MATH 322 (Mathematical Modeling) – Spring 2016 – Dr. Melvin Royer

Description:	An introduction to the principles and process of mathematical modeling. This course incorporates several projects in which students model open-ended scenarios from various disciplines. Relevant mathematical and statistical techniques, such as curve-fitting, optimization, and Monte Carlo methods are included on an as-needed basis. Various software packages and lab experiments are also incorporated. Prerequisite: MAT-130 or MAT-253
Objectives: Addresses IWU World Changing Aims 1c, 2b and Mathematics Program Outcomes #4, 5	1. Develop and evaluate mathematical models for open-ended problems 2. Apply supporting mathematical/statistical techniques, such as curve-fitting and optimization 3. Gain exposure to quantitative problems from fields such as biology, sociology, etc. 4. Demonstrate technical communication skills in project/lab reports 5. Apply mathematical/statistical software to simulate behaviors of real-world systems 6. Develop and demonstrate qualities of diligence, courtesy, integrity, and curiosity that are consistent with the values of a Christian world changer
Materials:	1. Texts: Mooney & Swift, A Course in Mathematical Modeling, MAA, 1999 2. 3-ring binder (for ease of collating notes) 3. Graphing calculator recommended 4. Access to software (Excel, Maple)
Instructor Contacts:	1. Email: melvin.royer@indwes.edu 2. Phone: 677-2987 (Office), 662-1673 (Home, before 9:30 PM) 3. FAX: 677-1704 4. Office: OHSN Room 170-D
Office hours: (or by appointment or drop-in)	

Times	Monday	Tuesday	Wednesday	Thursday	Friday
7:50					
8:55	Office	Office	Office	Office	Office
10:00	Chapel	Office	Chapel	Office	Chapel
11:15	MAT-223		MAT-223		MAT-223
12:20					
1:25	Office	MAT-322	Office	MAT-322	Office
2:30	MAT-204	MAT-322	MAT-204	MAT-322	MAT-204
3:35					

Tentative Schedule

Date	Day	Topics	Section	Homework
Jan 12	T	Introduction Modeling process – construction/classification	0.1, 0.2	p.7 – 1,2,3
Jan 14	R	Modeling process – classification/evaluation *Lab 1*		HW #1
Jan 19	T	Modeling process – evaluation/error Discrete dynamical systems – simulations	1.1, 1.2, 1.3	
Jan 21	R	Discrete dynamical systems – mathematics *Lab 2*	1.4	p. 38 – 1,2,3abd,4
Jan 26	T	Discrete dynamical systems – systems	1.5, 1.6	p. 45 – Project 1.7
Jan 28	R	Random variables and probability distributions	2.1, 2.2, 2.3	p.90 – 3c,4,6,8
Feb 2	T	**Test 1** (Methodology, dynamical systems)		
Feb 4	R	Stochastic models *Lab 3*	2.3	p. 90 – 5
Feb 9	T	Monte Carlo simulation		HW #2
Feb 11	R	Hypothesis testing ~~*Lab 4*~~	2.4	
Feb 16	T	Stochastic model evaluation	2.4	HW #3
Feb 18	R	State models – simulations Eigenvalues/eigenvectors *Lab 5*	3.1, 3,2, 3.3, 3.4, 3.5	p. 135 – 2
Feb 23	T	State models – mathematics, Markov chains	3.5, 3.6, 3.7, 3.8	p. 135 – 1,6,7ab
Feb 25	R	Linear least squares regression	4.1, 4.2, 4.3	p. 226 – 5 p. 226 – Project 4.3
Mar 1	T	Multiple linear regression *Lab 6*	4.12	
Mar 3	R	**Test 2** (Stochastic models, state models)		
Mar 8	T	SPRING BREAK		
Mar 10	R	SPRING BREAK		
Mar 15	T	Model construction using geometric similarity, model construction using graphs		HW #4
Mar 17	R	Curvilinear models *Lab 7*	4.4, 4.5, 4.6	p. 226 – Project 4.1
Mar 22	T	Curvilinear models	4.7, 4.8	p. 226 – 9
Mar 24	R	Statistics of regression *Lab 8*	4.10	p. 226 – 8
Mar 29	T	Time series		HW #5
Mar 31	R	Time series, artificial neural networks		
Apr 5	T	**Test 3** (Regression, curvilinear models)		
Apr 7	R	Artificial neural networks		HW #6
Apr 12	T	Artificial neural networks		
Apr 14	R	**Major project presentations**		
Apr 19	T	EARLY FRIDAY		
Apr 21	R	STUDY DAY		

