Curriculum of Diploma Programme

in

Renewable Energy

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(Cl)		Lab Instruction (LI)	Notional Hours (TW+SL)	Total Hours (Cl+LI+TW+SL)	Total Credits (C)
			L	T				
2425401	**PCC**	**Engineering Metrology and Instrumentation**	03	-	04	02	09	06
2425402	**PCC**	**Fluid Mechanics & HydraulicMachinery** (ME, ME (Auto), AE, FTS)	03	-	04	02	09	06
2425403	**PCC**	**Applied Thermodynamicsand HVAC**	03	-	04	02	09	06
2425404	**PCC**	**Theory of Machines** (ME, ME (Auto))	02	01	04	02	09	06
2470405	**PCC**	**Wind Energy System**	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. todeliver 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** (ME, ME (Auto), AE, FTS)	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
2470405	**PCC**	**Wind Energy System**	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 becarried 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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Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

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H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
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2425401	Engineering Metrology & Instrumentation	30	70	20	30	20	30	200

Legend:

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Note:

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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)
TSO 1a. Explain the importance of metrology as a means for achieving quality. *TSO 1b.* Explain the given terminology of Metrology. *TSO 1c.* Explain the given type of error in the measurement. *TSO 1d.* List the linear and angular direct/indirect measuring instrument(s). *TSO 1e.* Explain the procedure of using linear direct/indirect measuring instrument for the given measurement with justification. *TSO 1f.* Explain the procedure of using dial gauge for checking linear features of the given component with justification. *TSO 1g.* Explain the procedure of using slip gauges for measuring the given job. *TSO 1h.* Explain the procedure of using angular direct/indirect measuring instrument for the given situation with justification. *TSO 1i.* 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.	
TSO 2a. Explain the given limits, fits and tolerance. *TSO 2b.* Explain the given Geometric tolerance. *TSO 2c.* Explain the use of the given Plug and Ring gauge. *TSO 1j.* Explain the procedure of using device(s) to measure the given Geometric tolerance. *TSO 2d.* Select instrument(s) to measure the given Geometric tolerance (Straightness, Flatness, Squareness and Roundness) of the given job/situation with justification. *TSO 2e.* Explain the various terms associated with assessment of surface roughness. *TSO 2f.* Explain the given surface roughness unit. *TSO 2g.* Select the surface roughness instruments for the given job with justification. *TSO 2h.* 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)
TSO 3a. Identify the various elements of the given screw thread. *TSO 3b.* Explain the procedure of measurement of external or internal screw thread element using the given instrument. *TSO 3c.* Select measuring instrument/method for measuring the given external or internal screw thread element(s) with justification. *TSO 3d.* Identify various elements of the given gear. *TSO 3e.* Explain the procedure of measurement of gear element(s) element using the given instrument. *TSO 3f.* 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**
TSO 4a. List the various displacement/speed measuring instruments. *TSO 4b.* Explain the procedure to measure displacement/speed using the given instrument. *TSO 4c.* Select the relevant displacement/speed measuring instrument for the given situation with justification *TSO 4d.* 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)
TSO 4e. Explain the procedure to measure temperature using the given instrument. *TSO 4f.* 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).	
TSO 5a. List the various Flow/Pressure/Force/ Torque measuring instruments. *TSO 5b.* Explain the procedure to measure Flow/Pressure/Force/Torque using the given instrument. *TSO 5c.* Select the relevant Flow/Pressure/Force/ Torque measuring instrument for the given situation with justification *TSO 5d.* List the various Transducer used to measure different quantities *TSO 5e.* Explain the procedure to use the given Transducer to measure the given quantity. *TSO 5f.* 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)
LSO 1.1. Interpret the measuring elements of the given component drawing. *LSO 1.2.* 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
LSO 2.1. Calculate the least count of the given Vernier Caliper. *LSO 2.2.* 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
LSO 3.1. Calculate the least count of the given Micrometer. *LSO 3.2.* Use the given Micrometer for measurement of the given dimensions.	3*.	Measure the outside & inside diameters of a given job using Micrometer.	CO1, CO2
