**Sana'a University**
**Faculty of Engineering**
**Mechanical Engineering Department**
**Mechanical Engineering Program**

# Course Specification of Mechanical Measurements and Metrology

## I. Course Identification and General Information:

| | | | | | | |
|---|---|---|---|---|---|---|
| **1.** | Course Title: | Mechanical Measurements and Metrology | | | | |
| **2.** | Course Code & Number: | ME223 | | | | |
| **3.** | Credit hours: | Co. H. | | | | TOTAL CR HRS |
| | | Th. | Seminar/Tu | Pr | Tr. | |
| | | 2 | - | 2 | - | 3 |
| **4.** | Study level/ semester at which this course is offered: | Third Year- Second Semester. | | | | |
| **5.** | Pre –requisite (if any): | Electrical Machines(EE283), Fluid Mechanics-I (ME241) and Thermodynamics - I (ME251). | | | | |
| **6.** | Co –requisite (if any): | Fluid Mechanics – II (ME242) and Probability and Statistics (ME270 ) | | | | |
| **7.** | Program (s) in which the course is offered: | Mechanical Engineering Program | | | | |
| **8.** | Language of teaching the course: | English Language. | | | | |
| **9.** | Location of teaching the course: | Mechanical Engineering Department | | | | |
| **10.** | Prepared By: | Assoc. Prof. Dr. Khalil Al-Hatab<br>Eng. Mahran Alabsi | | | | |
| **11.** | Date of Approval: | | | | | |

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## II. Course Description:

The course includes lectures and laboratory exercises that provides a simple understanding of the mechanical measurement systems by introduces their function, operation, application and basic elements with emphasis on system characteristics, measurements methods and treatment of experimental data. The student will design and select measurement systems for temperature measurement, pressure, flow measurements, displacement and velocity measurement, measurement of force, torque and strain. In addition to, a linear and angular measurements, metrology of gear and screw threads and metrology of surface finish.

| III. Course Intended learning outcomes (CILOs) alignments of the course | | Referenced PILOs |
|---|---|---|
| **a1** | Define the measurement and metrology concepts, its advancements and measuring instruments and recognize measuring units, principles elements, characteristics and importance of various metrology and measurement systems used in the industry. | A2 |
| **a2** | Select proper measuring instrument for specific application as well as describe the working principle of various measurement systems and instrumental devices. | |
| **a3** | Explain measurement systems in terms of structure elements; function; operation conditions and limits; calibration methodology; performance characteristics and error analysis. | A3 |
| **b1** | Design of measuring system and estimate its measurement uncertainty using basic statistical methods. | B1 |
| **b2** | Create the mathematically model and analyse the measurement systems as well as differentiate the instrument's characteristics to choose the suitable one for specific application. | B2 |

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|---|---|---|
| **c1** | Demonstrate an ability to select and calibrate measuring systems based on used appropriate sensors convenient for the corresponding measurements and static and dynamic characteristics. | C1 |
| **c2** | Conduct measurements experiments, record observations, analyze and interpret results for quality with industrial environment. | C2 |
| **d1** | Cooperate effectively in teamwork projects/ experiments, to perform successful measurements in real industrial applications. | D1 |
| **d2** | Manage the tasks very well to overcome stressful environment and constraints. | D2 |
| **d3** | Assess measurement date, to estimate uncertainties and to achieve present traceable measurement results. | D5 |

**(A) Alignment Course Intended Learning Outcomes of Knowledge and Understanding to Teaching Strategies and Assessment Strategies:**

| Course Intended Learning Outcomes | | Teaching strategies | Assessment Strategies |
|---|---|---|---|
| **a1-** | Define the measurement and metrology concepts, its advancements and measuring instruments and recognize measuring units, principles elements, characteristics and importance of various metrology and measurement systems used in the industry. | Lectures. Laboratory, Class Discussion, Project | Examinations, Homework, Laboratory Report. Project Report & Presentation. |
| **a2-** | Identify proper measuring instrument for specific application as well as describe the working principle of various measurement systems and instrumental devices. | | |

