11.1.</i> Set the given Precision level/Autocollimator for measuring the Flatness of the given surface. <i>LSO 11.2.</i> Measure the Flatness of the given job using Precision level/Autocollimator. <i>LSO 11.3.</i> Compare the results from both the devices.	11.	Check the Flatness of the given job using Precision level/Autocollimator.	CO3
<i>LSO 12.1.</i> Set the given Engineer's Squareness tester for measuring the Squareness of given the job. <i>LSO 12.2.</i> Measure the Flatness of the given job using Squareness.	12*	Check the Squareness of a given job using indicator method or Engineer's Squareness tester.	CO3
<i>LSO 13.1.</i> Set the given V-block and Dial indicator for measuring the Roundness of the given job. <i>LSO 13.2.</i> Measure the Flatness of the given job using Roundness.	13.	Check the roundness of the given job using V-block and Dial indicator.	CO3

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 14.1.</i> Set the given Dial gauge for measuring the parallelism and perpendicularity of the given job. <i>LSO 14.2.</i> Measure the Flatness of the given job using Parallelism and perpendicularity.	14.	Check the parallelism and perpendicularity of a machine tool using Dial gauge.	CO3
<i>LSO 15.1.</i> Identify the suitable surface measurement unit based on the requirement. <i>LSO 15.2.</i> Measure the surface roughness value of the given job using the given instruments.	15.	Measure the surface roughness of a given sample using Taylor Hobson's Talysurf / surface roughness tester.	CO3
<i>LSO 16.1.</i> Select the suitable Resistance thermometer to measure the temperature in the given situation. <i>LSO 16.2.</i> Measure the temperature using the Resistance thermometer.	16.	Measure the effective diameter of a given screw thread using screw thread micrometer.	CO4
<i>LSO 17.1.</i> Select the suitable Screw Pitch gauge to measure the pitch of the given V-Thread. <i>LSO 17.2.</i> Measure the pitch using the selected Screw Pitch gauge.	17.	Measure the pitch of a given screw thread using Screw Pitch gauge.	CO4
<i>LSO 18.1.</i> Select the suitable Screw Pitch gauge to measure the pitch of the given V-Thread. <i>LSO 18.2.</i> Measure the pitch using the selected Screw Pitch gauge.	18.	Measure the geometrical dimensions of V-Thread using Thread Vernier gauge.	CO4
<i>LSO 19.1.</i> Set the Toolmaker's microscope to measure various elements of the given V-Thread Screw. <i>LSO 19.2.</i> Measure the various elements of the given V-Thread Screw using the Toolmaker's microscope.	19.	Measure the major diameter, minor diameter, pitch and included angle of a V-Thread using Toolmaker's microscope.	CO4
<i>LSO 20.1.</i> Identify Chordal and Normal thickness of a spur gear tooth. <i>LSO 20.2.</i> Set the Gear tooth Vernier caliper to measure the thickness of the given gear tooth. <i>LSO 20.3.</i> Measure the thickness of the given gear tooth using the Gear tooth Vernier caliper	20.	Measure the gear tooth thickness using Gear tooth Vernier caliper.	CO4
<i>LSO 21.1.</i> Set the Gear Toolmaker's microscope to measure the form of the given gear tooth. <i>LSO 21.2.</i> Measure the form of the given gear tooth using the Toolmaker's microscope.	21.	Check the gear tooth form using Toolmaker's microscope.	CO4
<i>LSO 22.1.</i> Set the given Strain gauge/Rosette for measuring the strain in the given job. <i>LSO 22.2.</i> Measure the Strain of the given job using Strain gauge/Rosette.	22*	Measure the strain of an object using Strain gauge.	CO5
<i>LSO 23.1.</i> Select the suitable transducer to measure the pressure of the given liquid/gas. <i>LSO 23.2.</i> Measure the pressure of the given job liquid/gas using the transducer.	23.	Measure the pressure of the gas and liquid with Transducer.	CO5
<i>LSO 24.1.</i> Set the Rotameter to measure the flow of the given situation. <i>LSO 24.2.</i> Measure the flow using the Rotameter.	24.	Measurement of flow with Rotameter.	CO5
<i>LSO 25.1.</i> Select the suitable Resistance thermometer to measure the temperature in the given situation. <i>LSO 25.2.</i> Measure the temperature using the Resistance thermometer.	25.	Measurement of temperature with Resistance thermometer.	CO5

A judicious mix of minimum 14 or more practical need to be performed, out of which, the practical marked as '' are compulsory.

L) Suggested Term Work and Self Learning: S2425401 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- i. Identify at least five situations in our daily life where we use measurement and inspection.
- ii. List at least five factors that affect each of the elements of the measuring system.
- iii. Compare line and end standards and give at least five examples of instruments based on each of these.
- iv. Compare Vernier caliper and Micrometer on the basis of accuracy, measuring range, advantages and limitations.
- v. For a given dimension and given set of slip gauge, suggest the gauge block piles (at least 5 problems)
- vi. Explain the method of finding least count of universal bevel protractor.
- vii. For a given angle and given set of angle gauges, select angle gauge blocks (at least 3 problems).
- viii. For measuring the angle of a given component select suitable angle measuring instrument and justify your choice.
- ix. Explain why measurement of straightness, flatness and squareness is important in engineering and prepare a list of engineering applications where these are required?
- x. Compare the accuracy of different methods of straightness measurement for a given job.
- xi. Differentiate the three basic units of indicating surface roughness, if represented on same profile, based on ease of measurement and reliability of assessment of surface roughness.
- xii. Explain the effect of pitch errors on the functioning of screw threads.
- xiii. Compare the different methods of pitch measurement on the basis of ease, accuracy, their relative advantages and limitations.
- xiv. Explain the effect of inaccurate Gear element on the performance of Gear operation.
- xv. Compare the Chordal thickness and constant chord method of gear tooth thickness measurement on the basis of ease and principle.
- xvi. List the various Displacement, Speed, Temperature, Flow, Pressure, Force and Torque measuring instruments.
- xvii. Explain the procedure to measure Displacement, Speed, Temperature, Flow, Pressure, Force and Torque using the given instrument.
- xviii. Prepare a detailed report on applications of Displacement, Speed, Temperature, Flow, Pressure, Force and Torque industrial measurement instruments.
- xix. Explain the procedure to use the given Transducer to measure the given quantity.
- xx. Explain the procedure to use the Strain gauge to measure the strain in the given situation.

b. Micro Projects:

- i. From a given drawing or actual component, find the linear variables to be measured, suggest suitable instrument to measure them and state the reason for choice.
- ii. Measure the same linear dimensions of a given job with vernier caliper and micrometer and compare them on the basis of accuracy, time of inspection, cost of inspection and error.
- iii. Prepare a chart showing the comparison of various angle measuring instruments on the basis of accuracy, measuring range, advantages and limitations.
- iv. Measure the same angular dimensions of a given job with universal bevel protractor and angle gauge and interpret the results.
- v. Prepare an exhaustive list of representative components/engineering applications where measurement of straightness, flatness, squareness and roundness would be relevant.
- vi. Measure the strain of an object using Strain gauge and transducer.
- vii. Prepare a technical report on specifications and critical features of instruments used to measure Displacement, Speed, Temperature, Flow, Pressure, Force and Torque.
- viii. Download video related to measuring procedures related to linear dimensions, angular dimensions, limits, fits, tolerance, surface finish, screw thread, gear thickness, gear form, strain transducers, displacement, speed, temperature, flow, pressure, force and torque.

c. Other Activities:**1. Seminar Topics:**

- Errors in Measurements
- Telescopic gauges
- Universal Bevel protractor
- Angle gauges
- Angle Dekkar
- Limits, Fits, and Tolerances
- Design of Plug and Ring Gauges (Go/No-GO gauges)
- Measurement of Roundness
- Measurements of Surface Roughness
- Measurement of displacement, speed, temperature, flow, pressure, force and torque

2. Visits:

- Visit a nearby industry/workshop/toolroom to identify and list the various measuring instruments used for linear dimensions, angular dimensions, limits, fits, tolerance, surface finish, screw thread, gear thickness, gear form, strain transducers, displacement, speed, temperature, flow, pressure, force and torque.

3. Self-Learning Topics:

- Digital Vernier caliper
- Autocollimator
- Sine Bar
- Taylor- Hobson Talysurf
- Surface finish symbols for Turning and Milling surface
- Surface finish symbols for Honing, Lapping, Buffing surface
- Gear tooth vernier caliper
- Stroboscopic tachometer
- K-Type thermocouple
- Velocity probes
- McLeod Gauge
- Strain Rosette

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	20%	20%	20%	20%	20%	20%	20%
CO-2	15%	15%	15%	20%	20%	25%	20%
CO-3	15%	15%	15%	20%	20%	25%	20%
CO-4	15%	15%	15%	20%	20%	20%	20%
CO-5	15%	15%	15%	20%	20%	10%	20%
CO-6	20%	20%	20%	-	-	-	-
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentages given are approximate.
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Linear and Angular Measurements	12	CO1, CO2	17	5	4	8
Unit-2.0 Limits, Fits, Tolerance, Measurements of Geometric Tolerances and Surface Roughness	08	CO3	12	4	2	6
Unit-3.0 Screw Thread and Gear Measurements	08	CO4	12	3	3	6
Unit-4.0 Displacement, Speed and Temperature Measurements	08	CO5	12	3	3	6
Unit-5.0 Transducers, Strain Gauges, Pressure, Flow, Force and Torque Measurements	12	CO5	17	5	4	8
Total	48	-	70	20	16	34

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Identify the type of linear and/or angular measurement device(s) required to measure the different dimensions of the given industrial component/Production drawing.	CO1, CO2	40	50	10
2.	Measure the linear dimensions (length, diameter – outside & inside) of the given job using Vernier caliper.	CO1, CO2	40	50	10
3.	Measure the outside & inside diameters of a given job using Micrometer.	CO1, CO2	40	50	10
4.	Measure the height of the given object using Vernier height gauge.	CO1, CO2	40	50	10
5.	Measure the depth of a given object using Depth gauge.	CO1, CO2	40	50	10
6.	Measure the thickness of ground MS plates using Slip gauges.	CO1, CO2	40	50	10
7.	Measure the angle of the machined surface using Sine bar with Slip gauges.	CO1, CO2	40	50	10

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
8.	Measure given angle of a component using Optical Bevel protractor and Universal Bevel protractor.	CO1, CO2	40	50	10
9.	Measure the angle of a given component with Angle Dekkar.	CO1, CO2	40	50	10
10.	Check the straightness of the given job using Precision level and Autocollimator.	CO3	40	50	10
11.	Check the Flatness of the given job using Precision level/Autocollimator.	CO3	40	50	10
12.	Check the Squareness of a given job using indicator method or Engineer's Squareness tester.	CO3	40	50	10
13.	Check the roundness of the given job using V-block and Dial indicator.	CO3	40	50	10
14.	Check the parallelism and perpendicularity of a machine tool using Dial gauge.	CO3	40	50	10
15.	Measure the surface roughness of a given sample using Taylor Hobson's Talysurf / surface roughness tester.	CO3	40	50	10
16.	Measure the effective diameter of a given screw thread using screw thread micrometer.	CO4	40	50	10
17.	Measure the pitch of a given screw thread using Screw Pitch gauge.	CO4	40	50	10
18.	Measure the geometrical dimensions of V-Thread using Thread Vernier gauge.	CO4	40	50	10
19.	Measure the major diameter, minor diameter, pitch and included angle of a V-Thread using Toolmaker's microscope.	CO4	40	50	10
20.	Measure the gear tooth thickness using Gear tooth Vernier caliper.	CO4	40	50	10
21.	Check the gear tooth form using Toolmaker's microscope.	CO4	40	50	10
22.	Measure the strain of an object using Strain gauge.	CO5	40	50	10
23.	Measure the pressure of the gas and liquid with Transducer.	CO5	40	50	10
24.	Measurement of flow with Rotameter.	CO5	40	50	10
25.	Measurement of temperature with Resistance thermometer.	CO5	40	50	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
1.	Vernier Calipers & Micrometers	Vernier calipers: stainless steel body, Range: 0-150mm Resolution: 0.1mm Micrometer: Material- Carbon Steel, Graduated to read up to 25mm in 0.01mm divisions with screw pitch of 0.5mm, ratchet lock nut	2,3
2.	Plug- Gauge	3 pieces Grade A/X	3, 13
3.	Limit Gauges	Adjustable snap guage range 0 to 300mm Fix type snap guage in single ended & double ended design, ring gauges in the range 4mm to 300mm	3, 13
4.	Steel Ring gauges	Grade A/X, 1.5-2.00, 2.0-4.0, 4.0-12.0, 12.0-20.0 mm	3, 13
5.	Feeler gauge	0.01 to 1.9 mm	3
6.	Vernier Height and Depth Gauge	0-300 mm (mechanical and digital) Graduation: 0.05mm or 0.02mm, Stainless steel	4
7.	Slip Gauge set	Grade 1, 87 Pieces	6
8.	Micrometer Depth Gauge	0-150 mm	5
9.	Sine Bar, Sine Centre	0-200 mm; A 200 IS: 5359 Made from high quality alloy steel. Accuracy for Flatness, Squareness & parallelism is within 0.005mm. Centre distance between rollers is within +0.005mm. Hardness - 60 + Rc & Tempered Accuracy as per IS Standard	7
10.	Universal bevel protractor	Graduation: 5min. (0°- 90°- 0°) Blade 150, 300 mm. Universal Bevel Protractor 187-901	8
11.	Angle gauges	Grade 1 (box)	8, 9, 10
12.	Angle Dekkar	Focal Length of Objective: 220mm Clear Aperture of Objective: 40mm Magnification: 11X Measuring Range: 60-0-60 minute in X-Y axis. Least Division on Reticle: 1 minute of arc Least Division with Micrometer Drum : 2 second of arc	9
13.	Precision Level	Size: 200 x 20 x 25 mm (L x W x H), Bubble opening 50 x 8 mm Sensitivity 2 Min. 30 Sec per 2 mm arc division of the vial, Least count of graduation 2 mm	10
14.	Autocollimator	Dual Axis. Read Out-Dual Axis Micrometer. Resolution. 1 Sec (5 microns/meter). Range of measurement. ± 20 Minutes. Max Working distance. 10 m. Clear Aperture. Centre Height. 35 mm.	10,11
15.	Surface Plate-Granite	200 x200x 50 mm	11
16.	Spirit Level	Base length : 200 mm + 1 mm; Base width : 20 mm + 0 – 1; Height : 25 + 1 mm; Bubble opening : 50 mm x 8 mm (length x width); Sensitivity : 2 Min. 30 Sec per 2 mm arc division of the vial; Least count of graduation : 2 mm; Effective length of bubble : 20 + 1 mm	11
17.	Roundness measuring machine	0-1000 mm	13
18.	V-block	Magnetic, made of steel, maximum dia of work piece 50 mm	13
19.	Optical flat	Set Range (0.2 μ m) Diameter/thickness 45/12mm and 60/15mm.	13

