The Mississippi is well worth reading about. It is not a commonplace river, but on the contrary is in all ways remarkable... It seems safe to say that it is also the crookedest river in the world, since in one part of its journey it uses up one thousand three hundred miles to cover the same ground that the crow would fly over in six hundred and seventy-five. It discharges three times as much water as the St. Lawrence, twenty-five times as much as the Rhine, and three hundred and thirty-eight times as much as the Thames. No other river has so vast a drainage-basin: it draws its water supply... from Delaware, on the Atlantic seaboard, and from all the country between that and Idaho on the Pacific slope - a spread of forty-five degrees of longitude. The Mississippi receives and carries to the Gulf water from fifty-four subordinate rivers that are navigable by steamboats, and from some hundreds that are navigable by flats and keels. The area of its drainage-basin is as great as the combined areas of England, Wales, Scotland, Ireland, France, Spain, Portugal, Germany, Austria, Italy, and Turkey; and almost all this wide region is fertile; the Mississippi valley, proper, is exceptionally so.

From Life on the Mississippi by Samuel L. Clemens (1883)¹

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**COURSE DESCRIPTION**

From the Graduate Catalog: “Through a systems approach, this course examines the outcome of physical and biological component modifications on system function. It provides the background to relate diverse and disparate facts and phenomena to one another in a dynamic environment. Lecture. Prerequisite: Graduate standing in the Ph.D. program in Environmental Systems.”

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In this course, we'll use fundamental principles of chemistry, physics, and biology to understand, describe, and predict the ways in which constituents interact and move in aquatic systems. After developing idealized models, we'll broaden our considerations to examine and account for the ways observed behavior in natural systems can deviate from our idealized predictions.

Natural water (rivers, streams, lakes, ponds) will be assumed to be the continuous phase throughout the semester unless otherwise noted. This doesn't mean that terrestrial and atmospheric environmental compartments will be neglected. Rather, these compartments will be considered to the extent that they impact water systems - typically at land-water and air-water interfaces.

COURSE POLICIES

Lecture

Lectures will be presented under the assumption that students have read the indicated text and supplementary materials prior to class. Attendance will not be formally monitored during lecture periods. However, attendance and class participation will be considered in the evaluation of a student's desire to learn.

Students will also be assigned a significant amount of guided outside reading and occasional field experience when schedules allow.

Please arrive on time for lecture. Late arrival to class is a distraction to both the instructor and students. Cell phones, pagers, and the like should be shut off or set to "silent" mode.

Exams

Three exams will be given during the regular semester. A comprehensive final examination will be given at the end of the semester. Exams may be in class, take home, or a combination of both.

Students are expected to bring calculators, pencils, etc. to each exam. Under no circumstances will the sharing of calculators be permitted.

Grading

Students will be excused from graded assignments for emergency reasons only (e.g., illness, family hardship, etc.) The instructor should be contacted prior to the exam. If the instructor cannot be reached, the student may leave a message with Ms. Robin Bauerly at 309/298.1632 or RR-Bauerly@wiu.edu. Makeup exams may be written, oral, or a combination of both. Unexcused absences will result in a score of zero.

Grades will be determined according to the following distribution:

Exam 1 = 20%
Exam 2 = 25%
Exam 3 = 25%
Final Exam = 30%

**TEXTBOOKS & REFERENCE MATERIALS**

**Required Textbook**


This book contains online supplementary files that utilize Mathcad for problem solving. Mathcad Prime 3.0 with an academic license is available directly from PTC® at [http://store.ptc.com/store/ptc/en_US/pd/productID.232679900/pgm.81293500/ThemeID.21925700/Currency.USD](http://store.ptc.com/store/ptc/en_US/pd/productID.232679900/pgm.81293500/ThemeID.21925700/Currency.USD). This is a fully functioning version of Mathcad Prime with a perpetual license at a savings of $1,450. An open source alternative to Mathcad Prime is GeoGebra (currently v.4.4) which is available at [http://www.geogebra.org/cms/en/](http://www.geogebra.org/cms/en/). This is entirely free and is available as a Google Chrome® app that can be accessed both on line and off line.

**Recommended Reference/Supplementary Readings**


**OUTSIDE WORK REQUIRED**

Often, undergraduate students are told that for every 1 s.h. of class time, about 3 hours of outside work are needed. However, Ph.D. students should expect that the commitment of time outside of class will often exceed three hours per semester hour per week. This will typically take the form of problem sets, readings, and other similar work. For ENVR 730, consider 12 hours of work outside of class to be the very minimum commitment needed to get the most from this course.

Additionally, there may be opportunities for students to participate in conferences, meetings with relevant stakeholder groups, etc. Every effort will be made to provide
ample notification prior to these events.

UNIVERSITY POLICIES

Detailed descriptions of important university policies are available at the URLs listed below. Students are responsible for knowing, understanding, and adhering to these policies.