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| **a3-** | Explain measurement systems in terms of structure elements; function; operation conditions and limits; calibration methodology; performance characteristics and error analysis. | | |

| **(B) Alignment Course Intended Learning Outcomes of Intellectual Skills to Teaching Strategies and Assessment Strategies:** | | | |
|---|---|---|---|
| | Course Intended Learning Outcomes | Teaching strategies | Assessment Strategies |
| **b1-** | Design of measuring system and estimate its measurement uncertainty using basic statistical methods. | Lectures. Laboratory, Class Discussion, Project | Examinations, Homework, Laboratory Report. Project Report & Presentation. |
| **b2-** | Create the mathematically model and analyse the measurement systems as well as differentiate the instrument's characteristics to choose the suitable one for specific application. | | |

| **© Alignment Course Intended Learning Outcomes of Professional and Practical Skills to Teaching Strategies and Assessment Strategies:** | | | |
|---|---|---|---|
| | Course Intended Learning Outcomes | Teaching strategies | Assessment Strategies |
| **c1-** | Demonstrate an ability to select and calibrate measuring systems based on used appropriate sensors convenient for the corresponding measurements and static and dynamic characteristics. | Lectures. Laboratory, Interactive Class Discussion, Project | Examinations, Homework, Laboratory Report, Project Report & Presentation. |

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|---|---|---|---|
| **c2-** | Conduct measurements experiments, record observations, analyze and interpret results for quality with industrial environment. | Laboratory, Interactive Class Discussion, Project | Examinations, Laboratory Report. Project Report & Presentation. |

**(D) Alignment Course Intended Learning Outcomes of Transferable Skills to Teaching Strategies and Assessment Strategies:**

| Course Intended Learning Outcomes | Teaching strategies | Assessment Strategies |
|---|---|---|
| **d1-** Cooperate effectively in teamwork projects/ experiments, to perform successful measurements in real industrial applications. | Laboratory, Project | Laboratory Report. Project Report & Presentation. |
| **d2-** Manage the tasks very well to overcome stressful environment and constraints. | | |
| **d3-** Assess measurement date, to estimate uncertainties and to achieve present traceable measurement results. | | |

## IV. Course Content:

### A – Theoretical Aspect:

| Order | Units/Topics List | Learning Outcomes | Sub topics List | Number of Weeks | Contact hours |
|---|---|---|---|---|---|
| **1.** | Fundamentals of Measurement Systems | a1,a2,a3,b1 | • Definitions of Measurement & Metrology<br>• Need of Mechanical Measurement<br>• Measurement Units<br>• Measurement System Design | 1 | 2 |

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| | | | ▪ Functional Elements of a Measurement System<br>▪ Choosing Appropriate Measuring Instruments<br>• Measurement Methods,<br>• Measurement System Applications<br>• Generalized Measurement System, | | |
| **2.** | Instrument Types and Performance Characteristics | a1,a2,a3,b1,b2,c1 | • Review of Instrument Types<br>• Static Characteristics of Instruments: Accuracy, Precision/Repeatability/Reproducibility, Tolerance, Range or Span, Hysteresis, Linearity, Sensitivity, Resolution, Threshold, Drift, Zero Stability, Loading Effect and Dead Space.<br>• Dynamic Characteristics of Instruments: 0, 1st & 2nd -Order Instruments<br>• Necessity for Calibration<br>• Principles of Calibration<br>• Control of Calibration Environment<br>• Calibration Chain and Traceability<br>• Calibration Records | 1 | 2 |
| **3.** | Uncertainty Analysis | a1,a3,b1,b2,c1 | • Sources of Systematic Error<br>• Reduction of Systematic Errors<br>• Quantification of Systematic Errors<br>• Sources and Treatment of Random Errors | 1 | 2 |

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|---|---|---|---|---|---|
| | | | • Statistical Analysis of Measurements Subject to Random Errors<br>• Aggregation of Measurement System Errors<br>• Display of Measurement Signals<br>• Recording of Measurement Data<br>• Presentation of Data | | |
| **4.** | Transducers | a1,a2,a3,b1 ,b2,c1 | • Transfer Efficiency<br>• Classification of Transducers<br>• Quality Attributes for Transducers<br>• Intermediate Modifying Devices<br>• Advantages of Electrical Intermediate Modifying Devices<br>• Electrical Intermediate Modifying Devices<br>• Terminating Devices<br>• Data-Acquisition Systems | 1 | 2 |
| **5.** | Temperature Measurements | a1,a2,a3,b1 ,b2,c1 | • Temperature Standards and Definition.<br>• Methods of Measuring Temperature<br>• Thermocouples<br>• Resistance Temperature Detectors<br>• Thermistors<br>• Pressure Thermometers<br>• Bimetallic Strip Thermometers<br>• Pyrometry | 1 | 2 |