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
20.	Dial Indicator	0-25mm with magnetic stand Resolution: 0.001mm, Metric. Graduation. Range -1mm	14
21.	Surface roughness Taylor Hobson's Tester	Max. sample length 0.8mm	15
22.	Profile projector with gear profile/Thread profile Templates	Opaque fine grained ground glass screen with 90°, 60°, 30° cross line Location; fitted with graduated ring (0-360°) L.C. 1min; Optics Std 10X, 20X, Measuring Range Std 100mm x 100mm; Opt X axis upto 400mm, Y axis upto 200mm; Focusing Travel 100mm; Magnification Accuracy Contour $\pm 0.05\%$ Surface $\pm 0.05\%$; Illumination Countor 24V/150W halogen lamp with illumination control; Resolution 0.005/0.001/0.0005 mm.	16,20
23.	Floating Carriage Micrometer	Least count: 0.001 mm; Standard micrometer or electronic type; Non rotary 8mm micrometer spindle; Indicator with 0.001mm std dial; Admit between center 200 mm; Max Diameter capacity 100mm; Standard Accuracy + or – 0.005mm;	16
24.	Screw thread micrometer	Micrometer Type: Screw Thread Micrometer, 14-18 TPI Range (in): 0 - 1" Capacity Pitch Diameter Graduations (in): .001" Anvil/Spindle Material: Steel Anvil Type: Double V-anvil Spindle Type: Pointed spindle	16
25.	Monochromatic light source unit	Light Source: 35W Sodium Wavelength: 0.575 micron; Power 220V/50HZ (110V available on request)	16
26.	Screw pitch gauge	0-25 mm and TPI For metric, whitworth and unified threads	17
27.	Gear tooth Vernier Caliper	Sizes: 1-26 mm, Graduation 0.02mm	20
28.	Tool maker's microscope	Monocular optical tube, erect image, angle reading: min 6', Range 360 degree, Eyepiece magnification 15x, Objective magnification 2x, Light source Tungstan bulb	19, 21
29.	Parkinson's Tester/ Gear Rolling Tester with master gears	Accuracy 0.25mm, Gear diameter of 40-80mm, Base size 320 x 100mm, Project magnification 5x, Involute profile testing.	19, 21
30.	Strain Gauge Kit with Cantilever	Parameter Measured: Strain in terms of grams on a cantilever beam Transducer: Temperature compensated strain gauge Type: Cu-Ni foil with polyamide carrier base Gauge Resistance : 350 Ohms (Nominal) Gauge Length: 6mm Gauge Width: 4 mm Gauge Base: 5 mm x 4.3 mm Gauge Factor: 2:1 (approx.) With complete mounting accessories.	22
31.	Diaphragm Pressure Gauge	dial size: 150mm: mercury / gas actuated stem & bulb :SS 316 stem & bulb DIA : 6mm, 8mm, 10mm & 12mm stem length (std.) : up to 300mm capillary material : MS / SS 316 micro bore capillary protection : SS 304 tubing, pvc, SS armored dial	23
32.	Sensor - Bourdon tube C type with digital Display	3.5 digit display for pressure/ displacement	23
33.	Dead Weight Pressure Tester	Dimension: 375 (W) X 425 (L) X 350 (H) mm, pressure range 0.6kg/cm ² to 60 kg/cm ²	23
34.	Differential Pressure Bellows	Range 0-80" water column to 0-800" water column (or Equivalent) Uni-Directional or Bi-Directional Accuracy $\pm 1\%$ F.S. Standard, $\pm 1/2\%$ F.S. Optional Dial Size 6" (Standard), 4-1/2" (Optional) Working Pressure up to 6000 PSIG (400 bar) Material of Construction – Body Aluminum, Brass, Carbon Steel, 316/316L	23

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
		Stainless Steel Materials of Construction - Internals Copper Alloy or Stainless Steel	
35.	Rotameter trainer	Standard glass rotameter, process tank with motor pump Display-float position on graduated scale.	24
36.	Venturimeter, Orifice, Pitot tube	Use equipments available in Fluid Mechanics Lab	23, 24
37.	Resistant Thermometer	High Accuracy Platinum Resistance Thermometer PRT (Master Sensors) Temperature range -80°C to 400°C Resistance at 0°C	25
38.	Thermocouple Tutor	Sensor- type k (Cr- Al) thermocouple, sensor assembly and water bath with heating arrangement Display 3.5 digit digital display	25
39.	Glass thermometer, Bimetallic thermometer	Bi metallic thermometer • Dual Scale Ranges to 1,000°F (525°C) Hermetically Sealed Case Design • 3" and 5" Dials • Stem Lengths to approx 24" • 1% Full Scale Accuracy Glass thermometer • Yellow Capillary • Temperature measurement in a range of -10 to +360 Degree Celsius • Mercury filled	25

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Engineering Metrology	R.K. Jain	Khanna Publishers, 22 nd Edition ISBN-13: 978-8174091536, ISBN-10: 9788174091536
2.	A Text Book of Engineering Metrology	I.C. Gupta	Dhanpat Rai & Sons ISBN-13: 978-8189928452, ISBN-10: 8189928457
3.	A Text Book of Engineering Metrology	M. Mahajan	Dhanpat Rai & Co., 1 st Edition ISBN-13: 978-8177000511, ISBN-10: 8177000519
4.	Engineering metrology & measurements	N V Raghavendra and L krishnamurthy	Oxford, Pap/Psc Edition ISBN-13: 9780198085492, ISBN-10: 9780198085492
5.	Principles of Engineering Metrology	Rega Rajendra	Jaico Publishing House 1 st Edition, 2008 ISBN: 9788179928370, 8179928373
6.	Metrology & Measurement	Annand K Bewoor, Vinay A Kulkarni	Mc Graw Hill Education, ISBN-13: 978-0070140004, ISBN-10: 9780070140004
7.	Mechanical measurements and instrumentation	R.K. Rajput	S.K. Kataria and Sons, New Delhi, ISBN: 9789350142851, 978930142851
8.	Mechanical and Industrial Measurements	R.K. Jain	Khanna Publications, New Delhi, ISBN-13: 978-8174091918, ISBN-10: 8174091912
9.	Instrumentation Measurement and Analysis	B C Nakra K K Chaudhary	McGraw Hill Publications, New Delhi, 4 th Edition ISBN-13: 978-9385880629, ISBN-10: 9385880624

(b) Online Educational Resources:

1. https://onlinecourses.nptel.ac.in/noc22_me75/preview
2. https://onlinecourses.nptel.ac.in/noc20_me94/preview
3. site.iugaza.edu.ps/aabuzarifa/files/METRO20152_CH1.pdf
4. nptel.ac.in/courses/112106179/19
5. <https://www.scribd.com/doc/.../Engineering-Metrology-and-Measurements-Notes>
6. uptusuccess.com/measurement-metrology-eme-403/
7. uptusuccess.com/measurement-metrology-eme-403/
8. <https://www.youtube.com/watch?v=M7w4XQJa-TY>
9. nptel.ac.in/courses/112106179/19
10. <https://lecturenotes.in/notes/7488-mechanical-measurement-metrology>
11. <https://www.youtube.com/watch?v=Die29LS1EAs>
12. <https://www.youtube.com/watch?v=Die29LS1EAs>
13. <https://www.khanacademy.org/.../displacement-velocity.../calculating-average-velocity...>
14. <https://www.youtube.com/watch?v=As5kzxkyT24>
15. <https://www.youtube.com/watch?v=J157oziu3zQ>
16. https://www.youtube.com/watch?v=GNOI_7ftbQ0
17. <https://www.youtube.com/watch?v=JKuoQ5FV2c8>
18. <https://www.youtube.com/watch?v=R9MJEjgrUq>
19. <https://www.youtube.com/watch?v=sHmjE21Fp9w>
20. <https://www.youtube.com/watch?v=iMIzApq1CQ0>
21. <https://www.youtube.com/watch?v=5q-WBYhR94Y>
22. <https://www.youtube.com/watch?v=RARjXXaFEQ0>
23. <https://www.youtube.com/watch?v=gByrUkZUnKo>
24. <https://www.youtube.com/watch?v=F2AOyQKpWSY>
25. <https://www.youtube.com/watch?v=oUd4WxjoHKY>
26. <https://www.youtube.com/watch?v=DD2bBLu6kLM>
27. <https://www.youtube.com/watch?v=IUjBmV4wMtA>
28. <https://www.youtube.com/watch?v=X4H0HaFQPJA>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others:

1. Lab Manuals
2. Users' Guide
3. Manufacturers' Manual
4. Manufacturers' Catalog
5. Learning Packages

- A) **Course Code** : 2425402 (T2425402/P2425402/S2425402)
- B) **Course Title** : Fluid Mechanics & Hydraulic Machinery (ME, ME (Auto), AE, FTS)
- C) **Pre- requisite Course(s)** : Engineering Mechanics
- D) **Rationale** :

In engineering field knowledge of fluid properties, fluid flow and fluid machinery are essential in all fields of engineering. Hydraulic machines have important role in water supply, irrigation, power generation and also in most of the engineering segments. This course is intended to develop the skills to estimate loss in pipes, efficiency of hydraulic machines like turbine pumps etc. and select a pump for a particular application. Diagnose and rectify the faults in pumps and turbines, replace pressure gauges and other accessories on hydraulic machines turbines, and apply their knowledge in hydraulics to select appropriate devices like pressure gauges, valves, flow devices, pipes etc. for different field applications.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1. Analyze various fluid characteristics.
- CO-2. Apply the fluid flow energy equations to real field situations.
- CO-3. Analyze various losses in flow through pipes
- CO-4. Select relevant turbine as per the situation.
- CO-5. Select a relevant pump as per the requirement

F) **Suggested Course Articulation Matrix (CAM):**

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2
CO-1	3	2	1	1	-	-	1	-	-
CO-2	2	2	1	1	-	-	1	-	-
CO-3	3	2	1	1	1	-	1	-	-
CO-4	3	2	-	1	1	1	1	-	-
CO-5	3	2	-	1	1	1	1	-	-

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2425402	Fluid Mechanics & Hydraulic Machinery	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2425402	Fluid Mechanics & Hydraulic Machinery	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

- I) Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2425402

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.1a Compare the given two fluids based on the given physical properties. TSO.1b Choose the relevant pressure TSO.1c Measuring device for the given situation with justification. TSO.1d Calculate the Hydrostatic forces in the given situation as per the given data. TSO.1e Calculate pressure head for a given condition. TSO.1f Calculate centre of pressure and total pressure of regular immersed bodies. TSO.1g Calculate Metacentric height and Centre of buoyancy of the given floating body.	Unit-1.0 Properties of Fluid and Fluid Pressure 1.1 Introduction and classification of fluid. 1.2 Fluid properties- Density, Specific gravity, specific weight, specific volume, Dynamic & Kinematic viscosity, Surface tension, Capillarity, Vapour pressure, Compressibility, Bulk modulus. 1.3 Types of fluids: Ideal, Real, Newtonian, Non-Newtonian, Plastic 1.4 Pressure, Fluid pressure, pressure head, Pressure Intensity, Concept of absolute Vacuum, Gauge Pressure, Atmospheric Pressure, Absolute Pressure, 1.5 Pressure measurement- Manometer, U- tube manometer, Incline manometer, Inverted U manometer, Piezometer. 1.6 Concept of Total pressure, Centre of pressure, Pascal's law, Hydrostatic forces on plane and curved surface immersed in liquid and simple problems on it, Metacenter	CO1
TSO.2a Identify the given type of fluid flow. TSO.2b Identify the various forms of energy related to given fluid flow. TSO.2c Calculate the total energy in a given fluid. TSO.2d Apply the continuity equation to given real system. TSO.2e Solve numerical problems on Bernoulli equations	Unit-2.0 Fluid Flow 2.1 Various forms of energies applicable to fluid flow – Potential energy, Kinetic energy, Pressure energy, Total energy, Types of fluid flows- Steady, unsteady, uniform, non-uniform, laminar and turbulent flow, Path line and Stream line, Concept of datum pressure, Velocity and total head of fluid in motion. 2.2 Continuity equation, Energy equation- Steady flow energy equation and derivation of Bernoulli Theorem and its assumption and practical application. 2.3 Flow measurement- Construction, Working and application of Venturi meter, Orifice meter and Pitot tube, Derivations for discharge, coefficient of discharge, Vena-Contraction, coefficient of contraction and numerical problems.	CO2
TSO.3a Determine the flow is laminar or turbulent in the pipe flow. TSO.3b Calculate the different types of minor and major losses. TSO.3c Calculate the loss of head in fluid flow through pipes in a given situation as per the given data.	Unit 3.0 Flow through Pipes 3.1 Flow Through Pipes- Laminar and turbulent flows 3.2 Viscous flow- Concept of viscosity of fluids, Reynolds number and its criteria for plate and pipes, Darcy's Weisbach equation and Chezy's equation for frictional losses, loss of head due	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO.3d</i> Explain various losses in flow through pipes, fittings and valves. <i>TSO.3e</i> Solve numerical based on continuity equation, laws of friction and losses in flow through pipes. <i>TSO.3f</i> Explain the effect of water hammer due to the sudden change in velocity and pressure of the given fluid.	to friction in pipe, Hagen- Poiseuille formula 3.3 Flow through pipes- Pipes in series, Pipes in parallel, Head losses- various types of minor and major energy loss occur in fluid flow through pipes. H.G.L. and T.E.L., surge tank, water hammer and its effects.	
<i>TSO.4a</i> Calculate the impact of jet on flat plate. <i>TSO.4b</i> Calculate the impact of jet on curved plate. <i>TSO.4c</i> Calculate the force exerted by impact of jet plate in stationary and moving blades <i>TSO.4d</i> Draw the layout of hydroelectric power pant. <i>TSO.4e</i> Select suitable turbine for a given site/situation with justification. <i>TSO.4f</i> Describe the construction and working of the given water turbines. <i>TSO.4g</i> Describe the construction and working of the given draft tube. <i>TSO.4h</i> Calculate the work done, power, efficiency of turbines. <i>TSO.4i</i> Analyze the performance of turbine.	Unit 4.0 Impact of jets & Hydraulic Turbines 4.1 Impact of jet on flat and curved plate in stationary and moving blades, Simple Numerical on work done and efficiency. 4.2 Layout of hydroelectric power plant, Features of Hydroelectric power plant, Classification of hydraulic turbines, 4.3 Functions and working principle of Impulse and reaction turbine, Comparison of impulse and reaction turbine 4.4 Construction, function and working principle of Pelton wheel, Francis and Kaplan turbines, Draft tubes– types and construction, Concept of cavitation in turbines and benefit of draft tubes 4.5 Calculation of Work done, Power, efficiency of turbines, and Unit quantities 4.6 Selection of turbine on the basis of head and discharge available. 4.7 Safety precaution on turbines	CO4
<i>TSO.5a</i> Identify the different types of hydraulic pumps <i>TSO.5b</i> Describes construction and working of the given pump. <i>TSO.5c</i> Select suitable Pump for a given application with justification. <i>TSO.5d</i> Explain construction and working of the given reciprocating pump. <i>TSO.5e</i> Calculate the work done and overall efficiency and power required for the given pump. <i>TSO.5f</i> Analyze the performance of pumps.	Unit-5.0 PUMPS 5.1 Centrifugal Pumps – construction, working Principle and applications of centrifugal pump, Classification of centrifugal pump, impellers, casing, 5.2 Concept of multistage, Priming and its methods, Cavitation, Manometric head, Work done, Manometric efficiency, Overall efficiency. 5.3 Reciprocating Pumps- Construction, working principle and applications of single and double acting reciprocating pumps, Concept of Slip, Negative slip, Cavitation and separation. use of air vessels, Comparison of centrifugal and reciprocating pump 5.4 Submersible pump- Construction, working principle and application of submersible pump.	CO5

Note: One major TSO may require more than one theory session/period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425402

