**University**: Benha University

**Faculty**: Faculty of Engineering at Shoubra

**Department offering the program**: Mechanical Engineering Department

**Department offering the course**: Mechanical Engineering Department

**1- Course Data (Basic Information)**

**Course Code:** MEC201 **Course Title:** Theory of Measurements & Sensors

**Semester/Level:** First/Second **Specialization:** Mechanical Engineering

**Prerequisite Course(s):** -- **Core or Elective**: Core Course

**Teaching Hours: Lecture:** 1 **Tutorial:** 1 **Practical:** 3 **Total:** 5

**2- Course Aims**

This course is designed to introduce the concepts of measurements and measuring instruments. Besides, practical examples and case studies will be presented during the course in which the participants will learn how to read and understand the instruments' specifications, identify major error sources, and carry out measurement uncertainty estimation using statistic process.

**For students undertaking this course, the aims are to:**

* Provide the student with the basic concepts of measurements,
* Provide the student with approaches to solve a measurement problem,
* Describe the main components of a measurement system and their functions,
* Help students to understand steps of the experimental test plan,
* Students should be able to calibrate various measuring instruments,
* Provide the student with static and dynamic characteristics of measuring instruments,
* Provide the student with different types of measurement errors and their sources,
* Students should be able to analyze measurement data statistically,
* Students should be able to do uncertainty analysis,
* Help students to use different measuring instruments.

**3- Course Contents**

**Basic Concepts of Measurement Methods** (Measurement process, Approaches to solve a measurement problem, General measurement system, Variables and parameters, Experimental test plan steps, Calibration, standard and calibration curve, Static Characteristics of Instruments), **Uncertainty Analysis**, **Dynamic Characteristics of Instrument Systems** (Why Dynamic Characteristics of Instruments, Measurement System Model, Zero Order System, First Order System (Step Function Input), First Order System (Periodic function input), Second order System), **Measuring Instruments** (Temperature Standards and Definition, Pressure Measurement, Fluid Velocity Measuring Systems, Flow Rate Concepts, Force Torque power and Stress measurements, Length Displacement and Area measurements)

**4- Program Competences Served by The Course (A1, A2, A5, B1, B4)**

**Level (A) General Engineering Competences**

**A.1** Identify, formulate, and solve complex engineering problems by applying engineering fundamentals, basic science and mathematics.

**A.2** Develop and conduct appropriate experimentation and/or simulation, analyze and interpret data, assess, and evaluate findings, and use statistical analyses and objective engineering judgment to draw conclusions.

**A.5** Practice research techniques and methods of investigation as an inherent part of learning.

**Level (B) Mechanical Engineering Competences**

**B.1** Model, analyze and design physical systems applicable to the specific discipline by applying the concepts of Thermodynamics, Heat Transfer, Fluid Mechanics, solid Mechanics, Material Processing, Material Properties, Measurements, Instrumentation, Control Theory and Systems, Mechanical Design and Analysis, Dynamics, and Vibrations.

**B.4** Adopt suitable national and international standards and codes, integrate legal, economic and financial aspects to design, build, operate, inspect and maintain mechanical equipment and systems.

**5- Learning Outcomes (LO’s)**

*At the end of the course, the student will be able to:*

|  |
| --- |
| **Cognitive Domain** |
| **#LO1** | Explain and design the main component and characteristics of measurement systems. |
| **#LO2** | Understand the steps of the experimental test plan. |
| **#LO3** | Analyze measurement data statistically. |
| **#LO4** | Analyze the uncertainty of the measured/calculated variables/parameters. |
| **#LO5** | Explain the working principles of the measuring devices |
| **Psychomotor Domain** |
| **#LO6** | Select the proper measuring device according to the set static and dynamic characteristics. |
| **Affective Domain** |
|  | None |

**6- Mapping Learning Outcomes (LO’s) with competences**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  **LO’s NARS** | **A1** | **A2** | **A5** | **B1** | **B4** |
| **Cognitive Domain** |
| **#LO1** |  |  | ◼ | ◼ |  |
| **#LO2** |  | ◼ |  |  |  |
| **#LO3** | ◼ | ◼ |  |  |  |
| **#LO4** | ◼ |  |  |  |  |
| **#LO5** |  |  | ◼ |  |  |
| **Psychomotor Domain** |
| **#LO6** |  |  |  |  | ◼ |
| **Affective Domain** |
|  |  |  |  |  |  |

