

INST 141 (Motor Controls)

NAME: _____

Session	Topic	Score
1	AC Review: transformers	;
2	AC Review: polyphase	;
3	Electrical safety (NFPA 70E)	;
4	AC motors	;
5	Motor starter circuits	;
6	Automatic motor starting	;
7	Open session	-----
8	<i>Exam 1</i> (written ; demonstration)	;
9	Variable frequency drives (VFDs)	;
10	Electrical safety (NFPA 70E)	;
11	Time-delay relays	;
12	Inrush-limited starting	;
13	Open session	-----
14	<i>Exam 2</i> (written ; demonstration)	;

Due	Experiment	Score
8	Measure DC motor inrush current using DMM	
8	Measure DC motor inrush current using DSO	
8	Measure AC motor inrush current using CT	
8	Demonstrate DC motor starter circuit	
14	Demonstrate a time-delay relay circuit	
14	SPICE modeling of a three-phase AC circuit	
14	Demonstrate inrush-limited DC motor starter	

Due	Troubleshooting	Score
8	Simulated fault in relay-controlled motor circuit	
14	Three-phase AC motor starter circuit	

Due	Project	Score
14	VFD-controlled AC induction motor	

Your grade for this course will be based on a percentage score, with each category weighted as follows:

- All mastery objectives complete by deadline dates = 40%
 - All written exams passed without error by the end of the next exam date (or end of quarter, whichever comes first)
 - All demonstration exam circuits correctly completed by the end of the next exam date (or end of quarter, whichever comes first)
 - All objectives of all experiments completed by their respective due date
 - All troubleshooting challenges completed by their respective due dates
 - All objectives of all projects completed by their respective due dates
- Written exam scores = 10%
- Demonstration exam scores = 10%
- Experiment scores = 20%
- Troubleshooting scores = 10%
- Project score(s) = 10%

Please note the importance of completing all mastery objectives by their deadline dates. Failure to complete *any* mastery objective in time deducts 40% from your total score. If this happens, it means the highest possible score you can earn for the course will be 60%, which is below the 70% threshold for a C-, the lowest passing grade. In other words, you *must* complete all mastery objectives by their due dates in order to pass the course, regardless of any other score.

Deductions to your course grade are based on your preparation for and participation within each theory session. Failure to arrive on time to a theory session, or arriving with incomplete preparatory work for that session results in a -1% deduction per session. Failure to positively and proactively contribute to the discussion during a theory session also results in a -1% deduction per session. Showing up on time, fully prepared, and genuinely contributing to every theory session is the *minimum* expectation.

A failing (F) grade will be earned if any mastery objectives are past deadline, or for any of the following behaviors: false testimony (lying), cheating on any assignment or assessment, plagiarism (presenting another's work as your own), willful violation of a safety policy, theft, harassment, sabotage, destruction of property, or intoxication. These behaviors are grounds for immediate termination in this career, and as such will not be tolerated here.

If for some reason you know you will be late or absent, submitting your work in electronic form (e.g. email attachment) prior to the scheduled time is acceptable for full credit. The standards are just as high for electronic submissions as for face-to-face demonstrations:

- For theory session preparation, submission of all assigned work (e.g. reading outline and reflections, answers and work for all assigned questions) before the scheduled start time of that theory session will count as full credit.
- For theory session contribution, answering all "Challenges" for assigned questions will count as full credit.
- For experiments, video documentation of you completing all objectives in their proper order will count as full credit.
- For projects, video documentation of you completing the objective(s) will count as full credit.

Absence during a scheduled exam will result in a 0% score for that exam, except in the case of a *documented emergency*.

file mgrading

Program Outcomes for Instrumentation and Control Technology (BTC)

#1 Communication

Communicate and express concepts and ideas across a variety of media (verbal, written, graphical) using industry-standard terms.

#2 Time management

Arrives on time and prepared to work; Budgets time and meets deadlines when performing tasks and projects.

#3 Safety

Complies with national, state, local, and college safety regulations when designing and performing work on systems.

#4 Analysis and Diagnosis

Analyze, evaluate, and diagnose systems related to instrumentation and control including electrical and electronic circuits, fluid power and signaling systems, computer networks, and mechanisms; Select and apply correct mathematical techniques to these analytical and diagnostic problems; Select and correctly use appropriate test equipment to collect data.

#5 Design and Commissioning

Select, design, construct, configure, and install components necessary for the proper function of systems related to instrumentation and control, applying industry standards and verifying correct system operation when complete.

#6 System optimization

Improve technical system functions by collecting data and evaluating performance; Implement strategies to optimize the function of these systems.

#7 Calibration

Assess instrument accuracy and correct inaccuracies using appropriate calibration procedures and test equipment; Select and apply correct mathematical techniques to these calibration tasks.

#8 Documentation

Interpret and create technical documents (e.g. electronic schematics, loop diagrams, functional diagrams, P&IDs, graphs, narratives) according to industry standards.

#9 Independent learning

Select and research information sources to learn new principles, technologies, and techniques.

#10 Job searching

Develop a professional resume and research job openings in the field of industrial instrumentation.