LSO 4.1. 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)
LSO 4.2. Use the given Vernier height gauge for measurement of the given dimensions.			
LSO 5.1. Calculate/Read the least count of the given Depth gauge. *LSO 5.2.* Use the given Depth gauge for measurement of the given dimensions.	5*.	Measure the depth of a given object using Depth gauge.	CO1, CO2
LSO 6.1. Identify different slip gauges available and their measuring values. *LSO 6.2.* Select the suitable set of Slip gauges to measure the given dimension. *LSO 6.3.* Perform wringing and un-wringing the Slip gauges to make/detach the stake. *LSO 6.4.* Measure the given dimension using given slip gauges.	6*.	Measure the thickness of ground MS plates using Slip gauges.	CO1, CO2
LSO 7.1. Identify different slip gauges available and their measuring values. *LSO 7.2.* Select the suitable Sine bar and other accessories for the angle to be measured. *LSO 7.3.* 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
LSO 8.1. Set the given Optical Bevel protractor/ Universal Bevel protractor for the angle to be measured. *LSO 8.2.* 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
LSO 9.1. Set the given Angle Dekkar for the angle to be measured. *LSO 9.2.* Measure the given angle using given Angle Dekkar. *LSO 9.3.* Compared the measured values with Optical Bevel protractor/ Universal Bevel protractor.	9*.	Measure the angle of a given component with Angle Dekkar.	CO1, CO2
LSO 10.1. Set the given Precision level/Autocollimator for the measuring Straightness of the given surface/edge. *LSO 10.2.* 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
LSO 11.1. Set the given Precision level/Autocollimator for measuring the Flatness of the given surface. *LSO 11.2.* Measure the Flatness of the given job using Precision level/Autocollimator. *LSO 11.3.* Compare the results from both the devices.	11.	Check the Flatness of the given job using Precision level/Autocollimator.	CO3
LSO 12.1. Set the given Engineer's Squareness tester for measuring the Squareness of given the job. *LSO 12.2.* 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
LSO 13.1. Set the given V-block and Dial indicator for measuring the Roundness of the given job. *LSO 13.2.* 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)
LSO 14.1. Set the given Dial gauge for measuring the parallelism and perpendicularity of the given job. *LSO 14.2.* 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
LSO 15.1. Identify the suitable surface measurement unit based on the requirement. *LSO 15.2.* 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
LSO 16.1. Select the suitable Resistance thermometer to measure the temperature in the given situation. *LSO 16.2.* Measure the temperature using the Resistance thermometer.	16*	Measure the effective diameter of a given screw thread using screw thread micrometer.	CO4
LSO 17.1. Select the suitable Screw Pitch gauge to measure the pitch of the given V-Thread. *LSO 17.2.* Measure the pitch using the selected Screw Pitch gauge.	17.	Measure the pitch of a given screw thread using Screw Pitch gauge.	CO4
LSO 18.1. Select the suitable Screw Pitch gauge to measure the pitch of the given V-Thread. *LSO 18.2.* Measure the pitch using the selected Screw Pitch gauge.	18.	Measure the geometrical dimensions of V-Thread using Thread Vernier gauge.	CO4
LSO 19.1. Set the Toolmaker's microscope to measure various elements of the given V-Thread Screw. *LSO 19.2.* 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
LSO 20.1. Identify Chordal and Normal thickness of a spur gear tooth. *LSO 20.2.* Set the Gear tooth Vernier caliper to measure the thickness of the given gear tooth. *LSO 20.3.* 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
LSO 21.1. Set the Gear Toolmaker's microscope to measure the form of the given gear tooth. *LSO 21.2.* Measure the form of the given gear tooth using the Toolmaker's microscope.	21.	Check the gear tooth form using Toolmaker's microscope.	CO4
LSO 22.1. Set the given Strain gauge/Rosette for measuring the strain in the given job. *LSO 22.2.* Measure the Strain of the given job using Strain gauge/Rosette.	22*	Measure the strain of an object using Strain gauge.	CO5
LSO 23.1. Select the suitable transducer to measure the pressure of the given liquid/gas. *LSO 23.2.* Measure the pressure of the given job liquid/gas using the transducer.	23.	Measure the pressure of the gas and liquid with Transducer.	CO5
LSO 24.1. Set the Rotameter to measure the flow of the given situation. *LSO 24.2.* Measure the flow using the Rotameter.	24*	Measurement of flow with Rotameter.	CO5
LSO 25.1. Select the suitable Resistance thermometer to measure the temperature in the given situation. *LSO 25.2.* Measure the temperature using the Resistance thermometer.	25.	Measurement of temperature with Resistance thermometer.	CO5

