UNIVERSITY OF NAIROBI

SCHOOL OF ENGINEERING

DEPARTMENT OF ENVIRONMENTAL & BIOSYSTEMS ENGINEERING

FEB 423- Heat and Mass Transfer (60 hrs)

LECTURE:	Friday 9:00 am to 1:00 pm
PRACTICALS:	Tuesday 2:00 pm to 4:00 pm
LECTURE THEATRE	EBE, Kabete Campus
OFFICE:	
Kabete Campus	Engineering Block, 2nd floor
Main Campus	Nuclear Science, Room No. 19
	Tel. +254318262 ext. 28471
CONSULTATION TIME:	Kabete Office Friday 2:00 to 4:00 pm
INSTRUCTOR:	Emmanuel Beauttah Kinyor Mutai
	Dip. Agric. Engin, B.sc. Agric. Engin, (Egerton),
	M.Sc. Agric. Engin. (UoN), PhD (UoN), (On going).
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GRADING FOR THE COURSE

CAT (2)	15%
HOMEWORK (5) (ASSIGNMENTS)	5%
PRACTICALS & QUIZES (5)	5%
TERM PAPER	5%
FINAL EXAM	70%
TOTAL	**100%**

PREREQUISITE COURSES

1. Thermodynamics
2. Fluid Mechanics
3. Calculus
4. Computer Applications

COURSE OBJECTIVES

The goal of this course is for students to learn to apply the fundamentals of transport phenomena to solve problems relevant to Environmental and Biosystems Engineering practice: Energy and mass transfer. In each case we will work through examples that help to explore both the intuitive concepts and the formal mathematical framework necessary to make predictions. Transport phenomena, along with Thermodynamics and food processing design, etc, define the fundamental skill set necessary for solving problems that arise in the Environmental and Biosystems profession. At the completion of this course, the students will be able to:

- Set up microscopic and macroscopic energy and mass balances (conservation principles)

- Know the flux laws for heat and mass transport
- Apply the conservation principles and flux laws to model transport process central to engineering
- Use physical and mathematical similarities between the processes of heat and mass transfer to solve problems by *analogy.*
- Perform basic unit operation calculations for heat and mass transfer equipment

In general, on completion of this course the student will:

- Have a physical understanding of conduction, convection and radiation, heat exchangers and mass transfer phenomena

- Develop a sound methodology enabling the formulation and solution of a broad variety of related engineering problems.

COURSE DESCRIPTION

Basic concepts; definition and terminology, modes of heat transfer; conduction, convection and radiation. Heat transfer by conduction; steady-state one dimension, two and three dimensions, unsteady-state (transient). Heat transfer by convection; Hydrodynamics, Dimensional analysis. Forced convection; Laminar and Turbulent flow. Free convection. Heat exchangers; types and analysis, LMTD, Overall Heat Transfer coefficient, NTU, pressure drop and pumping power. Heat transfer by Radiation; thermal radiation- basic relations. Radiation exchange between surfaces. Introduction to mass transfer. Modes of mass transfer, Fick's law, Diffusion equation. Steady state diffusion through a plain membrane, mass transfer coefficient. Convective mass transfer and correlations for mass transfer.

TOPICS COVERED

1. Introduction: modes of heat transfer, energy balances, problem solving methodology, units & dimensions.

2. Conduction: thermal properties, diffusion equation, one dimensional steady state, lumped capacitance transient conduction, semi-infinite solid transient conduction.

3. Convection: boundary layer concept, dimensional analysis, heat & mass transfer analogy, internal flow and external flow convection, cylinders in cross flow, impinging jets, mention to pipe flow.

4. Free convection: external free convection flows, free convection in channels, free convection in enclosures, mixed convection, convective mass transfer.

5. Radiation: radiation intensity, black body radiation, surface emissivity, absorption, reflection, transmission, Kirchhoff's law, gray surfaces, view factors, black body radiation exchange, radiation exchange between surfaces, additional effects.

6. Introduction to mass transfer. Modes of mass transfer, Fick's law, Diffusion equation. Steady state diffusion through a plain membrane, mass transfer coefficient. Convective mass transfer and correlations for mass transfer.

DETAILED COURSE OUTLINE FOR 2012/2013 CLASS

WEEK	DESCRIPTION	COMMENTS/ DURATION
1	**INTRODUCTION** Basic concepts; ● definition and terminology ● modes of heat transfer; - conduction - convection - radiation.	4 HRS
2	**HEAT CONDUCTION** - Derivation of heat conduction equations - heat conduction equation in cylindrical and spherical coordinates	4 HRS
3	- The steady state 1-D heat conduction in in simple geometries	4 HRS
4	- Two and three dimensions - heat from extended surfaces	4 HRS
5	**UNSTEADY HEAT CONDUCTION** - One-dimension unsteady-state (transient) conduction - Transient heat conduction in infinite plates, infinitely long cylinders and spheres, - The Heisler Charts for transient flow - application of solutions of one -dimension transient heat conduction to Multidimensional systems - Transient heat flow in semi-infinite solid - Semi-infinite solid; surface temperature periodic with time - Heat conduction in a body resulting from a moving heat source	6 HRS
6	**CAT 1**	**2 HRS**

