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<td>Session 60</td>
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### Essential information about this course:

- Learning to independently digest technical information and solve novel problems is even more important than learning electrical and electronic theory. To develop these skills we will read extensively to gain new knowledge, then tackle unfamiliar problems using that knowledge.

- This is a theory course, but it is not lecture-based. At-home reading assignments replace lecture, while discussions about the text and problem-solving practice occupy class time.

- Full preparation for and participation in every theory session is a basic expectation. Lack of preparation will result in point deductions, as will lack of participation and/or late arrival.

- Half of your course grade comes from “oral presentations” where you solve problems in full view of classmates and instructor just like during a technical job interview.

- Half of your course grade comes from written “mastery exams” where every question must be correctly answered to pass. Multiple re-tries are allowed on different exam versions, but only the first exam’s score counts toward your course grade.

- You should budget a minimum of 12 hours per week for this course, approximately 4 hours in-class and 8 hours out-of-class preparation.

- Successful students (1) prioritize their study time, (2) test themselves on upcoming oral presentation and written exam topics, (3) and master principles before memorizing procedures.
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.

file eet_values

3
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.
Course description

This course teaches the theory of AC and state-based digital logic circuits with an emphasis on physical conservation laws and other foundational concepts as unifying principles, including AC measurements, series-parallel reactive networks, transformers, harmonics, polyphase AC power systems, power conversion circuits, latch-based digital logic circuits, and programmable logic controller (PLC) counting and timing functions. Mastery-style written exams guarantee attainment of conceptual learning outcomes, while oral presentations and Socratic dialogue demonstrate communicative learning outcomes.

Course learning outcomes

- Compute voltages and currents in AC reactive circuits, passive filter networks, transformer circuits, polyphase power systems, and AC-DC rectifier circuits given schematic diagrams, component values, and other circuit parameters. (Addresses Program Learning Outcomes 4, 6)
- Compute component values necessary to achieve stated performance goals in filter circuits, transformer circuits, and discrete semiconductor power circuits. (Addresses Program Learning Outcomes 4, 6)
- Design and sketch simple filter networks, polyphase transformer banks, and AC motor starters to meet stated functional requirements. (Addresses Program Learning Outcomes 4, 5, 6)
- Articulate and apply technical principles related to AC theory, power conversion, and programmable logic controllers as requested by a critical audience. (Addresses Program Learning Outcomes 1, 2, 4, 6, 7)
- Identify probable faults in AC reactive circuits, transformer circuits, power conversion circuits, and latching logic circuits given schematic diagrams and reported symptoms. (Addresses Program Learning Outcomes 5, 6)
Required Tools, Supplies, and Software

Listed by IETTI course number and course type (Thy = theory, Exp = Experiments, Prj = Projects).

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Required Tools, Supplies, and Software

Scientific calculator – at minimum your calculator must perform trigonometric functions (sine, cosine, tangent, etc.), offer multiple memory registers, and display values in both scientific and “engineering” notations. I recommend the Texas Instruments model TI-36X Pro because it easily performs complex-number arithmetic necessary for AC circuit analysis and is inexpensive.

Personal computer – all course materials are available in electronic format and are free (most are also open-source), making a portable computer extremely useful. The school provides personal computers for on-campus use, but having your own will enable you to work outside of school. Most operating systems, size of hard drive, amount of RAM memory, and screen size is appropriate, but your computer must have a keyboard and mouse (i.e. no tablets). Avoid ChromeBooks. Useful features worth higher cost include an RJ-45 Ethernet port and an EIA/TIA-232 (9-pin) serial port.

Multimeter – this is your first and most important electronic test instrument. At minimum it must measure DC and AC voltage, DC and AC current (milliAmpere range), resistance, and “diode check” voltage drop. Useful features worth higher cost include microAmpere current measurement, true-RMS AC measurement (for second-semester courses and above), frequency measurement, capacitance measurement, and minimum/maximum value capture. Cost is a strong function of accuracy, frequency range, and safety (“Category” ratings for over-voltage exposure). The Fluke model 87-V is an excellent professional-grade choice for digital multimeters, and the Simpson 260 is an excellent professional-grade choice for analog multimeters. Note that Fluke offers a 25% educational discount for students.