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INST 141 (Motor Controls) Course Outcomes

Each and every outcome in this course is assessed at a mastery level (i.e. 100% competence)

- Independently calculate voltage, current and/or horsepower for both single- and three-phase electrical motors. [Ref: Program Learning Outcome #4]
- Independently determine the possibility of faults within three-phase motor starter circuits, given a schematic diagram and symptoms. [Ref: Program Learning Outcome #4]
- Research, plan, describe, execute, and evaluate experiments testing electrical principles, electrical/electronic components, and functioning motor circuits. [Ref: Program Learning Outcomes #1, #2, #3, #4, #5, #6, #8, and #9]
- Work within a team to configure, wire, document, and test a variable-frequency motor drive (VFD) for a given induction motor, speed-control method, and start/stop control method. [Ref: Program Learning Outcomes #1, #2, #3, #4, #5, #8, #9]
- Independently demonstrate proper lockout-tagout (LOTO) procedure on an AC motor circuit, as well as proper connection and use of an inductive current sensor on a conductor within that motor circuit randomly chosen by the instructor. [Ref: Program Learning Outcomes #3, #4, #5]
- Independently diagnose random faults placed in a three-phase reversing motor starter circuit within a limited time using no test equipment except a multimeter and clamp-on current probe, logically justifying your steps in the instructor's direct presence. [Ref: Program Learning Outcome #4]

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How to get the most out of academic reading:

- Outline, don't highlight! Identify every major idea presented in the text, and express these ideas in your own words. A suggested ratio is one sentence of your own thoughts per paragraph of text read.
- Articulate your thoughts as you read (i.e. "have a conversation" with the author). This will develop *metacognition*: active supervision of your own thoughts. Note points of agreement, disagreement, confusion, epiphanies, and connections between different concepts or applications.
- Work through all mathematical exercises shown within the text, to ensure you understand all the steps.
- Imagine explaining concepts you've just learned to someone else. Teaching forces you to distill concepts to their essence, thereby clarifying those concepts, revealing assumptions, and exposing misconceptions. Your goal is to create the simplest explanation that is still technically accurate.
- Create your own questions based on what you read, as a teacher would to challenge students.

How to effectively problem-solve and troubleshoot:

- Rely on principles, not procedures. Don't be satisfied with memorizing steps – learn *why* those steps work. Each step should make logical sense and have real-world meaning to you.
- Sketch a diagram to help visualize the problem. Sketch a graph showing how variables relate. When building a real system, always prototype it on paper and analyze its function *before* constructing it.
- Identify what it is you need to solve, identify all relevant data, identify all units of measurement, identify any general principles or formulae linking the given information to the solution, and then identify any "missing pieces" to a solution. Annotate all diagrams with this data.
- Perform "thought experiments" to explore the effects of different conditions for theoretical problems. When troubleshooting, perform *diagnostic tests* rather than just visually inspect for faults.
- Simplify the problem and solve that simplified problem to identify strategies applicable to the original problem (e.g. change quantitative to qualitative, or visa-versa; substitute easier numerical values; eliminate confusing details; add details to eliminate unknowns; consider simple limiting cases; apply an analogy). Remove components from a malfunctioning system to simplify it and better identify the nature and location of the problem.
- Check for exceptions – does your solution work for *all* conditions and criteria?
- Work "backward" from a hypothetical solution to a new set of given conditions.

How to manage your time:

- Avoid procrastination. Work now and play later, every single day.
- Consider the place you're in when deciding what to do. If there is project work to do and you have access to the lab, do that work and not something that could be done elsewhere (e.g. homework).
- Eliminate distractions. Kill your television and video games. Turn off your mobile phone, or just leave it at home. Study in places where you can concentrate, like the Library.
- Use your "in between" time productively. Don't leave campus for lunch. Arrive to school early. If you finish your assigned work early, begin working on the next assignment.

Above all, cultivate persistence, as this is necessary to master anything non-trivial. The keys to persistence are (1) having the desire to achieve that mastery, and (2) realizing challenges are normal and not an indication of something gone wrong. A common error is to equate *easy* with *effective*: students often believe learning should be easy if everything is done right. The truth is that mastery never comes easy!

file question0

Checklist when reading an instructional text

“Reading maketh a full man; conference a ready man; and writing an exact man” – Francis Bacon

Francis Bacon’s advice is a blueprint for effective education: reading provides the learner with knowledge, writing focuses the learner’s thoughts, and critical dialogue equips the learner to confidently communicate and apply their learning. Independent acquisition and application of knowledge is a powerful skill, well worth the effort to cultivate. To this end, students should read these educational resources closely, write their own outline and reflections on the reading, and discuss in detail their findings with classmates and instructor(s). You should be able to do all of the following after reading any instructional text:

Briefly **OUTLINE THE TEXT**, as though you were writing a detailed Table of Contents. Feel free to rearrange the order if it makes more sense that way. Prepare to articulate these points in detail and to answer questions from your classmates and instructor. Outlining is a good self-test of thorough reading because you cannot outline what you have not read or do not comprehend.

Demonstrate **ACTIVE READING STRATEGIES**, including verbalizing your impressions as you read, simplifying long passages to convey the same ideas using fewer words, annotating text and illustrations with your own interpretations, working through mathematical examples shown in the text, cross-referencing passages with relevant illustrations and/or other passages, identifying problem-solving strategies applied by the author, etc. Technical reading is a special case of problem-solving, and so these strategies work precisely because they help solve any problem: paying attention to your own thoughts (metacognition), eliminating unnecessary complexities, identifying what makes sense, paying close attention to details, drawing connections between separated facts, and noting the successful strategies of others.

