



Texas A&M University-San Antonio
College of Science and Arts

ESET 3301/3101 Foundation of Wireless Communication I Lecture & Lab

Fall 2024

Aug 26, 2024 – Dec 13, 2024

Instructor: Dr. Geetha Chandrasekaran
Email: geetha.chandrasekaran@tamusa.edu
Time: Monday & Wednesday **2:15 pm-3:30 pm**
Lab: Tuesday **2 pm- 4:45 pm**
Location: **STEM 243**

Office hours: Monday 5:00 pm-6:00 pm (or by appointment*)
Office Location: ???
Credit Hours: 3 Credits(Lecture) +1 Credit(Lab)
Assignments: Blackboard

Course Description:

This course is intended to be an introduction to the fundamentals of wireless communications, covering both analog and digital communication with a focus on key concepts such as signal representation, modulation techniques, noise modeling, and error control. The course will begin with a quick review of signal processing and later on, also introduce probability prerequisites necessary to understand the theory. Students will then explore analog/ digital modulation techniques, baseband and passband signal representation, Shannon capacity, information theory, and channel coding. The course also addresses practical aspects of wireless communications such as error control, error correction, and noise filtering, and delves into advanced demodulation methods like ML and MAP. Finally, key concepts are introduced including spread spectrum techniques, multi-user communications, and multi-carrier systems such as OFDM, with practical case studies on WiFi, LTE, and 5G. The course blends theoretical knowledge with real-world applications, preparing students for the complexities of modern telecommunications.

Students will engage in hands-on laboratory exercises and design projects to reinforce their understanding of the theoretical concepts. Students are expected to have an elementary working knowledge of MATLAB. Come prepared to participate in class discussions, and interact at any given time. Attendance is mandatory.



Primary Course Text:

- **Ref1:** Upamanyu Madhow, Introduction to Communication Systems, Cambridge University Press, 2014. ISBN-10: 1107022770
- **Ref2:** Simon Haykin, Communication Systems, Wiley & Sons, 4th edition. ISBN-10: 9788126509041

Supplementary Material:

- **Ref3:** Alan Oppenheim, Signals & Systems, Pearson, 2nd edition. ISBN-10: 7560509703
- **Ref4:** David Tse and Pramod Viswanath, Fundamentals of Wireless Communication, Cambridge University Press, 2005., ISBN-10: 0521845270

Suggestion: For Review of Algebra: <https://www.algebrahd.org/>, Khan Academy, virtual office hours, etc.

Corequisite: PHYS 2426, ESET 3101.

Tentative Schedule*

| | Topics/Daily Activities | Readings and Homework | Deliverable/ Due Dates |
|---------------|---|------------------------------|--|
| Week 1 | Intro to Analog & Digital Comm. | Readings: Chapter 1, Ref 1 | |
| Week 2 | Basics of Signals and Systems (LTI, Fourier, Spectral density) | Readings: Chapter 2, Ref 1 | Solved homeworks: End of Week 3 (henceforth written as EoW3) |
| Week 3 | Analog Modulation techniques (AM, FM, Pulse Modulation) | Readings: Chapter 3, Ref 1 | Solved homeworks: EoW4 |
| Week 4 | Wireless signal representation (Baseband, Passband) | Readings: Chapter 2, Ref 1 | Solved homeworks: EoW5 |
| Week 5 | Digital Modulation (Signal constellation, Power Spectral density, Nyquist sampling) Exam 1 | Readings: Chapter 4, Ref 1 | No homework |
| Week 6 | Probability & Random processes basics (Expectation, Stationarity, Qfunction) | Readings: Chapter 5, Ref 1 | Solve homeworks: EoW7 |