Oscilloscope – once too expensive for student purchase, entry-level USB-based oscilloscopes now cost less than a textbook. Pico Technology is an excellent brand, and their model 2204A comes with high-quality probes as well. Plugged into your personal computer using a USB cable, the Picoscope turns your computer’s monitor into a high-resolution oscilloscope display. Features include two measurement channels, 10 MHz bandwidth, built-in arbitrary waveform generator (AWG), ± 100 Volt over-voltage protection, digital “cursors” for precise interpretation of amplitude and frequency, meter-style measurement capability, Fast Fourier Transform algorithm for frequency-domain measurement, export ability to several graphic image formats as well as comma-separated variable (.csv) files, and serial communications signal decoding. Together with your multimeter, solderless breadboard and Development Board (which you will construct in the IETTI-102 Project course and is yours to keep) this forms a complete electronics laboratory for doing experiments and projects outside of school.

Soldering – the equipment you purchase for soldering need not be expensive, if you purchase the right solder. For electronics work you must use rosin-core solder. Kester is an excellent brand, and you should avoid cheap imported solders. For lead-based solder, a 63% tin and 37% lead alloy (Sn63/Pb37) works very well. A one-pound roll is likely more solder than you will need in these courses, so I recommend buying just a small tube or small roll. I recommend a fine-tipped soldering iron (15 Watts continuous power, although some with adjustable temperature controls may have higher power ratings to get up to soldering temperature more quickly) and a solder diameter 0.031 inches or smaller for doing fine printed-circuit board work. Also, keep the tip of your soldering iron clean by wiping it against a damp sponge or paper towel when hot, and not leaving it hot any longer than necessary. Hakko, X-tronic, and Lonove are all recommended brands.

PLC – these courses are not brand- or model-specific, but the Koyo “CLICK” series of Programmable Logic Controller sold by Automation Direct is highly recommended for low cost and ease of use.

Microcontroller – these courses are not brand- or model-specific, but the Texas Instruments MSP430 series is highly recommended for their powerful features, modern design, and programmability in multiple languages (assembly, C, C++, and Sketch). I particularly recommend the model MSP-EXP430G2ET “LaunchPad” development board (MSP430G2553IN20 microcontroller chip) with Code Composer Studio for the IDE software. A hobbyist-grade microcontroller such as the popular Arduino and Parallax BASIC Stamp are permissible only in first-year courses, but not in second-year courses.
Required Tools, Supplies, and Software

All software required for these courses is free, and some of it is open-source.

**Schematic editor** – this is used to draft schematic diagrams for circuits. A good one is TinyCAD, but there are also web-based CAD tools such as diagrams.net that are very effective and easy to use. KiCad offers an excellent schematic editor as well as other tools for translating schematic diagrams into printed circuit board (PCB) layouts, useful in later courses.

**Text editor** – this is used to create plain-text files, kind of like a word processor but lacking formatting features such as typeface, font size, etc. It is absolutely necessary for writing code of any kind. Notepad++ is a very good editor, but others work well too.

**NGSPICE** – this is a modern adaptation of the venerable SPICE circuit simulator which uses a text-coded “netlist” rather than a visual schematic diagram to describe circuits. Very powerful, and with decades of netlist examples from earlier versions of SPICE to use as references. The installer lacks sophistication, being nothing more than a compressed (zip) file that you unpack. Once installed, you should instruct your computer’s operating system to automatically associate any files ending in the extension .cir with the NGSPICE executable file ngspice.exe so that all of your netlist files will appear with the NGSPICE icon and will automatically load into NGSPICE when double-clicked.

**WSL** – Windows Subsystem for Linux is a “virtual machine” Linux operating system that runs within the Windows operating system, giving you a command-line user environment mimicking that of a Unix operating system. It is a free application from Microsoft, with instructions available from Microsoft on how to install. I recommend installing the “Debian” distribution of WSL. Once installed, you will issue these commands in the following order to install all the necessary programming tools:

- `sudo apt update`
- `sudo apt install build-essential`

**tshoot** – this is a specialized circuit-simulator program that inserts faults into circuits and tests your ability to locate them. The download consists of a single “tar” archive file which you must unpack and compile using the following two commands within a Unix-type operating system or within WSL. The fourth command listed below starts and runs the application:

- `mkdir tshoot ; mv -v *.tar tshoot ; cd tshoot`
- `tar xvf *.tar`
- `make`
- `./tshoot`

**IDE software** – an “Integrated Development Environment” is a software package used to write code, and for our purposes this would be code meant to run in a microcontroller. For the Texas Instruments MSP430 series, the main IDE is called Code Composer Studio, and it supports programming in assembly language, C, and C++. A third-party add-on to Code Composer Studio called Energia supports programming in the Sketch language, identical to that used by the popular Arduino microcontroller series.