Identify **IMPORTANT THEMES**, especially **GENERAL LAWS** and **PRINCIPLES**, expounded in the text and express them in the simplest of terms as though you were teaching an intelligent child. This emphasizes connections between related topics and develops your ability to communicate complex ideas to anyone.

Form **YOUR OWN QUESTIONS** based on the reading, and then pose them to your instructor and classmates for their consideration. Anticipate both correct and incorrect answers, the incorrect answer(s) assuming one or more plausible misconceptions. This helps you view the subject from different perspectives to grasp it more fully.

Devise **EXPERIMENTS** to test claims presented in the reading, or to disprove misconceptions. Predict possible outcomes of these experiments, and evaluate their meanings: what result(s) would confirm, and what would constitute disproof? Running mental simulations and evaluating results is essential to scientific and diagnostic reasoning.

Specifically identify any points you found **CONFUSING**. The reason for doing this is to help diagnose misconceptions and overcome barriers to learning.

General challenges following a tutorial reading assignment

- Summarize as much of the text as you can in one paragraph of your own words. A helpful strategy is to explain ideas as you would for an intelligent child: as simple as you can without compromising too much accuracy.
- Simplify a particular section of the text, for example a paragraph or even a single sentence, so as to capture the same fundamental idea in fewer words.
- Where did the text make the most sense to you? What was it about the text's presentation that made it clear?
- Identify where it might be easy for someone to misunderstand the text, and explain why you think it could be confusing.
- Identify any new concept(s) presented in the text, and explain in your own words.
- Identify any familiar concept(s) such as physical laws or principles applied or referenced in the text.
- Devise a proof of concept experiment demonstrating an important principle, physical law, or technical innovation represented in the text.
- Devise an experiment to disprove a plausible misconception.
- Did the text reveal any misconceptions you might have harbored? If so, describe the misconception(s) and the reason(s) why you now know them to be incorrect.
- Describe any useful problem-solving strategies applied in the text.
- Devise a question of your own to challenge a reader's comprehension of the text.

General follow-up challenges for assigned problems

- Identify where any fundamental laws or principles apply to the solution of this problem, especially before applying any mathematical techniques.
- Devise a thought experiment to explore the characteristics of the problem scenario, applying known laws and principles to mentally model its behavior.
- Describe in detail your own strategy for solving this problem. How did you identify and organized the given information? Did you sketch any diagrams to help frame the problem?
- Is there more than one way to solve this problem? Which method seems best to you?
- Show the work you did in solving this problem, even if the solution is incomplete or incorrect.
- What would you say was the most challenging part of this problem, and why was it so?
- Was any important information missing from the problem which you had to research or recall?
- Was there any extraneous information presented within this problem? If so, what was it and why did it not matter?
- Examine someone else's solution to identify where they applied fundamental laws or principles.
- Simplify the problem from its given form and show how to solve this simpler version of it. Examples include eliminating certain variables or conditions, altering values to simpler (usually whole) numbers, applying a limiting case (i.e. altering a variable to some extreme or ultimate value).
- For quantitative problems, identify the real-world meaning of all intermediate calculations: their units of measurement, where they fit into the scenario at hand. Annotate any diagrams or illustrations with these calculated values.
- For quantitative problems, try approaching it qualitatively instead, thinking in terms of "increase" and "decrease" rather than definite values.
- For qualitative problems, try approaching it quantitatively instead, proposing simple numerical values for the variables.
- Were there any assumptions you made while solving this problem? Would your solution change if one of those assumptions were altered?
- Identify where it would be easy for someone to go astray in attempting to solve this problem.
- Formulate your own problem based on what you learned solving this one.

Session 1

Source text – *Transformers* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_transformer.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the [Simplified Tutorial](#) chapter in its entirety.
- Read, outline, and reflect on the [Prototype electrical power transmission system](#) section of the [Historical References](#) chapter.
- Complete “Industrial control power transformer” in the [Conceptual Reasoning](#) section of the [Questions](#) chapter.
- Complete “Basic transformer calculations” in the [Quantitative Reasoning](#) section of the [Questions](#) chapter.
- Complete “Transformer-resistor circuit” in the [Quantitative Reasoning](#) section of the [Questions](#) chapter.
- Complete “Faulted transformer-lamp circuit” in the [Diagnostic Reasoning](#) section of the [Questions](#) chapter.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the ModEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the [Conceptual Reasoning](#) section of the [Questions](#) chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

Your instructor will challenge all students in the session to share what they learned and to think critically about the topic(s) at hand, examine students’ approach to solving problems, and offer helpful advice. You will be graded based on your positive contributions to the dialogue and good-faith effort to solve problems on your own.

Session grading is subtractive rather than additive, meaning that a perfect score contributes nothing to the course grade, but an imperfect score will detract from it. This is because showing up on time fully prepared and actively participating is both easy to accomplish and a bare-minimum standard for any professional field. Late arrival is equivalent to unpreparedness; absence is equivalent to non-participation. If for any reason you cannot attend, electronic submission of your work by the starting time of your scheduled session will be accepted for full credit, with grading based on thoroughness and accuracy (rather than by good-faith effort and participation).

