

EET ??? – ??? (EXPERIMENTS)

NAME: _____

Last update 26 December 2020

#	Due by	Experiment	Score
1	Session #12	???	
2	Session #12	???	
3	Session #12	???	
4	Session #12	???	
5	Session #12	???	
6	Session #12	???	
7	Session #12	???	
8	Session #24	???	
9	Session #24	???	
10	Session #24	???	
11	Session #24	???	
12	Session #24	???	
13	Session #24	???	
14	Session #24	???	
15	Session #36	???	
16	Session #36	???	
17	Session #36	???	
18	Session #36	???	
19	Session #36	???	
20	Session #36	???	
21	Session #36	???	
22	Session #48	???	
23	Session #48	???	
24	Session #48	???	
25	Session #48	???	
26	Session #48	???	
27	Session #48	???	
28	Session #48	???	
29	Session #60	???	
30	Session #60	???	
31	Session #60	???	
32	Session #60	???	
33	Session #60	???	
34	Session #60	???	
35	Session #60	???	

#	Due by	Troubleshooting activity	Score
36	Session #12	Computer simulation: ???	
37	Session #24	Real circuit: ???	
38	Session #36	Computer simulation: ???	
39	Session #48	Real circuit: ???	
40	Session #60	Real circuit: ???	

41	<i>Last all-lab day</i>	Lab clean-up activities	
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Essential information about this course:

- This course is based on *empirical learning*: acquiring knowledge and skill through direct hands-on experience. In it you will be challenged not only to apply concepts learned in your Theory coursework but also explore and discover new concepts by testing ideas on hardware. Your instructor will offer advice on how to solve these problems, but the actual solving of these problems is your responsibility.
- This is a laboratory course, but *the experiments are not pre-designed*. You will plan and execute each experiment, just like a real scientific experiment where the outcome is not necessarily known.
- These experiments follow concepts taught in that semester's theory course, which means the theory course document, your own Theory Journal, and source texts are essential resources for you here.
- Half of your course grade comes from the number of attempts necessary to correctly complete each stage of each experiment. Clarifying questions are welcome, but all results presented to the instructor will be assessed just like answers submitted on an exam.
- Half of your course grade comes from the number of attempts necessary to correctly complete each assessment activity (e.g. skills demonstrations and circuit troubleshooting). Just like the experiments, each assessment activity must be eventually completed correctly to pass the course.
- You should budget a minimum of 12 hours per week for this course. The lab is yours to use during all open-school hours. *Do not let the lack of prescribed hours for this course lead to procrastination – manage your time wisely!*
- Successful students (1) review relevant theory before planning experiments, (2) prioritize hands-on lab time, (3) read instructions carefully, (4) document data neatly and accurately, and (5) double-check their work for correctness before submitting for assessment.

EET Program Learning Outcomes

- (1) **COMMUNICATION and TEAMWORK** – Accurately communicate ideas across a variety of media (oral, written, graphical) to both technical and non-technical audiences; Function effectively as a member of a technical team.
- (2) **SELF-MANAGEMENT** – Arrive on time and prepared; Work diligently until the job is done; Budget resources appropriately to achieve objectives.
- (3) **SAFE WORK HABITS** – Comply with relevant national, state, local, and college safety regulations when designing, prototyping, building, and testing systems.
- (4) **ANALYSIS and DIAGNOSIS** – Select and apply appropriate principles and techniques for both qualitative and quantitative circuit analysis; Devise and execute appropriate tests to evaluate electronic system performance; Identify root causes of electronic system malfunctions.
- (5) **PROBLEM-SOLVING** – Devise and implement solutions for technical problems appropriate to the discipline.
- (6) **DOCUMENTATION** – Interpret and create technical documents (e.g. electronic schematic diagrams, block diagrams, graphs, reports) relevant to the discipline.
- (7) **INDEPENDENT LEARNING** – Select and research information sources to learn new principles, technologies, and/or techniques.