A judicial 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, Flow, 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, Laping, 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.(0º- 90º- 0º) 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 (0.2µm) 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 ±0.05% Surface ±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, Prject 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/cm2 to 60 kg/cm2	23
34.	Differential Pressure Bellows	Range 0-80" water column to 0-800" water column (or Equivalent) Uni-Directional or Bi-Directional Accuracy ±1% F.S. Standard, ± 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, 22nd 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., 1st 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 1st 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, 4th 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=lUjBmV4wMtA
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 recourses before use by the students.

(c) Others:

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

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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)
TSO.3d Explain various losses in flow through pipes, fittings and valves. *TSO.3e* Solve numerical based on continuity equation, laws of friction and losses in flow through pipes. *TSO.3f* 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.	
TSO.4a Calculate the impact of jet on flat plate. TSO.4b Calculate the impact of jet on curved plate. TSO.4c Calculate the force exerted by impact of jet plate in stationary and moving blades TSO.4d Draw the layout of hydroelectric power pant. TSO.4e Select suitable turbine for a given site/situation with justification. TSO.4f Describe the construction and working of the given water turbines. TSO.4g Describe the construction and working of the given draft tube. TSO.4h Calculate the work done, power, efficiency of turbines. TSO.4i 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**
TSO.5a Identify the different types of hydraulic pumps TSO.5b Describes construction and working of the given pump. TSO.5c Select suitable Pump for a given application with justification. TSO.5d Explain construction and working of the given reciprocating pump. TSO.5e Calculate the work done and overall efficiency and power required for the given pump. TSO.5f 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 tubine	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	7	3	2	2
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 Hydraulic turbine	9	CO4	14	3	5	6
Unit-5.0 Hydraulic pump	9	CO5	21	5	7	9
Total Marks	**48**	**-**	**70**	**20**	**22**	**28**

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 manometeric fluid	4
5	Differential Manometer	Glass tube 50 mm, Complete set up for demonstration of pressure measurement, wall or stand mounted, Mercury as manometeric 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 recourses 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)
TSO 1a. Select surface condenser for the given situation. *TSO 1b.* Compare the given steam turbine on the basis of given criteria. *TSO 1c.* Calculate efficiency of the given air compressor. *TSO 1d.* 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**
TSO 2a. Calculate thermal efficiency and draw P-V & T-S diagram of Rankine cycle. *TSO 2b.* Calculate thermal efficiency and draw P-V & T-S diagram of Brayton cycle. *TSO 2c.* Describe the working principle of the given type of jet propulsion. *TSO 2d.* Describe the working principle of the given type of nuclear reactor. *TSO 2e.* State the applications of hydroelectric power generation and give for using it. *TSO 2f.* 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.	
TSO 3a. Calculate unit of refrigeration & Coefficient of performance. *TSO 3b.* Draw P-V, P-H & T-S diagram of the given refrigeration cycle. *TSO 3c.* Solve numerical problems on refrigeration system. *TSO 3d.* 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**
TSO 4.a. Calculate psychrometric properties.	**Unit-4.0 Air Conditioning & Ventilation System**	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 4.b. Apply Psychrometric process for a given thermal system. *TSO 4.c.* Select A.C. system for the given situation. *TSO 4.d.* Explain the reason for using air conditioning system in given applications. *TSO 4.e.* 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.	
TSO 5a. Differentiate between Conduction, Convection and Radiation. *TSO 5b.* Solve numerical problems of conduction, convection and radiation. *TSO 5c.* 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.	Dissemble 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 & Dissembling 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 (Cl) 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.	Dissemble 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 VElectric 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 NH3+ H2O + 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.6th ISBN-10: **9390185289** ISBN-13: **9390185283-978**
4.	Thermodynamics an engineering approach	Yunus A. Cengel Michael A. Boles	McGraw Hill Education India, 2019 ISBN: 9789353165741, 9353165741

S.No.	Titles	Author(s)	Publisher and Edition with ISBN
		Mehmet Kanoglu	
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.2nd 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.3rd, 2021 ISBN-13: 978-8122436945
10.	Refrigeration and Air Conditioning	C. P. Arora	McGraw Hill Education, Ed.4th, 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 recourses 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.