Practical/Lab Session Outcomes (LSOs)	S.No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1 Determine viscosity of given liquid	1.	Use viscometer to determine the viscosity of a given liquid.	CO1
LSO 1.2 Measure the rise of liquid level	2.	Measure the rise of liquid level using capillary action in capillary tube.	CO1
LSO 1.3 Measure specific gravity of any given fluid	3.	Determine the specific gravity of any given fluid	CO1
LSO 1.4 Measure the pressure of the given fluid.	4.	Use manometer/ incline manometer to measure the pressure of the given fluid.	CO1
LSO 1.5 Measure meta-centric height of ship model.	5.	Determine the meta-centric height of ship model.	CO1
LSO 2.1 Measure discharge through a pipe using Venturi meter.	6.	Determine Coefficient of Discharge of Venturi meter.	CO2
LSO 2.2 Measure discharge through a pipe using Orifice meter.	7.	Determine Coefficient of Discharge, coefficient of contraction and coefficient of velocity of Orifice meter.	CO2
LSO 2.3 Determine the coefficient of friction of flow through pipes.	8.	Determine coefficient of friction of flow through pipes.	CO2
LSO 2.4 Measure static pressure	9.	Experimentally justify Bernoulli's theorem for a viscous and incompressible fluid.	CO2
LSO 2.5 Measure pressure energy, kinetic energy and datum energy of a given flowing fluid	10.	Determine the pressure energy, kinetic energy and datum energy of a given flowing fluid.	CO2
LSO 3.1 Measure discharge through given pipe	11.	Determine discharge through a given pipe using orifice meter, pitot tube and venturi meter.	CO3
LSO 3.2 Determine Cc, Cd, Cv for different types of orifices.	12.	Determine Cc, Cd, Cv for different types of orifices.	CO3
LSO 3.3 Determine head loss	13.	Determine loss of head due to A. Sudden enlargement B. Sudden contraction C. Friction in pipes	CO3
LSO 3.4 Determine the different types of flow Patterns	14.	Determine the different types of flow Patterns by Reynolds's experiment	CO3
LSO 3.5 Measure the flow characteristic	15.	Measure the flow characteristic of given flowing fluids	CO3
LSO 3.6 Calculate the minor losses of flow through pipes.	16.	Determination of minor losses of flow through pipes.	CO3
LSO 4.1 Calculate the overall efficiency of the given turbine.	17.	Determine overall efficiency using Pelton turbine.	CO4
	18.	Determine overall efficiency using Francis/Kaplan turbine.	CO4
LSO 4.2 Determine the reaction force produced by the impact of a jet of water on to various target vanes	19.	Investigate the reaction force produced by the impact of a jet of water on to various target vanes	CO4
LSO 4.3 Plot characteristics curve of the given turbine	20.	Plot the characteristic curves of • Pelton wheel • Francis Turbine • Kaplan turbine	CO4
LSO 5.1 Calculate overall efficiency of the given pump.	21.	Determine overall efficiency using Centrifugal pump.	CO5
	22.	Determine overall efficiency using Reciprocating pump.	CO5
LSO 5.2 Determine the performance characteristics and power required for the given pump	23.	Determine the power required to drive the given reciprocating pump.	CO5
	24.	Determine the performance characteristics of: • Centrifugal pump • Reciprocating Pump	CO5

L) Suggested Term Work and Self Learning: S2425402 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments:

- i. Explain the different types of pressure measuring devices.
- ii. Explain different types of discharge measuring devices.
- iii. Describe a hydroelectric power plant.
- iv. Differentiate the hydraulic turbine on the basis of head, input energy available.
- v. Explain the various types of head in the centrifugal pump.

b. Micro Projects:

- i. Prepare a pipe layout water supply of your lab from supply reservoir and calculate the loss of head.
- ii. Prepare a demonstration model of hydroelectric power plant.
- iii. Calculate running cost of your household pump and verify the electricity bill.
- iv. Visit a hydroelectric power plant and write report.
- v. Conduct market survey of hydraulic turbine suppliers and prepare report on technical specifications, area of applications, cost, material of different parts and maintenance procedure.
- vi. Download catalogue of pump manufacturer and compare their parameter.

c. Other Activities:

1. Seminar Topics:

- Different types of manometers and their applications.
- Comparison between orifice meter and venturi meter.
- Different types of hydraulic turbines and their application areas.
- Different types of hydraulic pumps and their application areas.

2. Visit:

- Visit nearby shops to identify different PVC and GI pipe fittings.
- Visit nearby shops to identify different pumps. Collect manufacturing catalogues related to the same and compare their salient features.

3. Self-Learning Topics:

- Prepare journals based on practical performed in laboratory.
- Use various mechanical measuring instruments and equipments related to fluid mechanics and machinery.
- Read and use specifications of the hydraulic machines and equipments.
- Prepare power point presentation or animation for understanding constructional details and working of different hydraulic machines.

- M) Suggested Course Evaluation Matrix:** The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	15%	10%	15%	-	-	20%	20%
CO-2	10%	20%	10%	25%	-	10%	20%
CO-3	15%	20%	15%	25%	33%	15%	20%
CO-4	30%	20%	30%	25%	33%	15%	20%
CO-5	30%	30%	30%	25%	34%	40%	20%
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentages given are approximate.
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

- N) Suggested Specification Table for End Semester Theory Assessment:** Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Properties of Fluid and Fluid Pressure	9	CO1	11	3	4	4
Unit-2.0 Fluid flow	11	CO2	14	4	4	6
Unit-3.0 Flow through pipes	10	CO3	14	5	4	5
Unit 4.0 Impact of jets & Hydraulic Turbines	9	CO4	14	3	5	6
Unit-5.0 Pumps	9	CO5	17	4	4	9
Total Marks	48	-	70	19	21	30

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

N) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number (s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Use viscometer to determine the viscosity of a given liquid.	CO1	40	50	10
2.	Measure the rise of liquid level using capillary action in capillary tube.	CO1	40	50	10
3.	Determine the specific gravity of any given fluid	CO1	40	50	10
4.	Use manometer/ incline manometer to measure the pressure of the given fluid.	CO1	40	50	10
5.	Determine the meta-centric height of ship model.	CO1	40	50	10
6.	Determine Coefficient of Discharge of Venturi meter.	CO2	40	50	10
7.	Determine Coefficient of Discharge, coefficient of contraction and coefficient of velocity of Orifice meter.	CO2	40	50	10
8.	Determine coefficient of friction of flow through pipes.	CO2	40	50	10
9.	Experimentally justify Bernoulli's theorem for a viscous and incompressible fluid.	CO2	40	50	10
10.	Determine the pressure energy, kinetic energy and datum energy of a given flowing fluid.	CO2	40	50	10
11.	Determine discharge through a given pipe using orifice meter, pitot tube and venturi meter.	CO3	40	50	10
12.	Determine Cc, Cd, Cv for different types of orifices.	CO3	40	50	10
13.	Determine loss of head due to - Sudden enlargement - Sudden contraction - Friction in pipes	CO3	40	50	10
14.	Determine the different types of flow Patterns by Reynolds's experiment	CO3	40	50	10
15.	Measure the flow characteristic of given flowing fluids	CO3	40	50	10
16.	Determination of minor losses of flow through pipes.	CO3	40	50	10
17.	Determine overall efficiency using Pelton turbine.	CO4	40	50	10
18.	Determine overall efficiency using Francis/Kaplan turbine.	CO4	40	50	10
19.	Investigate the reaction force produced by the impact of a jet of water on to various target vanes	CO4	40	50	10
20.	Plot the characteristic curves of - Pelton wheel - Francis Turbine - Kaplan turbine	CO4	40	50	10
21.	Determine overall efficiency using Centrifugal pump.	CO5	40	50	10
22.	Determine overall efficiency using Reciprocating pump.	CO5	40	50	10
23.	Determine the power required to drive the given reciprocating pump.	CO5	40	50	10
24.	Determine the performance characteristics of: - Centrifugal pump - Reciprocating Pump	CO5	40	50	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment and Tools: The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments. As well as aid to procure equipment by administrators.

S. No.	Name of Equipment	Broad Specifications	Relevant Experiment Number
1	Red wood viscometer	Electrically Heated with Digital temperature controller cum indicator	1
2	Capillary tube	Capillary tube of different diameters, beaker/petri dish,	2
3	Beaker, Pipette, Electronic balance, Thermometer	The Electronic Digital Balance 2kg x 0.5 gram, Beaker 500 ml, Pipette 50 ml, digital thermometer	3
4	manometer	Glass tube 50 mm, Complete set up for pressure measurement, wall or stand mounted, Mercury as manometric fluid	4
5	Differential Manometer	Glass tube 50 mm, Complete set up for demonstration of pressure measurement, wall or stand mounted, Mercury as manometric fluid	4
6	Venturimeter setup for measurement of discharge	Complete set up for measurement of discharge including power supply, water tank, and all accessories and instruments.	6,11
7	Orificemeter setup for measurement of discharge	Complete set up for measurement of discharge including power supply, water tank, and all accessories and instruments.	7,11
8	Setup for Bernoulli's Theorem	Complete set up for to verify the Bernoulli's theorem including power supply, water tank, and all accessories and instruments.	9
9	Setup for Friction losses through Pipes	Complete set up for friction losses including power supply, water tank, and all accessories and instruments.	8
10	Setup for losses due to enlargement & contraction in pipes	Complete set up of enlarge and contraction pipe, including power supply, water tank, and all accessories and instruments.	8, 10, 13
11	Reciprocating Pump test rig	Complete setup to test performance parameter of reciprocating pump up to 5 HP	22,23,24
12	Centrifugal Pump test rig	Complete setup to test performance parameter of Centrifugal Pump up to 5 HP	21,24
13	Pelton wheel test rig	Complete setup to test performance parameter and characteristics	17,20
14	Kaplan turbine test rig	Complete setup to test performance parameter and characteristics	18,20
15	Francis turbine test rig	Complete setup to test performance parameter and characteristics	18,20
16	Impact of jet apparatus	Complete set up including Sump Tank, Measuring tank, nozzles and vanes.	19
17	Reynolds Apparatus	Complete setup consisting of Borosilicate Glass tube, Stainless steel Dye vessel, Copper/Stainless Steel Capillary Tube, Water Tank, arrangement for flow measurement, stop watch and power supply	14
18	Metacentric height apparatus	Complete setup for Metacentric height calculation including tank , ship model	5

R) Suggested Learning Resources:**(a) Books:**

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Hydraulics, Fluid Mechanics and Hydraulic Machines.	Khurmi R.S. Khurmi N.	S. Chand and Co. Ltd., New Delhi, 2014 • ISBN-10: 8121901626 • ISBN-13: 978-8121901628
2.	Fluid mechanics and hydraulic machines.	Bansal R.K.	Laxami Publication, New Delhi, 2018 • ISBN-10: 8131808157 • ISBN-13: 978-8131808153
3.	Fluid mechanics and hydraulic machines	Rajput R.K.	S. Chand and Co. Ltd., New Delhi, 2006 • ISBN-10: 8121916666 • ISBN-13: 978-8121916660
4.	Hydraulics & Fluid Mechanics Including Hydraulics	Modi P.N. Seth S.M.	Rajsons Publications Pvt Ltd, New Delhi, 2017, ISBN-10: 8189401262 • ISBN-13: 978-8189401269
5.	Textbook of Fluid Mechanics and Hydraulic Machines	Pati Sukumar	McGraw Hill Education New Delhi, 2017 • ISBN-10: 1259006239 • ISBN-13: 978-1259006234

(b) Online Educational Resources:

1. Nptel course- <http://nptel.ac.in/courses/112105171/>
2. fluid and their propertie-https://www.youtube.com/results?search_query=fluid+and+their+propertie
3. Continuity equation-- https://www.youtube.com/results?search_query=Continuity+equation+
4. Pressure measurement- https://www.youtube.com/results?search_query=Pressure+measure
5. Pascal's law - https://www.youtube.com/results?search_query=Pascal%E2%80%99s+law
6. Metacenter-- https://www.youtube.com/results?search_query=2.4%09Metacenter
7. buoyancy - https://www.youtube.com/results?search_query=buoyancy
8. Fluid flow energy equation -
https://www.youtube.com/results?search_query=Fluid+flow+energy+equation
9. Fluid flow - https://www.youtube.com/results?search_query=Fluid+flow+
10. Flow measurement- https://www.youtube.com/results?search_query=2.%09Flow+measurement
11. Venturimeter- https://www.youtube.com/results?search_query=Venturimeter
12. Classification of hydraulic turbines-
https://www.youtube.com/results?search_query=5.1%09Classification+of+hydraulic+turbines+
13. Francis Turbine - https://www.youtube.com/results?search_query=%29+Francis+Turbine+
14. Kaplan turbine- https://www.youtube.com/results?search_query=Kaplan+turbine
15. Centrifugal pumps- https://www.youtube.com/results?search_query=Centrifugal+pumps-+
16. Reciprocating pumps- https://www.youtube.com/results?search_query=Reciprocating+pumps-

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others:

1. Lab Manuals
2. Users' Guide
3. Manufacturers' Manual
4. Learning Package

- A) **Course Code** : 2425403 (T2425403/P2425403/S2425403)
- B) **Course Title** : Applied Thermodynamics & HVAC
- C) **Pre-requisite Course(s)** :
- D) **Rationale** :

The main purpose of this course to understand the basic principle of energy generation, conversion, and energy transfer around our surroundings. This subject leads to study about a thermodynamic system includes anything whose thermodynamic properties are of interest. It is embedded in its surroundings; it can exchange heat with, and do work on, its environment through its boundary. Purposes of a Heating, Ventilation and Air-Conditioning (HVAC) system are to help maintain good indoor air quality (IAQ) through adequate ventilation with filtration and provide thermal comfort.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1** Apply law of thermodynamics to the given thermal systems.
- CO-2** Analyze processes involving in power generation.
- CO-3** Calculate COP of the given refrigeration System.
- CO-4** Select air conditioning system for the given situation.
- CO-5** Apply concepts of conduction, convection and radiation in daily life.