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|---|---|---|---|---|---|
| | | | • Physical Errors in Temperature Measurement | | |
| **6.** | Pressure and Velocity Measurements | a1,a2,a3,b1 ,b2,c1 | • Pressure Measurement Scales<br>• Methods of Pressure Measurement<br>• Ring Balance<br>• Inverted Bell Manometer<br>• Elastic Transducers<br>• Electrical Pressure Transducers<br>• Dead-weight Pressure Gauge<br>• Measurement of Vacuum<br>• Fluid Velocity Measuring Systems | 1 | 2 |
| **7** | Flow Measurements | a1,a2,a3,b1 ,b2,c1 | • Flow Rate Concepts<br>• Volume Flow Rate Through Velocity Determination<br>• Pressure Differential Meters<br>• Insertion Volume Flow Meters<br>• Mass Flow Meters<br>• Flow Meter Calibration and Standards<br>• Estimating Standard Flow Rate | 1 | 2 |
| **8** | Mid-Term Exam | a1,a2,a3,b1 ,b2,c1 | - All previous Topics | 1 | 2 |
| **9.** | Measurement of Strain, Force and Torque | a1,a2,a3,b1 ,b2,c1 | • Measurement of Strain<br>▪ Mechanical Strain Gauges<br>▪ Electrical Strain Gauges<br>▪ Strain Gauge Materials<br>▪ Gauge Factor<br>▪ Theory of Strain Gauges | 2 | 4 |

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| | | | ▪ Methods of Strain Measurement<br>▪ Strain Gauge Bridge Arrangement<br>• Measurement of Force: Direct Methods<br>• Measurement of Torque | | |
| **10** | Linear and Angular Measurements | a1,a2,a3,b1 ,b2,c1 | • Linear Measurement Instruments<br>▪ Surface Plate<br>▪ V-blocks<br>▪ Graduated Scales<br>▪ Scaled Instruments<br>▪ Vernier Instruments<br>▪ Micrometer Instruments<br>▪ Slip Gauges<br>• Angular Measurement<br>▪ Protractor<br>▪ Sine Bar<br>▪ Angle Gauges<br>▪ Spirit Level<br>▪ Optical Instruments for Angular | 1 | 2 |
| **11** | Comparators | a1,a2,a3,b1 ,b2,c1 | • Functional Requirements<br>• Classification of Comparators<br>• Mechanical Comparators<br>• Mechanical–Optical Comparator<br>• Electrical Comparators<br>• Pneumatic Comparators | 1 | 2 |
| **12** | Metrology of Gears and Screw Threads | a1,a2,a3,b1 ,b2,c1 | • Gear Terminology<br>• Errors in Spur Gears | 1 | 2 |

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| | | | • Measurement of Gear Elements<br>• Composite Method of Gear Inspection<br>• Screw Threads Terminology<br>• Measurement of Screw Threads<br>• Thread Gauges | | |
| **13** | Metrology of Surface Finish | a1,a2,a3,b1 ,b2,c1 | • Surface Metrology Concepts<br>• Surface Metrology Terminology<br>• Analysis of Surface Traces<br>• Specification of Surface Texture Characteristics<br>• Methods of Measuring Surface Finish | 1 | 2 |
| **14** | Miscellaneous Metrology | a1,a2,a3,b1 ,b2,c1 | • Precision Instrumentation Based on Laser Principles<br>• Coordinate Measuring Machines<br>• Machine Tool Metrology<br>• Automated Inspection<br>• Machine Vision | 1 | 2 |
| **15** | Final Exam | a1,a2,a3,b1 ,b2,c1 | - All Topics | 1 | 2 |
| **Number of Weeks /and Units Per Semester** | | | | **16** | **32** |

**B - Practical Aspect:**

| Order | Tasks/ Experiments | Number of Weeks | Contact hours | Learning Outcomes |
|---|---|---|---|---|
| **1.** | Lab-1 Overview on Measurement Laboratory: | 1 | 2 | a1 ,c2,d1,d2,d3 |

