ABEN 482/682: Instrumentation & Measurements
3 credits, Spring 2024

Meets in **Ladd Hall 201** & **GHILL 228** on MW 9:00-9:50 AM (Lecture) & TH 2:00 – 4:50 PM (Laboratory)

Instructor and contact information:
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Bulletin description:
Application of instrumentation and sensor concepts to measurement and control of environmental, biological, and mechanical parameters. Includes sensor principles, signal conditioning, data collection, and data analysis methods. 2 lectures, 1 three-hour laboratory. Prerequisites: PHYS 252. S (or ECE 301 or EE 206)

Course objectives:
After completing the course, the students will be able to:
1) design an experiment, conduct the experiment, collect experimental data, analyze the collected data, and draw conclusions from the analyzed data (ABET 6) - [A, student outcome 6 (Table 1)]
2) understand the use of equipment to measure and record data (ABET 6) - [A, student outcome 6 (Table 1)]
3) apply engineering knowledge of statics, the strength of materials, fluids, and electricity to understand their experiments (ABET 1) - [A, student learning outcome 1 (Table 1)]
4) communicate acquired information professionally (ABET 3) [B, Student outcome 3 (Table 1)]
5) understand basic principles of control systems and programmable control units (in the example of Arduino), (ABET 1) - [A, student learning outcome 1 (Table 1)].

Companies hire engineers to solve problems. Testing and measurement are complex issues that require fundamental and hands-on skills to work with various sensors, data loggers, and data acquisition and processing. An understanding of the fundamental principles of sensors and analog-to-digital and digital-to-analog converters can help you understand the operational principles of sensors and data acquisition tools.

Table 1. ABEN program educational objectives and supporting student outcomes. *****

Graduates are expected to have established themselves as practicing engineers who, within a few years of graduation:	
A	Successfully address emerging engineering challenges in the design or evaluation of machine systems, processing systems, and natural resources and environmental systems affecting the production of food, feed, and other biobased products.

	Technical learning outcomes include student outcomes (1), (2), and (6): 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (a, e)† 2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (c) 6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (b)
B	Effectively use professional communication, critical thinking, and interpersonal skills as team leaders and team members. Communicational learning outcomes include student outcomes (3) and (5): 3. an ability to communicate effectively with a range of audiences (g) 5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (d)
C	Responsibly serve the public and their employers by participating in professional development and by maintaining the highest standard of professional ethics. Contextual learning outcomes include student outcomes (4) and (7): 4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (f, h, j) 7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies (i)

***** See https://www.ndsu.edu/aben/about/abet_accredited/ for the current ABEN program educational objectives. See https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/ for information on ABET student outcomes 1-7, effective as part of the "Criteria for Accrediting Engineering Programs, 2021-2022."

† ABET student outcomes (a) – (k) from the previous review cycle are included for cross-referencing only. Former student outcome (k) is implied in (1), (2), and (6).

Note: The table shows how the course contributes to program outcomes, and how assessment is carried out to continually improve the course. The course is estimated to consist of 2 credits of "Instrumentation and data analysis" and 1 credit of "experimentation."

Required student resources:

Students are expected to have daily access to the course Blackboard website for access to course announcements, assignments, and projects, including online sources, and other reading materials. **A personal computer (laptop) with MATLAB/Simulink installed is needed.**

Useful resources are:

(1) Wheeler, A. J., Ganji, A. R., 1996. Introduction to Engineering Experimentation. Simon & Schuster, Upper Saddle River, NJ.

(2) Morris, A. S., Langari, R., 2020. Measurement and Instrumentation: Theory and Application, 3rd Edition.
(3) Eshkabilov, S. L., 2022. Beginning MATLAB and Simulink. From Beginner to Pro. Apress // Springer. 2nd Edition.