F) **Suggested Course Articulation Matrix (CAM):**

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2
CO-1	3	1	1	3	-	-	-		
CO-2	3	1	2	2	2	2	2		
CO-3	3	3	3	3	1	2	2		
CO-4	3	3	2	2	2	-	2		
CO-5	3	3	1	2	-	-	-		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2425403	Applied Thermodynamics & HVAC	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2425403	Applied Thermodynamics & HVAC	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2425403

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 1a.</i> Select surface condenser for the given situation. <i>TSO 1b.</i> Compare the given steam turbine on the basis of given criteria. <i>TSO 1c.</i> Calculate efficiency of the given air compressor. <i>TSO 1d.</i> Calculate the velocity of steam on exit of given type of nozzle.	Unit-1.0 Thermal Systems 1.1 Steam condenser: Function of steam condenser, Classification of steam condenser, Construction and working principle of Surface condenser & its applications. 1.2 Steam Turbines: Function of steam turbine, Classification of steam turbine, Construction and working principle of Curtis, De Laval and Parson turbine & its applications. 1.3 Air Compressors – Functions of air compressor, Types of air compressors, construction and working of reciprocating and rotary compressor using P-V diagram. Efficiency of compressor. 1.4 Steam Nozzles: Function of steam nozzle, Classification of steam nozzle, Flow of steam through nozzle; Velocity of steam at the exit of nozzle in terms of heat drop.	CO1
<i>TSO 2a.</i> Calculate thermal efficiency and draw P-V & T-S diagram of Rankine cycle. <i>TSO 2b.</i> Calculate thermal efficiency and draw P-V & T-S diagram of Brayton cycle. <i>TSO 2c.</i> Describe the working principle of the given type of jet propulsion. <i>TSO 2d.</i> Describe the working principle of the given type of nuclear reactor. <i>TSO 2e.</i> State the applications of hydroelectric power generation and give for using it. <i>TSO 2f.</i> Solve Numerical problems.	Unit-2.0 Power Generation: 2.1 Rankine cycle: Construction and Working of Rankine cycle, their P-V & T-S diagram and its application. 2.2 Open and closed cycle gas turbine, Brayton cycle: Construction and Working of Brayton cycle, their P-V & T-S diagram and its application. 2.3 Jet Propulsion: Function and Working Principle of Ram Jet engine & Rocket engine and its application. 2.4 Introduction to nuclear fission and fusion reaction. Components of nuclear reactor, pressurized water reactor and boiling water reactor. 2.5 Working principle of hydroelectric power plant.	
<i>TSO 3a.</i> Calculate unit of refrigeration & Coefficient of performance. <i>TSO 3b.</i> Draw P-V, P-H & T-S diagram of the given refrigeration cycle. <i>TSO 3c.</i> Solve numerical problems on refrigeration system. <i>TSO 3d.</i> Explain Construction and working of the given refrigeration cycle.	Unit-3.0 Refrigeration Systems: 3.1 Definition of Refrigeration; Refrigerating effect, Unit of refrigeration, standard components of refrigeration system, Coefficient of performance Reversed Carnot Cycle: COP and Representation of this cycles, in P-V, T-S and P-H diagrams with their flow diagrams. 3.2 Air refrigeration (Bell Coleman) cycle & its P-V & T-S diagram; Simple problems on COP. 3.3 Vapour compression refrigeration cycle: Basic Components, Construction & working of VCR cycle and their representation on P-H & T-S Diagram. Application of VCR system. 3.4 Vapour absorption refrigeration: Basic components of VAR system Construction and working of Simple Aqua-Ammonia VAR system and its flow diagram.	CO2
<i>TSO 4.a.</i> Calculate psychrometric properties.	Unit-4.0 Air Conditioning & Ventilation System	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 4.b.</i> Apply Psychrometric process for a given thermal system. <i>TSO 4.c.</i> Select A.C. system for the given situation. <i>TSO 4.d.</i> Explain the reason for using air conditioning system in given applications. <i>TSO 4.e.</i> Analyze ventilation uses at different situations.	4.1 Psychrometry: Definition, Properties: Specific humidity, Absolute humidity, Relative humidity, DBT, WBT, DPT, Degree of saturation. 4.2 Psychrometric processes (six process) and its representation on chart. 4.3 Classification of air-conditioning system, Component of air-conditioning system, Working principle of air-conditioning system and its application. 4.4 Ventilation system- Natural Ventilation and Mechanical Ventilation, limitation for natural ventilation, Types of ventilation single sided ventilation, cross ventilation, stack ventilation. 4.5 Duct design: Selection of material. 4.6 Supply system: Air intake system, Filters heating & cooling equipment's, Fans, Ducts, grills, Diffusers for distribution of air at workplace.	
<i>TSO 5a.</i> Differentiate between Conduction, Convection and Radiation. <i>TSO 5b.</i> Solve numerical problems of conduction, convection and radiation. <i>TSO 5c.</i> Explain mode of heat transfer for the given situations.	Unit-5.0 Heat Transfer. 5.1 Definition, Modes of heat transfer, Physical mechanism of Heat transfer in Conduction, Convection and Radiation. 5.2 Conduction: Introduction, Fourier law of heat conduction for isotropic material. 5.3 Convection: Introduction, Newton's law of cooling. 5.4 Radiation: Definition, Absorptivity, Reflectivity, Transmissivity, black body, White body, gray body, Emissivity; Law of radiation.	CO4

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425403

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Use different types of condensor	1.	Determine the efficiency of the given condensor	CO1
LSO 1.2. Use impulse steam turbine.	2.	Determine the power output & efficiency of an impulse steam turbine	CO1
LSO 1.3. Use reaction steam turbine.	3.	Determine the output & efficiency of a reaction steam turbine.	CO1
LSO 1.4. Use Reciprocating Air Compressor.	4.	Determine the volumetric efficiency of a reciprocating air compressor.	CO1
LSO 1.5. Use centrifugal air compressor.	5.	Determine the volumetric efficiency of a Centrifugal air compressor.	CO1
LSO 2.1. Use working model of Thermal Power Plant with Steam Engine Trainer	6.	Calculate the efficiency of steam power plant and do the Rankine cycle analysis.	CO2
LSO 2.2. Use working model of gas power plant.	7.	Calculate the efficiency of gas power plant.	CO2
LSO 2.3. Use working model of nuclear power plant	8.	Identify different parts and different process of nuclear power plant.	CO2
LSO 2.4. Use the model of hydroelectric power plant.	9.	Identify different parts and different process of hydroelectric power plant.	CO2
LSO 3.1. Use vapour compression refrigeration test rig.	10.	Determine COP of vapour compression refrigeration system.	CO3, CO4

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 3.2. Use refrigeration system.	11.	Disassemble and assemble the given refrigeration system	CO3, CO4
LSO 3.3. Use vapour absorption refrigeration test rig.	12.	Determine COP of vapour absorption refrigeration system.	CO3, CO4
LSO 3.4. Detect the refrigerant leakage.	13.	Detect refrigerant leakage in the given refrigeration system.	CO3, CO4
LSO 4.1. Use A.C. test rig.	14.	Determine COP of air-conditioning system	CO4
LSO 4.2. Use A.C system	15.	Assemble and disassemble the given A.C system	CO4
LSO 4.3. Use sling psychrometer	16.	Find out the different properties of moist air of your classroom using sling psychrometer.	CO4
LSO 5.1. Use natural convection test rig	17.	Determine heat transfer coefficient of natural convection	CO5
LSO 5.2. Use forced convection test rig.	18.	Determine heat transfer coefficient of forced convection	CO5
LSO 5.3. Use thermal conductivity apparatus	19.	Find thermal conductivity of metal rod	CO5
LSO 5.4. Use Stefan Boltzmann apparatus.	20.	Find out the Stefan Boltzmann constant.	CO5
LSO 5.5. Use thermal conductivity apparatus	21.	Determine the total thermal resistance and total thermal conductivity of a composite wall and plot the temperature distribution.	CO5

K) Suggested Term Work and Self Learning: S2425403 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted Cos.

1. Explain the different types of evaporators.
2. Explain the working of sling psychrometer.
3. A.C. system used in daily life uses.
4. Explain different kinds of heat exchanger.
5. Reheat & regeneration in rankine cycle.
6. Reheat & intercooling in brayton cycle.
7. Explain the fission reaction on sun.

b. Micro project:

1. Prepare the sling psychrometer by Thermometer.
2. Find the COP of a Refrigeration and an A.C. system working for same ambient temperature.
3. Prepare a model of Air Conditioning system of a Hospital/Hotel.
4. Prepare a model for showing all modes of heat transfer.
5. Prepare a water heater by using Solar Energy.

c. Other Activities:

- Identifying the Tonnage capacity of A. C. System of Office, Laboratories, Homes and Seminar Hall etc.
 - Assembling & Disassembling of an A. C. System.
1. Seminar Topics:
 - Evaporator.
 - Refrigeration system.

- Year-round A.C. system.
- Heat exchanger.

2. Visits:

- Visit and study a steam power plant and prepare a report on the refrigeration system components and heat exchanger components.
- Visit to an automobile company and prepare a report on the refrigeration system and radiator.
- Visit and study to a milk chilling plant and prepare a report on refrigeration system.
- Visit and study to a solar power based electric vehicle workshop and prepare a report on solar system.
- Visit and study to cold storage and prepare a report on it.

3. Self-Learning Topics:

- Types of Evaporators.
- Types of A.C. systems Used in Hospital/Hotel/College.
- Types of fins (Extended Surface).
- Types of heat exchangers.
- Types of Nuclear Fuels.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

COS	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	15%	15%	15%	-	20%	15%	20%
CO-2	15%	15%	15%	20%	20%	20%	20%
CO-3	25%	25%	25%	30%	20%	25%	20%
CO-4	20%	20%	20%	25%	20%	20%	20%
CO-5	25%	25%	25%	25%	20%	20%	20%
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentages given are approximate.
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

- N) Suggested Specification Table for End Semester Theory Assessment:** Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Thermal systems	10	CO1	14	4	6	4
Unit-2.0 Power Generation	10	CO5	15	4	6	5
Unit-3.0 Refrigeration system	8	CO2	12	4	4	4
Unit-4.0 Air Conditioning & Ventilation system	10	CO3	14	4	4	6
Unit-5.0 Heat Transfer	10	CO4	15	4	5	6
Total	48	-	70	20	25	25

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

- O) Suggested Assessment Table for Laboratory (Practical):**

S. No	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Determine the efficiency of the given condenser.	CO1	40	50	10
2.	Determine the power output & efficiency of an impulse steam turbine	CO1	40	50	10
3.	Determine the output & efficiency of a reaction steam turbine.	CO1	40	50	10
4.	Determine the volumetric efficiency of a reciprocating air compressor	CO1	40	50	10
5.	Determine the volumetric efficiency of a Centrifugal air compressor	CO1	40	50	10
6.	Calculate the efficiency of steam power plant and do the Rankine cycle analysis	CO2	40	50	10
7.	Calculate the efficiency for gas power plant	CO2	40	50	10
8.	Identify different parts and different process of nuclear power plant	CO2	40	50	10
9.	Identify different parts and different process of hydroelectric power plant	CO2	40	50	10
10.	Determine COP of vapour compression refrigeration system	CO3, CO4	40	50	10
11.	Disassemble and assemble the given refrigeration system	CO3, CO4	40	50	10
12.	Determine COP of vapour absorption refrigeration system	CO3, CO4	40	50	10
13.	Detect refrigerant leakage in the given refrigeration system.	CO3, CO4	40	50	10
14.	Determine COP of air-conditioning system	CO4	40	50	10
15.	Assemble and disassemble the given A.C system	CO4	40	50	10
16.	Find out the different properties of moist air of your classroom using sling psychrometer.	CO4	40	50	10
17.	Determine heat transfer coefficient of natural convection	CO5	40	50	10
18.	Determine heat transfer coefficient of forced convection	CO5	40	50	10
19.	Find thermal conductivity of metal rod	CO5	40	50	10
20.	Find out the Stefan Boltzmann constant.	CO5	40	50	10
21.	Determine the total thermal resistance and total thermal conductivity of a composite wall and plot the temperature distribution	CO5	40	50	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
1.	Working models of Surface condenser	Body material- stainless steel, process type- forced circulation	1
2.	Steam turbine test rig.	Steam Output: 300 kg/hr (F&A at 100C) , Working Pressure: 10.5 kg/cm sq Fuel : LDO/HSD, Power supply : 3_Ph, 415V, AC, 50HZ, 4 wires with neutral Capacity 0.5 HP - 5 HP Chimney diameter-200mm, Extraction pump- 0.5 HP, Speed 3000 RPM	2, 3
3.	Working models of reciprocating air compressor	3 Phase Horizontal Reciprocating Compressor, Voltage: 415 V Head- 3065, pressure 8Bar/ 115 psi, Tank capacity- 150Lt/40Gal, Motor – 4HP/3KW	4
4.	Working models of centrifugal air compressor.	Horse power-2hp, Air tank capacity- 300Litre, Maximum flow rate-500CFM, cooling method- air cooled, Voltage -240, tank material-Stainless steel	5
5.	Thermal Power Plant with Steam Engine Trainer	Trolley-mounted, mobile laboratory-scale steam plant, Operating temperature - +5°C to +40°C, operating relative humidity range - 80% at temperatures < 31°C decreasing linearly to 50% at 40°C Boiler -Maximum pressure approximately 350 kPa (set by 400 kPa pressure relief safety valve), Throttling calorimeter and thermocouple to measure the dryness fraction of the steam, Dynamometer and display unit for motor speed and power measurement, Pressure gauges for boiler and engine (motor) inlet pressures, including electronic transducers, Thermocouples and display for steam and cooling water temperatures, Power meter for heater power input and output, Calibrated vessel with stopwatch and thermometer for condensate (steam flow) measurement	6
6.	Gas power plant trainer	Trolley-mounted, Gas power plant trainer	7
7.	Nuclear power plant trainer	Trolley-mounted, Nuclear power plant trainer	8
8.	Hydroelectric power plant trainer	Trolley-mounted, Hydroelectric power plant trainer	9
9.	VCR Test Rig	Rated Current: 4.5 Amps - Input Power: 1.0 Kw - Supply: 220-240 Volts, 50 Hz, 1 Phase - Cooling Capacity: 450 Watts at Rated Test Conditions (1/8 Tr)	10
10.	Refrigeration system	Educational Refrigeration system, digital Voltmeter-0-300 V Electric Supply 5A-220 V, AC	11

11.	VAR Test Rig	Gross volume 40-50 liters, 220 – 240 volts AC, Power Rating 65-70 W, Refrigerant NH ₃ + H ₂ O + Hydrogen, Ammeter Digital, 0 – 20 A AC, Voltmeter Digital, 0 – 300 V AC, Temperature Indicator Digital Temperature Indicator, -50 to 150°C with TSS, Thermocouples Teflon coated Cr –Al (K-type)	12
12.	Refrigerant leak detector	Detectable Gases: R-134a, R-404A, R-407C, R-410A, R-22 etc. Sensitivity: H L R-22,134a 6g/year 30g/year R-404A,407C,410A 8g/year 40g/year Alarm Method: Buzzer, Tricolor LED bar Indicator. Power Usage: 4 AA size (6V DC) Alkaline Batteries Snake Tube Accessories: Alkaline batteries (AA), leak check bottle, carry case. Auto power OFF: approx. 10 minutes, Warm-Up Time: Approximately 90 seconds Operating Temperature & Humidity: 0 ~40 °C, < 80% RH Refrigerant Leak Detector 4 Storage Temperature & Humidity: -10 ~60 °C, < 70% RH Altitude: < 2000M (6500')	13
13.	Air-conditioning test Rig	AC Power Supply, Semi-Automatic, Single Phase, 230V, 15 A	14
14.	Air-conditioning unit	1.5 Ton Capacity	15
15.	Sling Psychrometer	Stainless Steel, Measuring Range- -5 Deg C to 50 Deg C (23 Deg F to 122 Deg F)	16
16.	Natural convection Apparatus/ test rig	Metal bar – copper, insulation shell along the length and water-cooled heat sink at the other end. Test length of the bar – 240-300 mm. Thermocouples – chromel / alumel, band nichrome heater, dimmer stat to control the heat input – 2a, 230, voltmeter and ammeter to measure the heater input. Multichannel digital temperature indicator, 0.1°C least count, 0-200°C with channel selector switch. Measuring flask to measure water flow.	17
17.	Forced Convection Apparatus/test rig	Singal phase, 220 V Power- 10 Amp, Material- Stainless steel, floor area-1.2m*0.5m	18
18.	Thermal conductivity apparatus	At least 12 inches long metal rod that can be made up of either steel, brass or copper, stove, water, burner, four digital thermometers	19
19.	Stefan Boltzmann setup	Semi-automatic, Heater, thermocouple, Multichannel digital temperature indicator 0-200 C with 0.1C least counts, Audible buzzer with timer to ring at every 5 seconds, condenser, control mode and cooling system	20
20.	Thermal conductivity apparatus for composite wall	electronic dimmer 1kw, teflon coated cr -al (k-type) thermocouple, computerized data acquisition system with software, digital temperature indicator ,0-400-degree c with TSS, digital ammeter of range 0-20a ac, heater, digital voltmeter of range 0-300v ac, standalone control panel	21

