MEDICAL PHYSICS 401

Intermediate Physics of Medicine and Biology

Instructors: Ernest Madsen, Ronald Wakai and Richard Frayne
Prerequisites: Physics 201 and 202 or Physics 207 and 208
Frequency of offering: spring semester, 3 lecture hours per week
Text: Intermediate Physics for Medicine and Biology (3rd Edition) by Russell Hobbie, Springer 1997 (copies in Medical Physics library, room 1530 MSC; hours, 8:00AM-4:30PM, M-F)

SYLLABUS

1. Rigid body mechanics of the musculo-skeletal system (2 lectures)
   a. Forces on the foot
   b. Forces on the hip with or without a cane

2. Physics of fluids (3 lectures)
   a. Review of definitions and principles of fluid statics
   b. Fluid dynamics -- reference: Life in Moving Fluids by Steven Vogel
      i. Bernoulli's law and its limitations
      ii. Viscosity and shear forces, laminar flow, parabolic flow, entrance region, Poiseuille's law, flow in large blood vessels
      iii. Turbulent flow: Reynolds number, drag forces, modelling, flow through pipes, entrance length, the converging aorta
      iv. Physics of the centrifuge

3. Transport in an infinite medium (5 lectures)
   a. Fick's first and second laws of diffusion
   b. The Einstein-Stokes relation between diffusion coefficient, temperature, viscosity and solute particle size
   c. Applications to nutrient and waste transport for a single cell
   d. General solution of Fick's second law in 3-D for an infinite homogeneous medium -- application to injection via needle
   e. Diffusion as random walk in 3-D
      -- mean displacement in time t
      -- microscope demonstration of Brownian motion

4. Transport through neutral membranes (9 lectures)
   a. Osmotic, hydrostatic, and driving pressures
   b. Clinical examples, e.g., waste and nutrient transport across capillary walls, edema due to heart failure, headache in renal dialysis
   c. Volume and solute transports
   d. The artificial kidney
   e. Glomerular filtration (kidney)

5. Electrical properties of nerves (7 lectures)
   a. Review of electrostatics, electrodynamics, and circuit analysis
   b. Derivation of the partial differential equation describing the propagating transmembrane potential for a nonmyelinated axon
   c. "Voltage clamp" and "space clamp" experiments on the squid giant axon
   d. The Hodgkin-Huxley model for the action potential pulse on the nonmyelinated axon
   e. Application to myelinated axons

6. The electrocardiogram with the body as an electrical conductor (5 lectures)
   a. Derivation of the electrical potential spatial distribution due to a depolarizing cardiac cell in an infinite conducting medium
   b. Application to the depolarizing heart muscles
   c. P, Q, R, S, and T waves
   d. The electrocardiographic "leads"
   e. Application to analysis of human electrocardiograms
   f. Visit to a cardiology lab

7. Biomagnetism (4 lectures)
   a. Application of the Biot-Savart and Ampere laws to estimate the magnetic induction due to the depolarizing heart and propagation of the nerve impulse along the axon
   b. The magnetocardiogram (MCG) and magnetoencephalogram (MEG)
   c. The DC SQUID (Superconducting Quantum Interference Device)
   d. Visit to the Biomagnetism unit at the VA Hospital

8. Biological effects in MR (1 lecture)

9. Biological effects of ultralow frequency e-m radiation (1 lecture)

10. Microscopy, including ordinary optical, electron, confocal (3 lectures)

11. Lasers in Medicine (3 lectures)

Method of evaluation: The primary method is through testing: two equal weight 50 minute tests and one 2 hour comprehensive final exam worth twice one 50 minute exam. However, projects for extra credit of up to one letter grade can be arranged with an interested student; past projects include a quantitative experimental test of van't Hoff's law for osmosis and a quantitative experimental test of Brownian motion predictions using random walk models. Homework is assigned. Problems not appearing in the text will be collected, graded, and count toward the final grade; problems assigned form the text will not be collected since there is a solutions manual which will be available in the Medical Physics library (hours:8:00AM-4:30PM, M-F).