## Appendix G – Performance Criteria and Rubrics

The following is a list of outcomes measured using direct quantitative assessments. For each outcome, the performance criteria and rubrics are presented. In the case of outcomes 9 (life-long learning) there are different sets of performance criteria for the different courses used in the assessments. However, they are consistent with the outcome.

**Outcome 1**. *An ability to apply knowledge of mathematics, science, and engineering.*

**Performance criteria and rubrics:** (*table continues on the next page*)

| **Performance criteria** | **Exemplary** | **Satisfactory** | **Marginal** | **Unsatisfactory** |
|---|---|---|---|---|
| *1a) Ability to apply knowledge of probability and statistics, including applications appropriate to computer eengineering.* | Thorough understanding of probabilistic methods and its application. | Good ability to applyof conditional probability, multiple random variables, correlation, properties of expectation and limit theorems to solve problems relevant to computer engineering. | Understanding of the axioms of probability and their consequences and single random variables. | Insufficient understanding of probabilistic foundations. |
| *1b) Ability to apply knowledge of mathematics through differential and integral calculus.* | Able to develop equivalent circuit models and solve associated mathematical models for computer engineering problems. | Able to solve second-order differntial equations and select approrpriate solution for physical systems. | Able to evaluate derivatives and integrals in various coordinate systems. | Insufficient knowledge of calculus. |
| *1c) Ability to apply knowledge of advanced mathematics (linear algebra) and circuit theory.* | In addition to the "Satisfactory" requirements, able to interpret and analyze the characteristics of the solutions using linear algebra and relate results to the relevant characteristics of physical models. | Able to correctly formulate and solve circuit problems using linear algebra. | Able to correctly formulate and solve simple circuit problems using linear algebra. | Unable to formulate a simple circuit problem using linear algebra. |

*Table continued from the previous page.*

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|
| *1d) Ability to apply knowledge of advanced mathematics (differential equations) in the context of computer engineering.* | Able to formulate computer engineering problems as differential equations and the mastery of multiple techniques for solving them. | Able to formulate computer engineering problems as differential equations and solving them by at least one technique. | Able to solve first-order differential equations with sinusoidal and exponential inputs. | Unable to formulate and solve differential equations for computer engineering problems. |
| *1e) Ability to apply knowledge of advanced mathematics (complex variables) and circuit theory.* | In addition to the "Satisfactory" requirements, able to interpret and analyze the characteristics of the solutions using complex variables and their relationship to real-time forms. | Able to formulate and solve sinusoidal responses of circuits using complex variables. | Able to do complex arithmetic, but unable to effectively apply complex variables to obtain sinusoidal responses of circuits. | Unable to do complex number arithmetic. |
| *1f) Ability to apply knowledge of advanced mathematics (discrete mathematics for probability) in the context of computer engineering.* | Thorough ability to apply combinatorial techniques and set theory operations to solve problems relevant to computer engineering. | Able to solve combinatorial problems using simple set theory operations and counting principles, (e.g. permutations and combinations). | Basic understanding of fundamental set theory operations. | Insufficient understanding of counting principles and simple set theory operations. |
| *1g) Ability to apply knowledge of sciences (defineed as biological, chemical, or physical science) and device theory.* | In addition to the "Satisfactory" requirement, have the skills to analyze/solve complex problems or design simple electronic structures. | Able to formulate and solve problems, and also have the ability to correctly analyze and interpret related physical phenomena and structures. | Understanding of physical sciences and ability to formulate and solve related simple problems in computer engineering. | Insufficient knowledge of physical sciences and inability to understand related concepts in computer engineering (such as solid state electronics and EM theory). |