**7- Lecture Plan**

Topics to be Covered weekly & Matrix of LO’s

| **Week** | **Topics** | **Planned****Hours** | **Learning Outcomes** |
| --- | --- | --- | --- |
| **LO1-1****A5** | **LO1-2****B1** | **LO2****A2** | **LO3-1****A1** | **LO3-2****A2** | **LO4****A1** | **LO5****A5** | **LO6****B4** |
| W1 | ***Basic Concepts of Measurement Methods:**** Measurement process
* Approaches to solve a measurement problem.
* General measurement system
* Variables and parameters
* Experimental test plan steps
* Calibration, standard and calibration curve
 | **5** | **◼** | **◼** | **◼** |  | **◼** |  |  |  |
| W2 | ***Static Characteristics of Instruments*** * Linearity
* Sensitivity
* Measurement Error and Its Types
* Rang and Span
* Resolution
* Accuracy
* Precision
 | **5** | **◼** | **◼** | **◼** |  |  |  |  |  |
| W3 | ***Static Characteristics of Instruments*** * Mean Reading
* Deviation
* Uncertainty
* Instrument Uncertainty
* Statistical Analysis of Measurement Data
 | **5** | **◼** | **◼** | **◼** | **◼** | **◼** |  |  | **◼** |
| W4 | ***Uncertainty Analysis**** Kline and McClintock Method
* Special Solution for Product Functions
* Special Solution for Additive Functions
 | **5** |  |  | **◼** | **◼** | **◼** | **◼** |  | **◼** |
| W5 | ***Dynamic Characteristics of Instrument Systems*** * Why Dynamic Characteristics of Instruments
* Measurement System Model
* Zero Order System
* First Order System (Step Function Input)
* Behavior
* Time Constant
* Rise Time
* First Order System (Periodic function input)
* Behavior
* Time Lag & Phase Shift
* Dynamic Error
* Magnitude Ratio
 | **5** |  |  | **◼** | **◼** |  |  |  | **◼** |
| W6 | ***Dynamic Characteristics of Instrument Systems*** * Second order System
* Behavior
* Time Lag & Phase Shift
* Dynamic Error
* Settling Time
* Peak Time
 | **5** |  |  | **◼** | **◼** |  |  |  | **◼** |
| W8 | ***Measuring Instruments**** Temperature Measuring Instruments
* Basic Concepts of Temperature
* Measuring Temperature (Mechanical Methods)
* Liquid-in-Glass Thermometer
* Bimetallic Strip Thermometer
* Filled Bulb Thermometer
* Measuring Temperature (Electrical Methods)
* Thermocouple
* Resistance Temperature Detector (RTD)
* Thermistor
 | **5** | **◼** | **◼** | **◼** |  |  |  | **◼** | **◼** |
| W9 | ***Measuring Instruments**** Pressure Measuring Instruments
* Basic Concepts of Pressure
* Measuring Pressure (Mechanical Methods)
* Deadweight Tester
* Manometer Method
* Elastic Pressure Transducers
 | **5** | **◼** | **◼** | **◼** |  |  |  | **◼** | **◼** |
| W10 | ***Measuring Instruments**** Pressure Measuring Instruments
* Measuring Pressure (Electrical Methods)
* Strain Gauge Pressure Transducers
* Potentiometer Pressure Transducers
* Capacitive Pressure Transducers
* Resonant Wire Pressure Transducers
* Piezeoelectric Pressure Transducers
 | **5** | **◼** | **◼** | **◼** |  |  |  | **◼** | **◼** |
| W11 | ***Measuring Instruments**** Flow Measuring Instruments
* Basic Concepts of Fluid and Fluid Flow Rate
* Types of Flow Measurement
* Direct Rate Measurement
* Indirect Rate Measurement
 | **5** | **◼** | **◼** | **◼** |  |  |  | **◼** | **◼** |
| W12 | ***Measuring Instruments**** Flow Measuring Instruments
* Indirect Rate Measurement
* Orifice Meter
* Venturi Meter
* Flow Nozzle
* Pitot Tube
 | **5** | **◼** | **◼** | **◼** |  |  |  | **◼** | **◼** |
| W13 | ***Measuring Instruments**** Flow Measuring Instruments
* Indirect Rate Measurement
* Variable Area Flow Meters
* Rotameter
* Movable Vane
* Velocity Type Flow Meters
* Turbine
* Magnetic
* Ultrasonic
* Mass Type Flow Meters
* Thermal
* Coriolis
 | **5** | **◼** | **◼** | **◼** |  |  |  | **◼** | **◼** |
| W14 | **Oral Exam** |  |  |  |  |  |  |  |  |  |