**PCB layout editor** – this is specialized drafting software intended for creating graphic files to be sent to printed circuit board (PCB) manufacturers so you can order your own custom PCBs. PCB Artist is free and exceptionally easy to use, but only exports files to the manufacturer Advanced Circuits. Free PCB layout editors capable of exporting “Gerber” format files which are universally accepted by PCB manufacturers include EasyEDA, KiCad, and pcb. Of these I recommend EasyEDA for beginners, or PCB Artist if you don’t mind being locked into one manufacturing option.

**Packet-sniffing software** – this is specialized software for monitoring network communications. An excellent (and free) option is Wireshark.
Grading standards for Theory courses

Your grade for this course is based on percentage scores (in every calculation rounded down to whole-numbered values), with each category weighted as follows:

- Oral presentation scores = 50%
- Written exam scores = 50% (Note: all exams are mastery-based, which means they must be eventually completed at 100% competence in order to pass the course)
- Unpreparedness for theory sessions = −1% per session
- Non-participation for theory sessions = −1% per session

All theory sessions are based on an “inverted” model of instruction rather than lecture. Instead of quietly listening to the instructor explain new concepts to you, you will independently explore those new concepts outside of class and then spend the class time discussing what you learned, what didn’t make sense, and solving problems. This instructional model has proven far more effective than lecture, principally for the reason that student engagement is mandatory and not optional. It also makes far more efficient use of students’ time, greatly minimizing the amount of necessary classroom hours to achieve the same learning.

Scoring for theory sessions is based on your preparation for and participation within each theory session. These scores are subtractive rather than additive; that is to say, arriving fully prepared and participating fully in each group discussion contributes nothing toward the course grade, but unpreparedness and/or non-participation detracts from the course grade. Showing up on time, fully prepared, and genuinely contributing to every activity is the minimum expectation for any professional career, and so this is the standard maintained in this course. 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 to your course grade. Satisfactory preparation is defined as a good-faith effort to complete all pre-work specified in the theory session plan. Note that this does not mean mastery of that session’s concepts, but simply a presentation of your best work. Failure to positively and proactively contribute to the discussion during a theory session similarly results in a −1% deduction per session. Half-point deductions are awarded for being mostly but not fully prepared/engaged.

If you must be late or absent for a theory session, 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 participation, answering all “Challenges” for assigned questions will substitute for dialogue and problem-solving with classmates and instructor.

Absence during a scheduled oral presentation or a scheduled written exam will result in a 0% score for that assessment, except in the case of a documented emergency. In such emergency cases, written exams may be taken at some later time for full credit, and oral presentations may also be completed at a later date for full credit. During any assessment you are free to ask the instructor for clarification, but the instructor will not help you solve any problem nor will confirm if an answer is correct prior to its submission for scoring.

A failing (F) grade will be earned for the entire course if any written exam not completed with 100% accuracy on or before the deadline date, 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.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the “Locating Employment” chapter of the *Career Guide* document
- Research open positions on job search engines (e.g. Indeed.com) searching for job titles listed in the “What is Electronics” chapter, focusing on those jobs listing a two-year (Associate’s) degree in electrical or electronics technology for education

Complete the following during the scheduled session:

- Discuss what you read in the *Career Guide*
- Discuss what you found in your job search:
  - What technical skills are common to these jobs?
  - What non-technical skills are common to these jobs?
- Calculate time commitment (3 hrs/week per semester-credit) for this semester’s courses
  - Full load = 12 credits = 36 hours/week total time commitment + General Education courses!
- Emphasize importance of daily contact with instructor, even in the event of an absence
- Emphasize importance of personal effort to solve problems prior to asking for help
- Identify the pre-work for tomorrow’s theory session
- [Optional] – sign FERPA release forms