R) Suggested Learning Resources:**(a) Books:**

S.No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Engineering Thermodynamics	James Ambrose Moyer	Maxwell Press, 2022 ISBN-10: 9355282001 ISBN-13: 9355282002-978
2.	Engineering Thermodynamics	R.K. Singal Mridul Singal Rishi Singal	Dreamtech Press, 2020 ISBN-10: 9389698669 , ISBN-13: 9389698664-978
3.	Heat and Mass Transfer - Fundamentals and Applications	Yunus A. Cengel Afshin J. Ghajar	McGraw Hill, Ed. 6 th ISBN-10: 9390185289 ISBN-13: 9390185283-978
4.	Thermodynamics an engineering approach	Yunus A. Cengel Michael A. Boles Mehmet Kanoglu	McGraw Hill Education India, 2019 ISBN: 9789353165741, 9353165741
5.	Applications of Thermodynamics	V. Kadambi T. R. Seetharam K. B. Subramanya Kumar	Wiley, 2019 ISBN-10: 8126571241 ISBN-13: 8126571246-978
6.	Basic and applied thermodynamics	P.K. Nag	McGraw Hill Education India, Ed. 2 nd 2017, ISBN: 9780070151314, 9780070151314
7.	Thermal Engineering	R.S. Khurmi	S Chand, 2020 ISBN-10: 9788121925730 ISBN-13: 8121925730-978
8.	A Text book of Refrigeration & Air conditioning	R.K Rajput	S.K. Kataria & Sons, 2013 ISBN-10: 9350142554 ISBN-13: 9350142554-978
9.	Refrigeration and Air Conditioning	Manohar Prasad	New Age International Pvt Ltd, Ed. 3 rd , 2021 ISBN-13: 978-8122436945
10.	Refrigeration and Air Conditioning	C. P. Arora	McGraw Hill Education, Ed. 4 th , 2021, ISBN-13978-9390385843
11.	A Course in Refrigeration and Air- conditioning	S. Domakundawar Arora	General, 2018 ASIN: B07NJ1VH8P

(b) Online Educational Resources:

1. <https://archive.nptel.ac.in/courses/112/103/112103307/>
2. <https://archive.nptel.ac.in/courses/112/105/112105129/>
3. <https://archive.nptel.ac.in/courses/112/108/112108149/>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others:

1. Conference paper
2. Journal paper
3. Lab Manuals
4. ISHRAE standard book for refrigeration and air conditioning.
5. Refrigeration and air conditioning data book, new age international publication.

- A) **Course Code** : 2425404 (T2425404/P2425404/S2425404)
- B) **Course Title** : Theory of Machines (ME, ME (Auto))
- C) **Pre-requisite Course(s)** :

- D) **Rationale** :

Knowledge of various mechanism and machines is a pre-requisite for enabling a mechanical engineer to work in Mechanical/Automobile/Textile/Printing Industries. This course provides the knowledge of Kinematics and dynamics of different machine elements and popular mechanisms, CAM-follower, Belt-Pulley, Gears, Flywheel, Brake and Clutch to enable a diploma holder to carryout simple calculation, selection and to supervise maintenance related to these parts. This course also serves as pre-requisite for course "Design of Machine Elements" and "Automobile Engineering" to be studied in later semesters.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/laboratory/workshop/field/ industry.

After completion of the course, the students will be able to-

- CO-1** Develop CAM profiles based on different follower motions required for engineering applications.
- CO-2** Select Suitable Drives for different industrial applications.
- CO-3** Calculate critical parameters related to effective functioning of flywheel and governors.
- CO-4** Calculate torque and power loss in various brakes, dynamometers, clutches and bearings used in various engineering applications.
- CO-5** Balance various rotor systems to estimate unbalanced forces and moments in different devices.

- F) **Suggested Course Articulation Matrix (CAM):**

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2
CO-1	3	2	3	2	1	-	-		
CO-2	3	2	-	2	1	-	-		
CO-3	3	2	-	2	-	-	-		
CO-4	3	2	-	2	1	-	-		
CO-5	3	2	-	2	-	-	-		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (C I)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2425404	Theory of Machines	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2425404	Theory of Machines	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2425404

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 1a.</i> Identify various links in the given mechanism and their functions. <i>TSO 1b.</i> Identify inversions of the given mechanism. <i>TSO 1c.</i> Describe the constructional details of the given mechanism. <i>TSO 1d.</i> Select suitable mechanism for the given application with justification. <i>TSO 1e.</i> Explain different types of cams and cam followers with their motions. <i>TSO 1f.</i> Estimate displacement, velocity and acceleration diagram for the given follower motion. <i>TSO 1g.</i> Construct the radial cam profile from the given data and follower motion.	Unit-1.0 Introduction to Planar Mechanisms and Cams-Followers Introduction to Planar Mechanisms 1.1 Kinematics of Machines: - Definition of Kinematics, Dynamics, Statics, Kinetics, Kinematic link, Kinematic Pair and its types, constrained motion and its types, Kinematic chain and its types, Mechanism, Machine and Structure. 1.2 Four link planar mechanisms and Inversions: i. Four bar chain: Locomotive coupler, Beam engine and Pantograph. ii. Single slider Crank chain: Pendulum pump, Rotary I.C. engine mechanism, Oscillating cylinder engine, Whitworth quick return Mechanism, Slotted Lever Quick return mechanism. iii. Double Slider chain: Scotch Yoke mechanism, Elliptical trammel, Oldham's Coupling. Cams and Followers 1.3 Cam and follower terminology. Classification of Cams and Followers. Applications of Cams and Followers. 1.4 Types of follower motions-uniform velocity, uniform acceleration and S.H.M and their displacement, velocity and acceleration diagrams. 1.5 Drawing of profile of a radial cam based on given motion of reciprocating knife-edge and roller follower with and without offset. (graphical method only)	CO1, CO2
<i>TSO 2a.</i> Compare different types of drive <i>TSO 2b.</i> Calculate the length of belt, velocity ratio, angle of contact and ratio of tight side and slack side tension for the given belt drive arrangement. <i>TSO 2c.</i> Estimate power transmitted and condition for maximum power transmission in the given belt drive through simple numerical situation. <i>TSO 2d.</i> Describe the spur gear terminology <i>TSO 2e.</i> Identify different types of gear and gear trains. <i>TSO 2f.</i> Identify the different types of gear trains and their field of applications	Unit-2.0 Power Transmission Elements 2.1 Types of Drives – Belt, Chain, Rope, Gear drives & their comparison; 2.2 Belt Drives – Introduction to Flat belt, V-belt & its applications, materials used for flat and V-belts. Introduction of timing belt and pulley. Angle of lap, length of belt, Slip and creep. Determination of velocity ratio of tight side and slack side tension, centrifugal tension and initial tension, condition for maximum power transmission. Merits, demerits and selection of belts for given applications. (Simple numerical)	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 2g.</i> Calculate Train value & velocity ratio for the given gear trains using spur and helical gears only. <i>TSO 2h.</i> Select suitable drives for the given application with justification.	2.3 Gear Drives – Spur gear terminology; Law of gearing, Types of gears and gear trains, their selection for different applications; 2.4 Gear trains- Train value & Velocity ratio for compound, reverted and simple epicyclic gear train; Methods of lubrication; 2.5 Chain Drives – Introduction to chain drives, Types of chains and sprockets, Methods of lubrication. Merits, demerits and selection of chains for given applications.	
<i>TSO 3a.</i> Explain the concept, function and terminology of governors. <i>TSO 3b.</i> Differentiate between flywheel and governor. <i>TSO 3c.</i> Draw a turning moment diagram for the given engine. <i>TSO 3d.</i> Apply the concept of fluctuation of speed and energy for the given flywheel. <i>TSO 3e.</i> Identify the working of different types of governor and their function. <i>TSO 3f.</i> Calculate the lift in case of the given governor. <i>TSO 3g.</i> Estimate mass and other geometric parameters of the given flywheel for given situation.	Unit-3.0 Flywheel and Governors 3.1 Flywheel: Concept, function and application of flywheel with the help of turning moment diagram for single cylinder 4-Stroke I.C. Engine (No Numerical); Co-efficient of fluctuation of energy, Coefficient of fluctuation of speed and its significance 3.2 Governors: Terminology of Governors; Comparison between Flywheel and Governor, Types and explanation with neat sketches (Centrifugal, Watt and Porter); Concept, function and applications. Equation for lift of governors. (No derivation) Terms related to governor like Sensitivity, stability, Isochronous, Governor Effort and Power. (No derivation)	CO4
<i>TSO 4a.</i> Explain various parts of the given brakes with their functions and constructional details. <i>TSO 4b.</i> Explain concept of self-locking and self-energizing. <i>TSO 4c.</i> Calculate braking force, braking torque and power lost in friction in the given shoe and band brake through simple numerical situation. <i>TSO 4d.</i> Describe working principle of the given clutch(s). <i>TSO 4e.</i> Explain various parts of the given clutch with their functions and constructional details. <i>TSO 4f.</i> Determine the power transmitted by the given clutch through simple numerical situation.	Unit-4.0 Brakes and Clutches 4.1 Brakes: Functions, Types, Applications Construction and working principle of - Shoe brake - Band brake - Internal expanding shoe brake - Disc Brake 4.2 Concept of Self Locking & Self energizing brakes; Numerical problems to find braking force and braking torque for shoe & band brakes. Comparison between brakes and dynamometers; 4.3 Clutches: Classification, Functions and Applications, Construction and principle of working of - Single-plate clutch, - Multi-plate clutch, - Centrifugal Clutch 4.4 Calculation of power loss assuming uniform pressure and uniform wear theory (No derivation).	CO5
<i>TSO 5a.</i> Explain the concept of balancing of single rotating mass <i>TSO 5b.</i> Describe the graphical method of balancing of several masses revolving in same plane	Unit-5.0 Balancing of Rotating Masses 5.1 Balancing- Need and types of balancing, Effects of unbalanced masses. Concept and terminology used in vibrations. Causes of vibrations in machines; their harmful effects	CO5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 5c.</i> Explain concept and terminology used in vibration <i>TSO 5d.</i> Explain the method of balancing a rotating mass as per the given conditions.	and remedies (No Numerical) 5.2 Balancing of single rotating mass in same and different plane; (Analytical Method) 5.3 Balancing of several masses revolving in same plane (Graphical method).	

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425404

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 1.1.</i> Identify the given of mechanisms. <i>LSO 1.2.</i> Explain the construction and working of the given four link mechanism.	1.	Draw line diagrams with dimensions of the working models of all the inversions of following mechanisms available in the lab. • Slider Crank Mechanism • Double Slider Crank Mechanism • Four bar Mechanism	CO1
<i>LSO 2.1.</i> Correlate the sizes, arrangement and working of actual mechanisms with theoretical counterparts.	2.	Dismantle and assemble • Wiper mechanism of any four wheeler • Steering Mechanism of Tractor • Slider Crank mechanism of any IC Engine • Any other similar mechanisms	CO1
<i>LSO 3.1.</i> Draw follower motion as per the given requirement to get the actual values of lift of the follower related to corresponding cam rotation. <i>LSO 3.2.</i> Correlate the effect of Cam-Follower terminology like Angle of Ascent, Angle of Descent, Dwell, zero Offset, Basic Circle etc. on Cam profile. <i>LSO 3.3.</i> Draw profile of the given Cam as per given motion of the follower.	3.	Draw the profile of radial CAM without offset for given follower (Knife edge and Roller follower) to obtained desired follower motion. (Minimum two problem on A2 size sheet)	CO1
<i>LSO 4.1.</i> Draw follower motion as per the given requirement to get the actual values of lift of the follower related to corresponding cam rotation. <i>LSO 4.2.</i> Correlate the effect of Cam-Follower terminology like Angle of Ascent, Angle of Descent, Dwell, Offset, Basic Circle etc. on Cam profile. <i>LSO 4.3.</i> Draw profile of the given Cam as per given motion of the follower.	4.	Draw the profile of radial CAM with offset for given follower to obtained desired follower motion. (Minimum two problem on A2 size sheet)	CO1
<i>LSO 5.1.</i> Identify the given Cam and follower combination. <i>LSO 5.2.</i> Correlate the effect of Angle of Ascent, Angle of Descent, Dwell, Offset, Basic Circle etc. with actual functioning of Cam-Follower. <i>LSO 5.3.</i> Estimate lift, velocity and acceleration of the given Cam-Follower combination.	5.	Measure main dimension of a Tangent flank cam and estimate lift, velocity and acceleration at critical points.	CO1

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 6.1.</i> Identify the given type of power transmission element. <i>LSO 6.2.</i> Explain the working of Chain sprocket mechanism. <i>LSO 6.3.</i> Identify the slack and tight side of the given drive. <i>LSO 6.4.</i> Estimate the value of slack and tight side tensions experimentally for different inputs and correlate them with theoretical counterparts.	6.	Measure slack side and tight side tension in Chain of sprocket of an experimental Bicycle setup.	CO2
<i>LSO 7.1.</i> Identify the given type of gear and gear train. <i>LSO 7.2.</i> Identify the main parameters/parts/elements of the given spur and helical gear. <i>LSO 7.3.</i> Explain the functioning and arrangement of the given gear train.	7.	Study of various types of gears and gear train	CO2
<i>LSO 8.1.</i> Correlate the sizes, arrangement and working of actual gear mechanisms with theoretical counterparts. <i>LSO 8.2.</i> Estimate the gear ratio and velocity ratio in actual gear trains experimentally.	8.	Find out velocity and gear ratio in • Lathe machine gear box. • Cane crushing machine. • Two wheelers • Drilling Machine	CO2
<i>LSO 9.1.</i> Correlate the experimental turning moment diagram with theoretical counterpart. <i>LSO 9.2.</i> Estimate value of Turning moment at corresponding crank rotation for the given engine/machine.	9.	Calculate and prepare turning moment diagram from given experimental data.	CO3
<i>LSO 10.1.</i> Identify the given type of governor. <i>LSO 10.2.</i> Explain the working of the given governor. <i>LSO 10.3.</i> Correlate the effect of governor speed on sleeve lift, upper arm inclination, lower arm inclination, radius of governor, height of the governor. <i>LSO 10.4.</i> Compare the measured values with theoretical counterparts,	10.	Measure the height, radius and mass of rotating ball for watt governor for different rotational speed	CO3
<i>LSO 11.1.</i> Identify the given type of governor. <i>LSO 11.2.</i> Explain the working of the given governor. <i>LSO 11.3.</i> Correlate the effect of governor speed and sleeve mass on sleeve lift, upper arm inclination, lower arm inclination, radius of governor, height of the governor. <i>LSO 11.4.</i> Compare the measured values with theoretical counterparts.	11.	Measure the height, radius and mass of rotating ball for porter governor for different rotational speed	CO3
<i>LSO 12.1.</i> Identify the given type of brake. <i>LSO 12.2.</i> Explain the working and construction of the given type of the brake. <i>LSO 12.3.</i> Estimate the braking torque required for the given brake in different load situations.	12.	Calculate the braking torque required for different brakes in different load situations	CO4
<i>LSO 13.1.</i> Identify the given type of dynamometer. <i>LSO 13.2.</i> Explain the working and construction of the given type of the dynamometer.	13.	Use rope/band brake dynamometer to calculate power in an IC Engine.	CO4

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 13.3.</i> Estimate the power required of the given IC engine at different speed situations.			
<i>LSO 14.1.</i> Identify the given type of Clutch. <i>LSO 14.2.</i> Identify the main parameters/elements of the given clutch. <i>LSO 14.3.</i> Correlate the functioning and arrangement/construction of the given Clutch with the theoretical concepts.	14.	Dismantle and Assemble following • Single plate clutch • Multi plate clutch • Centrifugal clutch	CO4
<i>LSO 15.1.</i> Identify the given type of Brake. <i>LSO 15.2.</i> Identify the main parameters/elements of the given Brake. <i>LSO 25.1.</i> Correlate the functioning and arrangement/construction of the given Brake with the theoretical concepts.	15.	Dismantle and Assemble a internal expanding brake and Disc Brake.	CO4
<i>LSO 16.1.</i> Identify the input and output parameters/elements of the given clutch. <i>LSO 16.2.</i> Estimate the torque transmitting capacity of the given single and multi plate clutch.	16.	Estimate torque transmitting capacity of single and multi plate clutch with the help of working model.	CO4
<i>LSO 17.1.</i> Observe the unbalanced/vibrations caused by the given single/multi rotating masses. <i>LSO 17.2.</i> Measure the parameters required for calculation of unbalance force/moment in the given unbalance setup. <i>LSO 17.3.</i> Suggest suitable balanced mass value and position to make the given system unbalanced system.	17.	Perform balancing of many unbalanced rotating masses in single plane using rotating balancing machine.	CO5

*A judicious mix of minimum 14 or more practical need to be performed, out of which, the practical marked as ‘**’ are compulsory.