Student Rights and Responsibilities: http://www.wiu.edu/provost/students.php
Academic Integrity: http://wiu.edu/policies/acintegrity.php
Grade Appeals: http://www.wiu.edu/policies/gradeapp.php
Final Exams: http://www.wiu.edu/policies/finexam.php

Americans With Disabilities Act/Disability Resource Center

“In accordance with University policy and the Americans with Disabilities Act (ADA), academic accommodations may be made for any student who notifies the instructor of the need for an accommodation. For the instructor to provide the proper accommodation(s) you must obtain documentation of the need for an accommodation through the Disability Resource Center (DRC) and provide it to the instructor. It is imperative that you take the initiative to bring such needs to the instructor’s attention, as he/she is not legally permitted to inquire about such particular needs of students. Students who may require special assistance in emergency evacuations (i.e., fire, tornado, etc.) should contact the instructor as to the most appropriate procedures to follow in such an emergency.”

The Disability Resource Center can be contacted at:
Memorial Hall 143
1 University Circle
Macomb, IL 61455
Phone: 309/298.2512
Email: disability@wiu.edu
URL: http://www.wiu.edu/student_services/disability_resource_center

On the Quad Cities Campus, DRC support can be obtained by contacting:
Audrey Adamson
WIU-QC Student Services
Phone: 309/762.9481, x62573
Email: anw-adamson@wiu.edu

Academic Integrity

My Thoughts on Integrity

As a Ph.D. student who will contribute new knowledge to the field of environmental science by conducting and reporting on the outcomes of your independent research, your reputation for outstanding scientific work is seconded only by your reputation for unimpeachable integrity.
The Thoughts of Others

"If you have integrity, nothing else matters. If you don't have integrity, nothing else matters." - Alan K. Simpson, U.S. Senator (R-WY)

"Integrity is doing the right thing, even when no one is watching." - C. S. Lewis

WIU's Student Academic Integrity Policy

"Western Illinois University, like all communities, functions best when its members treat one another with honesty, fairness, respect, and trust. Students have rights and responsibilities (http://www.wiu.edu/provost/students/) and students should realize that deception for individual gain is an offense against the members of the entire community, and it is the student's responsibility to be informed and to abide by all University regulations and policies on Academic Integrity.

Plagiarism, cheating, and other forms of academic dishonesty constitute a serious violation of University conduct regulations. Students who engage in dishonesty in any form shall be charged with academic dishonesty.

It is a duty of faculty members to take measures to preserve and transmit the values of the academic community in the learning environment that they create for their students and in their own academic pursuits. To this end, they are expected to instill in their students a respect for integrity and a desire to behave honestly. They are also expected to take measures to discourage student academic dishonesty, to adjust grades appropriately if academic dishonesty is encountered, and, when warranted, to recommend that additional administrative sanctions be considered. Grading policies are the exclusive prerogative of the faculty; administrative sanctions are under the authority of the Director of Student Judicial Programs.”

TENTATIVE COURSE OUTLINE/SCHEDULE/READING (SUBJECT TO CHANGE AT THE DISCRETION OF THE INSTRUCTOR):

Week 1 - ½ Week 2

Chapter 1. Introductory Remarks
   1.1 Perspective
   1.2 Organization and Objectives
      1.2.1 Water
      1.2.2 Concentration Units
      1.2.3 Chemical Equilibria and the Law of Mass Action
      1.2.4 Henry's Law
      1.2.5 Acids and Bases
      1.2.6 Mixing
      1.2.7 Reactions in Ideal Reactors
      1.2.8 Nonideal Reactors
      1.2.9 Acids and Bases: Advanced Principles
      1.2.10 Metal Complexation and Solubility
1.2.11 Oxidation and Reduction
1.3 Approach

Chapter 2. Water
2.1 Perspective
2.2 Important Properties of Water

Chapter 3. Concentration Units for Gases, Liquids, and Solids
3.1 Selected Concentration Units
3.2 The Ideal Gas Law and Gas Phase Concentration Units
3.3 Aqueous Concentration Units
3.4 Applications of Volume Fraction Units

½ Week 2 - Week 4

Chapter 4. The Law of Mass Action and Chemical Equilibria
4.1 Perspective
4.2 The Law of Mass Action
4.3 Gas/Water Distributions
4.4 Acid/Base Systems
4.5 Metal Complexation Systems
4.6 Water/Solid Systems (Solubility/Dissolution)
4.7 Oxidation/Reduction Half Reactions

Chapter 5. Air/Water Distribution: Henry’s Law
5.1 Perspective
5.2 Henry’s Law Constants
5.3 Applications of Henry’s Law