| | | | |
|----------------|--|---|---|
| Week 7 | Noise modeling, filtering, correlation | Readings: Chapter 5, Ref 1 No homework | Midterms |
| Week 8 | Demodulation techniques (ML, MAP, Error probabilities, Optimal reception AWGN) | Readings: Chapter 6, Ref 1 | Solve homeworks: EoW9 |
| Week 9 | Channel coding (Shannon capacity, Channel Coding theorem) | Readings: Chapter 9, Ref 2 | Solve homeworks: EoW10 |
| Week 10 | Error control (Discrete memoryless channels) | Readings: Chapter 10, Ref 2 | Solve homeworks: EoW11 |
| Week 11 | Spread spectrum Exam 2 | Readings: Chapter 7, Ref 2 | Solve homeworks: EoW12 |
| Week 12 | Multi-user Radio Communications | Readings: Chapter 8, Ref 2 | Solve homeworks: EoW13 |
| Week 13 | Introduction to ISI and Linear Equalization | Reading: slides/ handouts | Project: EoW 15 |
| Week 14 | Multi-carrier modulation and OFDM | Reading: slides/ handouts | No homework |
| Week 15 | OFDM Case studies: Wi-Fi and cellular (LTE and 5G) | Reading: slides/ handouts | No homework |
| FINAL | Exam 3 | | Date: For the date and time of the final for this class |

** Specific content and Schedule may be revised as deemed necessary by the instructor.*

Taking Notes: Numerous studies, including one from NPR (below), show the importance of note-taking and how it helps students comprehend the subject matter. You are expected to take notes of your own from each session. Supporting documents will be available on BB.

Link: <https://www.npr.org/2016/04/17/474525392/attention-students-put-your-laptops-away>

Contact: Suggest utilizing office hours, and other times, by appointment. All contact should only be via TAMUSA email (geetha@tamusa.edu). Expect a reply via email within 24-48 business hours. Usually, any



email sent on Friday(s) after 5 pm is answered the upcoming Monday. Upon Technical issues, contact Pearson or IT @ TAMUSA!

NOTE: The subject of the email messages to the instructor must begin with the course name, followed by a brief description of the subject. For example (i) sub: ESET 3302- Appointment request (ii) sub: Uni Phy1-Issue with HW3 Q2. If you do not follow this convention, expect delays!

Student Commitment: This course is not about memorizing formulas; I will discuss the concepts and ideas with you and provide resources and tools. You must first comprehend the material and then apply it to solve a wide range of problems, perform work, or participate during Class.

A standard is that for every hour a student spends in Class, they are expected to spend a minimum of 3 hours comprehending the material and doing the required assignment.

Total Lecture hours = 3 hr./ week (1.5 hr in-person 1.5 hr through Blackboard). Hence expected to spend a minimum of an additional 9 hours doing all the required assignments and comprehension. The total minimum Hours suggested for this course equals 9 Hrs/Week.

Technology Requirements:

Please contact IT (helpdesk@tamusa.edu/ call 210 784 4357) at TAMUSA with any technology-related questions, ASAP. You can keep me in the loop, and if you ask me anything I.T.-related, I will not be of any help; instead will ask you to contact IT.

You should have all the bells and whistles to access class material, perform assignments, take Exams, etc.

Bells and whistles (include but not all)

- A working computer/ Laptop with Windows, Mac, or Chromebook Operating system
- Proper internet connection
- Software to read/ write Word and PDF documents
- Working computer peripherals like a **camera, microphone**, etc.

Course Material + Access:

- **Reading Assignment (RA):** Students are required to read specific sections in the textbook before each lecture, to enable a teaching style somewhat similar to a “flipped classroom”, i.e., concentrating on the intuitive understanding of the material, computational problems, etc., instead of derivations of equations.
 - **RA (not graded) should be completed 10:59 pm CST every Friday, + Questions from students need to be posted on Discussion Board by midnight every Saturday!**
- **Homeworks** will be assigned, falling mainly into three categories
 - Computational exercises related to the specific chapters were treated during the past instruction week.
 - Computational exercises requiring a “big picture” approach, using material from different lectures throughout the semester
 - MATLAB simulations are to be written by the students to cover more realistic scenarios for which closed-form equations often do not exist.



- **Lab Report:** Due every **Wednesday**: See Blackboard tabs for Details
- **Final Project: See below**
- Students should be prepared to turn in their solutions by their due date. **No late assignments will be accepted, nor are make-ups allowed.**
- If you cannot submit answers to any assignment online and are within the deadline, you can only get credit for your work by emailing the instructor your completed assignment. Please take pictures/snapshots of the issue faced online so it can be addressed.
- Above mentioned assignments and ebooks can be accessed via BB. Before you start, ensure cookies and cache are cleared from your browser.