Final exam: Wednesday April 27, 1:00-2:50

Topics Outline

1. Philosophy and methodology

    a. Problem identification and variable selection
    b. Choice of approach (explicative vs. empirical, discrete vs. continuous, deterministic vs. probabilistic, dynamic vs static, etc.)
    c. Model construction, solution, and evaluation

2. Dynamic models (discrete dynamical systems)

    a. Difference equations
    b. Systems of difference equations
    c. Eigenvalue/stability analysis of discrete linear systems
    d. Sensitivity and robustness

3. Discrete probabilistic modeling

    a. Random number generation
    b. Monte Carlo simulation
    c. Markov processes

4. Empirical models (curve fitting)

    a. Model fitting and evaluation
        i. Graphical
        ii. Least squares regression
    b. Transformations
    c. Model types
        i. Linear
        ii. Curvilinear
        iii. Time series

5. Artificial neural networks (perceptrons)

Mathematics Department Mission Statement and Program Objectives

"The Department of Mathematics is committed to preparing students academically and spiritually for careers and/or advanced study. This preparation will occur through a Christian liberal arts curriculum developing solid foundations in mathematics content, technological skills, and critical analysis and problem solving ability. Communication, teamwork, and leadership skills will be developed through a multi-disciplinary philosophical approach in integrating faith, learning, and service."

1) PROOF: ...understand and proficiently implement the logical role and methodology of rigorous proof in the axiomatic development of mathematics.

2) CONTENT: …understand core mathematical content in standard areas of analysis, algebra, geometry, and probability.

3) NATURE: …proficiently articulate the overall nature of mathematics including its history; current organization; and interfaces with Christian faith, philosophy, and other academic disciplines.

4) APPLICATION: …proficiently analyze, model, and solve real-world problems using mathematical/statistical software as appropriate.

5) COMMUNICATION: …proficiently communicate mathematics in both written and oral form

MAT-322 primarily addresses objectives #4 and #5.

Advice & Encouragement:

1. "To every thing there is a season, and a time to every purpose under the heaven . . . a time to keep silent and a time to speak . . ." Eccl 3:1, 7. Usually in a college math course, there is more problem with students keeping silent than with them speaking. Questions are appropriate and appreciated at any time. Giving answers to <u>my</u> questions is also appreciated (unless you just answered the last question; then giving another student the opportunity to answer would be appropriate.)

2. "Consider the path for your feet and let all your ways be established." Prov 4:26. The schedule shows what we will be covering the next class period. The wise will have previewed the section(s) <u>before</u> coming to class; all the relevant studies in learning show that having some prior knowledge greatly increases the rate and level of comprehension.

   Physical preparedness is also important. Your mind resides in a body that was created to sleep, eat nutritious meals, etc. If you are constantly only one step ahead of your next deadline, please consult with your advisor and/or a trusted friend about simplifying your life – a good college experience <u>requires</u> spiritual and academic reflection time.

3. "… Talk about [these commandments] when you sit at home and when you walk along the road, when you lie down and when you get up. Tie them as symbols on your hands and bind them on your foreheads. Write them on the doorframes of your houses and on your gates." Deut 6:7-9. There is no substitute for consistently doing the homework. Mathematics has many characteristics of a foreign language. Your retention will be <u>much</u> better if you study every day than if you wait until the weekend or just before the exam to try to catch up.