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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)
TSO 1a. Identify various links in the given mechanism and their functions. *TSO 1b.* Identify inversions of the given mechanism. *TSO 1c.* Describe the constructional details of the given mechanism. *TSO 1d.* Select suitable mechanism for the given application with justification. *TSO 1e.* Explain different types of cams and cam followers with their motions. *TSO 1f.* Estimate displacement, velocity and acceleration diagram for the given follower motion. *TSO 1g.* Construct the radial cam profile from the given data ad 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**
TSO 2a. Compare different types of drive *TSO 2b.* 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. *TSO 2c.* Estimate power transmitted and condition for maximum power transmission in the given belt drive through simple numerical situation. *TSO 2d.* Describe the spur gear terminology *TSO 2e.* Identify different types of gear and gear trains. *TSO 2f.* 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)
TSO 2g. Calculate Train value & velocity ratio for the given gear trains using spur and helical gears only. *TSO 2h.* 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.	
TSO 3a. Explain the concept, function and terminology of governors. *TSO 3b.* Differentiate between flywheel and governor. *TSO 3c.* Draw a turning moment diagram for the given engine. *TSO 3d.* Apply the concept of fluctuation of speed and energy for the given flywheel. *TSO 3e.* Identify the working of different types of governor and their function. *TSO 3f.* Calculate the lift in case of the given governor. *TSO 3g.* 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**
TSO 4a. Explain various parts of the given brakes with their functions and constructional details. *TSO 4b.* Explain concept of self-locking and self-energizing. *TSO 4c.* Calculate braking force, braking torque and power lost in friction in the given shoe and band brake through simple numerical situation. *TSO 4d.* Describe working principle of the given clutch(s). *TSO 4e.* Explain various parts of the given clutch with their functions and constructional details. *TSO 4f.* 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 i. Shoe brake ii. Band brake iii. Internal expanding shoe brake iv. 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 i. Single-plate clutch, ii. Multi-plate clutch, iii. Centrifugal Clutch 4.4 Calculation of power loss assuming uniform pressure and uniform wear theory (No derivation).	**CO5**
TSO 5a. Explain the concept of balancing of single rotating mass *TSO 5b.* 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)
TSO 5c. Explain concept and terminology used in vibration *TSO 5d.* 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)
LSO 1.1. Identify the given of mechanisms. *LSO 1.2.* 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
LSO 2.1. 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
LSO 3.1. Draw follower motion as per the given requirement to get the actual values of lift of the follower related to corresponding cam rotation. *LSO 3.2.* Correlate the effect of Cam-Follower terminology like Angle of Ascent, Angle of Descent, Dwell, zero Offset, Basic Circle etc. on Cam profile. *LSO 3.3.* 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
LSO 4.1. Draw follower motion as per the given requirement to get the actual values of lift of the follower related to corresponding cam rotation. *LSO 4.2.* Correlate the effect of Cam-Follower terminology like Angle of Ascent, Angle of Descent, Dwell, Offset, Basic Circle etc. on Cam profile. *LSO 4.3.* 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
LSO 5.1. Identify the given Cam and follower combination. *LSO 5.2.* Correlate the effect of Angle of Ascent, Angle of Descent, Dwell, Offset, Basic Circle etc. with actual functioning of Cam-Follower. *LSO 5.3.* 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)
LSO 6.1. Identify the given type of power transmission element. *LSO 6.2.* Explain the working of Chain sprocket mechanism. *LSO 6.3.* Identify the slack and tight side of the given drive. *LSO 6.4.* 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
LSO 7.1. Identify the given type of gear and gear train. *LSO 7.2.* Identify the main parameters/parts/elements of the given spur and helical gear. *LSO 7.3.* Explain the functioning and arrangement of the given gear train.	7.	Study of various types of gears and gear train	CO2
LSO 8.1. Correlate the sizes, arrangement and working of actual gear mechanisms with theoretical counterparts. *LSO 8.2.* 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
LSO 9.1. Correlate the experimental turning moment diagram with theoretical counterpart. *LSO 9.2.* 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
LSO 10.1. Identify the given type of governor. *LSO 10.2.* Explain the working of the given governor. *LSO 10.3.* Correlate the effect of governor speed on sleeve lift, upper arm inclination, lower arm inclination, radius of governor, height of the governor. *LSO 10.4.* 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
LSO 11.1. Identify the given type of governor. *LSO 11.2.* Explain the working of the given governor. *LSO 11.3.* 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. *LSO 11.4.* 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
LSO 12.1. Identify the given type of brake. *LSO 12.2.* Explain the working and construction of the given type of the brake. *LSO 12.3.* 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
LSO 13.1. Identify the given type of dynamometer. *LSO 13.2.* 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)
LSO 13.3. Estimate the power required of the given IC engine at different speed situations.			
LSO 14.1. Identify the given type of Clutch. *LSO 14.2.* Identify the main parameters/elements of the given clutch. *LSO 14.3.* 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
LSO 15.1. Identify the given type of Brake. *LSO 15.2.* Identify the main parameters/elements of the given Brake. *LSO 25.1.* 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
LSO 16.1. Identify the input and output parameters/elements of the given clutch. *LSO 16.2.* 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
LSO 17.1. Observe the unbalanced/vibrations caused by the given single/multi rotating masses. *LSO 17.2.* Measure the parameters required for calculation of unbalance force/moment in the given unbalance setup. *LSO 17.3.* 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 judicial 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.