**Outcome 2**. *An ability to design and conduct experiments, as well as to analyze and interpret data.*

**Performance criteria and rubrics:** (*table continues on the next page*)

| **Performance criteria** | **Exemplary** | **Satisfactory** | **Marginal** | **Unsatisfactory** |
|---|---|---|---|---|
| *2a) Experimental Design* | Understands and uses proper scientific methods and procedures. Can design and evaluate more complex experiments. | Understands and uses proper scientific methods and procedures. Can design and evaluate simple experiments. | Knows proper scientific methods and procedures, but is unable to properly implement them. Can design and evaluate experiments only with assistance. | No knowledge of scientific methods and procedures. Incapable of designing or evaluating experiments. |
| *2b) Knowledge of theory, of the testing methods, and the experimental protocols* | Has perfect knowledge of the theory and can anticipate the most likely outcome of the experiment; knows all the details of the methods and is able to provide full justification of the protocols used. | Understands well the theory and its connection with the experiments. Knows how to use the testing methods appropriately (filling in details if necessary), and understands the meaning of most protocols' directions. | Knows some of the theory, but fails to see the connection with the experiment; knows how to use the instruments only by following detailed descriptions, and strictly follows directions of the handouts. | Does not understand the theory behind the experiment, cannot use the testing methods appropriately, and collects measurements randomly. |
| *2c) Experiment execution* | Can perform the experiments without any detailed instructions. | Can perform experiments with some degree of independence; does not strictly rely on handouts and/or the instructor. | Follows instructions on the handouts, but would not be able to modify it to different situations if not minimally. | Has to rely on other students/the instructor to execute the simplest measurement. |

*Table continued from the previous page.*

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|
| *2d) Data collection, analysis, representation, and interpretation* | All required data are collected and correctly reported. Always identifies and quantifies causes of inaccuracy. Has a deep knowledge of data analysis techniques and applies it appropriately. Always uses mathematical and charting tools to analyze and represent data. Always recognizes/ isolates experimental artifacts and errors due to assumptions and constraints, explains them, and suggests solutions. Accurate and appropriate interpretation of data. Not under- or overinterpreted. | Most data are collected appropriately. Is aware of inaccuracy, and in most cases is able to identify it and quantify it. Knows how to apply data analysis techniques. Often uses appropriate mathematical and charting tools to analyze and represent data. Significant level of interpretation attempted and most interpretations appropriate. Typically identifies artifacts/errors due to assumptions, reports them, and sometimes finds appropriate explanations. | Only the most basic data are collected. Is aware of inaccuracies, but can deal with it only occasionally. Applies data analysis only if instructed. Charts data sporadically. Occasionally identifies some artifacts/errors due to assumptions, but does not know how to deal with them. Interprets some data but some significant errors in interpretation. | Left to oneself, cannot gather any meaningful data. Is unaware of the concept of inaccuracy. See no need in data analysis. Reports purely unprocessed data, where clearly spurious results are never recognized. Little or no attempt at interpreting the data collected in the experiment. |

**Outcome 3**. *An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.*

## Performance criteria and rubrics:

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|
| *3a) Design strategy* | Can develop and follow a design strategy to meet a specified need with little or no guidance | Can develop and follow a design strategy to meet a specified need with guidance | Can follow a provided design strategy | No design strategy |
| *3b) Realistic design constraints such as economic, environmental, social, political, ethical, health and safety, and manufacturability, and sustainability.* | Can identify and meet all of the design constraints with little or no guidance. | Can identify and meet all of the of the design constraints with guidance. | Can identify and meet some of the design constraints with guidance. | Disregards or does not understand design objectives and constraints |
| *3c) Quality of design* | Multiple designs are obtained and the optimal design is identified and adequately justified. | Multiple designs are obtained but the optimal one is not identified | A design is obtained but not checked for quality | Cannot create a design |
| *d) Engineering standards* | Can identify and apply all standards relevant to the design problem with little or no guidance | Can identify and apply all standards relevant to the design problem with guidance | Can identify some standards relevant to the design problem with guidance | Unaware of any standards |

**Outcome 4**. *An ability to function on multidisciplinary teams.*

**Performance criteria and rubrics:**

| **Performance criteria** | **Exemplary** | **Satisfactory** | **Marginal** | **Unsatisfactory** |
|---|---|---|---|---|
| *4a) Fulfill team's role's duties* | Performs all duties of assigned team role. | Performs nearly all duties | Performs very little duties | Does not perform any duties of assigned team role. |
| *4b) Share equally* | Always does the assigned work without having to be reminded | Usually does the assigned work – rarely needs reminding | Rarely does assigned work – often needs reminding | Always relies on others to do the work. |
| *4c) Listen to other teammates* | Listens and speaks a fair amount. | Listen, but sometimes talks too much | Usually doing most of the talking – rarely allows others to speak | Is always talking – never allows anyone to speak |