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Values

This educational program exists for one purpose: to empower you with a comprehensive set of knowledge, skills, and habits to unlock opportunities in your chosen profession. The following values articulate personal attitudes guaranteed to fulfill this purpose, and the principles upon which this program is designed. They embody what I like to call a *strong learning ethic*, similar to a strong work ethic but applied to the learning process rather than a job.

Ownership – you are the sole proprietor of your education, of your career, and to a great extent your quality of life. No one can force you to learn, make you have a great career, or grant you a fulfilling life – these accomplishments are possible only when you accept responsibility for them.

Responsibility – *ensuring* the desired outcome, not just *attempting* to achieve the outcome. Responsibility is how we secure rights and privileges.

Initiative – independently recognizing needs and taking responsibility to meet them.

Integrity – living in a consistently principled manner, communicating clearly and honestly, applying your best effort, and never trying to advance at the expense of others. Integrity is the key to trust, and trust is the glue that binds all relationships personal, professional, and societal.

Perspective – prioritizing your attention and actions to the things we will all care about for years to come. Never letting short-term concerns eclipse the long-term.

Humility – no one is perfect, and there is always something new to learn. Making mistakes is a symptom of living, and for this reason we need to be gracious to ourselves and to others.

Safety – assessing hazards and avoiding unnecessary risk to yourself and to others.

Competence – your ability to consistently and independently apply knowledge and skill to the solution of practical problems. Competence includes the ability to verify the appropriateness of your solutions and the ability to communicate so that others understand how and why your solutions work.

Diligence – exercising self-discipline and persistence in learning, accepting the fact there is no easy way to absorb complex knowledge, master new skills, or overcome limiting habits. Diligence in work means the job is not done until it is done *correctly*: all objectives achieved, all documentation complete, and all root-causes of problems identified and corrected.

Community – your actions impact other peoples' lives, for good or for ill. Conduct yourself not just for your own interests, but also for the best interests of those whose lives you affect.

Respect is the acknowledgment of others' intrinsic capabilities, responsibilities, and worth. Everyone has something valuable to contribute, and everyone deserves to fully *own* their lives.

Course description

This course explores principles of ??? by scientific experiment. All experiments employ scientific method: proposing falsifiable hypotheses, devising procedures, gathering data, analyzing results, and developing documentation. Students also apply fundamental circuit principles to the diagnosis of simulated and real faults in these same types of circuits. Mastery standards applied to all experimental and diagnostic steps guarantee attainment of learning outcomes.

Course learning outcomes

- Rigorously demonstrate ???, ???, and ??? principles by means of scientific experimentation. (Addresses Program Learning Outcomes 2, 4, 6, 7)
- Troubleshoot faulted ???, ???, and ??? circuits from measurements taken at test points with circuit components and connections hidden from view. (Addresses Program Learning Outcomes 4, 6)
- Articulate diagnostic reasoning while troubleshooting these same circuits. (Addresses Program Learning Outcomes 1, 3)

Experiment 1

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 2

NAME: _____

DUE DATE: _____

Write and execute a SPICE simulation . . . Write and execute a C/C++ simulation . . .

You will find sample code with explanations in the “Gallery” chapter of the ??? learning module:
You will find sample code with explanations in the “Programming References” chapter of the ??? learning module:

http://ibiblio.org/kuphaldt/socratic/model/mod_00template.pdf

Stage #1 – Experiment planning documented in Journal

☐ Written hypothesis:

- Makes clear, original, and verifiable prediction(s) addressing all learning objectives
- Table or graph ready to receive data and easily compare with predictions
- Shows all supporting mathematical work for all quantitative predictions

☐ Written experimental plan:

- Includes schematic diagram of simulated circuit in full detail
- Cites any sampled source code and properly credits that code’s author

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

☐ Was the original hypothesis confirmed? If not, identify why.

