Fundamentals & Applications of Biomedical Microdevices & Sensors
Ph.D. Student Qualifying Exam

Issued: ***February 12 at 0800***
Return Completed Exam to mdaniel6@ncsu.edu By: ***February 15 at 0800***
Expected Time It Will Take to Complete the Exam: ***3 hrs.***

No matter what area of biomedical engineering you plan to pursue, being able to measure changes in biomolecules, biomaterials, and living systems is essential. Different types of measurements provide data that can be used to identify or measure change in biological systems. If you want to ask a question about a biological system, it is not only important to know which standard techniques you should use to measure parameters of interest, but it is necessary to know what the limitations of the technique are, and how to engineer better systems to make the desired measurement. This exam will focus on the critical analysis of devices and systems used to measure both chemical and physical signals from the human body.

Goals and Learning Objectives:

- Demonstrate fundamental understanding of biochemical recognition of biomolecules, transduction of biochemical events, physical transduction of biological signals, and electronic systems for amplification and processing of biological signals, ***as applied to relevant biomedical systems***.
- Identify the advantages and disadvantages of different sensing strategies.
- Integrate engineering principles into the design of biomedical microdevices and sensors.

Format:

- Combination of multiple choice and short answer questions.
- Student may use all resources for completion.
- Students must work individually.
- Exam must be submitted as a PDF named: “LastName_Qualifer_Feb2021”

Topics Covered:

- Principles of molecular recognition, structure of enzyme and antibody, as applied to different types of immunosensors and lateral flow assays.
- Principles of electrochemistry, as applied to electrodes, amperometric sensors, and potentiometric sensors.
- Principles of optical sensing, as applied to pulse oximetry and photoplethysmography.
- Principles of electrical signal amplification, and processing, as applied to tissue-electrode-electrolyte interfaces, pacemakers, cochlear implants, and acoustic aids.
- System level characterization, including determination of performance parameters such as throughput, detection limit, signal-to-noise ratio, and sensitivity.

Resources:

1. Altintas, Zeynep, ed. *Biosensors and Nanotechnology: Applications in Health Care Diagnostics*. John Wiley & Sons, 2017.
2. Zhang, Xueji, Huangxian Ju, and Joseph Wang, eds. *Electrochemical sensors, biosensors and their biomedical applications*. Academic Press, 2011.
3. Webster, John G. *Medical instrumentation application and design*. John Wiley & Sons, 2009.
4. *McAdams, Eric. "Bioelectrodes." Encyclopedia of Medical Devices and Instr. (2006).*
5. Wang, J. "Electrochemical glucose biosensors." Chemical Reviews 108.2 (2008): 814-825.
6. *Zhao, M., Gao, Y., Sun, J. and Gao, F., 2015. Mediatorless glucose biosensor and direct electron transfer type glucose/air biofuel cell enabled with carbon nanodots. Analytical Chemistry, 87(5), pp.2615-2622.*
7. *Lochner, Claire M., Yasser Khan, Adrien Pierre, and Ana C. Arias. "All-organic optoelectronic sensor for pulse oximetry." Nature communications 5, no. 1 (2014): 1-7.*
8. *Posthuma-Trumpie, Geertruida A., Jakob Korf, and Aart van Amerongen. "Lateral flow (immuno) assay: its strengths, weaknesses, opportunities and threats. A* literature survey." Analytical and bioanalytical chemistry 393.2 (2009): 569-582.
9. Justino, Celine IL, Teresa A. Rocha-Santos, and Armando C. Duarte. "Review of analytical figures of merit of sensors and biosensors in clinical applications." TrAC Trends in Analytical Chemistry 29.10 (2010): 1172-1183.
10. Reboud, Julien, Gaolian Xu, Alice Garrett, Moses Adriko, Zhugen Yang, Edridah M. Tukahebwa, Candia Rowell, and Jonathan M. Cooper. "Paper-based microfluidics for DNA diagnostics of malaria in low resource underserved rural communities." Proceedings of the National Academy of Sciences 116, no. 11 (2019): 4834-4842.

*** Resources 1-5 are fundamental overviews that should be used a refresher of basic knowledge. Resources 6-10 should be read and understood in full.

*** Students may wish to do additional reading that reinforces their understanding of the systems, techniques, and approaches described above.