**Fundamentals & Applications of Biomedical Microdevices & Sensors**

*Ph.D. Student Qualifying Exam*

*Date; Time:* ***July 12, 2024; 1000 EDT***

*Expected Time It Will Take to Complete the Exam:* ***2 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. Distinct 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 which indicate physiological or pathophysiological changes in the human body.

*Goals and Learning Objectives:*

* Demonstrate fundamental understanding of sample processing, 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 technologies***
* Identify the advantages and disadvantages of different sensing strategies.
* Integrate engineering principles into the design of biomedical microdevices and sensors.
* 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.

*Format:*

* Combination of multiple choice and short answer questions.
* Students may use all non-electronic resources for completion.
* Students must work individually.
* Students should be prepared to select 2 of the technologies below to answer questions about their fundamental operation, limitations, and analysis of their performance.

*Technologies to be Covered:*

* Lateral Flow Assays
* Glucose Meters & Electrochemical Assays
* Photoplethysmography and Pulse Oximetry
* Microfluidics
* Immunosensors & Immunoassays
* Microelectromechanical Systems (MEMS)
* Optical & Fluorometric Point-of-Care Sensors

*Resources:*

1. Altintas, Zeynep, ed. Biosensors and Nanotechnology: Applications in Health Care Diagnostics. John Wiley & Sons, 2017.
2. Wild, David, ed. The Immunoassay Handbook: Theory and Applications of Ligand Binding, ELISA and Related Techniques, Elsevier, 2013.
3. Squires, Todd M., and Stephen R. Quake. "Microfluidics: Fluid physics at the nanoliter scale." Reviews of Modern Physics 77, no. 3 (2005): 977.
4. Cunningham, D. D., & Stenken, J. A. (Eds.). (2009). In vivo glucose sensing. John Wiley & Sons.
5. Kyriacou, Panicos A., and John Allen, eds. Photoplethysmography: technology, signal analysis and applications. Academic Press, 2021.
6. Carrell, Cody, Alyssa Kava, Michael Nguyen, Ruth Menger, Zarina Munshi, Zachary Call, Mark Nussbaum, and Charles Henry. "Beyond the lateral flow assay: A review of paper-based microfluidics." Microelectronic engineering 206 (2019): 45-54.
7. 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.
8. Dijksma, M., Kamp, B., Hoogvliet, J.C. and Van Bennekom, W.P., 2001. Development of an electrochemical immunosensor for direct detection of interferon-γ at the attomolar level. *Analytical Chemistry*, *73*(5), pp.901-907.
9. Megalathan, A., Wijesinghe, K.M. and Dhakal, S., 2021. Single-molecule FRET-based dynamic DNA sensor. ACS sensors, 6(3), pp.1367-1374.
10. Dickert, F. L., Hayden, O., Bindeus, R., Mann, K. J., Blaas, D., & Waigmann, E. (2004). Bioimprinted QCM sensors for virus detection—screening of plant sap. Analytical and bioanalytical chemistry, 378, 1929-1934.

\*\*\* Resources 1-5 are fundamental overviews that should be used as a refresher of basic knowledge. Resources 6-10 are provided as suggested reading.

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