**8) Teaching and Learning Methods**

8.1 Lectures

8.2 Tutorial problem session

8.3 Class activity

8.4 Case study

8.5 Assignments/homework

8.6 Brainstorming

| **Learning Outcomes** | **Teaching and Learning Methods** |
| --- | --- |
| Face-to-face Lecture | Tutorial / Exercise | Class activity | Case study | Assignments/homework | Brainstorming  |
| **Cognitive Domain** | LO1 | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |
| LO2 | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |
| LO3 | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |
| LO4 | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |
| LO5 | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |
| **Psychomotor Domain** | LO6 | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |

**Student Academic Counseling and Support**

* Students are directed to contact teaching staff for academic support during specific office hours.
* Regarding this course, Instructor and TA will be available two hours a week as indicated on the timetable declared for students from the beginning of the semester.
* A Telegram group as well as the course site on the University Management Learning System are created where students can ask questions and share files with teaching staff. Moreover, these groups are used to announce the student marks, changes to the timetable, exam days …etc.

**9- Student Assessment**

**a) Student Assessment Methods**

| **Learning Outcomes** | **Assessment Methods\*** |
| --- | --- |
| Written Exams | Online Exams | Oral Exam | Pop Quizzes |  In-class Problem Solving | Take-Home Exam | Research Assignments | Reporting Assignments | Project Assignments | In-class Questions |
| **Cognitive Domain** | LO1 | **◼** |  | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |  | **◼** |
| LO2 | **◼** |  | **◼** | **◼** | **◼** | **◼** | **◼** |  |  | **◼** |
| LO3 | **◼** |  | **◼** | **◼** | **◼** | **◼** | **◼** |  |  | **◼** |
| LO4 | **◼** |  | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |  | **◼** |
| LO5 | **◼** |  | **◼** | **◼** | **◼** | **◼** | **◼** |  | **◼** | **◼** |
| **Psychomotor Domain** | LO6 | **◼** |  | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** | **◼** |
|  |  |  |  |  |  |  |  |  |  |  |  |

\*There is one formative assessment (Writing Exam), and all other assessments are summative.

**b- Assessment Schedule and Weight**

|  |  |  |
| --- | --- | --- |
| **Assessment Tools** | **Week** | **Weight** |
| Midterm Examination | 7 | 20% |
| Oral Examination | 14 | 20% |
| Final Examination | (As Scheduled) | 50% |
| Reports (#2) | 1, 4 | 1.3% |
| Quizzes (#2) | 2, 8 | 1.3% |
| Home assignments | 1, 2, 4, 5, 8, 9, 11 | 3.3% |
| Project Assignments | 11 | 4.0% |
| **Total** |  | **100 %** |

**10- Facilities**

The following facilities are needed for this course:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ■ | Classroom | □ | Smart Board | □ | Computer with software |
| ■ | Lecture Hall | ■ | White Board | □ | MIS system |
| ■ | Sound and Microphone | ■ | Data Show | □ | Internet Access |
| ■ | Measurement Lab. |  |  |  |  |

**11- List of References**

**a- Course Notes**

Course notes prepared by instructors.

**b- Books**

1. Richard S. Figliola and Clemson University, “Theory and Design for Mechanical Measurements”, 5th edition, John Wiley & Sons, Inc., 2011.
2. Alan S. Morris, “Measurement and Instrumentation Principles”, 3rd edition, Alan S. Morris, 2001.

**- Course Coordinator: Assoc. Prof. Dr. Mohamed Reda Salem Signature:**

**- Program Coordinator: Assoc. Prof. Dr. Mohamed Reda Salem Signature:**

**- Head of Mechanical Department: Prof. Dr. Sameh Shawky Habib Signature:**