Weeks 5 - 9

Chapter 6. Acid/Base Component Distributions
6.1 Perspective
6.2 Proton Abundance in Aqueous Solutions: pH and the Ion Product of Water
6.3 Acid Dissociation Constants
6.4 Mole Accounting Relations
6.5 Combination of Mole Balance and Acid/Base Equilibria
   6.5.1 Monoprotic Acids
   6.5.2 Diprotic Acids
   6.5.3 Triprotic and Tetraprotic Acids
   6.5.4 Abundance (Ionization) Fractions
6.6 Alkalinity, Acidity, and the Carbonate System
   6.6.1 The alkalinity test: carbonate system abundance and speciation
   6.6.2 Acidity
6.7 Applications of Acid/Base Principles in Selected Environmental Contexts
   6.7.1 Monoprotic Acids
   6.7.2 Diprotic Acids
Weeks 10 - 13

Chapter 7. Mass Balance, Ideal Reactors, and Mixing
  7.1 Perspective
  7.2 The Mass Balance
  7.3 Residence Time Distribution (RTD) Analyses
    7.3.1 RTD Experimental Apparatus
    7.3.2 Tracers
    7.3.3 Tracer Input Stimuli
  7.4 Exit Responses for Ideal Reactors
    7.4.1 The Ideal Plug-Flow Reactor (PFR)
    7.4.2 The Ideal Completely Mixed Flow Reactor (CMFR)
    7.4.3 The Ideal (Completely Mixed) Batch Reactor (CMBR)
  7.5 Modeling of Mixing in Ideal CMFRs
    7.5.1 Zero-Volume Applications
    7.5.2 Time-Dependent Mixing
  7.6 Applications of CMFR Mixing Principles in Environmental Systems

Chapter 8. Reactions in Ideal Reactors
  8.1 Perspective
  8.2 Chemical Stoichiometry and Mass/Volume Relations
    8.2.1 Stoichiometry and Overall Reaction Rates
    8.2.2 Some Useful Mass, Volume, and Density Relations
    8.2.3 Applications of Stoichiometry and Bulk Density Relations
  8.3 Reactions in Ideal Reactors
    8.3.1 Reaction Rate Laws
    8.3.2 Reactions in Completely Mixed Batch Reactors
    8.3.3 Reactions in Plug-Flow Reactors
    8.3.4 Reactions in Completely Mixed Flow Reactors
    8.3.5 Unsteady-State Applications of Reactions in Ideal Reactors
  8.4 Applications of Reactions in Ideal Reactors
    8.4.1 Batch Reactor Systems
    8.4.2 Plug-Flow Reactor Systems
    8.4.3 Completely Mixed Flow Reactor Systems
    8.4.4 Some Context-Specific Advanced Applications
  8.5 Interfacial Mass Transfer in Ideal Reactors
    8.5.1 Convective and Diffusive Flux
    8.5.2 Mass Transfer Coefficients
    8.5.3 Some Special Applications of Mass Transfer in Ideal Reactors

Chapter 9. Reactions in Nonideal Reactors
  9.1 Perspective
  9.2 Exit Concentration Versus Time Traces
    9.2.1 Impulse Stimulus
    9.2.2 Positive Step Stimulus
  9.3 Residence Time Distribution Density
9.3.1 $E(t)$ Curve and Quantitation of Tracer Mass
9.3.2 $E(t)$ and $E(q)$ RTD Density Curves
9.4 Cumulative Residence Time Distributions
9.5 Characterization of RTD Distributions
  9.5.1 Mean and Variance from RTD Density
  9.5.2 Mean and Variance from Cumulative RTD
9.6 Models for Addressing Longitudinal Dispersion in Reactors
  9.6.1 CMFRs (Tanks) in Series (TiS) Model
  9.6.2 Plug-Flow with Dispersion (PFD) Model
  9.6.3 Segregated Flow (SF) Model
9.7 Modeling Reactions in CMFRs in Series (TiS) Reactors
  9.7.1 Pseudo-First-Order Reaction Rate Law in TiS Reactors / 280
  9.7.2 Saturation Reaction Rate Law with the TiS Model
9.8 Modeling Reactions with the Plug-Flow with Dispersion Model
  9.8.1 Pseudo-First-Order Reaction Rate Law with the PFD Model
  9.8.2 Saturation Rate Law with the PFD Model
9.9 Modeling Reactions Using the Segregated Flow (SF) Model
9.10 Applications of Nonideal Reactor Models
  9.10.1 Translation of RTD Data for Use with Nonideal Models
  9.10.2 Modeling Pseudo-First-Order Reactions
  9.10.3 Modeling Saturation-Type Reactions with the TiS and SF Models
9.11 Considerations for Analyses of Spatially Variant Processes
  9.11.1 Internal Concentration Profiles in Real Reactors
  9.11.2 Oxygen Consumption in PFR-Like Reactors
9.12 Modeling Utilization and Growth in PFR-Like Reactors Using TiS and SF