[file m0014](#)

Source text – *Polyphase AC* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_polyphase.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Testing for single-phase or three-phase” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Balanced Delta source and Wye load” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Balanced Wye source and Delta load” in the Quantitative Reasoning section of the Questions chapter.

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Source text – *NFPA 70E Standard for Electrical Safety in the Workplace*

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the the following sections of this text:
 - [Article 110](#) (“General Requirements for Electrical Safety-Related Work Practices”)
 - [Article 120](#) (“Establishing an Electrically Safe Work Condition”)
 - [Informative Annex K](#) (“General Categories of Electrical Hazards”)
 - [Informative Annex J](#) (“Energized Electrical Work Permit”)

This text is an electrical safety standard document, typical of many safety standards in industry. In reading this, your goal is to comprehend the scope of the sections (i.e. what contexts and purposes they serve), acquire vocabulary specific to the standard, and project where this standard applies to your work both in school and in your chosen career. These reflective points (scope, vocabulary, application) take the place of assigned questions.

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[file m0016](#)

Source text – *AC Motors* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_acmotor.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Electric water pump nameplate example” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Electric water pump efficiency” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Stroboscope measuring motor speed” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of faults in a capacitor-start motor” in the Diagnostic Reasoning section of the Questions chapter.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the ModEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the Conceptual Reasoning section of the Questions chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

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Source text – *AC Induction Motor Starters* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_acstarter.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the the following sections of the Tutorial chapter:
 - Elementary motor starters
 - Latching motor starters
- Complete “Start/Jog control” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Three-motor starter circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Motor current calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Routine motor testing” in the Diagnostic Reasoning section of the Questions chapter.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the ModEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the Conceptual Reasoning section of the Questions chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

Your instructor will challenge all students in the session to share what they learned and to think critically about the topic(s) at hand, examine students’ approach to solving problems, and offer helpful advice. You will be graded based on your positive contributions to the dialogue and good-faith effort to solve problems on your own.

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file m0019

Source text – *AC Induction Motor Starters* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_acstarter.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the the following section of the Tutorial chapter:
→ Automatic motor starting
- Complete “Digital cooling fan control” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Wye motor fed by Delta source” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted lift station pump control” in the Diagnostic Reasoning section of the Questions chapter.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the ModEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the Conceptual Reasoning section of the Questions chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

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Open Session

Today's "open" class session is unstructured, and is intended to be a time for you to ask questions of your instructor, complete remaining work, prepare for any upcoming assessments, etc.

Open class sessions may be dropped from the calendar if any school days are lost due to inclement weather or other unforeseen interruptions.

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The written exam will consist of the following questions:

- (2 questions) Calculate voltages and/or currents in single-phase AC transformer circuits with resistive loads
- (2 questions) Calculate voltage, current and/or horsepower for both single-phase and three-phase electrical motors
- (1 question) Determine statuses within a relay ladder logic circuit given a schematic diagram and process switch (e.g. pressure switch, temperature switch) stimulus conditions
- (1 question) Identify possible faults within a malfunctioning three-phase motor starter circuit

The written exams are printed on paper, and will be handed to you at the beginning of the exam session. They are closed-book and closed-note. A scientific calculator is allowed, but no use of mobile phones or personal computers as calculators. Music played through earbuds is welcome. You may ask questions of the instructor, who will clarify questions but will not provide hints or any other form of help. Numerical answers must be within 1% of the correct (un-rounded) answer in order to be counted as correct.

The written exam is a mastery exam, which means passing the exam requires *all* questions be answered correctly, and that passing this exam is necessary to pass the course. If upon your first submission to the instructor any errors are found, the instructor will mark which sections of the exam have been passed (with “1” characters) and which sections have not (with “0” characters), and will return the exam to you for another attempt. If upon your second submission any errors remain (or new errors added), you must re-take a different version of the exam on a different day. Scoring is based on the number of attempts: the number of “1” marks divided by the total number of “0” and “1” marks. The score from the first version of the exam you take factors into your course grade. Re-take exams are not scored, but only checked for absence of all errors by the second submission. Exam re-takes occur during lab time, a maximum of one per day.

Following the written exam will be a demonstration exam where you will build a circuit at your desk using your Terminal Block Board and then demonstrate its correct operation to the instructor. A multimeter is permitted, but the circuit must not be energized with any form of electrical source except during demonstration. Circuit demonstration occurs at the front of the classroom where you will be given **2 minutes** to set up and demonstrate its correct operation to the instructor. If the demonstration is unsuccessful, you may return to your desk to fix the problem(s) and then re-try with the same time limit. The demonstration exam is closed-book, but component “pinout” references are allowed.

The demonstration exam is also a mastery exam, with re-takes (maximum of one per day) allowed. The exam’s score is based on the number of attempts (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 50% ; 4 attempts = 10% ; 5 or more attempts = 0%). Any violation of a safety standard (e.g. handling energized conductors) counts as a failed attempt.

Demonstration circuit parameters will be randomized by the instructor. Students will be made aware of the circuit options well in advance of the exam in order to master the necessary principles and procedures, but exact component values, test conditions, and other details will not be revealed until the exam begins. Terminal Block Boards must be “blank” (i.e. no pre-placed or pre-wired components) in order to ensure every student actually builds their own circuit during the exam session. Any re-takes after the scheduled exam date will be with new (randomized) circuits.