**Outcome 5**. *An ability to identify, formulate and solve engineering problems.*

**Performance criteria and rubrics:**

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfatory |
|---|---|---|---|---|
| *5a) Solution strategy* | Develops and follows efficient strategy leading to correct solutions. Able to solve difficult engineering problems. | Develops and follows acceptable solution strategies. Able to solve moderately difficult engineering problems | Can formulate some solution strategies but requires guidance to find strategies and solutions. | Has no strategy |
| *5b) Apply theoretical concepts* | Applies all of the theoretical concepts to computer engineering problem solving. | Applies most of the theoretical concepts to computer engineering problem solving. | Can apply at least some of the theoretical concepts to computer engineering problem solving. | Cannot apply theoretical concepts to computer engineering problem solving. |
| *5c) Identify and formulate engineering problems* | Can identify and formulate all of the computer engineering problems in an assignment or project, and can integrate their solutions effectively. | Can identify and formulate all of the computer engineering problems in an assignment or project. | Can identify and formulate at least half of the computer engineering problems in an assignment or project. | Unable to identify computer engineering problems in an assignment or project. |

**Outcome 6**. *An understanding of professional and ethical responsibility*.

**Performance criteria and rubrics:**

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|
| *6a) Demonstrate knowledge of ethical dilemmas and resolution approaches* | Can clearly apply a resolution approach to a particular ethical dilemma. | Recognizes dilemmas and can describe general dilemma resolution approaches. | Recognizes dilemmas but cannot indicate any path to resolution. | Cannot recognize ethical dilemmas. |
| *6b) Demonstrate knowledge of a professional engineering code of ethics* | Can clearly establish that he/she has read and understands a professional code of ethics. | Knows about various aspects of code of ethics but sometimes confuses personal ethics with professional ethics. | Student is aware of the existence of the code of ethics of the professional society in the engineering discipline. | Unaware of any codes of ethical behavior. |
| *6c) Evaluate the dimensions of professional engineering practices* | Can describe an application of a professional code of ethics related to engineering, with a clear connection between the code provisions and the application. | Can show familiarity with tools for applying ethics to engineering practice. | Can distinguish engineering ethics from personal ethics. | Can only describe ethical issues or applications outside engineering or that do not clearly involve ethics. |
| *6d) Demonstrate knowledge of ethical use of intellectual property* | Can clearly distinguish legal and ethical considerations regarding intellectual property. | Recognizes intellectual property and describe legal and ethical considerations, without distinguishing between legal and ethical considerations. | Recognizes intellectual property, but cannot identify ethical considerations. | Cannot identify intellectual property. |

**Outcome 7**: *An ability to communicate effectively*.

The outcome has four performance criteria and their rubrics:

- Written report organization and style
- Written report content
- Oral presentation content
- Oral presentation delivery.

Each performance criteria has hallmarks. The rubrics are with respect to these hallmarks.

*Written Report Organization and Style Hallmarks*

1. The report is organized into chapters and or sections including an introduction section and a conclusions, summary or final remarks section. The chapters and sections should be properly numbered and titled.
2. There should be a description of the organization of the report presented somewhere at the beginning, e.g., in the introduction section. The description should briefly explain the chapters and sections to give the reader an overview.
3. Sentences and paragraphs are clear and well organized.
4. Chapters and sections are clear and well organized. There should be good transitions between paragraphs.
5. There should be no spelling or grammatical errors
6. The report should follow any formatting instructions including but not limited to margins, font size, abstract, spacing, cover page format, etc
7. There should be a list of references and the list should follow the IEEE reference style or similar style.
8. Figures and tables should be properly formatted. Figures should have captions and tables should have titles, and the captions and titles should be well written. Figures and tables should be numbered. They should appear either on the same page they are first referenced, after they are first referenced (e.g., on the next page), or in the back of the report.
9. All unfamiliar technical terms should be italicized on first use and defined.
10. Tables and figures should be properly referenced within the text of the report. Citations to the reference list should be done properly.

*Written Report Content Hallmarks*

1. There should be a description of what the report is about including objectives, and if appropriate, motivation
2. The accomplishments and results are presented.
3. Clear description of procedures and work involved is given
4. Background material is presented, such as previous work, modeling information, etc.
5. Conclusions, summaries, and interpretations of the results are given wherever appropriate.
6. There should be concluding statements including summary of task, and any suggestions for future work.

7. A sufficient number of figures and tables are in the report. The figures and tables are clear, and they should improve the clarity of the report.
8. References to other work and documents and all appropriate citations are given within the body of the report.