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|---|---|---|---|---|
| | • Working Roles and Safety, | | | |
| **2.** | Lab-2 Measurement Analysis<br>• Calibration and Uncertainty Analysis. | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **3.** | Lab-3 Variable Conversion Elements:<br>• Bridge Circuits<br>• Resistance Measurement<br>• Inductance Measurement<br>• Capacitance Measurement<br>• Current Measurement<br>• Phase Measurement | 2 | 4 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **4.** | Lab-4 Data Acquisition with LabVIEW:<br>• Computer-Based Data Acquisition<br>• Software Tools for Laboratory Data Acquisition<br>• National Instruments LabVIEW<br>• Graphical Programming in LabVIEW<br>• Logic Operations in LabVIEW<br>• Loops in LabVIEW<br>• Case Structure in LabVIEW<br>• Data Acquisition Using LabVIEW<br>• LabVIEW Function Generation | 2 | 4 | a1,a2,a3,b1,b2,c1, c2,d1,d2,d3 |
| **5.** | Lab-5 Signal Processing with LabVIEW:<br>• Analogue Filters<br>• Digital Filters<br>• LabVIEW Implementation<br>• Simple Filter Solution | 1 | 2 | a1,a2,a3,b1,b2,c1, c2,d1,d2,d3 |

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| | • Matlab Solution to the Butterworth Filter Design | | | |
| **6** | Lab-6 Temperature Measurements | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **7** | Lab-7 Pressure, Velocity and Flow Measurements | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **8** | Lab-8 Strain, Force and Torque Measurements | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **9** | Lab-9 Linear and Angular Measurements | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **10** | Lab-10 Gears and Screw Threads Measurements | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **11** | Lab-11 Surface Finish Measurements | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **12** | Final Practical Exam | 1 | 2 | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **Number of Weeks /and Units Per Semester** | | **14** | **28** | |

## V. Teaching strategies of the course:

- Lectures,
- Interactive Class Discussion,
- Laboratory, and
- Projects.

## VI. Assignments:

| No | Assignments | Aligned CILOs(symbols) | Week Due | Mark |
|---|---|---|---|---|
| 1. | Homework | a1, a2, a3,b1,b2,c1 | Weekly | 10 |

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| 2. | Lab. Reports. | a1, a2, a3,b1, b2,c1,c2,d1,d2,d3 | Weekly | 10 |
| 3. | Mini-Projects Presentation & Report. | a1, a2, a3, b1, b2,c1,c2,d1,d2,d3 | 13th week | 10 |
| **Total** | | | | 30 |

## VII. Schedule of Assessment Tasks for Students During the Semester:

| No. | Assessment Method | Week Due | Mark | Proportion of Final Assessment | Aligned Course Learning Outcomes |
|---|---|---|---|---|---|
| **1** | Assignments | Weekly | 30 | 20% | a1, a2, a3,b1, b2,c1,c2, d1,d2,d3 |
| **2** | Quizzes | 4th & 11th weeks | 10 | 6.67% | a1, a2, a3,b1,b2,c1 |
| **3** | Mid-Term Exam | 8th week | 20 | 13.33% | a1, a2, a3,b1,b2,c1 |
| **4** | Final Practical Exam | 15th week | 15 | 10% | a1,a2,a3,b1,b2,c1,c2,d1, d2,d3 |
| **5** | Final Exam | 16th week | 75 | 50% | a1, a2, a3,b1,b2,c1 |
| **Total** | | | **150** | **100%** | |

## VIII. Learning Resources:

**1- Required Textbook(s) (maximum two ).**

1. Alan S. Morris, Reza Langari, 2011, Measurement and Instrumentation Theory and Application, 1st Edition, Elsevier, USA.
2. N.V. Raghavendra L. Krishnamurthy, 2013, Engineering Metrology and Measurements, 1st Edition, Oxford University Press.

**2- Essential References.**

1. Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard, 2006, Mechanical Measurements, 6th Edition, Pearson.

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2. Anand K. Bewoor & Vinay A.Kulkarni, 2009, Metrology & Measurement, Tata McGraw Hill Pvt. Ltd., New-Delhi.
3. Alan S. Morris, 2013, Measurement and Instrumentation Principles, 3rd Edition, Butterworth-Heinemann.
4. Morse, Ivan E.; Tse, Francis S, 2018, Measurement and Instrumentation in Engineering: Principles and Basic Laboratory Experiments, 1st Edition, CRC Press.
5. S.P. Venkateshan, 2015, Mechanical Measurements, 2nd Edition, John Wiley & Sons Ltd.
6. Richard S. Figliola, Donald E. Beasley, 2011, n, Theory and Design for Mechanical Measurements, 5th Edition, John Wiley & Sons Ltd.