This exam’s demonstration circuit is a latching DC motor starter circuit controlled by momentary actuation of a “Start” switch and a “Stop” switch. You may use the toggle switches on your Terminal Block Board in lieu of momentary pushbutton switches (momentarily toggling each to simulate the actions of pushbutton switches). The instructor will provide the DC motor, rated at 12 VDC. Your task is to demonstrate that the motor starts and stops as it should when connected to your starter circuit.

file m9003

Source text – *Variable Frequency AC Motor Drives* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_vfd.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the the following sections of the Tutorial chapter:
 - Basic VFD function
 - AC motor braking
 - Important VFD parameters
- Complete “VFD configuration example” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Currents within a VFD circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Line reactor resonance” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Predicting effects of VFD component faults” in the Diagnostic Reasoning section of the Questions chapter.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the MODEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the Conceptual Reasoning section of the Questions chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

Your instructor will challenge all students in the session to share what they learned and to think critically about the topic(s) at hand, examine students’ approach to solving problems, and offer helpful advice. You will be graded based on your positive contributions to the dialogue and good-faith effort to solve problems on your own.

Session grading is subtractive rather than additive, meaning that a perfect score contributes nothing to the course grade, but an imperfect score will detract from it. This is because showing up on time fully prepared and actively participating is both easy to accomplish and a bare-minimum standard for any professional field. Late arrival is equivalent to unpreparedness; absence is equivalent to non-participation. If for any reason you cannot attend, electronic submission of your work by the starting time of your scheduled session will be accepted for full credit, with grading based on thoroughness and accuracy (rather than by good-faith effort and participation).

file m0003

Source text – *NFPA 70E Standard for Electrical Safety in the Workplace*

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the the following sections of this text:
 - [Article 130](#) (“Work Involving Electrical Hazards”)
 - [Informative Annex C](#) (“Limits of Approach”)

This text is an electrical safety standard document, typical of many safety standards in industry. In reading this, your goal is to comprehend the scope of the sections (i.e. what contexts and purposes they serve), acquire vocabulary specific to the standard, and project where this standard applies to your work both in school and in your chosen career. These reflective points (scope, vocabulary, application) take the place of assigned questions.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the ModEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the [Conceptual Reasoning](#) section of the [Questions](#) chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

Your instructor will challenge all students in the session to share what they learned and to think critically about the topic(s) at hand, examine students’ approach to solving problems, and offer helpful advice. You will be graded based on your positive contributions to the dialogue and good-faith effort to solve problems on your own.

Session grading is subtractive rather than additive, meaning that a perfect score contributes nothing to the course grade, but an imperfect score will detract from it. This is because showing up on time fully prepared and actively participating is both easy to accomplish and a bare-minimum standard for any professional field. Late arrival is equivalent to unpreparedness; absence is equivalent to non-participation. If for any reason you cannot attend, electronic submission of your work by the starting time of your scheduled session will be accepted for full credit, with grading based on thoroughness and accuracy (rather than by good-faith effort and participation).

[file m0020](#)

Source text – *Electromechanical Relays* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_relay.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Complete “Time-delay relay circuit function” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Capacitive time-delay relay” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted time-delay circuit” in the Diagnostic Reasoning section of the Questions chapter.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the ModEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the Conceptual Reasoning section of the Questions chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

Your instructor will challenge all students in the session to share what they learned and to think critically about the topic(s) at hand, examine students’ approach to solving problems, and offer helpful advice. You will be graded based on your positive contributions to the dialogue and good-faith effort to solve problems on your own.

Session grading is subtractive rather than additive, meaning that a perfect score contributes nothing to the course grade, but an imperfect score will detract from it. This is because showing up on time fully prepared and actively participating is both easy to accomplish and a bare-minimum standard for any professional field. Late arrival is equivalent to unpreparedness; absence is equivalent to non-participation. If for any reason you cannot attend, electronic submission of your work by the starting time of your scheduled session will be accepted for full credit, with grading based on thoroughness and accuracy (rather than by good-faith effort and participation).

file m0021

Source text – *AC Induction Motor Starters* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_acstarter.pdf

Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the the following sections of the Tutorial chapter:
 - Inrush current
 - Inrush-limited starting
- Complete “Inrush current for a reactance starter” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Autotransformer starter calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted wye/delta starter” in the Diagnostic Reasoning section of the Questions chapter.

The session will begin with a graded assessment of your preparation: that you have read, outlined, and reflected on the assigned reading and have made a good-faith effort to answer all assigned questions. If the assignment is based on a learning module (from the ModEL Project), you will find the “Reading Outline and Reflections” and “Foundational Concepts” subsections in the Conceptual Reasoning section of the Questions chapter of that module helpful in offering strategies and structure for your study. Bringing your own questions to the discussion will improve the quality of the dialogue and improve your own comprehension.

Your instructor will challenge all students in the session to share what they learned and to think critically about the topic(s) at hand, examine students’ approach to solving problems, and offer helpful advice. You will be graded based on your positive contributions to the dialogue and good-faith effort to solve problems on your own.