☐ Correctly demonstrate every learning objective (see below) in the instructor’s presence, referencing the final data consisting of screen captures from the execution of your code and/or the final version of the source code. Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

Experiment 3

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{Measured - Predicted}{Predicted} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 4

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 5

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 6

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 7

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 8

NAME: _____

DUE DATE: _____

You may choose your own experiment, ideally one that will help you strengthen your understanding of one or more foundational principles. One suggestion is to choose a concept misunderstood or misapplied on a previous assessment (e.g. a failed exam question).

Checklists for physical experiments, computer simulations, microcontroller-based experiments, and equipment repair appear on the following three pages. Your choice may be any of these types. The instructor will help you identify learning objectives for the experiment you choose.

Checklist for physical experiment

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Checklist for computer simulation

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram of simulated circuit in full detail
 - Cites any sampled source code and properly credits that code's author

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of screen captures from the execution of your code and/or the final version of the source code. Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Checklist for microcontroller-based experiment

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build
 - Lists any special steps or conditions necessary for the experiment to run successfully
 - Cites any sampled source code and properly credits that code's author
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of live demonstration and/or captured images from the instrument(s). Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Checklist for equipment repair

Stage #1 – Repair planning documented in Journal

- ☐ Written assessment of equipment malfunction:
 - Documents your own observations of the equipment malfunctioning
 - Includes an hypothesis accounting for this malfunction
- ☐ Written theory of operation:
 - Describes the basic principle(s) by which the equipment is supposed to function
 - Includes references to relevant documentation from the manufacturer
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies hardware risks (e.g. ways in which your repair work might cause further damage)

☐ *Instructor certifies ready to proceed* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Repair work recorded in Journal

Investigate the cause(s) of the equipment malfunction and repair where possible. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Were you able to repair the equipment? If not, identify why.
- ☐ Identify the root cause of the problem; i.e. that which when corrected will prevent this same malfunction from occurring again in the future.

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 9

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 10

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 11

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 12

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 13

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 14

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 15

NAME: _____

DUE DATE: _____

You may choose your own experiment, ideally one that will help you strengthen your understanding of one or more foundational principles. One suggestion is to choose a concept misunderstood or misapplied on a previous assessment (e.g. a failed exam question).

Checklists for physical experiments, computer simulations, microcontroller-based experiments, and equipment repair appear on the following three pages. Your choice may be any of these types. The instructor will help you identify learning objectives for the experiment you choose.

Checklist for physical experiment

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
-
-

Checklist for computer simulation

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram of simulated circuit in full detail
 - Cites any sampled source code and properly credits that code's author

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of screen captures from the execution of your code and/or the final version of the source code. Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
-
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Checklist for microcontroller-based experiment

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build
 - Lists any special steps or conditions necessary for the experiment to run successfully
 - Cites any sampled source code and properly credits that code's author
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of live demonstration and/or captured images from the instrument(s). Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Checklist for equipment repair

Stage #1 – Repair planning documented in Journal

- ☐ Written assessment of equipment malfunction:
 - Documents your own observations of the equipment malfunctioning
 - Includes an hypothesis accounting for this malfunction
- ☐ Written theory of operation:
 - Describes the basic principle(s) by which the equipment is supposed to function
 - Includes references to relevant documentation from the manufacturer
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies hardware risks (e.g. ways in which your repair work might cause further damage)

☐ *Instructor certifies ready to proceed* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Repair work recorded in Journal

Investigate the cause(s) of the equipment malfunction and repair where possible. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Were you able to repair the equipment? If not, identify why.
- ☐ Identify the root cause of the problem; i.e. that which when corrected will prevent this same malfunction from occurring again in the future.

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 16

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 17

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 18

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 19

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 20

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 21

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 22

NAME: _____

DUE DATE: _____

You may choose your own experiment, ideally one that will help you strengthen your understanding of one or more foundational principles. One suggestion is to choose a concept misunderstood or misapplied on a previous assessment (e.g. a failed exam question).