**3- Electronic Materials and Web Sites *etc*.**

- https://nptel.ac.in/
- https://www.youtube.com/watch?v=uwZGtFRtGoU
- https://www.youtube.com/watch?v=iamxq4Jsimo
- https://www.youtube.com/watch?v=yetXIqoEsn0

## IX. Course Policies:

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| 1. | **Class Attendance:**<br>-A student should attend not less than 75 % of total hours of the subject; otherwise he will not be able to take the exam and will be considered as exam failure. If the student is absent due to illness, he/she should bring a proof statement from university Clinic |
| 2. | **Tardy:**<br>- For late in attending the class, the student will be initially notified. If he repeated lateness in attending class he will be considered as absent. |
| 3. | **Exam Attendance/Punctuality:**<br>- A student should attend the exam on time. He is Permitted to attend an exam half one hour from exam beginning, after that he/she will not be permitted to take the exam and he/she will be considered as absent in exam. |
| 4. | **Assignments & Projects:** |

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| | - The assignment is given to the students after each chapter; the student has to submit all the assignments for checking on time. |
| 5. | **Cheating**:<br>- For cheating in exam, a student will be considered as fail. In case the cheating is repeated three times during his/her study the student will be disengaged from the Faculty. |
| 6. | **Plagiarism**:<br>Plagiarism is the attending of a student the exam of a course instead of another student. If the examination committee proofed a plagiarism of a student, he will be disengaged from the Faculty. The final disengagement of the student from the Faculty should be confirmed from the Student Council Affair of the university. |
| **7.** | **Other policies:**<br>- Mobile phones are not allowed to use during a class lecture. It must be closed, otherwise the student will be asked to leave the lecture room<br>- Mobile phones are not allowed in class during the examination.<br>Lecture notes and assignments my given directly to students using soft or hard copy |

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| **Reviewed By** | **Vice Dean for Academic Affairs and Post Graduate Studies: Asst. Prof. Dr. Tarek A. Barakat**<br>**President of Quality Assurance Unit: Assoc. Prof. Dr. Mohammed Algorafi**<br>**Name of Reviewer from the Department: Assoc.Prof. Dr. Khalil Al-Hatab** |
| | **Deputy Rector for Academic Affairs Asst. Prof. Dr. Ibrahim AlMutaa**<br>**Assoc. Prof. Dr. Ahmed Mujahed**<br>**Asst. Prof. Dr. Munasar Alsubri** |

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# Course Plan of Mechanical Measurements and Metrology

| I. - Information about Faculty Member Responsible for the Course: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Name of Faculty Member** | Eng. Mahran Alabsie | **Office Hours** | | | | | | |
| **Location & Telephone No.** | 772764549 | **SAT** | **SUN** | **MON** | **TUE** | **WED** | **THU** |
| **E-mail** | mhran.150@gmail.com | | | | | | |

| II. Course Identification and General information: | | | | | | |
|---|---|---|---|---|---|---|
| **1-** | Course Title: | Mechanical Measurements and Metrology. | | | | |
| **2-** | Course Number & Code: | ME223 | | | | |
| **3-** | Credit hours: | C.H | | | | TOTAL CR. HRS |
| | | Th. | Seminar/Tu | Pr | Tr. | |
| | | 2 | - | 2 | - | 3 |
| **4-** | Study level/year at which this course is offered: | Third Year- Second Semester. | | | | |
| **5-** | Pre –requisite (if any): | Electrical Machines(EE283), Fluid Mechanics-I (ME241) and Thermodynamics - I(ME251) | | | | |
| **6-** | Co –requisite (if any): | Fluid Mechanics – II (ME242) and Probability and Statistics (ME270 ). | | | | |
| **7-** | Program (s) in which the course is offered | Mechanical Engineering Program. | | | | |
| **8-** | Language of teaching the course: | English Language. | | | | |
| **9-** | System of Study: | Semesters. | | | | |
| **10-** | Mode of delivery: | Lectures & Lab Based Work**.** | | | | |
| **11-** | Location of teaching the course: | Mechanical Engineering Department. | | | | |

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## III. Course Description:

The course includes lectures and laboratory exercises that provides a simple understanding of the mechanical measurement systems by introduces their function, operation, application and basic elements with emphasis on system characteristics, measurements methods and treatment of experimental data. The student will design and select measurement systems for temperature measurement, pressure, flow measurements, displacement and velocity measurement, measurement of force, torque and strain. In addition to, a linear and angular measurements, metrology of gear and screw threads and metrology of surface finish.