Office hours:

Students need to attend these sessions as scheduled every **Monday, Tuesday & Wednesday**. No new topic will be discussed. We may have a class Quiz, followed by a discussion, then a Reading Assignment-based critical Questionnaire discussion and Discussion of concepts or problems on the topic at hand that Week or earlier, as needed.

Instructor Policies

Cell Phone Use

Cell phone use is prohibited once Class begins, and they are to be silenced and put away where they are not seen. If a call is expected, take it out of the Class, and anyone that interrupts Class due to a cell phone will be asked to leave.

Laptop Use

Turn off the personal laptop. During lecture time, the laptop is not needed. For project discussions, the personal laptop is allowed only when the instructor gives permission.

Food in Class

Eating or drinking is NOT permitted in the classes. Students with food or drink will be asked to discard them or leave the room.

Exams:

There will be three (3) exams during the semester: all to be taken at the scheduled date, time, and location(in Class)/ no makeup allowed!

Schedule of Exam and content

| Exam#(%) | Content | Time allowed | Format | Tentative Date |
|----------------|---|----------------|--|--|
| Exam1 (10%) | Ref1: Chapter 2- Chapter 3 | 1hr 30 minutes | Questions will be very similar to Pop quiz/ homework problems | Sep 25, Wednesday in Class from 2:15 pm |
| Exam2 (15%) | Ref1: Chapter 5,6 Ref2:Chapter 9- 10 | 1hr 30 minutes | Questions will be very similar to Pop quiz/ homework problems | Oct 30, Wednesday in Class from 2:15 pm |



| | | | | |
|----------------|------------------------------------|----------------|---|---|
| Exam3 (20%) | Ref2: Chapter 7-8 + handouts | 2hr 30 minutes | Questions will be very similar to Pop quiz/ homework problems | Week 15, Wednesday in Class from 2:15 pm?? |
|----------------|------------------------------------|----------------|---|---|

CURVE: One lowest grade among weekly assignments will be dropped. *All exams are mandatory and no grade replacement is possible!

No make-up Exams, but if you miss an exam, you should contact me by email (**with a valid documented excuse, see below**), at least one week in advance or within 24-hrs of the scheduled exam date for emergency cases. Any missed exam counts as a 0 unless the student has a **valid documented excuse**.

Examples of valid documented excuses are sickness documented with a doctor's note, death in the family documented with a copy of the death notice, and attending university-sponsored events with a Dean's (**Dean of Students**) excuse.

Lab Report: Due every **Wednesday** next week. See Appendix A below for Laboratory Report Format and Guidelines + General Rubrics.

Final Project: Students must prepare a report and present it during Finals week. Final exams cannot be rescheduled or missed. Students will work in teams (2-3 students/team). Each team will identify (or use previous) a practical electronic engineering project (e.g., research, prototype, product, or design) and submit their project plan with a timeline at **week 4** to the instructor for approval. Each team will have to submit a report that describes and analyzes the main findings (Week 14-15) and present the work in Class (during Finals week). The Report should not exceed 10 pages double-spaced, 12 font size with 1-inch margins, and the Final presentation should not exceed 25 slides. The project should demonstrate the student's ability to transfer the knowledge and skills acquired in the course to real-world applications.

See Appendix B: Project Grading Rubric.

Grading Policy

The final course grade for Lecture is calculated as follows:

- Class work 40 %: Quizzes 15%, Homework & Computer Assignments 25%.
- Final Project: 10%. Presentation related to case studies in Wireless Communications (**Details under Final Projects Tab on BB.**)
- Exams: 50% (**15%, 15%, 20%**)

Course grades are awarded as follows:

A: Over 80.0%; B: 70 ~ 79.99%; C: 60.0 ~ 69.99%; D: 50.0 ~ 59.99%; F: less than 49.99%.

Academic Calendar:

<http://www.tamusa.edu/provost/academicresources/academiccalendar.html>



TEXAS A&M UNIVERSITY
SAN ANTONIO

ACADEMIC INTEGRITY:

We take this very seriously!!!

(See <https://www.tamusa.edu/studentengagementsuccess/studentrightsandresponsibilities/academic-misconduct/index.html>)

"According to the Student Code of Conduct, the following are violations of Academic misconduct: Cheating, Plagiarism, Multiple Submissions, Collusion, Lying, and Bribery.