4. "As iron sharpens iron, so one man sharpens another." Prov 27:17. My observation has been that students perform better (often much better) when they make a serious effort to become part of the class "community." Academic benefits of studying and socializing together include the following: extra feedback to get your misconceptions corrected, other perspectives on what the important issues really are, emotional energy when preparing for tests, an emergency contact when you forget what assignment is due…

5. "And unto one he gave five talents, to another two, and to another one…" Matt 25:15. There will probably be a wide range of backgrounds and abilities in the class. Be respectful of others. Compete against your own God-given ability, not against each other. Don't be too embarrassed to ask "stupid" questions.

6. "Therefore, since I myself have carefully investigated everything from the beginning, it seemed good also to me to write an orderly account for you …" Luke 1:3 Don't wait until the exam to try to write an orderly account of what you think you know – you need prior feedback. If you don't understand a homework problem, unless I specifically say so, it would be less than wise to ignore it and hope it goes away. Your professors have office hours for a reason, but it must be <u>you</u> who makes the effort to make contact.

7. "For God so loved the world that He gave His one and only Son, that whoever believes in Him shall not perish but have eternal life." John 3:16. Work hard and take the course seriously, but don't neglect your spiritual life. Ultimately, the only mathematics you need to know is that God has only <u>one</u> Son, and that there are only <u>two</u> places to spend eternity.

Grading:

1. *Homework / Labs*

   Homework, class activities, and labs will be collected weekly; randomly chosen problems will be graded. Work must be shown on all problems which cannot be done entirely mentally. Working together is strongly encouraged; be sure you understand that "working together" and "borrowing solutions" are different activities. All such assignments will be worth the same number of points. Your lowest homework score will be dropped. Assignments must be submitted on the due date – no late work will be accepted. Exceptions to this policy will be made only upon submission of official university documentation of an illness or university sponsored function. If you know you must miss a class, make arrangements with me ahead of time to complete the assignment early.

2. *Chapter Projects*

   Since the concepts of this course can only be fully understood by actively working through open-ended problems, two specific projects will be assigned. Formal write-ups will be required. Assignments must be submitted on the due date – no late work will be accepted. (Note: Textbook projects assigned as homework are not subject to the formal standards required of the official course projects).

3. *Major Project*

   A major project on a topic of the students' choice (subject to instructor approval) will be assigned. The project will require students to obtain their own data, choose and justify their analysis techniques, and present their results in a formal report.

4. *Class Participation*

   During some classes, activities such as group discussion, student presentations, worksheets, etc, will be held. These activities will be graded leniently but will not always be announced and may not be made up. Attending class is necessary to get these points.

5. *Tests*

   Three tests will be given in class near the dates indicated on the schedule. (The exact date will be announced at least one week in advance). If you must miss a test and provide me with a legitimate reason in advance, you may take a makeup test without penalty. If you do not obtain prior approval, you may not be allowed to take a makeup at all, or points may be deducted as a penalty. In case of an emergency, please notify me immediately -- my willingness to make accommodations will be based on your prompt efforts to contact me.

6. *Comprehensive Final Exam*

   The final exam will be comprehensive. It must be taken at the scheduled time unless you have more than two final exams on the same day. In this case, please make prior arrangements to take the final at another time (which must be later than the scheduled time). If your percentage on the final exam if higher than your lowest test percentage, I will replace that test score with one corresponding to your final exam percentage.

7. *Professional Development*

Participation in any of the following out-of-class activities will add the indicated number of points to the student's point total as well as his/her points possible. For example, suppose Students #1 and #2 each earn 900 total class points, but Student #2 also earns 50 professional development points. Student #1 will then have a course average of 900/1100 = 81.8%, while student #2 will have an average of 950/1150 = 82.6%. A maximum of 50 professional development points is allowed. Students may suggest other activities for consideration.