i. Draw bicycle brake applying mechanism and identify the type of links and joints.
ii. Draw line diagram of car and tractor steering mechanisms
iii. Compare wiper mechanism of a typical bus with wiper mechanism of a typical car.
iv. Compare slider crank mechanism used in a Bike and a Car.
v. List the various types of machines where Cam and Follower are used.
vi. Draw the profile of radial CAM for given follower to obtained desired follower motion. (Minimum two problem)
vii. Measure slack side and tight side tension in belt of pulleys of a floor mill.
viii. Calculate the length of belt for different belt arrangement.
ix. Calculate velocity ratio, belt tensions, slip and angle of contact in the given belt drive arrangement through simple numerical situation.
x. Estimate power transmitted and condition for maximum power transmission in the given belt drive through simple numerical situation.
xi. 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 scarp 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 (Cl) 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	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/thermocol Acrylic models/ metallic models	1, 2
2.	Different Types of cams, followers and cam/follower arrangements	Working Models / wooden/thermocol 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, epicyclical).	Working Models/ wooden/thermocol 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/thermocol 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=qmcriUdYBW0
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=PL46AAEDA6ABAFCA78
7. user.engineering.uiowa.edu/~mie032/support/eg/eg07_section_views.pd
   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 recourses before use by the students.

(c) Others:

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

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A) Course Code **: 2470405 (T2470405) / P2470405/ S2470405)**

B) Course Title **:** Wind Energy System

C) Pre- requisite Course(s) **:** Introduction to Renewable Energy

D) Rationale **:**

With growing concerns about climate change and the need to reduce greenhouse gas emissions, there is a global shift towards renewable energy sources. Wind energy is one of the fastest-growing renewable energy technologies and plays a crucial role in diversifying the energy mix away from fossil fuels. This subject aims at introducing basic concepts of wind energy conversion, component details & features of a wind turbine required for a wind Mill. The knowledge gained through this course will help the students to learn about the concepts of wind power conversion technology and economics relating to it and equip them with skills to troubleshoot the problems encountered in wind energy sector.

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 Interpret the fundamental principles of wind energy conversion and its role in renewable energy systems.