Checklists for physical experiments, computer simulations, microcontroller-based experiments, and equipment repair appear on the following three pages. Your choice may be any of these types. The instructor will help you identify learning objectives for the experiment you choose.

Checklist for physical experiment

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
-
-

Checklist for computer simulation

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram of simulated circuit in full detail
 - Cites any sampled source code and properly credits that code's author

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of screen captures from the execution of your code and/or the final version of the source code. Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Checklist for microcontroller-based experiment

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build
 - Lists any special steps or conditions necessary for the experiment to run successfully
 - Cites any sampled source code and properly credits that code's author
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of live demonstration and/or captured images from the instrument(s). Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Checklist for equipment repair

Stage #1 – Repair planning documented in Journal

- ☐ Written assessment of equipment malfunction:
 - Documents your own observations of the equipment malfunctioning
 - Includes an hypothesis accounting for this malfunction
- ☐ Written theory of operation:
 - Describes the basic principle(s) by which the equipment is supposed to function
 - Includes references to relevant documentation from the manufacturer
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies hardware risks (e.g. ways in which your repair work might cause further damage)

☐ *Instructor certifies ready to proceed* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Repair work recorded in Journal

Investigate the cause(s) of the equipment malfunction and repair where possible. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Were you able to repair the equipment? If not, identify why.
- ☐ Identify the root cause of the problem; i.e. that which when corrected will prevent this same malfunction from occurring again in the future.

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 23

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 24

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 25

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Experiment 26

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 27

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 28

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 29

NAME: _____

DUE DATE: _____

You may choose your own experiment, ideally one that will help you strengthen your understanding of one or more foundational principles. One suggestion is to choose a concept misunderstood or misapplied on a previous assessment (e.g. a failed exam question).

Checklists for physical experiments, computer simulations, microcontroller-based experiments, and equipment repair appear on the following three pages. Your choice may be any of these types. The instructor will help you identify learning objectives for the experiment you choose.

Checklist for physical experiment

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
-
-

Checklist for computer simulation

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram of simulated circuit in full detail
 - Cites any sampled source code and properly credits that code's author

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of screen captures from the execution of your code and/or the final version of the source code. Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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Checklist for microcontroller-based experiment

Stage #1 – Experiment planning documented in Journal

- ☐ Written hypothesis:
 - Makes clear, original, and verifiable prediction(s) addressing all learning objectives
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build
 - Lists any special steps or conditions necessary for the experiment to run successfully
 - Cites any sampled source code and properly credits that code's author
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Journal

Run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate every learning objective (see below) in the instructor's presence, referencing the final data consisting of live demonstration and/or captured images from the instrument(s). Note: have a calculator or appropriate software ready for analyzing the data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
-
-

Checklist for equipment repair

Stage #1 – Repair planning documented in Journal

- ☐ Written assessment of equipment malfunction:
 - Documents your own observations of the equipment malfunctioning
 - Includes an hypothesis accounting for this malfunction
- ☐ Written theory of operation:
 - Describes the basic principle(s) by which the equipment is supposed to function
 - Includes references to relevant documentation from the manufacturer
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies hardware risks (e.g. ways in which your repair work might cause further damage)

☐ *Instructor certifies ready to proceed* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Repair work recorded in Journal

Investigate the cause(s) of the equipment malfunction and repair where possible. Record all data, including any mistakes, in a single digital document along with your instructor-certified planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Were you able to repair the equipment? If not, identify why.
- ☐ Identify the root cause of the problem; i.e. that which when corrected will prevent this same malfunction from occurring again in the future.

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
-
-

Experiment 30

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 31

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 32

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 33

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Experiment 34

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values (Error = $\frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
-
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-

file we_0000

Experiment 35

NAME: _____

DUE DATE: _____

Plan and conduct an experiment . . .

Sample hypothesis: “???”

Recommend doing ??? first, then ???, etc.

Risk analysis should include ???