Activity	*Points*
IWU MAC Meeting	10
IWU Math Colloquium (attending/presenting)	10/20
IWU Math Dept guest speaker presentation	20
Off-campus math conference (pre-approved by instructor)	Up to 50
COMAP Contest https://www.comap.com/undergraduate/contests/mcm/	50

8. *Weighting*

Homework / Labs	250 pts	23%
Chapter projects	150 pts	14%
Major project	200 pts	18%
Class participation	50 pts	5%
3 tests	300 pts	27%
Comprehensive final exam	150 pts (+ possible test replacement)	14%
TOTAL	1100 points (+ up to 50 pts professional development	100%

9. *Scale*

The following minimum percentages will guarantee the indicated grade. At the end of the course, the scale may be curved to be more lenient, but do not count on this.

Grade	A	A-	B+	B	B-	C+	C	C-	D+	D
Guaranteed Percentage	93	90	87	83	80	77	73	70	67	60

Citizenship:

Attendance:

Enrolled students are responsible for attending all sessions of this class. Attendance may be taken without notice on any given class day and used as a homework score. Poor attendance has always been a leading cause of failure in math courses. Our mutual goal is your success in this course.

Distractions:

Tardiness is an unacceptable distraction to the other members of the class. Everyone occasionally runs a few minutes behind, but being tardy an excessive amount or an excessive number of times may result in denial of credit for work due that week.

<u>Usage of cell phones, MP3 players, laptops (other than for note-taking or classwork), etc., during class is inappropriate and discourteous to other members of the class.</u>

Dishonesty:

Cheating is defined as submitting work for academic evaluation that is not the student's own, copying answers from another student during an examination, using prepared notes or materials during an examination, or other misrepresentations of academic achievement submitted for evaluation and a grade. Plagiarism in research writing is considered cheating. Plagiarism is defined by the MLA Handbook as "the act of using another person's ideas or expressions in writing without acknowledging the source... to repeat as your own someone else's sentences, more or less verbatim."

Working together on homework is strongly encouraged, but any collaboration should be a mutual learning experience rather than simply exchanging answers (which is considered a form of plagiarism). In particular, you should never submit work for grading that you do not personally understand by the time it was submitted – that is a sure sign of simply copying someone else's work. Knowingly allowing someone else to copy your own work is considered just as dishonest as you copying his/hers.

Open communication with your instructor is the best way to avoid misunderstandings about what collaboration is acceptable. If you worked with someone else on a homework assignment, that fact should always be noted in writing at the top of your paper (e.g. "I worked with Jane Doe and Richard Roe on problems #36 and #38"). Your instructor can then do spot checks to verify the collaboration is appropriate. Unless your instructor indicates otherwise, copying homework solutions posted on the internet or using a solutions manual designated for instructors is considered plagiarism.

It is the responsibility of each student to be aware of policies regulating academic conduct including definitions of academic dishonesty, the possible sanctions, and the appeals process. Any undergraduate student apprehended and charged with cheating, including plagiarism, during his or her college matriculation, shall receive the following discipline:

1. First incident of cheating: failure in paper, assignment, or exam.
2. Second incident of cheating: failure in the course involved.
3. Third incident of cheating: dismissal from the university.

Disabilities:

If you have a disability for which you may need academic accommodation (including special testing, auxiliary aids, non-traditional formats, etc), please provide the instructor with documentation from the Center for Student Success as soon as possible. The Center for Student Success is located on the 2nd floor of the Student Center, Extension 2257.

Email:

If necessary, email will be sent to students' IWU student email accounts. Such email is considered official university correspondence and students are responsible for checking their email on a daily basis.

Tutoring:

Students may receive assistance on a walk-in basis from an upperclassman math major in the Mathematics Learning Lab. The Learning Lab will be held Monday through Thursday evenings from 7:00 – 8:00 p.m. in OHSN 163 beginning the second week of class (the hours may be delayed during Summit to avoid a time conflict). Students wanting more regular assistance may contact the Center for Student Success to request free group tutoring sessions. In addition, students are always welcome to stop by the instructor's office for assistance, both during and outside normal office hours.