*Oral Presentation Content Hallmarks*

1. Clear, strong thesis statement
2. Main points were clear
3. Main points were substantive
4. Supporting evidence was provided when necessary
5. Sources of information were cited.
6. Review of main points were included in conclusion
7. Concluding statement was clear - presentation ended smoothly

*Oral Presentation Delivery Hallmarks*

1. Extemporaneous delivery
2. Effective eye contact
3. Clear vocal delivery
4. Appropriate and effective language use
5. Effective articulation and pronouncement of words
6. Well prepared slides (if appropriate) with sufficient figures and tables and or other appropriate visual and audio aids.
7. Provides clear and appropriate answers

**Performance criteria and rubrics:**

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfatory |
|---|---|---|---|---|
| *7a) Writing organization and style* | Meets all hallmarks at a high level. | Meets all nearly all hallmarks at a high level and has some effort in the remaining hallmarks. | Meets at least half the hallmark at a high level and has some effort in the remaining hallmarks. | Does not meet half of the hallmarks at a high level or there is at least one hallmark with no effort. |
| *7b) Writing content* | Meets all hallmarks at a high level | Meets all nearly all hallmarks at a high level and has some effort in the remaining hallmarks. | Meets at least half the hallmark at a high level and has some effort in the remaining hallmarks. | Does not meet half of the hallmarks at a high level or there is at least one hallmark with no effort. |
| *7c) Oral presentation delivery* | Meets all hallmarks at a high level | Meets all nearly all hallmarks at a high level and has some effort in the remaining hallmarks. | Meets at least half the hallmark at a high level and has some effort in the remaining hallmarks. | Does not meet half of the hallmarks at a high level or there is at least one hallmark with no effort. |
| *7d) Oral presentation content* | Meets all hallmarks at a high level | Meets all nearly all hallmarks at a high level and has some effort in the remaining hallmarks. | Meets at least half the hallmark at a high level and has some effort in the remaining hallmarks. | Does not meet half of the hallmarks at a high level or there is at least one hallmark with no effort. |

**Outcome 8:** *The broad education necessary to understand the impact of engineering solutions in global, economic, environmental, and societal context*

**Performance criteria and rubrics:**

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|
| *8a) Global economy* | Can discuss how engineering solutions in a technical field might affect the global economy in the future. | Can identify how engineering solutions affect the global economy. | Understands computer engineering is in a global economy but does not understand how engineering solutions affect the economy and vice versa. | Does not understand that engineering is in a global economy. |
| *8b) Societal* | Can analyze comprehensively how an engineering solution might impact the society both positively and negatively. Can discuss the tradeoffs. | Is aware that engineering solutions can impact the society, and can discuss how a specific engineering solution may impact the society. | Is aware that engineering solutions can impact the society. | Is unaware that engineering solutions can impact the society. |
| *8c) Environment* | Can analyze comprehensively how an engineering solution might impact the environment, including some quantitative estimates of the impact. | Is aware that engineering solutions can impact the environment, and can discuss how a specific engineering solution may impact the environment. | Is aware that engineering solutions can impact the environment. | Is unaware that engineering solutions can impact the environment. |

**Outcome 9:** *A recognition of the need for and an ability to engage in life-long learning (LLL)*

**Performance criteria and rubrics:**

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|
| *9a) Recognition of the need for life-long learning* | Aware of the need, actively search and learn new tools and methods, and show the potential to learn beyond the project need. | Aware of the need, and actively search and learn new tools and methods. | Aware of the need, but do not actively search and learn new tools and methods | Not aware of the need, and wait for someone to tell them what to do. |
| *9b) Ability to engage in life-long learning* | Can identify deficiencies and new tools/techniques needed in research, is able to master the use of them, and is able to explain the basic concepts and theory behind them. | Can identify deficiencies and new tools/methods needed in research, apply them in projects, with limited understanding of the theory or method behind the tools/techniques. | Able to identify deficiencies and new tools/methods needed, but is not able to use them very well. | Cannot identify deficiencies and new tools/methods needed for the project. |

These performance criteria and rubrics are used to measure the level of achievement in the EE 496 Capstone Design Project. The assessments were based on oral presentations in a poster session.

However, we use a different performance criteria and rubrics when measuring the level of achievement in EE 367L Computer Data Structures and Algorithms Lab. The criteria is different since the measurements are based on a written report rather than a poster session. The following are the performance criteria and rubrics.

