BIEN 3420 Biosensors and Bioinstrumentation for Healthcare

Lecture: WeFR 1:30 PM – 2:50 PM in 5583
Tutorial: Th 9:30 AM – 10:20 AM in G009A, CYT

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Course Description

This course offers an introduction to the sensors and devices used to monitor human health. We will begin by exploring how our bodies generate basic biosignals and how different technologies capture them. You will be introduced to the essential components of the critical medical instruments, from those in hospitals to the point-of-care and wearable devices (like smartwatches and rapid test kits) that are changing how we manage health. The goal is to build a strong foundational understanding of these technologies and prepare you for future studies and careers in the dynamic field of biomedical engineering and health tech.

Textbook (recommended, not required)

Medical Instrumentation: Application and Design by John G. Webster

Prerequisites

This course covers diverse disciplines. Students are expected to have introductory knowledge of bioengineering and chemistry. BIEN 1600

Course Objectives

As a result of this course, students will be able to

- Explain the fundamental principles of how physical, optical, and chemical biosensors capture physiological signals.
- Describe the operating mechanism behind common diagnostic devices, from ECG monitors to glucose meters and rapid tests.
- Connect the underlying physics and chemistry of sensing to real-world clinical and consumer health applications.

Grade Breakdown

- Homework (4) – 5 % each
- Midterm exam (1) – 25 %
- Group project (1) – 20 %
- Final exam – 35 %

Teaching schedule

The tentative lecture schedule is given below and subject to change at the instructor's discretion.

Week	Date	Topic	Tasks
1	4-Feb	Introduction to diagnostics in healthcare	
	6-Feb	How biosensors "sense"	
2	11-Feb	Origins of bioelectric signals	
	13-Feb	Electrodes and interface	
3	18-Feb	Holiday	
	20-Feb	ECG: Principles, Leads & Volume Conductor	
4	25-Feb	Other common bioelectric signals	HW 1 out
	27-Feb	Blood pressure monitors	
5	4-Mar	Respiratory mechanics & sensors	HW 1 due
	6-Mar	Spirometry & Impedance Pneumography	
6	11-Mar**	No class (A make-up class will be held during tutorial session on April 9th.)	
	13-Mar	Light-matter interaction and pulse oximetry	
7	18-Mar	Chemical sensor foundations	HW 2 out
	20-Mar	Potentiometry & ion-selective electrodes (ISE)	
8	25-Mar	Amperometry & voltammetry	HW 2 due
	27-Mar	Biosensor architecture	
9	1-Apr	Mid-term	HW 3 out
	3-Apr	Holiday	
10	9-Apr**	Blood glucose monitors (This is tutorial session time.)	
	10-Apr	Key metrics in sensors	HW 3 due
11	15-Apr	Immunosensors	
	17-Apr	Key platforms (ELISA, SPR, Lateral flow)	
12	22-Apr	Standards and regulation (FDA, ISO)	HW 4 out
	24-Apr	Bringing a device to market	
13	29-Apr	Modern biosensors	HW 4 due
	1-May	Holiday	
14	6-May	Presentations	All materials due at noon
	8-May	Presentations	
	TBD	Final exam	

Homework

Homework are due via Canvas. You will be given a week from the date assigned to complete them. NO late submission is allowed unless prior arrangements are made with the instructor for valid excuses.

You may work in a small group, yet you should submit your individual homework that is written in your own words. Verbatim copying of other students' solutions or of external sources or AI are acts of plagiarism and are strictly NOT allowed.

Mid-term

There will be NO makeup exams. If you have a valid reason for missing the exam, you should talk to the instructor at the earliest possible. Request on or beyond the exam date will not be accommodated.

Final

Final will be a comprehensive exam covering all the contents taught in the course.

Final Project

Each group (2-4) will be assigned one biosensor sensor topic through a random draw (held in class or via an online randomizer). You cannot change your assigned topic. This encourages you to explore new areas and apply what you've learned throughout the semester.
The goal is to become an "expert" on your assigned sensor by deeply researching how it works from first principles to real-world use. You will explain the science behind it, how the signal is generated and captured, and how it is turned into a useful readout.
You will need to submit the followings for the project.
Concise 1-page summary (Times new roman, single spacing, + a 15-minute presentation containing:

- Introduction to the sensor (you are assigned): real-world application, importance in healthcare/biomedical engineering.
- Biophysical/chemical principle of signal generation: core biological/chemical/physical event producing the signal, step-by-step mechanism, key equations (e.g., Nernst, Beer-Lambert, Michaelis-Menten), and supporting diagrams (ion flows, reaction schemes, light paths).
- Key transduction mechanism: how the biological/chemical event is converted into a measurable signal (electrical current/voltage, optical intensity, impedance change, etc.), explained step-by-step.
- Main materials and design choices + why they are used: primary materials (e.g., electrode type, membrane, enzyme), key design features (e.g., immobilization method, geometry, coating), and reasoned explanations for each choice (performance benefits, stability, selectivity, biocompatibility, cost, manufacturability, interference reduction) — include diagrams/photos and 1–2 comparisons if helpful.
- Signal acquisition chain: full pathway from sensor output to readout (pre-amplification/conditioning, filtering, noise/artifacts handling, ADC requirements like sampling rate/resolution).
- Commercial implementations: 2–3 real devices/products using this sensor (names, manufacturers), with comparison of key specs (accuracy, range, response time), strengths, limitations, and approximate cost/market positioning.
- Critical analysis & future directions: performance limits (LOD, sensitivity, selectivity, interference, drift, calibration needs), main drawbacks, and potential improvements (new materials, miniaturization, wireless integration, AI, etc.).

Re-grading policy

If you would like to request a re-grade, you will need to do the followings or you will not receive a response.
You will need to submit a written request to the instructor (and cc'd TAs) containing

- Name, student ID
- Assignment/exam in question, problem number in question
- A written description of the suspected mis-grading. You should clearly state the valid reasons for needing a re-grade.

- Your original assignment/exam

Simple fixes such as addition errors will be rectified immediately.
Upon your submission of re-grading request, instructor may reject or completely re-grade the entire question. This can result in lowering or increasing your grade. Results of the re-grading will be final.

Cheating and Plagiarism

Academic integrity and honesty are the key values at HKUST. All students should uphold the Academic Honor Code.
The course has zero tolerance policy to cheating and plagiarism. Students caught cheating will receive a failing grade.

Note: There will be no video recordings available for the course.