Plagiarism, or copying the words of others with the intent of making it look like your own. Whether you use someone else's phrase word for word, or whether you try and change a few words, or even if you just borrow someone else's original idea and don't give them credit, that's unethical. Use your own words whenever possible, give credit to wherever, and put direct quotes inside quotation marks.

Cheating involves trying to trick me or others into thinking you did work that you did not do.

Searching the Internet for homework solutions and copying what you find is considered cheating.

Searching the Internet for help on a topic is okay. For example, suppose a question asks, "What are Newton's Laws of Motion." Typing that phrase into any internet search engine and cutting and pasting the text in the answer box is considered cheating. Typing " What are Newton's Laws of Motion " into any internet search engine, reading a few web pages, and summarizing the information in your own words is not cheating.

o Borrowing a previous student's homework, exams, or solution sets is considered cheating.

Collusion is defined as working with another person to cheat. This can include copying someone else's answers to an exam or assignment, doing work for another student, buying or otherwise obtaining homework/exam solutions from any source online or offline, or any other instance of multiple people engaging in some form of Cheating or Dishonesty. Working with other students on an assignment is fine as long as everyone contributes, and each student does their work."

Overall, If you have any doubt whatsoever whether a specific action is considered dishonest, please ask me *before* engaging in the activity. There is no need to be embarrassed about asking, and I will not penalize you for asking!

IMPORTANT POLICIES AND RESOURCES

Academic Accommodations for Persons with Disabilities The Americans with Disabilities Act of 1990, as amended, and the Rehabilitation Act of 1973 are federal anti-discrimination statutes that provide comprehensive civil rights protection for individuals with disabilities. Title II of the ADA and Section 504 of the Rehabilitation Act require that students with disabilities be guaranteed equal Access to the learning environment through the provision of reasonable and appropriate accommodation of their disability. If you have a disability that may require accommodation, please contact Disability Support Services (DSS) for the coordination of services. The phone number for DSS is (210) 784-1335 and email is dss@tamusa.edu.

Academic Learning Center All currently enrolled students at Texas A&M University-San Antonio can utilize the Academic Learning Center for subject-area tutoring. The Academic Learning Center is an appointment based center where appointments are made through the Navigate platform. Students Access Navigate through Jagwire in the Student Services tab. The Center is active on campus outreaching to students to highlight services offered. You can contact the Academic Learning Center by emailing



tutoring@tamusa.edu or calling (210)-784-1332. Appointments can also be made through JagWire under the services tab.

Counseling Resources As a college student, there may be times when personal stress interferes with your academic performance and/or negatively impacts your daily functioning. If you or someone you know is experiencing life stressors, emotional difficulties, or mental health concerns at Texas A&M University – San Antonio, please contact the Student Counseling Center (SCC) located in Modular C, Room 166 (rear entrance) or call 210-784-1331 between the hours of 8:00 am and 5:00 pm, Monday – Friday. After-hours crisis support is available by calling 210-784-1331 (select option "2"). Please contact UPD at 911 if harm to self or harm to others is imminent.

All mental health services provided by the SCC are free, confidential (as the law allows), and are not part of a student's academic or university record. SCC provides brief individual and group therapy, crisis intervention, consultation, case management, and prevention services. For more information, please visit www.tamusa.edu/studentcounseling

Emergency Preparedness JagE Alert is Texas A&M University-San Antonio's mass notification. In the event of an emergency, such as inclement weather, students, staff and faculty, who are registered, will have the option to receive a text message, email and/or phone call with instructions and updates. To register or update your information visit: <https://tamusa.bbcportal.com/> More information about Emergency Preparedness and the Emergency Response Guide can be found here: <https://www.tamusa.edu/upd/index.html>

Financial Aid and Verification of Attendance According to the following federal regulation, 34 CFR 668.21: US Department of Education (DoE) Title IV regulation, a student can only receive Title IV funds based on Title IV eligibility criteria which include class attendance. If Title IV funds are disbursed to ineligible students (including students who fail to begin attendance), the institution must return these funds to the US DoE within 30 days of becoming aware that the student will not or has not begun attendance. Faculty will provide the Office of Financial Aid with an electronic notification if a student has not attended the first Week of Class. Any student receiving federal financial aid who does not attend the first Week of Class will have their aid terminated and returned to the DoE. Please note that any student who stops attending at any time during the semester may also need to return a portion of their federal aid.