**Forms provided by the instructor for today’s session:**

- FERPA release form
- IETTI-104 Theory course document (printed from cover page through Theory Session 2)
- IETTI-112 Experiments course document (only if you are enrolled in this course as well)
- IETTI-105 Projects course document (only if you are enrolled in this course as well)

**Important resources:**

- [http://ibiblio.org/kuphaldt/socratic/model](http://ibiblio.org/kuphaldt/socratic/model), the *Modular Electronics Learning Project* web page containing all course documents, tutorials, and problem sets you will need in these courses
  - [http://ibiblio.org/kuphaldt/socratic/model/index#courses](http://ibiblio.org/kuphaldt/socratic/model/index#courses), links to all IETTI course documents
- [http://ibiblio.org/kuphaldt/socratic/model/calendar.html](http://ibiblio.org/kuphaldt/socratic/model/calendar.html), our semester calendar showing dates for theory sessions, special events, and all-lab project sessions
- [http://ibiblio.org/kuphaldt/socratic/model/daily_schedule.pdf](http://ibiblio.org/kuphaldt/socratic/model/daily_schedule.pdf), showing Monday-Friday class schedule
- “Required Tools, Supplies, and Software” page (in this document)
- “Grading standards for Theory courses” page (in this document)
- EETREF – a collection of digital documents often referenced in homework assignments, stored as a folder on the Desktop of every computer in the lab

file wt_1002
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Safe to touch?” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Shock hazard calculation” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Electrically verifying hot, neutral, and ground” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial in its entirety.
- Answer the following questions:
  - What is rosin (flux), and what does it do?
  - How should you apply the solder to a connection?
  - Identify some safety precautions when soldering
  - What purpose does the wet sponge serve when soldering?
  - What should a properly-soldered connection look like?
  - What is solder made of?
  - How may you remove excess solder from a circuit board?

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

- Browse the slideshow to identify several examples of improperly-soldered connections, and explain what is wrong with each one.
- Browse the slideshow to identify several examples of acceptable soldered connections, and explain what is correct with each one.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Full Tutorial chapter in its entirety.
- Complete “Controlling the rate of de-energization” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Rail gun capacitor” in the Quantitative Reasoning section of the Questions chapter.
- Complete “High-voltage surge supply” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Squaring a house foundation” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Radian/degree angle conversions” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Unknown angles and side lengths” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find the mistake(s)” in the Diagnostic Reasoning section of the Questions chapter.

NOTE: there are many calculations required to perform right-triangle analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. Unless and until you can do the problem(s) on your own, you have not yet learned the concept!
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- If you haven’t already, purchase a scientific calculator capable of complex-number arithmetic. *The TI-36X Pro is recommended.* Top-end TI calculators (e.g. TI-89) also offer this functionality, but the TI-36X Pro is much cheaper! The TI-83 and TI-84 calculator models can also perform these functions, but they do so in a more clumsy way than either the TI-89 or TI-36X Pro.
- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Wire and insulation sizing” in the Conceptual Reasoning section of the Questions chapter.
- Complete “AC voltage oscillographs” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Phase shift from oscillographs” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Detecting AC mains distortion” in the Diagnostic Reasoning section of the Questions chapter.

*NOTE: there are many calculations required to perform AC circuit analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:*

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. *Unless and until you can do the problem(s) on your own, you have not yet learned the concept!*
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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- Read, outline, and reflect on the following sections of the Full Tutorial chapter:
  - AC versus DC
  - Additive quantities
  - Trigonometric conversions

- Complete “Practice: complex number calculations” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Simple phasor diagrams” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Series AC voltages” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Incorrect voltage calculation” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Simplified Tutorial chapter in its entirety.
- Run PicoScope software in its “Demo” mode and experiment with measuring the amplitude, period, and frequency of a simulated waveform, and show the final results.
- Complete “Measuring waveform parameters” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Diagnosing incorrect display settings” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Full Tutorial chapter:
  - Probes
  - Triggering
  - Differential measurements
  - X-Y mode

- Run PicoScope software in its “Demo” mode and experiment with measuring the trigger settings to see what effect they have on the waveform’s display. Be sure to document your results.

- Complete “Uses of a x10 probe” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Measuring motor inrush current” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Frequency ratios” in the Quantitative Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
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 “Example circuit #1” section of the Full Tutorial chapter.
- Read, outline, and reflect on the “Example circuit #2” section of the Full Tutorial chapter.
- Read, outline, and reflect on the “Example circuit #3” section of the Full Tutorial chapter.
- Complete “Parasitic inductance and capacitance” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Simple AC circuits” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Identifying an unmarked component” in the Diagnostic Reasoning section of the Questions chapter.