L) Suggested Term Work and Self Learning: S2425404 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Draw bicycle brake applying mechanism and identify the type of links and joints.
- Draw line diagram of car and tractor steering mechanisms
- Compare wiper mechanism of a typical bus with wiper mechanism of a typical car.
- Compare slider crank mechanism used in a Bike and a Car.
- List the various types of machines where Cam and Follower are used.
- Draw the profile of radial CAM for given follower to obtained desired follower motion. (Minimum two problem)
- Measure slack side and tight side tension in belt of pulleys of a floor mill.
- Calculate the length of belt for different belt arrangement.
- Calculate velocity ratio, belt tensions, slip and angle of contact in the given belt drive arrangement through simple numerical situation.
- Estimate power transmitted and condition for maximum power transmission in the given belt drive through simple numerical situation.
- Calculate mass of flywheel and coefficient of fluctuation of a flywheel through simple numerical situation.

- xii. Draw a turning moment diagram for a given engine through simple numerical situation.
- xiii. Measure the Kinetic Energy stored in the given flywheel after 15 seconds for a given starting torque.
- xiv. Determine the fluctuation of energy of two stroke and four stroke petrol engines and justify the size of flywheels.
- xv. Estimate the balancing mass and its position analytically and graphically for many given unbalance masses rotating in a single plane through a numerical situation.

b. Micro Projects:

- i. Prepare card sheet/stick/thermocole/Acrylic sheet models of at least four mechanisms (group work with group size of five students each)
- ii. Study a sewing machine and prepare a list of various mechanisms used in it.
- iii. Prepare a list of different mechanisms used in automobile, domestic appliances, devices, industrial machines etc. (group work with group size of five students each)
- iv. Collect photographs of all the mechanisms identified in Sr. no. (3) and prepare a chart (group work with group size of five students each)
- v. Collect different Cam and Follower combinations used in different devices and machines. (group work with group size of five students each).
- vi. Develop Acrylic models of various Cam-Follower combinations.
- vii. Prepare a slide show of working animation of cam and follower using open source software.
- viii. Collect specified contours Cams (Tangent Cams and Convex flanks Cams) from scrap market.
- ix. Market survey of belts for collecting specifications.
- x. Market survey of gears for collecting specifications.
- xi. Select V-belt for a given application through manufacturer catalog and justify.
- xii. Collect five samples of different types of used belts and fix them on a single board with labels. (group work with group size of five students each).
- xiii. Calculate the length of belt and open and cross belt drive
- xiv. Collect different types of gears from scrap market and fix them on a single board with labels. (group work with group size of five students each).
- xv. Explain the complete procedure of selection of a V-belt for a particular application using manufacturers catalog.
- xvi. Collect five photographs of different Epicyclic gear trains used in different devices.
- xvii. Field survey to collect information about different types of flywheels and governors also their applications.
- xviii. Identify and measure the dimensions of Flywheel used in various automobiles.
- xix. Calculate the size/mass of flywheel fitted to a shearing or punching machine and justify.
- xx. Collect photographs of various governors and flywheels fitted to different engine.
- xxi. Prepare a list in which you write the name of different types of clutch and brake used in automobile and bicycle.

c. Other Activities:**1. Seminar Topics:**

- Advancement in braking system used in automobile and bicycle
- Application of CAM in IC engine
- Necessity of balancing of rotating mass rotating in same plane
- Use of flywheel and governor in automobile

2. Visits:

- Visit nearby automobile workshop/industry/shop having clutch, cam and follower, Brakes, gears and governor facilities. Prepare report of visit with special comments on different brakes, clutch, governor, gear and cam arrangements used in automobiles.

- Visit nearby automobile workshop and perform balancing of a car wheel with the help of a 'Vehicle Alignment and Balancing Shop' and justify the position and magnitude of Balancing mass used through analytical method.

3. Self-Learning Topics:

- Slider Crank Mechanism and its applications.
- Cams and followers used in IC engines.
- Use of flywheel and governor IC Engine and other machines.
- Function and Comparison between brakes and dynamometers
- Comparison between Belt, Chain, Rope and Gear drives

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work& Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	20%	25%	20%	20%	20%	25%	20%
CO-2	25%	20%	20%	20%	20%	15%	20%
CO-3	25%	20%	20%	20%	20%	15%	20%
CO-4	15%	20%	20%	20%	20%	25%	20%
CO-5	15%	15%	20%	20%	20%	20%	20%
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentages given are approximate.
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction to Planar Mechanisms and Cams-Followers	10	CO1,CO2	16	5	4	7
Unit-2.0 Power Transmission Elements	10	CO3	14	4	2	8
Unit-3.0 Flywheel and Governors	10	CO4	14	4	4	6
Unit-4.0 Brakes and Clutches	10	CO5	14	4	4	6
Unit-5.0 Balancing of Rotating Masses	08	CO5	12	3	3	6
Total	48	-	70	20	17	33

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Draw line diagrams with dimensions of the working models of all the inversions of following mechanisms available in the lab. - Slider Crank Mechanism - Double Slider Crank Mechanism - Four bar Mechanism	CO1	40	50	10
2.	Dismantle and assemble wiper mechanism of any four-wheeler.	CO1	40	50	10
3.	Draw the profile of radial CAM with offset for given follower (Knife edge and Roller follower) to obtained desired follower motion. (Minimum two problem on A2 size sheet)	CO1	40	50	10
4.	Draw the profile of radial CAM without offset for given follower to obtained desired follower motion. (Minimum two problem on A2 size sheet)	CO1	40	50	10
5.	Measure main dimension of a Tangent flank cam and estimate lift, velocity and acceleration at critical points.	CO1	40	50	10
6.	Measure slack side and tight side tension in Chain of sprocket of a Bicycle.	CO2	40	50	10
7.	Study of various types of gears and gear train	CO2	40	50	10
8.	Find out velocity and gear ratio in - Lathe machine gear box. - cane crushing machine. - two wheelers - Drilling Machine	CO2	40	50	10

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
9.	Calculate and prepare turning moment diagram from given experimental data.	CO3	40	50	10
10.	Measure the height, radius and mass of rotating ball for watt governor for different rotational speed	CO3	40	50	10
11.	Measure the height, radius and mass of rotating ball for porter governor for different rotational speed	CO3	40	50	10
12.	Calculate the braking torque required for different brakes in different load situations	CO4	40	50	10
13.	Use rope brake dynamometer to calculate power in an IC Engine.	CO4	40	50	10
14.	Dismantle and Assemble following • single plate clutch • multi plate clutch • centrifugal clutch	CO4	40	50	10
15.	Dismantle and Assemble a internal expanding brake and Disc Brake.	CO4	40	50	10
16.	Estimate torque transmitting capacity of single and multi plate clutch with the help of working model.	CO4	40	50	10
17.	Perform balancing of many unbalanced rotating masses in single plane using rotating balancing machine.	CO5	40	50	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

- O) Suggested Instructional/Implementation Strategies:** Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
1.	bicycle free wheel sprocket mechanism, Geneva mechanism, Ackerman's steering gear mechanism and foot operated air pump mechanism, slider crank mechanism, hooks joint, inversions of four bar mechanisms- locomotive coupler, Beam engine, Pantograph, Pendulum pump, Rotary I.C. engine mechanism, Oscillating cylinder engine, Whitworth quick return Mechanism, Quick return mechanism of shaper, Scotch Yoke mechanism, Elliptical trammel and Oldham's Coupling.	Working Models / wooden/thermocool Acrylic models/ metallic models	1, 2
2.	Different Types of cams, followers and cam/follower arrangements	Working Models / wooden/thermocool Acrylic models/ metallic models	3, 4, 5
3.	Various belt drives, chain and sprocket, various gear drives.	Actual items	6
4.	Different belts in different arrangements	Working models	6
5.	Working models of Gear trains - all types. (Simple, compound, reverted, epicyclic).	Working Models/ wooden/thermocool Acrylic models/metallic models	7, 8
6.	Any machine having flywheel (Single cylinder 4-Stroke I.C engine with flywheel)	IC Engine Lab	9
7.	Governors - all types	Working Models / wooden/thermocool Acrylic models/metallic models	10
8.	Various types of brake assemblies	Working and cut section models	11, 12, 15
9.	Dynamometers - all types	Rope Brake, Eddy current, Electrical	13
10.	Various types of clutch assemblies.	Working and cut section models	14, 16
11.	Vehicle Tyre balancing machine	Rim Diameter 10"-24" or 265 - 615 mm Rim Width 1.5" - 20" or 40 - 510 mm Distance between wheel and machine 0 - 25 cm. Balancing Accuracy 1 gm. Power Supply 220 - 240 V, 50 - 60 Hz Single Phase Motor 0.33 kW Maximum Power Consumption 0.6 kW. RPM 60 Wheels weighing upto 75 kg Dimensions with Wheel Guard WxLxH1350 (Hood open) x1220x1670 Net Weight with Wheel Guard 160 kg (Excluding Adaptors)	17
12.	Static and Dynamic Balancing Apparatus	Weighing Capacity 10-50kg, Power Source Electric Voltage 240 V Frequency 50 Hz	17

R) Suggested Learning Resources:**(a) Books:**

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Theory of Machines	S S Ratan	Tata Mcgraw Hills;5th edition, 2019 ISBN-978-9353166281
2.	Theory of Machines	R. S. Khurmi J. K. Gupta	S. CHAND; 14th edition,2020 ISBN-978-8121925242
3.	Theory of machines	R.K.Bansal	Laxmi publications; Revised,2016 ISBN-978-8131808054
4.	Theory of machines	Jagdishlal	Metropolitan Book Co. (p) Ltd. ISBN-978-8120002722
5.	Dynamics of Machines	J. B. K. Das	Sapna Book House, 2008 ISBN-978-8128009112

(b) Online Educational Resources:

1. https://onlinecourses.nptel.ac.in/noc22_me75/preview
2. <https://www.youtube.com/watch?v=qmcridUdYBW0>
3. <https://nptel.ac.in/courses/112106270>
4. <https://nptel.ac.in/courses/112104121>
5. https://onlinecourses.nptel.ac.in/noc20_me21/preview
6. <https://www.youtube.com/watch?v=p075LPq3Eas&list=PL46AAEDA6ABAFA78>
7. user.engineering.uiowa.edu/~mie032/support/eg/eg07_section_views.pdf
web.aeromech.usyd.edu.au/.../Engineering%20Drawings%20Lecture%20Sectioning
8. <http://nptel.iitm.ac.in/video.php?subjectId=112104121>
9. <http://www.technologystudent.com/gears1/gears7.htm>
10. <http://kmoddl.library.cornell.edu/model.php?m=20>
11. <http://www3.ul.ie/~kirwanp/whatisacamandfollowersyste.htm>
12. <http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT-Delhi/Kinematics%20of%20Machine/index.htm>
13. http://elearning.vtu.ac.in/12/enotes/Des_Mac-Ele2/Unit6-RK.pdf

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others:

1. Lab Manuals
2. Users' Guide
3. Manufacturers' Manual
4. Manufacturers' Catalog
5. Learning Packages

- A) **Course Code** : 2425405 (T2425405/P2425405/S2425405)
- B) **Course Title** : Advanced Manufacturing Engineering and Cost Estimation
- C) **Pre-requisite Course(s)** : Manufacturing Engineering and Cost Estimation
- D) **Rationale** :

With the advent of newer machining materials and technologies in manufacturing sector it is becoming easy to achieve hard to machine materials with complex shapes and good surface-finishing. Newer difficult to machine materials and complex shapes with high surface finish is the demand of the manufacturing sector and conventional manufacturing processes alone cannot cater this need. To fulfill such needs of industries, students must have the knowledge of advanced manufacturing methods, powder metallurgy, CNC, SPM and super-finishing operations. The knowledge gained through this course will help the students to manufacture product using these advanced manufacturing processes.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/laboratory/workshop/field/ industry.

After completion of the course, the students will be able to-

- CO-1** Select suitable advanced casting, welding, forming manufacturing process(s) to produce various components.
- CO-2** Prepare product using non-traditional machining processes.
- CO-3** Prepare product using Plastic manufacturing and Powder metallurgy processes.
- CO-4** Produce jobs using CNC and Special Purpose Machines.
- CO-5** Choose super finishing operation for various situations.
- CO-6** Perform estimation and costing related calculations for components produced from mentioned manufacturing processes.