(Under development)

Sample diagram:

Stage #1 – Experiment planning documented in Experiment Journal before running

- ☐ Written hypothesis:
 - Makes clear prediction(s) sure to be either proven or disproven by the results of this experiment
 - Table or graph ready to receive data and easily compare with predictions
 - Shows all supporting mathematical work for all quantitative predictions
- ☐ Written experimental plan:
 - Includes schematic diagram showing everything you will build *prior to building it*
 - Lists any special steps or conditions necessary for the experiment to run successfully
- ☐ Written risk analysis:
 - Identifies all personal risks (e.g. shock, burns, inhalation) and mitigations
 - Identifies/calculates hardware risks (e.g. excessive voltage, current, and/or power) and mitigations, citing applicable component ratings from datasheets and/or other trustworthy sources

☐ *Instructor certifies ready to run* – Re-try if detail(s) missing or incomplete = ____ (–10% per re-try)

Stage #2 – Experimental run and data recorded in Experiment Journal

Only after your instructor certifies stage #1, you are cleared to run and revise the experiment as often as necessary until you fully understand it, as scientific method is a *learning process*. Record all data, including any mistakes, in a single digital document along with your planning work from stage #1.

Stage #3 – Presentation and review

- ☐ Was the original hypothesis confirmed? If not, identify why.
- ☐ Correctly demonstrate and/or explain every learning objective (see below) for the instructor, either live or by electronically recorded data, using a calculator or appropriate software to analyze that data!

☐ *Instructor certifies* – Re-try if any answer incorrect or incomplete = ____ (–10% per re-try)

Learning objectives for this experiment:

- Calculate error between predicted vs. measured values ($\text{Error} = \frac{\text{Measured} - \text{Predicted}}{\text{Predicted}} \times 100\%$), commenting on the sign of the error and also identifying possible causes
- Accurately predict and then demonstrate the effect(s) of one of the components failing open (chosen at random by the instructor)
- Accurately predict and then demonstrate the effect(s) of one of the components failing shorted (chosen at random by the instructor)
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file we_0000

Troubleshoot 36

NAME: _____

DUE DATE: _____

Troubleshoot a fault within a ??? circuit. This circuit shall be constructed in such a manner that all circuit components and simulated faults must be hidden from view (e.g. covering it up with a box or towel) but test points will be available for contact with a multimeter's probes. A schematic diagram showing the circuit and its test points will be allowed for use during the troubleshooting exercise.

The circuit shall be ???. Possible faults include:

- Any cable failed open
- Any cable failed shorted
- Any component failed open
- Any component failed shorted
- Any component value altered

First, you will demonstrate that the system functions properly. Then the instructor will either set up or supervise other students setting up a random fault in that system (hidden from view) while you are out of the room. You will then have a limited amount of time to independently perform measurements and other tests while under the continuous observation of the instructor. A successful troubleshooting exercise consists of both correctly identifying the location and nature of the fault, as well as logically defending the necessity of each diagnostic step. Incorrect fault identification, unnecessary steps, and/or incorrect defense of any step will result in a failed attempt. Your only access to the faulted circuit will be via the test points, and only one unpowered test will be permitted.

If you must work remotely rather than in-person, the faulted system must be at the instructor's location while you request measurements and other diagnostic tests of the instructor via teleconferencing system (e.g. videoconference, telephone, text messaging).

Troubleshooting is *mastery-based*, meaning every one must be competently completed in order to pass the course, and you will be given multiple opportunities to re-try if you do not pass on the first attempt. Each re-try begins with another randomized fault on the same circuit. Scoring is based on the number of attempts necessary to successfully troubleshoot a circuit (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 60% ; 4 attempts = 40% ; 5 attempts = 20% ; 6 or more attempts = 0%).

file we 1000

Troubleshoot 37

NAME: _____

DUE DATE: _____

Troubleshoot a fault within a ??? circuit. This circuit shall be constructed in such a manner that all circuit components and simulated faults must be hidden from view (e.g. covering it up with a box or towel) but test points will be available for contact with a multimeter's probes. A schematic diagram showing the circuit and its test points will be allowed for use during the troubleshooting exercise.