Meeting Basic Needs If you face challenges securing food, housing or other basic needs, you are not alone, and A&M- San Antonio can help during this time of crisis. We invite you to learn about the many resources available to support you by visiting the [Dean of Student's website](#) or by reaching out via dos@tamusa.edu. Additionally, it is not unusual for students to encounter temporary illness or injuries that may interfere with your academic success. Students may request temporary illness/disability assistance by reaching out to the [Dean of Student's Office](#) (210) 784-1354. If you are comfortable doing so, please notify the professor of any issues so that they may provide additional resources.

Military Affairs Veterans and active-duty military personnel are welcomed and encouraged to communicate, in advance if possible, and in special circumstances (e.g., upcoming deployment, drill requirements, disability accommodations). You are also encouraged to visit the Patriots' Casa in-person room 202, or to contact the Office of Military Affairs with any questions at military.va@tamusa.edu, or (210)784-1397.

Religious Observances Texas A&M University-San Antonio recognizes the diversity of faiths represented among the campus community and protects the rights of students, faculty, and staff to observe religious holidays according to their tradition. Under the policy, students are provided an opportunity to make up



any examination, study, or work requirements that may be missed due to a religious observance provided they notify their instructors before the end of the second Week of classes for regular session classes.

Respect for Diversity We understand that our students represent diverse backgrounds and perspectives. When we are equity-minded, we are aware of differences and inequalities and are willing to discuss them so we can act to resolve them. The University is committed to building cultural competencies, or the attitudes, skills, and knowledge that enable individuals and organizations to acknowledge cultural differences and incorporate these differences in working with people from diverse cultures. Respecting and accepting people different than you is vital to your success in the Class, on campus, and as a future professional in the global community. While working together to build this community we ask all members to:

- Share their unique experiences, values, and beliefs.
- Be open to the views of others.
- Honor the uniqueness of their colleagues.
- Value each other's opinions and communicate respectfully.
- Keep confidential discussions that the community has of a personal (or professional) nature.
- Use this opportunity together to discuss ways in which we can create an inclusive environment in this course and across the A&M-San Antonio community.

The Six-Drop Rule Students are subject to the requirements of Senate Bill (SB) 1231 passed by the Texas Legislature in 2007. SB 1231 limits students to a maximum of six (6) non-punitive course drops (i.e., courses a student chooses to drop) during their undergraduate careers. A non-punitive drop does not affect the student's GPA. However, course drops that exceed the maximum allowed by SB 1231 will be treated as "F" grades and will impact the student's GPA.

Statement of Harassment and Discrimination Texas A&M University-San Antonio is committed to the fundamental principles of academic freedom, equality of opportunity, and human dignity. To fulfill its multiple missions as an institution of higher learning, A&M-San Antonio encourages a climate that values and nurtures collegiality, diversity, pluralism, and the uniqueness of the individual within our state, nation, and world. All decisions and actions involving students and employees should be based on applicable law and individual merit. Texas A&M University-San Antonio, in accordance with applicable federal and state law, prohibits discrimination, including harassment, on the basis of race, color, sex, religion, national origin, age, disability, genetic information, veteran status, sexual orientation, gender identity, or gender expression. Individuals who believe they have experienced harassment or discrimination prohibited by this statement are encouraged to contact the appropriate offices within their respective units.

Texas A&M University-San Antonio faculty are committed to helping create a safe learning environment for all students and for the university as a whole. If you have experienced any form of sex- or gender-based discrimination or harassment, including sexual assault, sexual harassment, domestic or dating violence, or stalking, know that help and support are available. A&M-San Antonio has staff members trained to support survivors in navigating campus life, accessing health and counseling services, providing academic and housing accommodations, and more. The university strongly encourages all students to report any such incidents to the university. Please be aware that all A&M-San Antonio employees (other than those designated as confidential resources such as counselors and other healthcare providers) are required to report information about such discrimination and harassment to



the university. This means that if you tell a faculty member about a situation of sexual harassment, sexual violence, or other related misconduct, the faculty member must share that information with the university's Title IX Coordinator. If you wish to speak to a confidential employee who does not have this reporting responsibility, you can contact the Student Counseling Center at (210) 784-1331, Modular C.