Writing Center

The Writing Center is a valuable resource for the writing you will do in this class. Trained Writing Consultants will help you with any stage of the writing process, from developing your topic to polishing your final draft. They WILL NOT write or edit your papers for you, but they WILL help you recognize your weaknesses as writers and provide you with tools for strengthening your writing and editing skills. The Writing Center is located in Elder Hall, Room 222, and is open from 8:00 a.m. -10:00 p.m. Monday through Thursday, 8:00 a.m. - 5:00 p.m. on Friday, and noon to 5:00 p.m. on Saturday. To make an appointment, go to http://indwes.mywconline.com/, call extension 2189, or stop by the Writing Center.

Technology Access

Many of the homework problems and projects will require software (Excel, Minitab, Maple) for completion. All such software is installed on the computers in OHSN 155, 157, 163, 180; for convenience and future use, students are encouraged to acquire copies for their own computer.

Chapter Project Specifications

A project paper should be written from the point of view of a consultant report to your contractor. In other words, an intelligent person, but someone who is unfamiliar with the situation, has hired you as experts in the area to investigate a situation and prepare a formal written document giving the background, analysis, and conclusions of your investigation.

Note that your employer is not interested in seeing long routine algebraic derivations and computations. Rather, s/he wants to clearly see the approach you took to the problem, any and all assumptions you made, a statement of the exact mathematical model you arrived at, the general solution technique you used, and (especially) the significance of your results and any recommendations you may have. If you collected data, you should include the raw data in the report if the data set is small or a summary of the data if the data set is large.

Requirements:

1. *Length*

   At least 4 double-spaced pages of text, **not** including title page, executive summary, graphs, data tables, and appendices.

2. *Style*

   The paper, including its mathematical symbols, must be typed. Graphs and tables must be computer generated and should be numbered (and referred to by number in the text). Graphs should be put near their associated text rather than at the end.

   Justify your choice of techniques used and explain the degree of reliability you place on your final results. Identify and acknowledge the weaknesses and limitations of your results, but emphasize their strong points.

   The writing style should be formal (though not stilted), clear and concise, and organized. Limited use of 1st person plural ("we") is acceptable; 2nd person ("you") must be avoided. Personal opinion should be minimized and clearly identified as such.

3. *Organization*

   A title page should include your name, date, course name, and a descriptive title (e.g. "Ferocity Levels of Cat/Dog Interactions in Small Town Back Yards").

   The paper should begin with an executive summary (approximately ½ page) that presents the most important ideas/results and explains the organization of the rest of the paper. Even though the executive summary appears first, it should be written last after you fully understand the outcome of your study.

   The remainder of the paper should be in topical sections, each preceded by a section heading. The last section should be a brief conclusion that ties any loose ends together

and mentions any related topics you know about that you feel are significant but chose not to cover.

4. *Level*

   The paper should be written so that an upperclassman math major who had not taken this class would be able to understand most of what is being said, yet would learn something new and significant.

5. *References*

   If you used outside sources (not a requirement unless otherwise specified), the paper should include a bibliography giving complete references.

6. *Sample Grading Criteria*

   Note: Point values may be adjusted depending on the number of projects given and their relative levels of difficulty.

Criteria	**Points**
Mathematical depth/creativity	20
Accuracy of mathematical content	20
Readability(organization, new vocabulary/ideas explained, helpful figures, etc)	20
Appearance and mechanics (page layout, grammar, diction, concise style, etc.)	15
TOTAL	75

Major Project Specifications

Timeline:

Component	**Due Date**	**Point Value**
Team / Topic / Data	February 18	15
Meeting with instructor	March 17	15
Rough draft	March 31	30
Final draft	April 12	100
Oral presentation	April 14	40
		200

Length: Final draft: At least 8 double-spaced pages of text, excluding cover page, executive summary, graphs/tables, bibliography, and appendices

Oral presentation: 10 – 13 minutes plus question-and-answer time

Components:

1. Team / Topic / Data

   Submit a 1 or 2 paragraph proposal including:

   a. Team members' names (2-3 per team)

   b. Summary of what question(s) you plan to answer. Your response variable(s) *must* be quantitative; you will have more mathematical options if most of your predictor variables are also quantitative.

   c. Explanation of where/how the raw data will be obtained (either a description of your own collection procedure or a direct web link to the raw data). Data collection by survey is strongly discouraged since it is difficult to collect unbiased samples and permission must be obtained from the administration before doing a survey on campus. Preferred approaches include either doing an easily repeatable experiment or finding a raw data file on the internet. Check with me for suitability before proceeding further. Some likely sources for locating raw data include:

      http://www.data.gov
      http://lib.stat.cmu.edu/DASL/
      http://www.statsci.org/datasets.html
      http://pewinternet.org/Data-Tools/Download-Data.aspx

   Also submit a spreadsheet containing the data and a Word document giving a brief description of the contents of each spreadsheet column along with its units of measurement or any coding done (e.g. 1 = "female", 2 = "male")

2. Meeting with instructor

   Your group will schedule and have a 15-20 minute meeting with the instructor by the due date. You will present your progress to date as well as questions/concerns you may have. The instructor will provide feedback as appropriate.

3. Rough draft

   The rough draft should be nearly full length – at least 6 typed double-spaced pages of text, not including graphs/tables. It should be written from the point of view of a consultant report to your contractor. Omit long routine algebraic derivations – focus on the statement of the problem, the general approach you took, assumptions you made, a statement of the exact mathematical model(s) you arrived at, the general solution technique(s) you used, and the significance of your results and any recommendations you may have. Include the raw data as an appendix if the data set is small or a summary of the data if the data set is large.

   Your paper should explore the topic in depth. Multiple analysis techniques from this course should be used. Justify your choice of techniques and quantitatively evaluate the effectiveness of your final model(s). Identify and acknowledge the weaknesses and limitations of your results, but emphasize their strong points.

   Although grammar, etc., will not be graded on the rough draft, it is easier to write correctly the first time than to make stylistic changes later. The paper should be written in a formal style. Limited use of 1st person plural ("we") is acceptable; 2nd person should be avoided. Personal opinion should be minimized and clearly identified as such.

Criteria	**Point Value**
Depth/creativity of mathematical content	10
Accuracy of mathematical content	10
Readability (organization, new vocabulary/ideas explained, helpful figures/tables, etc)	10
Deductions	
TOTAL	30

4. Final draft

   At least 8 typed double-spaced pages of text, not including graphs/tables, plus a cover page, one paragraph abstract, and complete bibliography. Mathematics must be typeset; graphs and figures must be computer generated. The paper should be in topical sections preceded by section headings. Graphs and tables must appear professional and be numbered and referred to by number in the text; they should be appropriately sized to be legible while allowing placement of the associated text on the same page whenever possible.

Criteria	**Point Value**
Depth/creativity of mathematical content	25
Accuracy of mathematical content	25
Readability (organization, new vocabulary/ideas explained, helpful figures/tables, etc)	25
Mechanics	25
Deductions	
TOTAL	100

5. Oral presentation

Presentations will take place the last two days of class and project groups will randomly be assigned to a 10-13 minute presentation time. All group members must participate in the presentation to an approximately equal extent. You must submit a printed copy of the final version of your PowerPoint slides **before** you present. Rehearsal is important since you will be penalized if you finish early or late. After finishing, you should be prepared to take questions from the audience.

You will be penalized if your presentation fails to run properly (except for the unlikely case of hardware problems), so verify ahead of time that your file loads and runs on the room computer. It is not necessary to dress up, but avoid shorts, hats, etc. It is important to present with confidence, face the audience as much as possible, speak audibly and clearly, and use standard English.

Criteria	**Point Value**
Mechanics – demeanor, speech	10
Coherency – defining the problem, organization, clarity, pace	10
Depth/creativity of mathematical content	10
Accuracy of mathematical content	10
Deductions	
TOTAL	40