## IV. Intended learning outcomes (ILOs) of the course:

- Brief summary of the knowledge or skill the course is intended to develop:

1. Define the measurement and metrology concepts, its advancements and measuring instruments and recognize measuring units, principles elements, characteristics and importance of various metrology and measurement systems used in the industry.
2. Identify proper measuring instrument for specific application as well as describe the working principle of various measurement systems and instrumental devices.
3. Explain measurement systems in terms of structure elements; function; operation conditions and limits; calibration methodology; performance characteristics and error analysis.
4. Design of measuring system and estimate its measurement uncertainty using basic statistical methods.
5. Create the mathematically model and analyse the measurement systems as well as differentiate the instrument's characteristics to choose the suitable one for specific application.
6. Demonstrate an ability to select and calibrate measuring systems based on used appropriate sensors convenient for the corresponding measurements and static and dynamic characteristics.
7. Conduct measurements experiments, record observations, analyze and interpret results for quality with industrial environment.

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| **8.** | Cooperate effectively in teamwork projects/ experiments, to perform successful measurements in real industrial applications. |
| **9.** | Assess measurement date, to estimate uncertainties and to achieve present traceable measurement results. |

## V. Course Content:

- Distribution **of** Semester Weekly Plan of Course topics/Items and Activities.

### A – Theoretical Aspect:

| Order | Topics List | Sub topics List | Week Due | Contact Hours |
|---|---|---|---|---|
| **1** | Fundamentals of Measurement Systems | • Definitions of Measurement & Metrology<br>• Need of Mechanical Measurement<br>• Measurement Units<br>• Measurement System Design<br>▪ Functional Elements of a Measurement System<br>▪ Choosing Appropriate Measuring Instruments<br>• Measurement Methods,<br>• Measurement System Applications<br>• Generalized Measurement System, | 1st week | 2 |
| **2** | Instrument Types and Performance Characteristics | • Review of Instrument Types<br>• Static Characteristics of Instruments: Accuracy, Precision/Repeatability/Reproducibility, Tolerance, Range or Span, Hysteresis, | 2nd week | 2 |

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|---|---|---|---|---|
| | | Linearity, Sensitivity, Resolution, Threshold, Drift, Zero Stability, Loading Effect and Dead Space.<br>• Dynamic Characteristics of Instruments: 0, 1st & 2nd -Order Instruments<br>• Necessity for Calibration<br>• Principles of Calibration<br>• Control of Calibration Environment<br>• Calibration Chain and Traceability<br>• Calibration Records | | |
| **3** | Uncertainty Analysis | • Sources of Systematic Error<br>• Reduction of Systematic Errors<br>• Quantification of Systematic Errors<br>• Sources and Treatment of Random Errors<br>• Statistical Analysis of Measurements Subject to Random Errors<br>• Aggregation of Measurement System Errors<br>• Display of Measurement Signals<br>• Recording of Measurement Data<br>• Presentation of Data | 3rd week | 2 |
| **4** | Transducers | • Transfer Efficiency<br>• Classification of Transducers<br>• Quality Attributes for Transducers<br>• Intermediate Modifying Devices<br>• Advantages of Electrical Intermediate Modifying Devices | 4th week | 2 |

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|---|---|---|---|---|
| | | • Electrical Intermediate Modifying Devices<br>• Terminating Devices<br>• Data-Acquisition Systems | | |
| **5** | Temperature Measurements | • Temperature Standards and Definition.<br>• Methods of Measuring Temperature<br>• Thermocouples<br>• Resistance Temperature Detectors<br>• Thermistors<br>• Pressure Thermometers<br>• Bimetallic Strip Thermometers<br>• Pyrometry<br>• Physical Errors in Temperature Measurement | 5th week | 2 |
| **6** | Pressure and Velocity Measurements | • Pressure Measurement Scales<br>• Methods of Pressure Measurement<br>• Ring Balance<br>• Inverted Bell Manometer<br>• Elastic Transducers<br>• Electrical Pressure Transducers<br>• Dead-weight Pressure Gauge<br>• Measurement of Vacuum<br>• Fluid Velocity Measuring Systems | 6th week | 2 |
| **7** | Flow Measurements | • Flow Rate Concepts<br>• Volume Flow Rate Through Velocity Determination<br>• Pressure Differential Meters<br>• Insertion Volume Flow Meters | 7th week | 2 |

