Introduction to Fields and Electric Discharges in Medicine and Biology

This course sequence is designed for learning about connections between electric fields, electric discharges (plasma) and magnetic fields with many areas of biology and modern medicine. Electric fields play a critical role in determining the behavior of cells including cells associated with our nervous system, muscles, bones and other tissues. They have been used for decades to transfer genetic material across cell membranes, for example. Electric discharges (plasma), besides being valuable tools in modern surgical practice, are now being investigated for various subtle effects on tissues including tumor reduction in some cases and faster wound healing in others. Magnetic fields are playing a critical role in medical imaging (MRI) and, in conjunction with magnetic nanoparticles are being investigated for cell and drug delivery in the body. In certain diseases, such as malaria, magnetic particles naturally accumulating within malaria parasites, are important for disease detection and are being investigated as a natural target for treatment. Transcranial magnetic stimulation of the brain appears to offer promise for treatment of epilepsy, psychological disorders and even learning disabilities.

Despite the importance of electric fields, electric discharges and magnetic fields in biology as well as significant research and commercial activity in this field, engineering and biomedical students learn too little about this area in their regular classes. This course is designed to remedy this situation at least partly. The course material will contain 3 critical parts:

- Review of fundamentals: electric fields, electric discharges, magnetic fields, basic statistical thermodynamics, basic biochemistry and cell biology including roles of oxygen radicals and examples of bio-molecular cell behavior regulation pathways, and basic physiology. The review material is meant to make this class as self-contained as possible.
- Electric fields and discharges in biology and medicine: electric fields across cell membranes (various membranes within cells and around them) and their natural regulation, voltage dependent channels, electroporation, nerve cell models and behavior, electrical properties of tissues at various frequencies, effects of radicals and oxidative species produced by plasma and ionizing radiation on extracellular biomolecules, effects of electric fields and plasmas on cell migration, wound healing, cell proliferation and apoptosis.
- Magnetic fields in biology and medicine: introduction to nuclear and electron paramagnetic magnetic resonance and magnetic resonance imaging, magnetic nano- and microparticles, magnetic nanoparticle labeling technology and its applications in biotechnology, separation of cells in diagnostic and treatment applications, magnetically targeted delivery of cells and drugs in the body, magnetic particle imaging in medicine.

This course will not cover the use of light (infrared, visible or UV) in medicine and biology as this topic by itself is rather broad. The areas of 1) *electric fields and discharges* and 2) *magnetic fields* will be treated *in two separate courses* that are part

of the same sequence. A third course in the sequence might focus on small projects and current research topics. The review material will be introduced throughout the sequence as needed. At the moment, no book has been selected for the courses as there seems to be no texts covering the entire material and providing an appropriate review. Knowledge of basic biology, basic electricity and magnetism and basic linear systems theory including Fourier transform is required to enlist in this sequence. No course with similar content exists in the university.