- F) **Suggested Course Articulation Matrix (CAM):**

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2
CO-1	3	2	-	2	-	1	1		
CO-2	3	2	-	2	-	1	1		
CO-3	3	2	-	2	-	1	1		
CO-4	3	2	-	2	-	1	1		
CO-5	3	2	-	2	-	1	1		
CO-6	3	2	-	-	-	3	1		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2425405	Advanced Manufacturing Engineering and Cost Estimation	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work& Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2425405	Advanced Manufacturing Engineering and Cost Estimation	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2425405

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 1a.</i> Justify need of non-conventional/modern/advanced manufacturing processes. <i>TSO 1b.</i> Explain the given modern Casting method. <i>TSO 1c.</i> List area of applications of the given modern Casting method. <i>TSO 1d.</i> Explain the given modern Welding method. <i>TSO 1e.</i> List area of applications of the given modern Welding method. <i>TSO 1f.</i> Explain the given modern Forming method. <i>TSO 1g.</i> List area of applications of the given modern Forming method.	Unit-1.0 Advanced Casting, Welding, and Forming Manufacturing Processes 1.1 Need of advance manufacturing, manufacturing trends and challenges, manufacturing aspects. 1.2 Modern Casting Methods-Principle and application of shell moulding, precision investment casting, permanent mould casting, diecasting, vacuum casting, centrifugal casting, continuous casting. 1.3 Modern Welding methods-Principle and application of electron beam welding, Orbital TIG welding, Electro slag welding, Laser beam welding, Underwater welding, Forge welding, friction welding, thermoforming. 1.4 Advanced Metal forming-Principle and application of High energy rate forming, Electromagnetic forming, Explosive forming, Electrohydraulic forming, Stretch forming, Contour roll forming.	CO1
<i>TSO 2a.</i> Explain the given casting process. <i>TSO 2b.</i> Explain working of the given non-traditional/advanced machining processes using schematic diagram/setup. <i>TSO 2c.</i> List process parameters of the given non-traditional/advanced machining processes. <i>TSO 2d.</i> List the areas of application of the given non-traditional/advanced machining processes. <i>TSO 2e.</i> Suggest appropriate non-traditional/advanced machining process for a given application with justification. <i>TSO 2f.</i> Perform estimation and costing related calculations for the given product to be produced using any non-traditional machining operation.	Unit-2.0 Non-Traditional Machining Processes 2.1 Types of non conventional machining processes and energy source utilized. 2.2 Water jet machining: process principle, equipment, process parameter, application. 2.3 Ultrasonic machining: process principles, equipment, process parameter, application. 2.4 Electrochemical machining: process principle, equipment, process parameter application. 2.5 Chemical machining: process principle, equipment, process parameter, application. 2.6 Electrical discharge machining: process principles, equipment, process parameter, application. 2.7 Electron beam machining: process principle, equipment, process parameter, application. 2.8 Laser beam machining: process principle, equipment, process parameter, application. 2.9 Estimation and costing of non-traditional machining components.	CO2, CO6
<i>TSO 3a.</i> Explain the given Plastic processing method. <i>TSO 3b.</i> List the areas of the given plastic processing method. <i>TSO 3c.</i> List the advantages and disadvantages of Powder metallurgy. <i>TSO 3d.</i> List the areas of application of Powder metallurgy.	Unit-3.0 Plastic Processing, Powder Metallurgy and Superfinishing processes 3.1 Plastic processing: introduction, plastic materials, extrusion of plastics, Principle and application of injection moulding, blow	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 3e.</i> List the various superfinishing operation. <i>TSO 3f.</i> Explain the given superfinishing operation. <i>TSO 3g.</i> List the areas of application of the given superfinishing operation. <i>TSO 3h.</i> Explain the given grinding machine. <i>TSO 3i.</i> Explain the given grinding wheel designation. <i>TSO 3j.</i> Select suitable grinding wheel as per the given requirement.	moulding, compression moulding, transfer moulding and calendaring. 3.2 Powder Metallurgy: Introduction, application, advantages and disadvantages, Powder metallurgy process: Powder making, blending, compacting, sintering, infiltration and impregnation. 3.3 Super finishing process: introduction, principles. 3.4 Grinder and types of grinding wheel, Types of abrasive materials and their properties, Bonding materials, Grinding wheel classification, condition for selection of grinding wheels, balancing of grinding wheels, glazing, loading dressing and Truing. Designation of grinding wheel 3.5 Principles of working of grinding machines and functions of main parts, types of grinding processes, function of tool and work holding devices, Table drive in surface and cylindrical grinders, Types of lubricants and coolants used in Grinding. 3.6 Finishing Processes, definition of micro finishing, honing, lapping, super finishing, polishing and buffing operations, equipment involved, materials used, Tolerances obtained, limitations and applications.	
<i>TSO 4a.</i> Explain working and use of the given CNC machine element/component. <i>TSO 4b.</i> Apply the given CNC coordinate and positioning values. <i>TSO 4c.</i> Use correct CNC tooling for the given operation. <i>TSO 4d.</i> Develop simple part program for the given turning operation (straight turning and taper turning) <i>TSO 4e.</i> Develop simple part program for the given milling operation. <i>TSO 4f.</i> Develop simple part program for the given milling operation using various compensations. <i>TSO 4g.</i> Develop simple CNC turning/milling part program using canned cycles, Do loops and Subroutine. <i>TSO 4h.</i> Explain Computer assisted part programing. <i>TSO 4i.</i> Perform estimation and costing related calculations for the given product to be produced using CNC machine.	Unit-4.0 CNC Machining 4.1 CAM - concept and definition. 4.2 NC (Numerical Control), CNC (Computerized Numerical Control) and DNC (Direct Numerical Control) - concept, features and differences. 4.3 Elements of CNC machines - Types, working and importance of: Slide ways; Re-circulating ball screw; Feedback devices (transducers, encoders); Automatic tool changer (ATC); Automatic pallet changer (APC); 4.4 CNC axes and motion nomenclature. 4.5 CNC coordinate and positioning systems. 4.6 CNC tooling: Tool presetting-concept and importance; Qualified tools-definition need and advantages; Tool holders- types and applications. 4.7 CNC part programming: programming format and structure of part programme. 4.8 ISO G and M codes for turning and milling-meaning and applications of important codes. 4.9 Simple part programming for turning using ISO format having straight turning and taper turning (linear interpolation). 4.10 Simple part programming for milling using ISO format having linear and circular interpolations. 4.11 Importance, types, applications and format for: Canned cycles; Macro; Do loops; Subroutine; 4.12 CNC turning and milling part programming using canned cycles, Do loops and Subroutine. 4.13 Need and importance of various compensations: Tool length compensation;	CO4, CO6

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	Pitch error compensation; Tool radius compensation; Tool offset. 4.14 Simple part programming using various compensations 4.15 Computer assisted part programming. 4.16 Estimation and costing of parts produced by CNC machining.	
<i>TSO 5a.</i> Explain the given special purpose machine. <i>TSO 5b.</i> List the areas of application of SPM. <i>TSO 5c.</i> Explain the working principle of the given 3D Printing process (FDM, SLS, SLS). <i>TSO 5d.</i> List the materials for the given 3D Printing process (FDM, SLS, SLS). <i>TSO 5e.</i> Explain CIM <i>TSO 5f.</i> Explain Group Technology and use of part families. <i>TSO 5g.</i> Explain FMS and its components. <i>TSO 5h.</i> List benefits of FMS and Group Technology. <i>TSO 5i.</i> Explain the given type of Automation. <i>TSO 5j.</i> Explain the given component(s) of a typical robot. <i>TSO 5k.</i> List areas of application of Automation and Robots.	Unit-5.0 Special Purpose Machines (SPM) and Recent trends in CAM Special Purpose machines: 5.1 Concept of general-purpose machines. 5.2 Elements of SPM. 5.3 Special purpose lathe machine and milling machines. 5.4 Productivity improvement by SPM. Recent trends in CAM: 5.5 Additive manufacturing: 3D printing, Principle and types, introduction about FDM, SLA, SLS 3D Printing processes and Materials. 5.6 Computer Integrated Manufacturing (CIM): concept, definition, areas covered, benefits. 5.7 Group Technology: concept, basis for developing part families, part classification and coding, concept of cellular manufacturing. Advantages and limitations. 5.8 Flexible Manufacturing System (FMS): concept, evaluation, main elements and their functions, layout and its importance, applications. 5.9 Automation: definition, need of automation, high and low-cost automation, examples of automations. Types of Automation - Fixed (Hard) automation, programmable automations and Flexible automations (Soft). 5.10 Robot: definition, terminology, classification and types, components of Robot: manipulator, end effectors, actuators, sensors, controller, processor, software and applications.	CO5

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425405

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 1.1.</i> Interpret the drawing of the component. <i>LSO 1.2.</i> Identify type of pattern. <i>LSO 1.3.</i> Prepare the mould. <i>LSO 1.4.</i> Use furnace to melt the metal at pouring temperature. <i>LSO 1.5.</i> Pour the molten metal with safety and in minimum time inside the mould cavity. <i>LSO 1.6.</i> Monitoring solidification of casting and remove the casted part from the mould without damaging the part. <i>LSO 1.7.</i> Cleaning the casted part.	1.	Prepare a casting product using shell molding process.	CO1
<i>LSO 2.1.</i> Interpret the drawing of the component. <i>LSO 2.2.</i> Set the Electromagnetic forming machine at the required parameter values. <i>LSO 2.3.</i> Operate Electromagnetic forming machine. <i>LSO 2.4.</i> Recover the formed part.	2.	Prepare a simple job using Electromagnetic forming/ Observe the same in an industry.	CO1
<i>LSO 3.1.</i> Interpret the drawing of the component. <i>LSO 3.2.</i> Set the Electron beam welding machine at the required parameter values. <i>LSO 3.3.</i> Operate Electron beam welding machine.	3.	Prepare a job of a given design using Electron beam welding/Observe the same in an industry.	CO1
<i>LSO 4.1.</i> Interpret the drawing of the component. <i>LSO 4.2.</i> Set the Laser beam welding machine at the required parameter values. <i>LSO 4.3.</i> Operate Laser beam welding machine.	4.	Prepare a job of a given design using Laser beam welding/Observe the same in an industry.	CO1
<i>LSO 5.1.</i> Interpret the drawing of the component. <i>LSO 5.2.</i> Set the Ultrasonic beam welding machine at the required parameter values. <i>LSO 5.3.</i> Operate Ultrasonic beam welding machine.	5.	Prepare a job of a given design using Ultrasonic welding/Observe the same in an industry.	CO2
<i>LSO 6.1.</i> Interpret the drawing of the component. <i>LSO 6.2.</i> Set the Electro Discharge machine at the required parameter values. <i>LSO 6.3.</i> Operate Electro Discharge machine.	6.	Prepare a job using Electro Discharge Machining die sinking type/Observe the same in an industry.	CO2
<i>LSO 7.1.</i> Interpret the drawing of the component. <i>LSO 7.2.</i> Set the Electro Discharge machine at the required parameter values. <i>LSO 7.3.</i> Operate Electro Discharge machine.	7.	Prepare a job using Electro Discharge Machining wire cut type /Observe the same in an industry.	CO2
<i>LSO 8.1.</i> Interpret the drawing of the component. <i>LSO 8.2.</i> Set the Electro Chemical machine at the required parameter values. <i>LSO 8.3.</i> Operate Electro Chemical machine.	8.	Prepare a job using Electro Chemical Machining/Observe the same in an industry.	CO2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 9.1.</i> Interpret the drawing of the component. <i>LSO 9.2.</i> Set the Injection moulding machine at the required parameter values. <i>LSO 9.3.</i> Operate Injection moulding machine.	9.	Prepare a job using Injection moulding/Observe the same in an industry.	CO3
<i>LSO 10.1.</i> Interpret the drawing of the component. <i>LSO 10.2.</i> Set the Blow moulding machine at the required parameter values. <i>LSO 10.3.</i> Operate Blow moulding machine.	10.	Prepare a job using Blow moulding/Observe the same in an industry.	CO3
<i>LSO 11.1.</i> Interpret the drawing for surface finish symbols on the desired surface of the component. <i>LSO 11.2.</i> Set the Grinding machine at the required internal/external grinding parameter values. <i>LSO 11.3.</i> Select appropriate Grinding wheel. <i>LSO 11.4.</i> Decode the grinding wheel specification <i>LSO 11.5.</i> Operate Grinding machine in external and internal grinding mode.	11.	Perform an external and internal grinding on the given job.	CO3
<i>LSO 12.1.</i> Interpret the drawing for surface finish symbols on the desired surface of the component. <i>LSO 12.2.</i> Set the Grinding machine at the required parameter values. <i>LSO 12.3.</i> Select appropriate Grinding wheel. <i>LSO 12.4.</i> Decode the grinding wheel specification. <i>LSO 12.5.</i> Operate Grinding machine.	12.	Prepare at least 2 jobs using surface grinder/ cylindrical grinder.	CO3
<i>LSO 13.1.</i> Interpret the drawing for surface finish symbols on the desired surface of the component. <i>LSO 13.2.</i> Set the Superfrininshing machine at the required parameter values. <i>LSO 13.3.</i> Select appropriate polishing wheel. <i>LSO 13.4.</i> Operate Superfrininshing machine.	13.	Perform Super-finishing on job produced by casting, forming & welding process and estimate the cost.	CO3
<i>LSO 14.1.</i> Identify different parts of a CNC Lathe machine. <i>LSO 14.2.</i> Start the CNC lathe machine. <i>LSO 14.3.</i> Set the machining parameters. <i>LSO 14.4.</i> Operate CNC lathe machine. <i>LSO 14.5.</i> Observe the effect of different machining parameters.	14.	Operate CNC turning machine and try to change different parameters and controls to see their effect during machining.	CO4
<i>LSO 15.1.</i> Identify different codes as per ISO. <i>LSO 15.2.</i> Interpret the drawing of given object. <i>LSO 15.3.</i> Prepare the part program as per the drawing. <i>LSO 15.4.</i> Load and unload the workpiece and tools. <i>LSO 15.5.</i> Debug the program. <i>LSO 15.6.</i> Set the machining parameters. <i>LSO 15.7.</i> Produce the component using Straight turning on the given CNC Lathe machine.	15.	Prepare CNC part programme using G and M codes with ISO format for plain/straight turning of part and produce the part.	CO4

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 16.1.</i> Identify different codes as per ISO. <i>LSO 16.2.</i> Interpret the drawing of given object. <i>LSO 16.3.</i> Prepare the part program as per the drawing. <i>LSO 16.4.</i> Load and unload the workpiece and tools. <i>LSO 16.5.</i> Debug the program. <i>LSO 16.6.</i> Set the machining parameters. <i>LSO 16.7.</i> Produce the component using Taper turning on the given CNC Lathe machine.	16.	Prepare CNC part programme using G and M codes with ISO format for taper turning and produce the part.	CO4
<i>LSO 17.1.</i> Identify different parts of a CNC Milling machine. <i>LSO 17.2.</i> Start the CNC Milling machine. <i>LSO 17.3.</i> Set the machining parameters. <i>LSO 17.4.</i> Operate CNC Milling machine. <i>LSO 17.5.</i> Observe the effect of different machining parameters.	17.	Operate CNC milling machine and try to change different parameters and controls to see their effect during machining.	CO4
<i>LSO 18.1.</i> Identify different codes as per ISO. <i>LSO 18.2.</i> Interpret the drawing of given object. <i>LSO 18.3.</i> Prepare the part program as per the drawing. <i>LSO 18.4.</i> Load and unload the workpiece and cutter/tools. <i>LSO 18.5.</i> Debug the program. <i>LSO 18.6.</i> Set the machining parameters. <i>LSO 18.7.</i> Produce the component on the given CNC Milling machine.	18.	Prepare CNC part programme using G and M codes with ISO format for Simple contour milling of part and produce the part.	CO4
<i>LSO 19.1.</i> Prepare/download solid/part model using CAD software. <i>LSO 19.2.</i> Perform slicing using 3D printing software. <i>LSO 19.3.</i> Set the 3D Printing parameters. <i>LSO 19.4.</i> Load material. <i>LSO 19.5.</i> Produce the component on the given 3D Printing parameters.	19.	Print a simple component using available 3D printer.	CO5

L) Suggested Term Work and Self Learning: S2425405 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Explain the recent trends in non-conventional/modern/advanced manufacturing processes.
- Compare the conventional manufacturing with advanced manufacturing process.
- Describe advantages, limitations and applications of the given advanced casting/welding/forming/machining method.
- Explain working and setup of the given advanced casting/welding/forming/machining process with schematic diagram.
- Compare the Hybrid EPC and Vacuum EPC.
- List the recent trends in advanced welding and forming processes.
- Compare the stretch forming and Contour roll forming.
- Identify various CAD/CAM software and hardware.
- Compare commercially available graphics packages used for modeling of mechanical components.