Students' Rights and Responsibilities The purpose of the following statement is to enumerate the essential provisions for the student's freedom and responsibility to learn at Texas A&M University-San Antonio. All students are required to follow all policies and regulations as set forth by The Texas A&M University System. This includes the [A&M-San Antonio Student Code of Conduct](#).

Students' Rights

1. A student shall have the right to participate in a free exchange of ideas, and there shall be no university rule or procedure that in any way abridges the rights of freedom of speech, expression, petition and peaceful assembly as set forth in the US Constitution.
2. Each student shall have the right to participate in all areas and activities of the university, free from any form of discrimination, including harassment, on the basis of race, color, national or ethnic origin, religion, sex, disability, age, sexual orientation, genetic information, veteran status, gender identity, or gender expression in accordance with applicable federal and state laws.
3. A student has the right to personal privacy except as otherwise provided by law, and this will be observed by students and University authorities alike.
4. Each student subject to disciplinary action arising from violations of university student rules shall be assured a fundamentally fair process.

Students' Responsibilities

1. A student has the responsibility to respect the rights and property of others, including other students, the faculty and the administration.
2. A student has the responsibility to be fully acquainted with the published University Student Rules found in the Student Handbook, Student Code of Conduct, on our website, University Catalog and students must comply with them and the laws of the land.
3. A student has the responsibility to recognize that student actions reflect upon the individuals involved and upon the entire university community.
4. A student has the responsibility to recognize the University's obligation to provide an environment for learning.
5. A student has the responsibility to check their university email for any updates or official university notification.
6. We expect that students will behave in a manner that is dignified, respectful, and courteous to all people, regardless of sex, ethnic/racial origin, religious background, sexual orientation or disability. Behaviors that infringe on the rights of another individual will not be tolerated.

Writing, Language, and Digital Composing Center The Writing, Language, and Digital Composing Center supports graduate and undergraduate students in all three colleges as well as faculty and staff. Tutors work with students to develop reading skills, prepare oral presentations, and plan, draft, and revise their written assignments. Our language tutors support students enrolled in Spanish courses and students



composing in Spanish for any assignment. Our digital studio tutors support students working on digital projects such as eportfolios, class presentations, or other digital multimedia projects. Students can schedule appointments through JagWire under the Student Services tab. Click on "Writing, Language, and Digital Composing Center" to make your appointment. The Center offers face-to-face, synchronous online, and asynchronous digital appointments. More information about what services we offer, how to make an appointment, and how to access your appointment can be found on our website at <https://bit.ly/WLDCCenter>.

APPENDIX A

Laboratory Report Format and Guidelines

It is essential that students be able to express their ideas and defend their arguments with clarity, detail and subtlety.

Similarly, it is important that they can read and critique the ideas and arguments of others in like manner. The creation of lab reports assists in this endeavor.

Unless otherwise specified, all lab exercises require a write-up. All reports should be neat and legible. Standard technical writing style is expected along with proper grammar and spelling. This means that active voice, first person, personal pronouns, and the like should be avoided. For example, don't write "I set the power supply to 6 volts". Instead use "The power supply was set to 6 volts". Reports are an individual endeavor. Although it is perfectly fine to discuss your data and experimental results with your lab partner, the creation of the Report itself is an individual exercise. Plagiarism will not be tolerated. A report should conform to the following outline, in the order given:

1) Objective / Hypothesis. These are statements regarding the items, relationships, characteristics, etc. that you are investigating in this particular exercise. This is the first part that you write. Indeed, it can be written before you even step foot into the lab. An hypothesis tends to be narrow and focused, but not so focused that it only applies to this particular exercise. Examples might be "The speed of sound in air increases as the air temperature rises" or "The voltage across a given resistance is directly proportional to the current through it". This section tends to be fairly short.

2) Conclusion. Address the hypothesis: was it verified? These are concise statements of fact regarding the circuit action(s) under investigation. Make sure that you have moved from the specific lab situation to the general case. If all works well, these should match nicely with your Objective/Hypothesis section. Under no circumstances should you reach a conclusion that is not supported by your data, even if that conclusion is stated in the text or in lecture. What matters here is what you did and your analysis of it. If there is a discrepancy between your results and theory, state the discrepancy and don't ignore your results. The Conclusion is the final section that you write. It addresses the Objective and is supported by the Discussion. Think of it as an Executive Summary.