Assignment Overview and Policy

- **About 10 in-class unannounced pop-up quizzes** based on in-class covered materials, reading assignments, and self-study exercises. Out of 10 quizzes, **randomly chosen 5 quizzes** will be graded. **No make-up** quizzes are allowed, except for a prior justification and approval of the instructor at least **24 hours** before the class.
- **About 10 homework assignments** based on in-class covered materials and self-study exercises. Out of 10 assignments, **randomly chosen 5 assignments** will be graded. **No make-up** homework assignments are allowed, except for a prior justification and approval of the instructor at least **24 hours** before the class.
- **About 10 lab reports** based on the learned outcomes from the guest speaker presentations, industry visits, and collected data from the laboratory materials. Lab reports of graduate students will be of a higher standard than the ones of undergraduate students.
- **Tests**. There will be two in-class tests: **Test 1** on Week 6 and **Test 2** on Week 12/13. Before tests, there will be pre-test reviews of the questions included in Tests. For a **make-up exam**, the instructor's approval for any excusable justification at least 48 hours before the test date is needed as described in NDSU policy 333: https://www.ndsu.edu/fileadmin/policy/333.pdf
- **One team project (a project report) and presentation** for undergraduate students **(ABEN482)**
- **One individual project (with a project report), presentation, and one 7-page long research paper** for graduate students (**ABEN 682**).
- **Self-study homework** assignments based on covered and additional learning materials.
- **Due dates** for assignments and lab reports will be announced with the assignments. Late assignments will be accepted with a 10% penalty per NDSU class day, but will not be accepted after solutions are posted/handed out/discussed in class.
- **Attendance is mandatory.** A prior justification and approval of the instructor at least **24 hours** before the class is required to get an excuse.
- **Active participation** during in-class discussions is strongly encouraged. Note that you will earn extra credits by actively participating in class discussions.

Table 2. Course Outline* (Tentative):

Week	Topics/Events
Week 1: 01/08 -01/12	Course introduction, syllabus, policy, and assignments. Introduction to Instrumentation and Measurement.

	Computer Lab Exercises: MATLAB Environment and Programming Essentials
Week 2: 01/15-01/19	**Unit 1.** Applications of Engineering Experimentation and Measurement. Basic concepts, Units, Tools **Laboratory # 1.** MATLAB Programming Exercises – Part 1. Matrices, Arrays, Tables, Math Operations, Statistical Analysis
Week 3: 01/22-01/26	**Unit 2.** General Characteristics of Measurement Systems. Statistical Analysis of Experimental Data. **Laboratory # 2.** MATLAB Programming Exercises – Part 2. Data Import, Visualization, and Regression Analysis Exercises in MATLAB
Week 4: 01/29-02/02	**Unit 3.** Correlation of Experimental Data: Curve Fitting and Least Squares Criterion. Data Sampling and Filtering. Fourier Series. **Laboratory # 3.** Multimeters. Circuits
Week 5: 02/05-02/09	**Unit 4.** Analog-to-Digital (AD) and Digital-to-Analog (DA) converters. Analog and Digital Signal Measurement Instruments. **Laboratory # 4.** Arduino IDE - Temperature and Humidity (Moisture) Measurement. Thermocouples, RTDs, thermistors, etc.
Week 6: 02/12-02/16	**Unit 5.** Analog and Digital Signal Measurement Instruments. Data Acquisition System. Measurement sampling time or sampling frequency Review of week 1-5 materials: **Test 1**
Week 7: 02/19-02/23	**Unit 5.** Analog and Digital Sensors. AD and DA conversion. Uncertainty in Measurements. Errors. **Laboratory # 5.** Potentiometer and Voltage
Week 8: 02/26-03/02	**Unit 6.** Uncertainty in Measurements. Errors. Calibration of Sensors **Laboratory # 6.** Measure Light Intensity. Measure H-beat
Week 9: 03/04-03/08	Spring Break
Week 10: 03/11-03/15	**Unit 7.** Errors. Calibration of Sensors **Laboratory # 7.** Soil/Grain Moisture Level Meter
Week 11: 03/18-03/22	**Unit 8.** Data Acquisition with different systems: Arduino IDE, MATLAB, LabVIEW. Measurement of Solid-Mechanical Quantities. Strain Gages. **Laboratory # 8.** Measure Sound and Loudness Assessment
Week 12: 03/25 – 03/29	**Unit 9.** Review of week 6-11: **Test 2**
Week 13: 04/01 – 04/05	**Unit 10.** Measurement of Solid-Mechanical Quantities. Strain Gages **Laboratory # 9.** Strain Gages. Weight Scale Design
Week 14: 04/08 -04/12	**Unit 10.** Measurement of Solid-Mechanical Quantities. Measuring Strain, Displacement, Velocity, Acceleration, Force, Pressure **Laboratory # 10.** Flow Meter
Week 15: 04/15-04/19	**Unit 11.** Signal Processing. Low- and High-pass Analog and Digital Filters **Laboratory (# 11).** Building Analog Low-pass and High-pass filters
Week 16: 04/22-04/26	**Unit 12.** Signal Processing. Low-pass and High-pass Analog and Digital Filters