- x. Differentiate between NC, CNC and DNC.
- xi. Prepare a list of CNC milling machine accessories.
- xii. Explain the working and constructional details of Head Stock, Tail stock Quill and CNC control panel of a typical CNC Turning/Milling machine.
- xiii. Describe functions of Display unit and Servo Control unit of the given CNC Turning/Milling machine.
- xiv. Explain the merits of popular Additive manufacturing processes.
- xv. Explain CNC axes and nomenclature of the given CNC Turning/Milling machine.
- xvi. Explain the meaning and utility of 4th axis in a CNC milling machine.
- xvii. Prepare part program using applicable codes like G and M etc. for any turning/milling component according to Fanuc/Seimens/Fagor/ (any one) controller.
- xviii. Explain the construction and working of the given 3D printer.
- xix. Explain the procedure to print the given component(s) using 3D printer/Rapid prototyping machine.
- xx. Justify the use of FMS in the given situation.
- xxi. List various industrial applications of robots.

b. Micro Projects:

- i. Prepare a list of industrial components which are produced through advanced casting/forming/welding/machining processes and describe the manufacturing procedure of the same in brief.
- ii. Prepare a technical report on specifications, operating procedure, selection of operational parameters, machine setting, product details being manufactured using advanced casting/forming/welding/machining processes.
- iii. Develop/download Flash/Animations to explain various concepts of advanced casting/forming/welding/machining processes.
- iv. Watch various videos on you tube or any particular website related to advance casting/forming/welding/machining processes used to produce a component.
- v. Prepare list of industrial robots and their usage.
- vi. 3D printing/RPT: Each student will visit a nearby institute/industry. Collect information regarding working, construction, specification of 3D printer/Rapid prototyping machine and prepare a report.
- vii. Collect information about the different materials available for 3D printing their cost and mechanical properties.
- viii. Prepare power point presentation (including animation) for Flexible Manufacturing Systems/Cellular Manufacturing/ Group Technology.
- ix. Collect quotation from different vendors and prepare final specification for a CAD workstation. (group work with group size of five students each)
- x. Collect photographs of all the cutting tools generally used in today's industries with CBN, PCBN, TC inserts (group work with group size of five students each)
- xi. Prepare list of controllers that are generally being used in CNC machines.
- xii. Collect/download at least four different CNC turning tooling manufacturer's catalogues and prepare a chart for type of tool inserts and optimized machining parameters required to turn components of Mild steel, Stainless steel, Aluminium, Brass.
- xiii. Prepare a list of industrial components which are produced through CNC turning.
- xiv. Collect videos of manufacturing of different components which involve CNC turning operation. Watch them and practice them.
- xv. Collect/download at least four different CNC turning machine manufacturer's catalogues and at least one catalogue each of cutting tool, work holding device and tool holder related to CNC

tuning machine.

- xvi. Collect/download at least four different CNC turning tooling manufacturer's catalogues and prepare a chart for type of tool inserts and optimized machining parameters required to turn components of Mild steel, Stainless steel, Aluminium, Brass.
- xvii. Prepare a list of industrial components which are produced through CNC turning.
- xviii. Collect videos of manufacturing of different components which involve CNC turning operation. Watch them and practice them.
- xix. Collect/download at least four different CNC turning machine manufacturer's catalogues and at least one catalogue each of cutting tool, work holding device and tool holder related to CNC tuning machine.
- xx. Collect the samples of grinding wheel of different grades.
- xxi. Make a comparative study of finishing processes e.g. honing, lapping, super and super finishing operations based on tolerances obtained, limitations and applications.
- xxii. Collect/download at least four different machine tool manufacturer's catalogues and at least one catalogue grinding wheels related to Grinding machine.
- xxiii. Prepare list of 10 industrial/domestic items/components on which superfinishing operations are required.

c. Other Activities:

1. Seminar Topics:

- Additive and Subtractive manufacturing processes
- Blow molding
- Plastic injection machines
- Investment Casting
- Shell Casting
- Various extrusion machines.
- Various forging machines.
- Different deep drawing punches and dies.
- Welding of Stainless Steel
- Procedure to measure cutting forces in CNC Lathe and Milling operations using dynamometers.

2. Visits:

- Visit a nearby industry/workshop to identify and list the various types of manufacturing processes used.
- Visit institute/industry having Advanced Casting/Forming/Welding machines.
- Visit institute/industry having any of the EDM/ECM/Water Jetting/Ultrasonic/Laser beam machine.
- Visit institute/industry having CNC/Superfinishing machines.

3. Self-Learning Topics:

- Various Mechanical engineering materials.
- Slush Casting
- Deep Drawing,
- Stretch Forming
- Resistance welding
- Spinning on Lathe
- Honning Process
- Automatic Tool Changer in CNC machines
- Internal Turning
- Classification of Robots.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work& Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	20%	20%	20%	20%	20%	20%	20%
CO-2	15%	15%	15%	20%	20%	25%	20%
CO-3	15%	15%	15%	20%	20%	25%	20%
CO-4	15%	15%	15%	20%	20%	20%	20%
CO-5	15%	15%	15%	20%	20%	10%	20%
CO-6	20%	20%	20%	-	-	-	-
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**.: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentages given are approximate.
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Advanced Casting, Welding, and Forming Manufacturing Processes	10	CO1	12	3	3	6
Unit-2.0 Non-Traditional Machining Processes	10	CO2, CO6	17	5	4	8
Unit-3.0 Plastic Processing, Powder Metallurgy and Superfinishing processes	10	CO3	12	3	3	6
Unit-4.0 CNC Machining	10	CO4, CO6	17	5	4	8
Unit-5.0 Special Purpose Machines (SPM) and Recent trends in CAM	08	CO5	12	3	3	6
Total	48	-	70	20	17	34

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Prepare a casting product using shell molding process.	CO1	40	50	10
2.	Prepare a simple job using Electromagnetic forming/ Observe the same in an industry.	CO1	40	50	10
3.	Prepare a job of a given design using Electron beam welding/Observe the same in an industry.	CO1	40	50	10
4.	Prepare a job of a given design using Laser beam welding/Observe the same in an industry.	CO1	40	50	10
5.	Prepare a job of a given design using Ultrasonic welding/Observe the same in an industry.	CO2	40	50	10
6.	Prepare a job using Electro Discharge Machining die sinking type/Observe the same in an industry.	CO2	40	50	10
7.	Prepare a job using Electro Discharge Machining wire cut type /Observe the same in an industry.	CO2	40	50	10
8.	Prepare a job using Electro Chemical Machining/Observe the same in an industry.	CO2	40	50	10
9.	Prepare a job using Injection moulding/Observe the same in an industry.	CO3	40	50	10
10.	Prepare a job using Blow moulding/Observe the same in an industry.	CO3	40	50	10
11.	Perform an external and internal grinding on the given job.	CO3	40	50	10
12.	Prepare at least 2 jobs using surface grinder/cylindrical grinder.	CO3	40	50	10
13.	Perform Super-finishing on job produced by casting, forming & welding process and estimate the cost.	CO3	40	50	10
14.	Operate CNC turning machine and try to change different parameters and controls to see their effect during machining.	CO4	40	50	10
15.	Prepare CNC part programme using G and M codes with ISO format for plain/straight turning of part and produce the part.	CO4	40	50	10
16.	Prepare CNC part programme using G and M codes with ISO format for taper turning and produce the part.	CO4	40	50	10
17.	Operate CNC milling machine and try to change different parameters and controls to see their effect during machining.	CO4	40	50	10
18.	Prepare CNC part programme using G and M codes with ISO format for Simple contour milling of part and produce the part.	CO4	40	50	10
19.	Print a simple component using available 3D printer.	CO5	40	50	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
1.	Advanced Casting equipment's and tools	Standard pattern materials Commonly used moulding sand Size varies from 200mm to 600mm square by 75mm to 1000mm deep, screw motor drive, reciprocating crew and barrel, heaters, thermocouple, ring plunger, mold, tie bar, shovel, trowel, mallet, bellows, clamps, sand rammer, bellow lifter, vent wiredraw spike	1
2.	Forging equipment's and tools	Anvil (WEIGHT-167 lbs, horn-73/4", face length-10", rear-71/2"), hammer (double face sledge hammer 10 kg), scaling hammer, chipping hammer, tongs (500g, flat nose size 15 inch) open hearth, air blower (60 hp capacity 40000 m3/hr.), swage block (14X14X5 inch material iron)	1
3.	Shell Core Shooter Moulding Machine	Core Box Thickness. 150 mm, Sand Hopper Capacity. 120 kg, Model Number. SCSHE: - 2424, Blow Area. 315 x 315 mm, Pneumatic Pressure. 7 to 8 Kg/cm2, Electrical Load. 28 KW, Core Box Weight. 300 kg, Core Weight. 12 kg.	1
4.	Electro Magnetic Forming Equipment	Energy -70kJ, 25Kv, Peak Short Circuit Current-400kA (maximum permissible) Capacitor Charging-Charging Time: 45 seconds Repetition Rate-Minimum one Discharge in every five minutes Power Supply-Input: 415V, 3 phase, 15 Amp, 50 Hz Output - 0 to 25kVDC, 200 mA	2
5.	ELECTRON BEAM MACHINE	Electron gun & Power Supply 80 V, 12 kW EB gun, Long filament life under welding conditions (~ 20 hours),Medium frequency type HVDC power supply, CCTV for job alignment	3
6.	LASER BEAM MACHINE	Laser type-Ndyv.4, wavelength -1064nm, operation mode-Q switch, average power-30 w, pulse frequency- 1/100 khz, focus diameter-40 nm	4
7.	ULTRASONIC MACHINE	Weight. 70 Kg, Model Name/Number. USM 100, Type of Application. Production, Dimension. 780 x 620 x 550 mm, Drive. 1,2/1,8 kW (3~VAC), Tool Revolution. 392/592 rpm, Internal Skiving. 3/4" - 2 1/2", External Skiving. 1/4" - 2"	5
8.	EDM	Machine Tool: 500 x 300, Work tank size: 725 x 415 x 315 mm, Work table size: 500 x 300 mm, T slots for fixing: 3 of 10 mm, Longitudinal travel (X): 280 mm, Transverse travel (Y): 200 mm, Quill travel (Z): 250 mm, Max. permitted load on the table: 175 Kg, Max. electrode weigh: 50 Kg, Max. height above the table: 250 mm, Servo system (z axis): DC servo, Dielectric capacity: 250 Liters, Filter element: 10 urn paper filter, Pump motor rating: 1 HP, 3 phase, Overall dimensions: 1420 x 1140 x 2100 mm	6,7
9.	ECM	TRAVEL distance X-350, Y-350, Z-100, Maximum movement speed-400mm/m, motor type -stepper, motion transmission -16/5 ball screw, table -22.5mm t channel aluminium	8
10.	Injection moulding machine	Clamping Force: 0-100 ton, Automation Grade: Manual, Raw Material: HDPE, PP, PVC Machine Structure: Vertical	9
11.	Blow moulding	Automation Grade: Automatic., Production Capacity (Bottles Per Hour): 120kg/hr., Raw Material: HDPE., Mould Cavity: 1 cavity. Material: Mild Steel., Voltage: 260V., Driven Type: Electric., Power: 3HP.	10

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
12.	Grinding machine	Power Pack Motor-2 HP/ 3 HP/ 5 HP Main Head Motor-2 HP/ 3 HP/ 5 HP/ 7.5 HP Grinding Wheel Diameter-250/ 300 mm Grinding Length -450/ 600/ 800/ 1000/ 1500/ 2000 mm Grinding Width -150/ 200/ 250/ 300/ 400/ 500 mm	11,12
13.	Post processing equipment and tools	Honing machines sunnen mbb-1660 & tools, polishing tools-no. of grinders -2, control mode-double disk/single control, rotation speed-50-1000r/min, motor voltage-220v 50Hz.etc	13
14.	CNC	Technical Specification, Capacity, Length of table 700 min, Width of table 400 min, Max load on table 300 kg, X travel 700 mm min, Y travel 400 mm min, Z travel 300 mm min, Machine Spindle, Spindle Speed Min 8000 Rpm, Main Spindle Power 7Kw or more, Spindle taper ISO/BT/SK 40/50, ATC 15 min, Accuracy, Positional accuracy 0.01 mm in full length, Repeatability 0.005 or better, Coolant System, Tank capacity Min 100 Ltr, High pressure filtration system Min 20 Bar with filtration system, Axis drive and Control, Digital controlled drive and motors For all Axis, Guide way LM guide way, Rapid Speed Min 20m/min, Feed rate Min 6m/min	14,15,16,17,18
15.	3D printer	Product 3D printer Model-eDee, Trade name-YSoft be3D eDee, Printing technology-FFF (Fused Filament Fabrication), Printing area-150 × 150 × 150 mm, Nozzle diameter-0.4 mm (expected lifetime 1 500 h), Print bed type-Glass, removable, Calibration-Automatic Safety elements Door locks, print bed sensor, Total dimensions-496 × 414 × 397 mm, Weight 27.5 kg (shipping weight: 31 kg), Recommended operation conditions-15–30°C (59–86°F), max. 60% humidity, Supply voltage External source 24 V/3.75 A (90 W, input 230 V/110 V)	19
16.	CNC SOFTWARE	FUSION-30, modelling, assembling, CAM simulation, g-code editor, InkSpace, solid works, Aspire	14,15,16,17,18

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Manufacturing technology volume 1	P.N. Rao	McGraw Hill Education, 2017 ISBN: 978-1259062575
2.	Manufacturing technology volume 2	P.N. Rao	McGraw Hill Education, 2018 ISBN: 978-9353160524, 9789353160524
3.	A Textbook of manufacturing Technology-1	P.C. Sharma	S. Chand, 2011 ISBN: 9788211928212
4.	A Textbook of manufacturing Technology-2	P.C. Sharma	S. Chand, 2013 ISBN: 9788211928465
5.	CNC machines	B. S. Pabla & M. Adithan	New Age international limited, 2018 ISBN: 978-8122434262
6.	Non-traditional manufacturing processes	Gray F. benedict	CRC press, 2019 ISBN: 978-0367403393
7.	Modern machining process	P.C. pandey, H.S. Shan	McGraw Hill Education, 2017 ISBN: 978-0070965539
8.	Advanced manufacturing and processing technology	Chander Prakash, Sun Preet Singh, J Paulo Davin	CRC press, 2020 ISBN: 978-0367275129

(b) Online Educational Resources:

1. Advance Manufacturing- <https://nptel.ac.in/courses/112107078/>
2. Evaporative pattern casing process-
https://www.youtube.com/results?search_query=Evaporative+pattern+casing+process
3. Centrifugal and pressure die casting-
https://www.youtube.com/results?search_query=Centrifugal+and+pressure+die+casting
4. Hybrid EPC process - https://www.youtube.com/results?search_query=Hybrid+EPC+process
5. Electron beam welding-
https://www.youtube.com/results?search_query=Electron+beam+welding
6. laser beam welding- https://www.youtube.com/results?search_query=Laser+beam+welding+
7. metal forming- https://www.youtube.com/results?search_query=metal+forming
8. advance machining process-
https://www.youtube.com/results?search_query=advance+machining+process
Flexible Manufacturing System:
9. <https://www.autodesk.com/products/fusion-360/blog/computer-aided-manufacturing-beginners/>
10. <https://www.youtube.com/watch?v=JrmYZlrcuMs>
11. <https://www.youtube.com/watch?v=7L0VbqrNDAY>
12. https://www.youtube.com/watch?v=FdipJNG_vV8
13. https://czjyjc.en.made-in-china.com/?gclid=CjwKCAiAlajvBRB_EiwA4vAqiMrva9tozNpSAsfjQdD6-d4Ju3vZ2hFfamuwJsQX-zPLu2zpPF244hoCzYcQAvD_BwE
14. <https://www.youtube.com/watch?v=MwgobIVj4fU>
Robotics
15. <https://www.youtube.com/watch?v=Br2eEpiiwwU>
16. <https://www.youtube.com/watch?v=YGtg4OPSFhc>
17. <https://www.youtube.com/watch?v=nlrr5b1XWoY>
18. <https://www.youtube.com/watch?v=q-XHWifmAFA>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

(c) Others:

1. Lab Manuals
2. Users' Guide
3. Manufacturers' Manual
4. Learning Packages