CO-2 Describe the aerodynamic principles governing wind turbine operation and design.

CO-3 Analyze wind resources and perform site assessment for wind energy projects.

CO-4 Interpret structure and components of electrical grids including transmission lines, substations, and distribution networks and how they interact with wind power systems.

CO-5 Design offshore wind farms, considering factors such as turbine layout optimization, cable routing to maximize energy production and minimize environmental impact.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes(POs)							Programme SpecificOutcomes* (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	-	3	2	-	-	2		
CO-2	3	2	-	2	-	-	-		
CO-3	3	3	-	2	3	-	-		
CO-4	3	3	-	2	-	-	-		
CO-5	3	-	3	3	-	3	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				
2470405	Wind Energy Systems	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)	
2470405	**Wind Energy Systems**	**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:

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: T2470405

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Discuss the significance of wind energy in the context of renewable energy sources. *TSO 1b.* Analyze the limitations and challenges associated with the widespread adoption of wind energy. *TSO 1c.* Examine the factors influencing wind energy generation, including atmospheric conditions and geographical features. *TSO 1d.* Calculate wind power density and its significance in assessing wind energy potential. *TSO 1e.* Discuss the relationship between wind velocities and height from the ground, considering boundary layer effects and atmospheric stability. *TSO 1f.* Define energy pattern factor and its importance in characterizing wind energy variability.	**Unit-1.0 Wind Energy Fundamentals** 1.1 Introduction, Application and Historical background, Merits and Limitations of Wind Energy. 1.2 Nature and origin of wind, wind Energy Quantum, Variables in Wind energy conversion systems 1.3 Wind power density, Power in Wind Stream, Wind Turbine efficiency, Power of Wind Turbine. 1.4 Forces on the Blade of a Propeller, Wind Velocities and Height from Ground, Mean Wind Velocity 1.5 Energy Pattern Factor, Wind Power duration Characteristics	**CO1**
TSO 2a. Identify and describe the major components of a wind turbine, including rotor blades, hub, shafts, gearbox, and generator. *TSO 2b.* Explain the operating principle of VAWTs and the aerodynamic forces involved in their operation. *TSO 2c.* Examine the constructional details and operating Principle of HAWTs and the aerodynamic principles governing their performance. *TSO 2d.* Discuss the aerodynamic forces acting on wind turbine blades and their impact on performance and structural integrity. *TSO 2e.* Examine the components and operation of wind turbine drive trains, including low-speed and high-speed shafts, gearboxes, and bearings. *TSO 2f.* Define pitch and yaw control systems and their importance in wind turbine operation and performance optimization.	**Unit-2.0 Wind Turbine Technology** 2.1 Parts of wind turbine – Rotor blades, Blade count, Blade materials, Hub, Low speed shaft, Gearbox, High speed shaft 2.2 Vertical axis Wind Turbine (VAWT) – Types, Constructional details, Operating principle, Advantage & Disadvantages of VAWT 2.3 Horizontal axis Wind Turbine (HAWT) – Types, Constructional details, Operating principle, Advantage & Disadvantages of HAWT. 2.4 Blade Design and aerodynamics 2.5 Drive train and generator systems 2.6 Pitch and yaw control mechanisms	**CO2**
TSO 3a. Use instruments employed in measuring wind speed and direction. *TSO 3b.* Explain the principles behind anemometry and remote sensing technologies for wind data collection. *TSO 3c.* Analyze wind data sets using statistical and numerical techniques.	**Unit-3.0 Wind Resource Assessment** 3.1 Measuring wind speed and direction 3.2 Wind data collection techniques (e.g., anemometry, remote sensing) 3.3 Wind data analysis and modeling 3.4 Wind shear and turbulence effects 3.5 Site selection for wind farms	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 3d. Discuss the causes and effects of wind shear and turbulence on turbine performance, structural loading. *TSO 3e.* Evaluate potential sites for wind farm development based on various criteria, including wind resource, land availability etc.		
TSO 4a. Explain the principles of wind farm layout optimization for maximizing energy production and minimizing wake effects. *TSO 4b.* Design electrical layouts for wind farms, considering factors like grid connection requirements and voltage levels. *TSO 4c.* Explain grid codes and interconnection standards relevant to wind energy systems. *TSO 4d.* Interpret impact of wind energy integration on grid stability and power quality. *TSO 4e.* Summarize different energy storage technologies, including batteries, pumped hydro storage, and flywheels, and their suitability for wind energy applications.	**Unit-4.0 Grid Integration of Wind Power** 4.1 Wind farm layout and spacing 4.2 Electrical infrastructure and sub-station design 4.3 Grid codes and interconnection standards 4.4 Grid stability and power quality 4.5 Energy Storage Requirements with Wind Energy System	**CO4**
TSO 5a. Select key components of offshore wind farms, such as offshore turbines, foundations, and support structures. *TSO 5b.* List different floating platform designs and its advantages for deep-water wind energy development. *TSO 5c.* Explain submarine cable design considerations, including cable routing, burial depth, and protection against marine hazards. *TSO 5d.* Outline the policy framework governing offshore wind energy development in India. *TSO 5e.* Identify environmental impacts associated with offshore wind energy development.	**Unit-5.0 Offshore Wind Energy** 5.1 Introduction, offshore wind energy technology, future technological development 5.2 Floating wind turbine technology 5.3 Submarine cables and offshore substation design 5.4 National Offshore Wind Energy Policy of India 5.5 Environmental considerations and challenges	**CO5**