	Laboratory (# 12). Wireless Measurement. Humidity. Temperature. Light
Week 17: 04/29-05/03	**Unit 13.** Wireless Communication and Measurement **Laboratory (# 13).** Wireless Measurement. Acceleration. Gyroscope. Pressure
Week 18: 05/06-05/10	Project presentation

Disclaimer

The course outline is subject to change.

Grade Distribution: ABEN 482

Your grade in this course will be based on the following point breakdown.

Assessment	Number	Point Value	Total Points
Quiz	10 (5 graded)	1	5
Homework	10 (5 graded)	1	5
Test 1	1	15	15
Test 2	1	15	15
Laboratory Report	10	2.5	25
Project Report	1	25	25
Project Presentation	1	5	5
Attendance	1	5	5
Total Course Points			**100**

Grade Distribution: ABEN682

Your grade in this course will be based on the following point breakdown.

Assessment	Number	Point Value	Total Points
Quiz	10 (5 graded)	1	5
Homework	10 (5 graded)	1	5
Test 1	1	15	15
Test 2	1	15	15
Laboratory Report	10	2.5	25
Project Report	1	10	10
Research Paper	1	15	15
Project Presentation	1	5	5
Attendance	1	5	5

Total Course Points	100

Grades will follow the standard NDSU grading scale:
A: 100-90% B: 80-89% C: 70-79% D: 60-69% F: <60%

Attendance: According to NDSU policy 333 - https://www.ndsu.edu/fileadmin/policy/333.pdf, attendance in classes is expected. *Your attendance and full participation is expected,* through classroom discussions, volunteering answers to questions, asking appropriate questions, thoughtful evaluation of a team oral presentation, evaluating team members' participation in projects, and by helping to create a spirit of cooperation within the class. The mode of instruction is face-to-face. You are required to attend lectures, projects, and lab demonstrations in-person. However, there will be a Zoom option for lectures only if you get sick and need to quarantine because of COVID. You must notify me at least an hour before class because I expect to see you in person, especially during project demonstrations.

Students who exceed two absences for the semester should provide documentation of a valid excuse, such as from a medical professional or advisor of an NDSU student organization, to avoid a grade penalty of ***2 points per unexcused absence****.*

Students with Special Needs and/or Circumstances: Any students with disabilities or other special needs, who need special accommodations in this course are invited to share these concerns or requests with the instructor and contact the Disability Services Office as soon as possible. Recorded lectures will be made available. Veterans and student soldiers with special circumstances or who are activated are encouraged to notify the instructor in advance.

COE Honor Pledge: "On my honor I will not give nor receive unauthorized assistance in completing assignments and work submitted for review or assessment. Furthermore, I understand the requirements in the College of Engineering Honor System and accept the responsibility I have to complete all my work with complete integrity. Students who are suspected of academic dishonesty may not withdraw from the course in which dishonesty is suspected while the case is under review by the Honor Commission (NDSU Policy 335, 5b)."

Last updated: August 19, 2021