NOTE: There are many calculations required to perform AC circuit analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. Unless and until you can do the problem(s) on your own, you have not yet learned the concept!
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Oral Presentations

Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, be graded on technical accuracy, and be followed by constructive criticism from the audience. You are allowed to bring notes for reference, but not allowed to read them to your audience. When you are chosen to present, you will have a brief period of time to gather your thoughts and set up for your presentation.

Your instructor will not provide answers to you prior to or during the presentation; you are solely responsible for any research, experimentation, and other actions necessary to adequately prepare for your presentation. If you inquire for help, the instructor may clarify what you will need to present on, and/or point you toward specific resources (e.g. “Try setting up a SPICE simulation”, “Try building a test circuit on your breadboard”, “Find and read the datasheet(s)”, “Research application notes written on this topic”, etc.), but do not expect them to give you answers or check your work because by this point in time you will have studied the necessary concepts to verify results for yourself, or at least to know where to go to find verification.

During your presentation the instructor and audience members are free to pose questions relevant to the graded objectives for your assigned problem. This may be done for the simple purpose of clarifying an unclear answer, or to probe for misconceptions.

The benefits of this exercise include honing your independent research skills, reinforcing your foundational knowledge of electronics, gaining confidence speaking to groups, and preparation for job interviews where being able to articulate your knowledge and solve realistic problems before a critical audience sets you apart from lesser-qualified candidates.

A problem will be randomly assigned to you from the options listed on the next several pages. No student will know which problem will be assigned to them until it is their turn to present, which means all students should be prepared to present on every problem shown. Furthermore, problems may contain unspecified parameters which will also be randomized at presentation time. Full credit will be given only for answers that are correct and logically supported by trusted principles and sources (e.g. Conservation of Energy, Ohm’s Law, datasheets, etc.).

You are to regard your audience as technically adept (i.e. assuming everyone in attendance is familiar with the technical concepts and language; “skilled in the art”).
Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Conservation of Energy</th>
<th>Amplitude, period, frequency</th>
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<tr>
<td>Behavior of sources vs. loads</td>
<td>R vs. X vs. Z</td>
</tr>
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<td>Ohm’s Law</td>
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<tr>
<td>Joule’s Law</td>
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<tr>
<td>Effects of opens vs. shorts</td>
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<td>Properties of series networks</td>
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<td>Kirchhoff’s Voltage Law</td>
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<td>Behavior of FETs</td>
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<td>Sinking vs. sourcing current</td>
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<td>Behavior of thyristors</td>
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One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem! Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Problem #1
(Side lengths and angles randomly chosen by instructor):

Grading

- [20%] Calculate all unspecified side lengths
- [20%] Calculate all unspecified angles
- [20%] Demonstrate three different ways to calculate the value of a single angle
- [20%] Demonstrate three different ways to calculate the value of a single side length
- [20%] Identify the (adjacent/opposite) side relative to angle ______

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2

Demonstrate the measurement of an AC signal voltage using an oscilloscope. You may elect to do a live demonstration where you use real test equipment, or you may demonstrate this using a live computer simulation (e.g. Picoscope software in “demo” mode).

Grading

- [20%] Predict and demonstrate how an (increase/decrease) in signal voltage will affect the oscilloscope’s view of the signal
- [20%] Predict and demonstrate how an (increase/decrease) in signal frequency will affect the oscilloscope’s view of the signal
- [20%] Demonstrate how to measure the signal’s peak-to-peak voltage
- [20%] Calculate the signal’s RMS voltage
- [20%] Explain and demonstrate how triggering works to lock a particular point of the waveform on the screen

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #3

(Component values randomly chosen by instructor; assume an oscilloscope is ready to measure voltages, with its ground clip already connected to node 0):

Note: the instructor will choose component values simple enough that you will not need an electronic calculator to obtain exact solutions. For this reason, you will not be permitted to use any calculating device when analyzing this circuit! This prohibition of calculating devices is typical during technical interviews for electronics technician jobs.