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2470405

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Select instrumentation needed to measure anemometers, tachometers, load cells, power meters, and environmental sensors.	1.	set up instrumentation for measuring key parameters such as wind speed, rotor speed, power output, and environmental conditions	**CO1**
LSO 1.2. Construct prototype blades using appropriate materials and fabrication techniques	2.	Design and construct wind turbine blades for optimal energy capture.	**CO2**
LSO 2.1. Analyze the performance of control algorithms through simulations and experimental testing.	3.	Study and test control systems for wind turbines.	**CO2**
LSO 3.1. Evaluate the performance characteristics of a wind turbine under different wind speeds, directions, and turbulence levels.	4.	Analyze the performance of a wind turbine under varying wind conditions.	**CO3**
LSO 4.1. Simulate offshore wind turbine behavior using computational tools and models.	5.	Simulate the performance and dynamics of off shore wind turbines.	**CO5**
LSO 5.1. Explore solutions such as advanced grid control strategies, energy storage systems, and grid-friendly turbine technologies.	6.	Study the grid integration challenges and solutions for wind power.	**CO4**
LSO 6.1. Analyze wind resource data, turbine characteristics, and site constraints to determine optimal turbine placement and spacing.	7.	Optimize the layout of a wind farm for maximum energy generation.	**CO4**
LSO 7.1. Identify and troubleshoot common mechanical and electrical issues on a wind turbine model.	8.	Perform maintenance tasks on a wind turbine model.	**CO2**

L) Suggested Term Work and Self Learning: S2470405 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.

b. Micro Projects:

1. Design wind turbine blades using 3D modeling software and composite materials such as fibre glass or carbon fibre.
2. Develop a control system for a small-scale wind turbine connected to a micro grid.
3. Collect and analyze wind resource data for the site, including wind speed, direction, and turbulence characteristics.
4. Present a comprehensive report detailing the site assessment findings, layout optimization results, and recommendations for wind farm development.

c. Other Activities:

1. Seminar Topics:
    - Advances in Wind Turbine Technology
    - Analysis of the opportunities and challenges associated with offshore wind farms
    - Wind Farm Optimization and Layout Design
    - Discussion on the economic aspects of wind energy projects

2. Visits: Visit nearby wind turbine sites to observe the machinery up close and gain an understanding of its scale and complexity. Prepare report of visit with special comments on maintenance activities being performed on wind turbines, such as blade inspections, lubrication of moving parts, and electrical system checks.