Session grading is subtractive rather than additive, meaning that a perfect score contributes nothing to the course grade, but an imperfect score will detract from it. This is because showing up on time fully prepared and actively participating is both easy to accomplish and a bare-minimum standard for any professional field. Late arrival is equivalent to unpreparedness; absence is equivalent to non-participation. If for any reason you cannot attend, electronic submission of your work by the starting time of your scheduled session will be accepted for full credit, with grading based on thoroughness and accuracy (rather than by good-faith effort and participation).

file m0022

Open Session

Today's "open" class session is unstructured, and is intended to be a time for you to ask questions of your instructor, complete remaining work, prepare for any upcoming assessments, etc.

Open class sessions may be dropped from the calendar if any school days are lost due to inclement weather or other unforeseen interruptions.

file m0001

The written exam will consist of the following questions:

- (1 question) Calculate voltage, current and/or horsepower for both single-phase and three-phase electrical motors
- (1 question) Sketch proper wire connections for a latching motor starter circuit
- (2 questions) Calculate voltage, current, resistance, and/or power in balanced three-phase AC circuits
- (1 question) Determine statuses within a time-delay relay ladder logic circuit given a schematic diagram and a timing diagram showing switch states
- (1 question) Identify possible faults within a malfunctioning three-phase motor starter circuit

The written exams are printed on paper, and will be handed to you at the beginning of the exam session. They are closed-book and closed-note. A scientific calculator is allowed, but no use of mobile phones or personal computers as calculators. Music played through earbuds is welcome. You may ask questions of the instructor, who will clarify questions but will not provide hints or any other form of help. Numerical answers must be within 1% of the correct (un-rounded) answer in order to be counted as correct.

The written exam is a mastery exam, which means passing the exam requires *all* questions be answered correctly, and that passing this exam is necessary to pass the course. If upon your first submission to the instructor any errors are found, the instructor will mark which sections of the exam have been passed (with “1” characters) and which sections have not (with “0” characters), and will return the exam to you for another attempt. If upon your second submission any errors remain (or new errors added), you must re-take a different version of the exam on a different day. Scoring is based on the number of attempts: the number of “1” marks divided by the total number of “0” and “1” marks. The score from the first version of the exam you take factors into your course grade. Re-take exams are not scored, but only checked for absence of all errors by the second submission. Exam re-takes occur during lab time, a maximum of one per day.

Following the written exam will be a demonstration exam where you will build a circuit at your desk using your Terminal Block Board and then demonstrate its correct operation to the instructor. A multimeter is permitted, but the circuit must not be energized with any form of electrical source except during demonstration. Circuit demonstration occurs at the front of the classroom where you will be given **2 minutes** to set up and demonstrate its correct operation to the instructor. If the demonstration is unsuccessful, you may return to your desk to fix the problem(s) and then re-try with the same time limit. The demonstration exam is closed-book, but component “pinout” references are allowed.

The demonstration exam is also a mastery exam, with re-takes (maximum of one per day) allowed. The exam’s score is based on the number of attempts (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 50% ; 4 attempts = 10% ; 5 or more attempts = 0%). Any violation of a safety standard (e.g. handling energized conductors) counts as a failed attempt.

Demonstration circuit parameters will be randomized by the instructor. Students will be made aware of the circuit options well in advance of the exam in order to master the necessary principles and procedures, but exact component values, test conditions, and other details will not be revealed until the exam begins. Terminal Block Boards must be “blank” (i.e. no pre-placed or pre-wired components) in order to ensure every student actually builds their own circuit during the exam session. Any re-takes after the scheduled exam date will be with new (randomized) circuits.

This exam’s demonstration circuit is a time-delay relay circuit driving a 120 VAC load. The instructor will provide the time delay specification (e.g. NOTO, NOTC, NCTO, NCTC) as well as the AC load. Your task is to demonstrate that the time-delay relay function is correct and that the load energizes as it should.

file m9004

Experiments

NAME: _____

DUE DATE: _____

Experiment source text – *AC Motors* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_acmotor.pdf

Independently prepare for and execute the “Experiment: Measure DC motor inrush current using DMM” outlined in the [Projects and Experiments](#) chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

[file m1008](#)

NAME: _____

DUE DATE: _____

Experiment source text – *AC Motors* learning moduleURL – <http://ibiblio.org/kuphaldt/socratic/model/mod.acmotor.pdf>

Independently prepare for and execute the “Experiment: Measure DC motor inrush current using DSO” outlined in the [Projects and Experiments](#) chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

[file m1009](#)

NAME: _____

DUE DATE: _____

Experiment source text – AC Motors learning module

URL – <http://ibiblio.org/kuphaldt/socratic/model/mod.acmotor.pdf>

Independently prepare for and execute the “Experiment: Measure AC motor inrush current using CT” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1010

NAME: _____

DUE DATE: _____

Experiment source text – AC Induction Motor Starters learning module

URL – <http://ibiblio.org/kuphaldt/socratic/model/mod.acstarter.pdf>

Independently prepare for and execute the “Experiment: Demonstrate DC motor starter circuit” outlined in the [Projects and Experiments](#) chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

[file m1011](#)

NAME: _____

DUE DATE: _____

Experiment source text – *Electromechanical Relays* learning moduleURL – <http://ibiblio.org/kuphaldt/socratic/model/mod.relay.pdf>

Independently prepare for and execute the “Experiment: Demonstrate a time-delay relay circuit” outlined in the [Projects and Experiments](#) chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

[file m1013](#)