3) Discussion (AKA Analysis). Reduce and analyze your data. Explain circuit action or concepts under investigation. Relate theoretical results to the lab results. Don't just state what happened, but comment on why and its implications. Derive your conclusions from this section. The Discussion is not a rewording of the procedure, however, any deviations from the procedure as given by the lab manual must be noted in this section. Otherwise the procedure used is assumed to be the same as in the lab manual. The Discussion



is the penultimate part that you write and tends to be the longest section. When performing your analysis, always keep in mind that you should be trying to affirm the null hypothesis. The null hypothesis is, in essence, the inverse of the stated hypothesis. You can think of it as the default situation. Using the first example hypothesis above, the null would be "The speed of sound in air is not dependent on air temperature". In your data tables, you'd be looking to see if the null is true, i.e., that there is no relationship between speed and temperature. In this case, if your data were correct, they would indicate an increase in speed as temperature rose, so the null is not true, and therefore your hypothesis is a valid candidate for describing reality. Having this mindset helps you to avoid cherry picking the data, that is, only seeing the things that confirm what you want and ignoring the rest. Cherry picking is a form of observer bias, is intellectually dishonest, and any good investigation needs to avoid it.

4) Final Data Sheet. Include all derived and calculated data. Make sure that you include percent deviations for each theory/measurement pair. Use Percent Deviation = $(\text{Measured}-\text{Theory})/\text{Theory} * 100$, and include the sign. Include the model and serial numbers of all test equipment. Along with the graphs, this is the second part of the Report that you write. Until this section is completed, it is not possible to complete an analysis and write the Discussion section.

5) Graphs, Answers to questions at the end of the exercise, Other. All graphs must be properly titled, created using appropriate scales, and identified with labels. It is suggested that graphs be created with a plotting program or a spreadsheet. Alternately, graphs may be created manually but must be drawn using either a straight edge or a french curve (depending on the type of graph) on appropriate graph paper.

- You can get details on graphing under Blackboard Tab(LabGraph Sample)
- You can see an example lab report under Blackboard Tab(LabReport Sample).

Make sure that you leave sufficient space in the margins and between sections for my comments. 1.5 line spacing is fine. Multi-page reports should be printed single-sided and must be stapled in the upper left corner. Paper clips, fold-overs, bits of hook-up wire, etc. are not acceptable. Reports are due no later than the start of the next lab period following the date performed. Late reports are reduced by one letter grade for the first half week late and two letter grades for the second half week. Reports are not acceptable beyond one week late. Below is the grading standard.

Grade of A: The Report meets or exceeds the assignment particulars. The Report is neat and professional in appearance, including proper spelling and syntax. The analysis is at the appropriate level and of sufficient detail. Data tables and graphical data are presented in a clear and concise manner. Problem solutions are sufficiently detailed and correct. Diagrams have a professional appearance.

Grade of B: The Report is close to the ideal although it suffers from some minor drawbacks which may include some spelling or grammatical errors, analyses which may lack sufficient detail, minor omissions in tabular or graphical data, and the like. In general, the Report is solid but could use refinement or tightening.

Grade of C: The Report is serviceable and conveys the major ideas although it may be vague in spots. Spelling and grammatical errors may be more numerous than those found in a grade A or B report. Some gaps in data or omissions in explanations may be seen.

Grade of D: Besides typical spelling and grammatical errors, the Report suffers from logical errors such as conclusions which are not supported by laboratory data. Analyses tend to be vague and possibly misleading. Graphs and diagrams are drawn in an unclear manner.



Grade of F: The Report exhibits many of the following deficiencies: Excessive spelling and grammatical errors, missing sections such as graphs, tables, and analyses, blatantly incorrect analyses, wayward or incomprehensible data, problem solutions tend to be incorrect or missing, and graphical data or diagrams are presented in a shoddy manner.

APPENDIX B

Final Project Grading Rubric

Rubric for grading:

- 1) (10 marks) Project Plan
- 2) (10 marks) Introduction, and Objectives
- 3) (10 marks) Organization and clarity
- 4) (20 marks) Methodology and Contributions*
- 5) (20 marks) Analysis and Results
- 6) (10 marks) References & Citations*
- 7) (20 marks) Presentation
- 8) (25 marks) Bonus – Innovative, conference/ journal submissions