3. Self-learning topics:
    - Wind Resource Assessment Techniques
    - Aerodynamics of Wind Turbines
    - Environmental Impacts of Wind Energy
    - Emerging Technologies and Trends in Wind Energy

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%	20%
CO-2	10%	10%	10%	25%	-	10%	20%
CO-3	15%	15%	15%	25%	33%	15%	20%
CO-4	30%	30%	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 percentage 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 (Cl) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Wind Energy Fundamentals	12	CO1	20	5	6	9
Unit-2.0 Wind Turbine Technology	12	CO2	20	4	6	10
Unit-3.0 Wind Resource Assessment	8	CO3	10	5	2	3
Unit-4.0 Grid Integration of Wind Power	8	CO4	10	3	3	4
Unit-5.0 Offshore Wind Energy	8	CO5	10	3	2	51`
Total	**48**	**-**	**70**	**20**	**19**	**31**

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.	set up instrumentation for measuring key parameters such as wind speed, rotor speed, power output, and environmental conditions	CO1	30	60	10
2.	Design and construct wind turbine blades for optimal energy capture.	CO2	30	60	10
3.	Study and test control systems for wind turbines.	CO2	40	50	10
4.	Analyze the performance of a wind turbine under varying wind conditions.	CO3	30	60	10
5.	Simulate the performance and dynamics of offshore wind turbines.	CO5	30	60	10
6.	Study the grid integration challenges and solutions for wind power.	CO4	30	60	10
7.	Optimize the layout of a wind farm for maximum energy generation.	CO4	30	60	10
8.	Perform maintenance tasks on a wind turbine model.	CO2	30	60	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.	Wind turbine blade materials, wind tunnel	Energy Lab Mild Steel Wind Turbine Blade Rotor Diameter 600 mm Blade Material Mild Steel Blade Size 1200mm Usage/Application For Energy Generation Surface Finish Powder Coated Minimum Order Quantity 3 Piece	
2.	Wind turbine controller, simulator.	Unloading Way PWM Electrodeless and noiseless unloading Working Temperature -20~+60°C 35~85%RH Dimension 80*80*15mm Net Weight 0.4kg	
3.	Wind turbine model, anemometer.	Rotor Diameter 8 ft (2.44 m) Blade Length 40 in (20.3 cm) Swept Area 25.4 sq. ft (7.7 m) Hub Height 25 ft (7.6 m) Nacelle Weight N/A Rotor Weight 180 lb (82 kg) Wind Speed Furl Out N/A Cut in Wind Speed Energy Output 5 mph (2.2 m/s) Power Efficiency 80% Noise Level 25 db Warranty Limited to 20 yrs	
4.	Offshore wind turbine simulation software, data analysis tools.		
5.	Grid integration equipment, simulation software.		
6.	Wind farm layout simulation software, wind farm models		
7.	Wind turbine model, maintenance tools.		
8.	Data analysis software, wind energy data.		

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Wind Energy: Renewable Energy and the Environment	Vaughn Nelson	CRC Press, 2009 ISBN-13 978-1420075687
2.	WIND ENERGY HANDBOOK, 3RD EDITION	Tony L. Burton (Author), Nick Jenkins (Author), Ervin Bossanyi (Author), David Sharpe (Author)	Wiley,2021 ISBN-13 : 978-1119451099
3.	WIND ELECTRICAL SYSTEMS	S. N. Bhadra (Author), D. Kastha (Author), S. Banerjee (Author)	Publisher: Oxford Edition: Seventh Impression, 2005 ISBN-13: 978-0195670936
4.	WIND POWER TECHNOLOGY, 3RD EDITION	Joshua Earnest (Author), Sthuthi' Rachel (Author)	PHI LEARNING PVT. LTD., 2019 ISBN-13 978-9388028493

(b) Online Educational Resources:

1. https://www.youtube.com/watch?v=zYeYN80SJCY
2. https://archive.nptel.ac.in/courses/112/104/112104265/
3. https://onlinecourses.nptel.ac.in/noc...

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. "Wind Energy Explained: Theory, Design and Application" by J.F. Manwell, J.G. McGowan, and A.L. Rogers.
2. "Wind Energy Handbook" by Tony Burton, Nick Jenkins, David Sharpe, and Ervin Bossanyi.
3. Wind Energy Users' Guide
4. Wind Energy Technology Handbook
5. Lab Manuals

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