The circuit shall be ???. Possible faults include:

- Any cable failed open
- Any cable failed shorted
- Any component failed open
- Any component failed shorted
- Any component value altered

First, you will demonstrate that the system functions properly. Then the instructor will either set up or supervise other students setting up a random fault in that system (hidden from view) while you are out of the room. You will then have a limited amount of time to independently perform measurements and other tests while under the continuous observation of the instructor. A successful troubleshooting exercise consists of both correctly identifying the location and nature of the fault, as well as logically defending the necessity of each diagnostic step. Incorrect fault identification, unnecessary steps, and/or incorrect defense of any step will result in a failed attempt. Your only access to the faulted circuit will be via the test points, and only one unpowered test will be permitted.

If you must work remotely rather than in-person, the faulted system must be at the instructor's location while you request measurements and other diagnostic tests of the instructor via teleconferencing system (e.g. videoconference, telephone, text messaging).

Troubleshooting is *mastery-based*, meaning every one must be competently completed in order to pass the course, and you will be given multiple opportunities to re-try if you do not pass on the first attempt. Each re-try begins with another randomized fault on the same circuit. Scoring is based on the number of attempts necessary to successfully troubleshoot a circuit (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 60% ; 4 attempts = 40% ; 5 attempts = 20% ; 6 or more attempts = 0%).

file we 1000

Troubleshoot 38

NAME: _____

DUE DATE: _____

Troubleshoot a fault within a ??? circuit. This circuit shall be constructed in such a manner that all circuit components and simulated faults must be hidden from view (e.g. covering it up with a box or towel) but test points will be available for contact with a multimeter's probes. A schematic diagram showing the circuit and its test points will be allowed for use during the troubleshooting exercise.

The circuit shall be ???. Possible faults include:

- Any cable failed open
- Any cable failed shorted
- Any component failed open
- Any component failed shorted
- Any component value altered

First, you will demonstrate that the system functions properly. Then the instructor will either set up or supervise other students setting up a random fault in that system (hidden from view) while you are out of the room. You will then have a limited amount of time to independently perform measurements and other tests while under the continuous observation of the instructor. A successful troubleshooting exercise consists of both correctly identifying the location and nature of the fault, as well as logically defending the necessity of each diagnostic step. Incorrect fault identification, unnecessary steps, and/or incorrect defense of any step will result in a failed attempt. Your only access to the faulted circuit will be via the test points, and only one unpowered test will be permitted.

If you must work remotely rather than in-person, the faulted system must be at the instructor's location while you request measurements and other diagnostic tests of the instructor via teleconferencing system (e.g. videoconference, telephone, text messaging).

Troubleshooting is *mastery-based*, meaning every one must be competently completed in order to pass the course, and you will be given multiple opportunities to re-try if you do not pass on the first attempt. Each re-try begins with another randomized fault on the same circuit. Scoring is based on the number of attempts necessary to successfully troubleshoot a circuit (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 60% ; 4 attempts = 40% ; 5 attempts = 20% ; 6 or more attempts = 0%).

file we 1000

Troubleshoot 39

NAME: _____

DUE DATE: _____

Troubleshoot a fault within a ??? circuit. This circuit shall be constructed in such a manner that all circuit components and simulated faults must be hidden from view (e.g. covering it up with a box or towel) but test points will be available for contact with a multimeter's probes. A schematic diagram showing the circuit and its test points will be allowed for use during the troubleshooting exercise.