**Performance criteria and rubrics used in EE 367L Computer Data Structures and Algorithms Lab:**

| **Performance criteria** | **Exemplary** | **Satisfactory** | **Marginal** | **Unacceptable** |
|---|---|---|---|---|
| *9a) Independent learning* | Can always complete the given task independently and goes beyond what is required. | Often can complete a task independently, but completes only what is required. | Requires guidance to complete a task. | Requires step-by-step instructions to complete a task. |
| *9b) Identify life-long learning opportunities* | Identifies many life-long learning opportunities | Identifies some life-long learning opportunities | Identifies very few life-long learning opportunities | Identifies no life-long learning opportunities |
| *9c) Explain the importance of life-long learning* | Excellent understanding of the importance of life-long learning | Some understanding of the importance of life-long learning | Very limited understanding of the importance of life-long learning | No understanding of the importance of life-long learning |
| *9d) The ability to research and gather information* | Use the references to literature as evidence here in the rubrics. Collects a great deal of information most of which is relevant. | Use the references to literature as evidence here in the rubrics Collects some information with some relevance. | Use the references to literature as evidence here in the rubrics. Collects a little information with a little relevance. | Use the references to literature as evidence here in the rubrics. Collects no or irrelevant information |

**Outcome 10:** *A knowledge of contemporary issues*

**Performance criteria and rubrics:**

| **Performance criteria** | **Exemplary** | **Satisfactory** | **Marginal** | **Unsatisfactory** |
|---|---|---|---|---|
| *10a) Contemporary ethical issues* | Very good knowledge of contemporary ethics and understands more difficult issues. | Good knowledge of contemporary ethics and good grasp of concepts. | Some knowledge of contemporary ethics with fair grasp of concepts. | Poor or no knowledge of contemporary engineering ethics. |
| *10b) Contemporary technical issues* | Has very good knowledge of current technical issues and has some vision. | Has reasonable knowledge of current technical issues and can discuss these issues. | Has some knowledge of current technical issues,but not well articulated. | Has poor knowledge of current technical issues. |
| *10c) Contemporary political, economic, and social issues* | Has in depth understanding of current political, economic, and social issues and makes good connection to engineering problems. | Has understanding of current political, economic, and social issues and makes some connection to engineering problems. | Has some understanding of current political, economic, and social issues, but does not connect well to engineering problems. | Has little or no understanding of current political, economic, and social issues. |

**Outcome 11**. *An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

**Performance criteria and rubrics:**

| **Performance indicators** | **Exemplary** | **Satisfactory** | **Marginal** | **Unsatisfatory** |
|---|---|---|---|---|
| *11a) Laboratory equipment* | Able to use all the equipment with little or no guidance. | Able to use all the equipment with guidance | Able to use most of the equipment but with repeated guidance. | Does not know how to use laboratory equipment, even with guidance |
| *11b) Research resources* | Able to use the Internet and library resources to complete an assignment. | Able to use the Internet and library resources to find information to adequately complete an assignment but misses some key references. | Able to use the Internet and library resources to gather some information towards an assignment. | Does not show any interest in outside sources. |
| *11c) Software Design Tools* | Able to do complicated design tasks with software tools | Able to do moderately difficult design tasks with software tools | Able to do simple tasks with software tools | Cannot use software tools |

**Outcome 12.** *A knowledge of discrete mathematics*

## Performance indicators and rubrics

| Performance criteria | Exemplary | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|
| *12a) Apply Boolean algebra and logic* | Can apply boolean algebra and logic to design circuits and develop software | Understands boolean algebra and logic | Partially understands boolean algebra and logic | Doesn't know boolean algebra or logic |
| *12b) Understands graphs, graph theory, and graph algorithms* | Can apply graphs, graph theory, and graph algorithms | Can apply tree data structures and algorithms | Understands trees and binary search | Doesn't know what a tree data structure is |
| *12c) Analyze algorithms* | Can prove the correctness of simple graph algorithms and analyze their time complexities | Can prove the correctness of simple tree and sorting algorithms and analyze their time complexities | Can analyze the time complexity of simple tree and sorting algorithms | Cannot prove anything |
| *12d) Understands counting formulas and discrete probability* | Understands and can apply discrete probability and counting formulas | Understands simple discrete probability theory | Can apply counting formulas | Does not know counting formulas |