NAME: _____

DUE DATE: _____

Experiment source text – Polyphase AC learning module

URL – <http://ibiblio.org/kuphaldt/socratic/model/mod.polyphase.pdf>

Independently prepare for and execute the “Experiment: SPICE modeling of a three-phase AC circuit” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1014

NAME: _____

DUE DATE: _____

Experiment source text – AC Induction Motor Starters learning module

URL – <http://ibiblio.org/kuphaldt/socratic/model/mod.acstarter.pdf>

Independently prepare for and execute the “Experiment: Demonstrate inrush-limited DC motor starter” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1012

Troubleshooting

NAME: _____

DUE DATE: _____

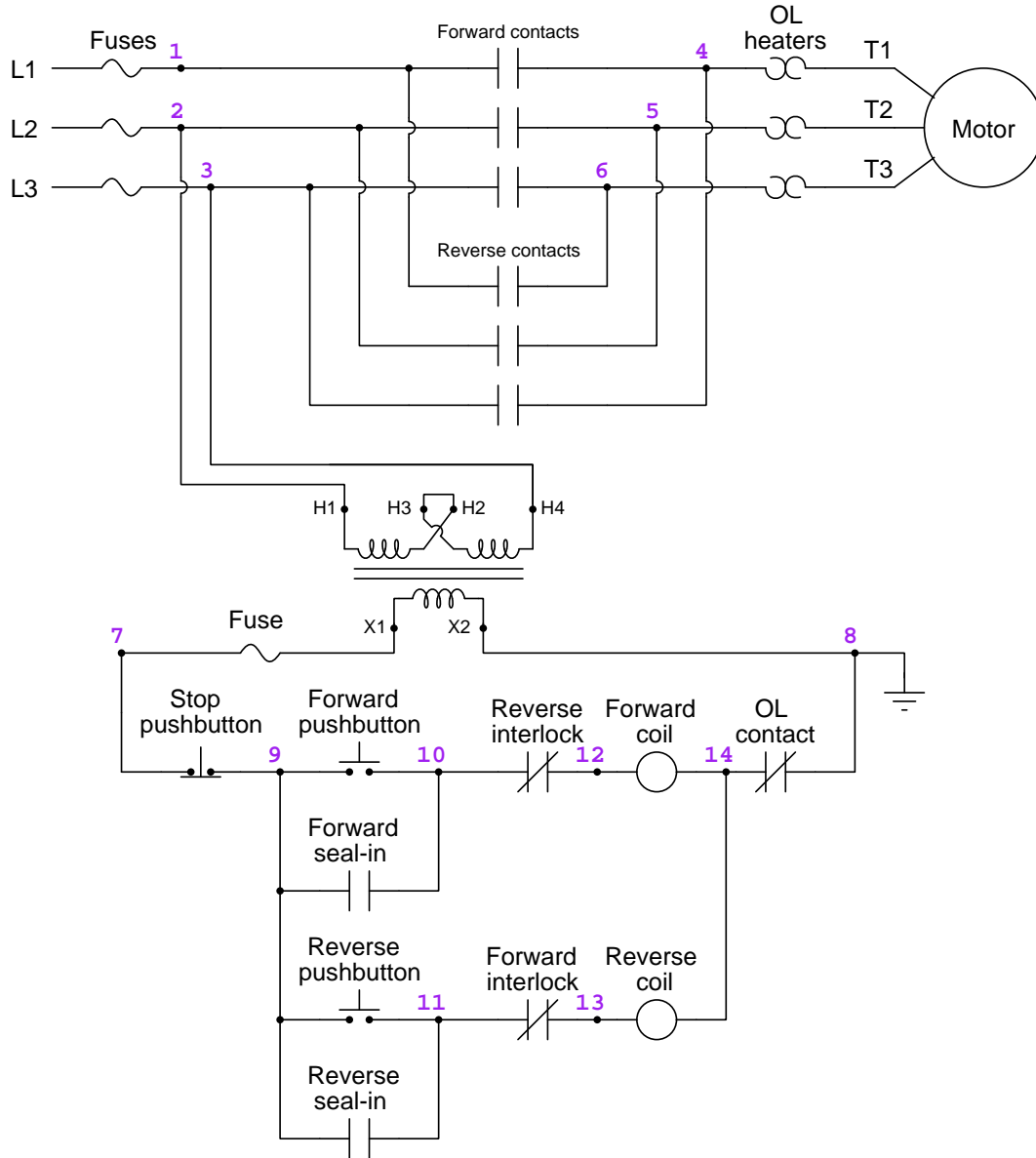
Troubleshooting challenge	Attempts	Completed
Simulation: Simulated fault in relay-controlled motor circuit		

Troubleshooting is *mastery-based*, meaning every one must be competently completed by the due date 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. Re-tries will be performed on a randomized scenario. 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%). Troubleshooting assessments are closed-book and closed-note.

You may *practice* troubleshooting as often as you wish using the open-source computer-based simulation program TROUBLESHOOT. If the troubleshooting exercise is based on a circuit you construct, you may practice by having classmates introduce faults which you then attempt to diagnose. If the troubleshooting is based on a shared system owned by the college, you may practice using the system unfaulted, but will not be permitted to practice with faults. The reason for this is that we have found when students practice inserting faults into a common system, they often leave that system for others in a state of disrepair. Therefore, only unfaulted practice is allowed on college-owned systems.