The circuit shall be ???. Possible faults include:

- Any cable failed open
- Any cable failed shorted
- Any component failed open
- Any component failed shorted
- Any component value altered

First, you will demonstrate that the system functions properly. Then the instructor will either set up or supervise other students setting up a random fault in that system (hidden from view) while you are out of the room. You will then have a limited amount of time to independently perform measurements and other tests while under the continuous observation of the instructor. A successful troubleshooting exercise consists of both correctly identifying the location and nature of the fault, as well as logically defending the necessity of each diagnostic step. Incorrect fault identification, unnecessary steps, and/or incorrect defense of any step will result in a failed attempt. Your only access to the faulted circuit will be via the test points, and only one unpowered test will be permitted.

If you must work remotely rather than in-person, the faulted system must be at the instructor's location while you request measurements and other diagnostic tests of the instructor via teleconferencing system (e.g. videoconference, telephone, text messaging).

Troubleshooting is *mastery-based*, meaning every one must be competently completed in order to pass the course, and you will be given multiple opportunities to re-try if you do not pass on the first attempt. Each re-try begins with another randomized fault on the same circuit. Scoring is based on the number of attempts necessary to successfully troubleshoot a circuit (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 60% ; 4 attempts = 40% ; 5 attempts = 20% ; 6 or more attempts = 0%).

file we 1000

Troubleshoot 40

NAME: _____

DUE DATE: _____

Troubleshoot a fault within a ??? circuit. This circuit shall be constructed in such a manner that all circuit components and simulated faults must be hidden from view (e.g. covering it up with a box or towel) but test points will be available for contact with a multimeter's probes. A schematic diagram showing the circuit and its test points will be allowed for use during the troubleshooting exercise.

The circuit shall be ???. Possible faults include:

- Any cable failed open
- Any cable failed shorted
- Any component failed open
- Any component failed shorted
- Any component value altered

First, you will demonstrate that the system functions properly. Then the instructor will either set up or supervise other students setting up a random fault in that system (hidden from view) while you are out of the room. You will then have a limited amount of time to independently perform measurements and other tests while under the continuous observation of the instructor. A successful troubleshooting exercise consists of both correctly identifying the location and nature of the fault, as well as logically defending the necessity of each diagnostic step. Incorrect fault identification, unnecessary steps, and/or incorrect defense of any step will result in a failed attempt. Your only access to the faulted circuit will be via the test points, and only one unpowered test will be permitted.

If you must work remotely rather than in-person, the faulted system must be at the instructor's location while you request measurements and other diagnostic tests of the instructor via teleconferencing system (e.g. videoconference, telephone, text messaging).

Troubleshooting is *mastery-based*, meaning every one must be competently completed in order to pass the course, and you will be given multiple opportunities to re-try if you do not pass on the first attempt. Each re-try begins with another randomized fault on the same circuit. Scoring is based on the number of attempts necessary to successfully troubleshoot a circuit (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 60% ; 4 attempts = 40% ; 5 attempts = 20% ; 6 or more attempts = 0%).

file we 1000

Lab clean-up 41

NAME: _____

This list represents all of the major work-items that must be done at every semester's end to prepare the lab space for the upcoming semester. Each student will have at least one task assigned to them.

Non-technical tasks

- ☐ Thoroughly clean whiteboard(s) and all table/workbench surfaces
- ☐ Vacuum-clean the floor of all debris after picking any and all larger pieces
- ☐ Organize all wires, cables, power cords, and test leads neatly into their storage locations
- ☐ Vacuum-clean the exterior and interior of all electrical enclosures and cabinets
- ☐ Move test equipment to their proper places and clean their outer surfaces
- ☐ Note any depleted bins (electronic components, threaded fasteners, cables, etc.)
 - Check boxes and spools of components to see if depleted bins may be re-filled from these
 - Report to instructor for re-ordering in preparation for next semester
- ☐ Note any depleted PCBs (e.g. fuseholder PCBs, proto PCBs, etc.)
- ☐ Power up each lab PC to check for routine software updates, then power down for the break

