TO: The Engineering Faculty

FROM: The Faculty of the Department of Biomedical Engineering

RE: New Undergraduate-Level Course

The faculty of the Department of Biomedical Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

BME 304 Bioheat and Mass Transfer

Sem. 2. Class 3, cr. 3.

Prerequisite: ME 309 or equivalent

Fundamentals of heat and mass transport concepts in the context of biomedical applications. Heat transfer concepts include: steady- and unsteady-state thermal conductivity, convection, radiation, and combined mechanisms of heat transfer. Mass transport concepts include: steady and unsteady-state molecular mass transfer, diffusion, interphase mass transport, and convective mass transport. Integrated biological topics include fluid and mass transport in the body, pathological conditions (such as fever and arteriosclerosis), forced convection (i.e., dialysis), radiation exposure to cells/tissues, unsteady-state molecular diffusion such as in drug delivery mechanisms.

Reason: Introducing students to the heat and mass transfer concepts which can be used to understand physiological systems in a biomedical engineering context.

George Wodicka
Professor and Head

Supporting Documentation:

1. Level: Undergraduate – junior year

2. Course Instructor: Thomas J. Webster

3. Course Outline:

Topics in order

Introduction to Heat Transfer (2 lectures):

- Definitions: thermal conductivity / convection / radiation combined mechanisms of heat transfer
- Importance of heat transfer on mass transport in the body (i.e., in vasculature, central and peripheral nervous system, surgical procedures, etc.)

Differential Equations of Heat Transfer (2 lectures):

- General differential equation for energy transfer / special forms of the differential energy equation / boundary conditions
- Examples of boundary conditions for heat transfer in the body, influences from the body to maintain homeostasis

Steady-State Conduction (5 lectures):

- One-dimensional conduction / one-dimensional conduction with internal generation of energy
- Heat generation of central and peripheral nervous system and influence on respective cells/tissue
- Heat transfer from extended surfaces
- Heat generation and its effects through use of biomaterials (e.g., PMMA for bone prostheses, etc.)
- Two- and three-dimensional systems

Unsteady-State Conduction (3 lectures):

- Analytical solutions / temperature-time charts for simple geometric shapes
- Unsteady-state generation of heat during pathological conditions (such as fever conditions)
- Schmidt plot: graphical solution for one-dimensional transient energy flow/integral method for one-dimensional unsteady conduction

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Convective Heat Transfer (7 lectures):

– Dimensional analysis of convective energy transfer / exact analysis of the laminar boundary layer / approximate integral analysis of the thermal boundary layer
– Energy and momentum transfer analogies
– Turbulent flow considerations
– Heat transfer in arteriosclerosis (turbulent flow) conditions emphasizing tissue-tissue and tissue-cell interfaces
– Natural convection / forced convection for internal and external flow
– Stagnation-point heat transfer
– Integrated life sciences : examples of natural and forced convection (dialysis)

Radiation Heat Transfer (3 lectures):

– Thermal radiation / Planck's law, Stefan-Boltzmann law of radiation
– Emissivity and adsorptivity of solid surfaces
– Influences of radiation on cells and tissues

Introduction to Mass Transfer (2 lectures):

– Definitions: molecular mass transfer / diffusion coefficient / convective mass transfer
– Importance of mass transfer in the body (*i.e.*, facilitated compared to unfacilitated mass transfer in cells)

Differential Equations of Mass Transfer (2 lectures):

– General differential equation for mass transfer / special forms of the differential mass equation / boundary conditions
– Examples of boundary conditions for mass transfer in the body, influences from the body to maintain homeostasis

Steady-State Molecular Diffusion (3 lectures):

– One-dimensional mass transfer with and without chemical reactions
– Mass transfer in the body independent and dependent on chemical reactions (*i.e.*, oxygen and carbon dioxide and transfer of ions)
– Two and three-dimensional mass transfer / Importance of coordinated effects of momentum, heat, and mass transfer

Unsteady-State Molecular Diffusion (2 lectures):

– Analytical solutions / temperature-time charts for simple geometric shapes/ Modified Schmidt plot
– Examples of unsteady-state molecular diffusion such as in drug delivery mechanisms and effects on cell and tissues

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Convective Mass Transfer (3 lectures):

– Dimensional analysis of convective mass transfer / exact analysis of the laminar concentration boundary layer / approximate analysis of the concentration boundary layer
– Mass and momentum transfer analogies
– Models for convective mass-transfer coefficients

Interphase Mass Transfer (1 lecture):

– Equilibrium / Two-Resistance theory

Convective Mass Transfer Correlations (5 lectures):

– Mass transfer in plates, cylinders, and spheres
– Comparison of mass transfer in lungs (plates), cardiovascular system (cylinders), and cells (spheres)
– Mass transfer involving turbulent flow through pipes
– Mass transfer to endothelial cells under arteriosclerosis (turbulent flow) conditions
– Mass transfer in wetted-wall columns / packed and fluidized beds

EXAMS (Four)

Total Lectures *44*

4. Text: *Cooney, D.O. Biomedical Engineering Principles. An Introduction to Fluid, Heat, and Mass Transport Processes. Dekker, Inc., NY, 1976.*

5. Grading: based on exams, homework, quizzes, and computational assignments.