Troubleshooting challenge	Attempts	Completed
Three-phase AC motor starter circuit		

For this troubleshooting challenge you will work with a pre-constructed three-phase reversing AC motor starter circuit where all system components are hidden from view and you will have access only to a terminal block with wires connecting to labeled test points within the circuit.



Troubleshooting is *mastery-based*, meaning every one must be competently completed by the due date 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. Re-tries will be performed on a randomized scenario. 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%). Troubleshooting assessments are closed-book and closed-note.

You may *practice* troubleshooting as often as you wish using the open-source computer-based simulation program TROUBLESHOOT. If the troubleshooting exercise is based on a circuit you construct, you may practice by having classmates introduce faults which you then attempt to diagnose. If the troubleshooting is based on a shared system owned by the college, you may practice using the system unfaulted, but will not be permitted to practice with faults. The reason for this is that we have found when students practice inserting faults into a common system, they often leave that system for others in a state of disrepair. Therefore, only unfaulted practice is allowed on college-owned systems.

Projects

NAME: _____

DUE DATE: _____

Project source text – *Variable Frequency AC Motor Drives* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_vfd.pdf

- Complete the following objectives within a team of no more than four people for the project documented as “Project: VFD-controlled AC induction motor” in the Projects and Experiments chapter. Alternatives to this project are authorized by instructor permission, so long as all the same learning objectives are met.

Pre-construction objective	Attempts	Completed
<i>(Team)</i> – Prototype diagram and project scope		
<i>(Team)</i> – Risk assessment/mitigation plan		
<i>(Team)</i> – Project timeline and action plan		

NOTE: All pre-construction objectives must be verified complete by the instructor before any project construction or live testing begins! Since projects usually include components and resources of substantial cost, it is important to have a solid plan before proceeding.

Objective	Attempts	Completed
<i>(Team)</i> – Demonstration of working system		
<i>(Individual)</i> – Project diagrams and coding		
<i>(Team)</i> – Bill of Materials		
<i>(Individual)</i> – Written summary of lessons learned		
Fractional score / Percentage score	Score = /	Raw score = %
Deductions for unprofessionalism	Instances =	Adj. score = %

The instructor will certify completion of each objective at your request. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard. A full description of each objective and its corresponding standard begins on the next page of this document. You may ask a question or request help from the instructor at any time without counting as an attempt.

Scoring is based on the number of attempts necessary to fulfill all objectives: the number of objectives divided by the total number of attempts to complete all objectives, expressed as a percentage. Thus, a perfect score is possible only by completing all objectives on the first attempt. If one or more members of a team repeatedly compromise team performance, they may be removed from the team and required to complete the project alone. Every project is a *mastery* item for the course, meaning that every objective of every project must be completed by the due date in order to pass the course.

Deductions will be levied for any instance of unprofessional behavior, and affect the Adjusted score. This includes unsafe work practices (–20%), improper equipment usage (–10%), poor teamwork (–10%), etc. Expectations include maintaining an orderly work environment and returning all tools and test equipment by the end of every day, as well as following clear instructions (e.g. instructions given in equipment manuals, learning modules, verbally by the instructor), communicating with teammates, and productively managing time.

Objective descriptions and standards

Prototype diagram and project scope

Prior to any construction, the team must present diagrams of what they intend to build along with a description of what the project will do. *For this particular project the prototype documentation includes a correct wiring diagram based on information from the VFD manufacturer's manual, as well as a list of VFD parameters that will need to be programmed.* The prototype diagram(s) must include all components, component values, wiring connections, terminal labels, essential parameter settings, etc. The project scope is a written description of what the completed project should actually do, and it should be as practical and reasonable as time will allow. This step is critically important, as poor planning leads to poor project execution!

Risk assessment/mitigation plan

The team must assess all risks associated with the project's construction and operation, both equipment-related and personal, along with practical steps to mitigate those risks. *This project will involve 120 VAC electrical power, and therefore there is a non-trivial risk of electrical shock and fire. To address this you will need overcurrent protection and wiring practices appropriate for 120 VAC line power.*

Project timeline and action plan

The team will present a simple timeline of expected construction and testing progress, culminating at the project deadline date. Deviations from this plan may occur, but it is still important to formulate a plan in order to budget time and resources.

Demonstration of working system

The team will demonstrate proper operation of the project. *For this particular project, full start/stop and speed control of the induction motor must be demonstrated.*

Project diagrams and coding

Each individual team member will present their own copy of diagrams for the project using industry-standard formats and symbols. Any programming code must also be fully documented, complete with comments written within the text of the code.

Bill of Materials

The team will present a simple Bill of Materials listing all components and materials necessary to build the project, along with current cost estimates for each. Assembled devices given to students (e.g. Terminal Block Boards) need not have their internal components itemized but may be listed as single line-items in the Bill of Materials. The total cost of a Terminal Block Board is about \$200.

Written summary of lessons learned

Each individual team member will present their own written summary describing key points they learned during the construction and testing of the project. It is strongly encouraged that everyone document their own mistakes, as they *will* inevitably occur, and it is important that they serve as learning opportunities. The scope of this summary may be as wide as you wish, reflecting on everything from technical lessons learned, to interpersonal lessons learned, to ways of improving time management, etc.