7	**CONVECTION** **REVIEW OF FLUID MECHANICS** **HYDRODYNAMICS AND DIMENSIONAL ANALYSIS.** ✧ Governing equations of fluid flow ✧ The Napier-Stokes equations - Internal flow - Laminar flow - Turbulent flow - External flow ✧ Mechanism of convective heat transfer ✧ Dimensionless Expression of heat transfer coefficient ✧ A brief review of incompressible viscous flow	**6 HRS**
8	**PRINCIPLES OF FORCED CONVECTION** ✧ Derivation of energy equation ✧ Non-dimensionalization of energy equation and recognition of pertinent dimensionless terms governing its solution for temperature field. ✧ Thermal boundary layer ✧ convective heat transfer in external flows ✧ Convective heat transfer in internal flows - basic concepts ✧ Convective heat transfer in a Hagen-Poiseuille flow ✧ Heat transfer in the entrance of a pipe flow ✧ Heat transfer in plane Poiseuille flow ✧ Heat transfer to liquid metals in pipe flow ✧ Heat transfer augmentation NB: ***Principles of free Convection will be a reading exercise. It will not be covered in this course.***	**6 hrs**
9	**PRINCIPLES OF HEAT EXCHANGERS** ✧ Classification of heat exchangers - Shell and tube heat exchanger - Compact heat exchangers - Regenerators ✧ Mathematical analysis of heat exchangers ✧ Selection criteria of heat exchangers	**6 HRS**

10	**RADIATION HEAT TRANSFER** ✧ Physical mechanism ✧ Concept of radiation intensity and emissive power ✧ Blackbody radiation ✧ Radiation properties of surfaces ✧ View factor ✧ Radiation energy exchange between Nonblack surfaces ✧ Radiation in an absorbing emitting medium ✧ Solar radiation	**6 HRS**
11	**PRINCIPLES OF MASS TRANSFER** ✧ Definitions of concentrations ✧ Fick's Law of Diffusion ✧ Steady state Mass Diffusion through a wall ✧ Diffusion in a moving medium ✧ Diffusion of vapour through a stationary Gas: Concept of Stefan flow	**6 HRS**
12	**REVISION**	**1 HRS**
13	**CAT II**	**2 HRS**
14	**REVISION**	**1 HRS**
15	**EXAMINATION**	**2 HRS**
		60 **HRS**

TEXTBOOKS

1. **F.P. Incropera & D.P. DeWitt (2002).** Fundamentals of heat and mass transfer, 3rd edition, Wiley, 2002. ISBN 0-471-38650
2. **J.P Holma (1989).** Heat and Mass Transfer. SI Edition, McGraw-Hill Book Company
3. **R.K. Rajput (2008).** Heat and Mass Transfer, in SI Units, Multicolour Illustrative Edition, S.Chand & Company Ltd. ISBN 81-219-2617-3
4. **S.K Som (2008)**. Introduction to Heat and Mass Transfer. PHI Learning Private Limited New Delhi. ISBN 978-81-203-3060-3
5. **S.P Sukhatme (2005).** A text book on Heat and Mass Transfer, 4th Edition, University Press Private Limited, Hyderabad. ISBN 81-737-1544-0
6. **J.H Lienhard IV and J.H. Lienhard V (2006).** A heat Transfer Text Book , 3rd Edition, Phlogiston Press, Cambridge Massachusetts. Http://web.mit.edu/lienhard/www/ahtt.html.

ETHICS AND MISCONCONDUCT

Students are expected to follow the highest of ethical, social and moral standards as specified in the Student Code of Conduct in the UoN Student Handbook. Cheating will be disciplined as described in the Academic Misconduct section of the Student Handbook. Student suspected of cheating will receive zero credit for the assignment. It is encouraged to collaborate on homework assignments, but each student must submit his or her own solutions. Submission of identical homework solutions will be treated as academic misconduct.

Attendance:

- Required for all lectures
- A class list must be signed on attendance of every lecture and analysis of attendance will be done at the end of the semester. You will be allowed to sit for examination ONLY if you attain the minimum threshold attendance. Failure to attain this requirement as stipulated in the examination rules and regulations of the school of Engineering, University of Nairobi, you will not be allowed to sit for the final examination of this course unit.

HOMEWORK POLICY

All students are required to finish homework assignments and submit them on time. Late homework will not be accepted for credit, except in the case of excused absence. A class website will be created for accessing homework and worked examples.

Term papers, CATS, Quizes and Homework are compulsory are earn credit for the course.

HOMEWORK PROBLEM SOLUTION FORMAT

It is highly recommended that all problem solutions be presented in the following format:

- **Known:** State concisely what is known about the problem
- **Find:** State concisely what must be found
- **Schematic:** Draw a schematic of the physical system being considered
- **Properties:** List the solid and /or fluid thermophysical properties used in your solution
- **Assumptions:** It is important that you put all the assumptions in one place so that they can be reviewed
- **Analysis:** Provide in sentence format, comments that make clear the logic and organization of your analysis

SUGGESTED STUDY METHODS

- Manage your time and stick to schedule
- Read the textbook before class. The eBook by Lienhard in Pdf format can even be downloaded to your phone and you can access and read it anywhere. The download link Http://web.mit.edu/lienhard/www/ahtt.html.
- Take notes if necessary during class
- Review the topics before doing homework
- Finish homework independently
- Good sleep before major exams