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|---|---|---|---|---|
| | | • Mass Flow Meters<br>• Flow Meter Calibration and Standards<br>• Estimating Standard Flow Rate | | |
| **8** | Mid-Term Exam | All previous Topics | 8th week | 2 |
| **9** | Measurement of Strain, Force and Torque | • Measurement of Strain<br>▪ Mechanical Strain Gauges<br>▪ Electrical Strain Gauges<br>▪ Strain Gauge Materials<br>▪ Gauge Factor<br>▪ Theory of Strain Gauges<br>▪ Methods of Strain Measurement<br>▪ Strain Gauge Bridge Arrangement<br>• Measurement of Force: Direct Methods<br>Measurement of Torque | 9th &10th weeks | 4 |
| **10** | Linear and Angular Measurements | • Linear Measurement Instruments<br>▪ Surface Plate<br>▪ V-blocks<br>▪ Graduated Scales<br>▪ Scaled Instruments<br>▪ Vernier Instruments<br>▪ Micrometer Instruments<br>▪ Slip Gauges<br>• Angular Measurement<br>▪ Protractor<br>▪ Sine Bar<br>▪ Angle Gauges | 11th week | 2 |

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| | | ▪ Spirit Level<br>▪ Optical Instruments for Angular | | |
| **11** | Comparators | • Functional Requirements<br>• Classification of Comparators<br>• Mechanical Comparators<br>• Mechanical–Optical Comparator<br>• Electrical Comparators<br>• Pneumatic Comparators | 12th week | 2 |
| **12** | Metrology of Gears and Screw Threads | • Gear Terminology<br>• Errors in Spur Gears<br>• Measurement of Gear Elements<br>• Composite Method of Gear Inspection<br>• Screw Threads Terminology<br>• Measurement of Screw Threads<br>• Thread Gauges | 13th week | 2 |
| **13** | Metrology of Surface Finish | • Surface Metrology Concepts<br>• Surface Metrology Terminology<br>• Analysis of Surface Traces<br>• Specification of Surface Texture Characteristics<br>• Methods of Measuring Surface Finish | 14th week | 2 |
| **14** | Miscellaneous Metrology | • Precision Instrumentation Based on Laser Principles<br>• Coordinate Measuring Machines<br>• Machine Tool Metrology<br>• Automated Inspection | 15th week | 2 |

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|---|---|---|---|---|
| | | • Machine Vision | | |
| **15** | Final Exam | • All Topics | 16th week | 2 |
| **Number of Weeks /and Units Per Semester** | | | **16** | **32** |

## B – Practical aspect:

| Order | Topics List | Week Due | Contact Hours |
|---|---|---|---|
| **1.** | Lab-1 Overview on Measurement Laboratory:<br>• Working Roles and Safety, | 2nd week | 2 |
| **2.** | Lab-2 Measurement Analysis<br>• Calibration and Uncertainty Analysis. | 3rd week | 2 |
| **3.** | Lab-3 Variable Conversion Elements:<br>• Bridge Circuits<br>• Resistance Measurement<br>• Inductance Measurement<br>• Capacitance Measurement<br>• Current Measurement<br>• Phase Measurement | 4th & 5th weeks | 4 |
| **4.** | Lab-4 Data Acquisition with LabVIEW:<br>• Computer-Based Data Acquisition<br>• Software Tools for Laboratory Data Acquisition<br>• National Instruments LabVIEW<br>• Graphical Programming in LabVIEW<br>• Logic Operations in LabVIEW | 6th& 7th weeks | 4 |

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|---|---|---|---|
| | • Loops in LabVIEW<br>• Case Structure in LabVIEW<br>• Data Acquisition Using LabVIEW<br>• LabVIEW Function Generation | | |
| **5.** | Lab-5 Signal Processing with LabVIEW:<br>• Analogue Filters<br>• Digital Filters<br>• LabVIEW Implementation<br>• Simple Filter Solution<br>• Matlab Solution to the Butterworth Filter Design | 8th week | 2 |
| **6.** | Lab-6 Temperature Measurements | 9th week | 2 |
| **7.** | Lab-7 Pressure , Velocity and Flow Measurements | 10th week | 2 |
| **8.** | Lab-8 Strain, Force and Torque Measurements | 11th week | 2 |
| **9.** | Lab-9 Linear and Angular Measurements | 12th week | 2 |
| **10.** | Lab-10 Gears and Screw Threads Measurements | 13th week | 2 |
| **11.** | Lab-11 Surface Finish Measurements | 14th week | 2 |
| **12.** | Final Practical Exam | 15th week | 2 |
| **Number of Weeks /and Units Per Semester** | | **14** | **28** |

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## VI. Teaching strategies of the course:

- Lectures,
- Interactive Class Discussion,
- Laboratory, and
- Projects.