Technical tasks

- ☐ Check fastener storage bins to ensure none are misplaced
- ☐ Check resistor storage bins to ensure none are misplaced
- ☐ Check fuse storage bins to ensure none are misplaced
- ☐ Check inductor/transformer storage bins to ensure none are misplaced
- ☐ Check capacitor storage bins to ensure none are misplaced
- ☐ Check semiconductor device storage bins to ensure none are misplaced
- ☐ Test power supplies and benchtop multimeters for basic functionality (e.g. all *power supply* voltage adjustments functional, current limits functional, voltage/current meters functional ; all *multimeter* all voltage ranges functional, all current ranges functional, overcurrent fuse good)
- ☐ Test oscilloscopes and signal generators for basic functionality (e.g. all *oscilloscope* channels functional, all vertical sensitivity settings functional, all timebase settings functional, triggering functions properly ; all *signal generator* waveshapes functional, magnitude and frequency adjustments functional)
- ☐ Test and clean all soldering stations (e.g. clean/replace porous and brass-wool cleaning pads, check tips for wear, ensure correct temperature settings and that the tip solders well)
- ☐ Test all lab power system (e.g. solar power grid, hand-crank generator) circuit breakers and fuses
- ☐ Test all special lab systems for basic functionality ; ensure schematic diagrams are in place
 - Digital clock, window crane system, window sensors, precision voltage reference
 - Ping all installed Ethernet addresses to ensure devices respond (e.g. PLC processors)

General Troubleshooting Advice

All electronic circuit faults fall into at least one of these categories:

- **Connection fault** – the components are not properly connected together.
- **Design flaw** – the circuit cannot work because something about it is incorrectly designed.
- **Lack of power/signal or poor quality** – the power and/or signal source is “dead” or “noisy”
- **Component fault** – one or more components is faulty.
- **Test equipment** – either the test equipment itself is faulty, or is not being used appropriately.

Of these categories, the one causing more problems for students initially learning about circuits than all the others is the first: *connection fault*. This is because the ability to translate an idea and/or a schematic diagram into a physical circuit is a skill requiring time to develop. Many such problems may be avoided by (1) drawing a complete schematic of what you intend to build before you build it, (2) marking that schematic to show which connections have been made and which are left to make as you are wiring it, and (3) using an ohmmeter (not your eyes!) to verify that every pair of points which should be connected are connected and that no points which should be electrically distinct from each other are in fact electrically common.

Troubleshooting strategies

- **Verify the symptom(s)** – Always check to see that the symptom(s) match what you’ve been told by others. Even if the symptoms were correctly reported, you may notice additional (unreported) symptoms helpful in identifying the fault.
- **Use test equipment rather than your eyes to find problems** – your multimeter (and other tools) will show you things your eyes cannot see, and this will build habits and skills invaluable in situations where visual inspection is impossible.
- **Verify good power quality** – Is the source voltage within specifications, and relatively free of “ripple” and other noise?
- **Check signals at component terminals** – Use an oscilloscope or multimeter to check for proper signals at each of the component pins, to see if each one matches your expectations. An important check, especially for integrated circuits, is whether the measured output signal(s) are appropriate for the measured input signal(s).
- **Simplify the system** – If possible, re-configure the circuit to be as simple as possible, because complexity makes faults harder to find.
- **Take more and different measurements to get un-stuck** – if the source of trouble is still not apparent, take measurements in places you haven’t tried yet to obtain new data. Also, use different test instruments that will show you other facets of the signals, for example try using an oscilloscope to test a signal if you’ve only been using a multimeter since an oscilloscope will reveal things a multimeter cannot.
- **Swap identical components** – If particular a component is suspected of being faulty, and you are able to swap another (identical) component for it, do so to see whether or not the problem moves with the old component. If so, that component is to blame; if not, the problem lies elsewhere.
- **Always look for Root Cause(s)** – don’t declare success simply by finding the proximate (i.e. the most direct) cause, but continue your search to find what design flaw, circumstance, or other distal cause led to it.

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