## VII. Assignments:

| No | Assignments | Aligned CILOs(symbols) | Week Due | Mark |
|---|---|---|---|---|
| **1.** | Homework. | a1, a2, a3,b1,b2,c1 | Weekly | 10 |
| **2.** | Lab Reports | a1, a2, a3,b1, b2,c1,c2,d1,d2,d3 | Weekly | 10 |
| **3.** | Mini-Projects Presentation & Report | a1, a2, a3, b1, b2,c1,c2,d1,d2,d3 | 13th week | 10 |
| | **Total** | | | **30** |

## VIII. Schedule of assessment Tasks for Students During the Semester:

| Assessment | Type of assessment Tasks | Week Due | Mark | Proportion of Final assessment |
|---|---|---|---|---|
| 1 | Assignments | Weekly | 30 | 20% |
| 2 | Quizzes | 4$^{th}$ & 11$^{th}$ weeks | 10 | 6.67% |
| 3 | Mid-Term Exam | 8$^{th}$ week | 20 | 13.33% |
| 4 | Final Practical Exam | 15$^{th}$ week | 15 | 10% |
| 5 | Final Exam | 16$^{th}$ week | 75 | 50% |
| **Total** | | | **150** | **100%** |

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## IX. Learning Resources:

**1- Required Textbook(s) (maximum two ).**

1. Alan S. Morris, Reza Langari, 2011, Measurement and Instrumentation Theory and Application, 1st Edition, Elsevier, USA.
2. N.V. Raghavendra L. Krishnamurthy, 2013, Engineering Metrology and Measurements, 1st Edition, Oxford University Press.

**2- Essential References.**

1. Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard, 2006, Mechanical Measurements, 6th Edition, Pearson.
2. Anand K. Bewoor & Vinay A.Kulkarni, 2009, Metrology & Measurement, Tata McGraw Hill Pvt. Ltd., New-Delhi.
3. Alan S. Morris, 2013, Measurement and Instrumentation Principles, 3rd Edition, Butterworth-Heinemann.
4. Morse, Ivan E.; Tse, Francis S, 2018, Measurement and Instrumentation in Engineering: Principles and Basic Laboratory Experiments, 1st Edition, CRC Press.
5. S.P. Venkateshan, 2015, Mechanical Measurements, 2nd Edition, John Wiley & Sons Ltd.
6. Richard S. Figliola, Donald E. Beasley, 2011, n, Theory and Design for Mechanical Measurements, 5th Edition, John Wiley & Sons Ltd.

**3- Electronic Materials and Web Sites *etc*.**

- https://nptel.ac.in/
- https://www.youtube.com/watch?v=uwZGtFRtGoU
- https://www.youtube.com/watch?v=iamxq4Jsimo
- https://www.youtube.com/watch?v=yetXIqoEsn0
- https://www.youtube.com/watch?v=ZwXtPW0gdD0

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## X. Course Policies:

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|---|---|
| 1. | **Class Attendance:**<br>-A student should attend not less than 75 % of total hours of the subject; otherwise he will not be able to take the exam and will be considered as exam failure. If the student is absent due to illness, he/she should bring a proof statement from university Clinic |
| 2. | **Tardy:**<br>- For late in attending the class, the student will be initially notified. If he repeated lateness in attending class he will be considered as absent. |
| 3. | **Exam Attendance/Punctuality:**<br>- A student should attend the exam on time. He is Permitted to attend an exam half one hour from exam beginning, after that he/she will not be permitted to take the exam and he/she will be considered as absent in exam. |
| 4. | **Assignments & Projects:**<br>- The assignment is given to the students after each chapter; the student has to submit all the assignments for checking on time. |
| 5. | **Cheating**:<br>- For cheating in exam, a student will be considered as fail. In case the cheating is repeated three times during his/her study the student will be disengaged from the Faculty. |
| 6. | **Plagiarism**:<br>Plagiarism is the attending of a student the exam of a course instead of another student. If the examination committee proofed a plagiarism of a student, he will be disengaged from the Faculty. The final disengagement of the student from the Faculty should be confirmed from the Student Council Affair of the university. |
| **7.** | **Other policies:**<br>- Mobile phones are not allowed to use during a class lecture. It must be closed, otherwise the student will be asked to leave the lecture room |

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|---|---|
| | - Mobile phones are not allowed in class during the examination.<br>Lecture notes and assignments my given directly to students using soft or hard copy |

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