Grading

- [20%] Current magnitude through node 3 ($I_3$)
- [20%] Voltage measured by oscilloscope at node with the circuit healthy
- [20%] Voltage measured by oscilloscope at node with failed open
- [20%] Voltage measured by oscilloscope at node with failed shorted

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #4

(Component types and values randomly chosen by instructor; source may be AC voltage or AC current, load may be $R$, $C$, or $L$):

\begin{center}
\begin{tikzpicture}
  \node (a) at (0,0) {AC source};
  \node (b) at (2,0) {Load};
  \draw (a) -- (b);
\end{tikzpicture}
\end{center}

Grading

- [20%] Reactance of load as a scalar value
- [20%] Impedance of load as a complex (phasor) value
- [20%] Current magnitude and phase angle
- [20%] Voltage magnitude and phase angle
- [20%] Predict effects of source frequency (increasing/decreasing)

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #5
A simplified schematic diagram of a typical residential 120/240 Volt split-phase electrical system appears below:

Grading

- [20%] Identify all wires that would be dangerous to touch with all circuit breakers closed
- [20%] Identify two different places you could measure 120 Volts with a voltmeter
- [20%] Identify two different places you could measure 240 Volts with a voltmeter
- [20%] Describe complete lock-out, tag-out and safety verification procedure for isolating power to receptacle #___ prior to replacing that receptacle
- [20%] Trace path of fault current if the appliance plugged into receptacle #___ develops an internal short-circuit

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6
(Symptoms and switch positions randomly chosen by instructor):

![Circuit Diagram]

<table>
<thead>
<tr>
<th>Fault</th>
<th>Possible</th>
<th>Impossible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open wire at node C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open wire at node D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead source</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blown fuse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamp failed open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamp failed shorted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch 1 failed open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch 2 failed open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open wire between nodes B and G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open wire between node G and earth ground</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Grading

○ Percentage of correct possible/impossible selections

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
The written exam will consist of the following types of questions and their related principles:

- **(Question #1)** Interpret amplitude values (peak, peak-peak, RMS), period values, phase shifts, and/or frequency values from an oscillograph display.
  *Oscilloscope operation, AC measurements, RMS vs peak ratios for sine and square and triangle/ramp waveforms*

- **(Question #2)** Calculate voltages and currents in single-source, single-load AC circuits.
  *Ohm’s Law, inductive reactance, capacitive reactance, impedance, complex-number arithmetic, polar and rectangular forms of complex numbers, AC phasors*

- **(Question #3)** Identify good versus poor solder connections by photograph.
  *Soldering practices*

- **(Question #4)** Identify electrical shock hazards in an AC power circuit schematic.
  *Kirchhoff’s Laws, electrically common points, transformers, power system grounding, effects of opens vs. shorts*

- **(Question #5)** Apply right-triangle trigonometry to the solution of practical distance problems.
  *Law of sines, Pythagorean Theorem, sine function, cosine function, tangent function*

- **(Question #6 – REVIEW)** Determine possible faults in an elementary circuit.
  *Voltage, current, effects of opens vs. shorts, behavior of sources vs. loads*

- **(Question #7 – REVIEW)** Determine the nominal, low, and high resistance values for four-band resistors given their band colors.
  *Resistor 4-band color codes, percentage calculations, tolerance*

- **(Question #8 – REVIEW)** Sketch proper multimeter connections to measure voltage, current, or resistance in a pictorial diagram of a circuit.
  *Voltage, current, behavior of sources vs. loads, multimeter usage*

- **(Question #9 – REVIEW)** Qualitatively predict voltage, current, and power changes in a series or parallel resistor circuit resulting from one component change.
  *Properties of series and parallel networks, effects of opens vs. shorts, behavior of sources and loads, properties of voltage sources, properties of current sources*
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “VIZ table for series RC circuit” in the Quantitative Reasoning section of the Questions chapter.
- Complete “LL and RL phasor diagrams” in the Quantitative Reasoning section of the Questions chapter.
- Run at least one simulation of a three-resistor voltage divider (circuit_001) using tshoot software, and show the final results.
  → Base each of your diagnostic tests on the application of some foundational concept of electric circuits (e.g. properties of series/parallel networks, Kirchhoff’s Laws, etc.)

**NOTE:** there are many calculations required to perform AC circuit analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. *Unless and until you can do the problem(s) on your own, you have not yet learned the concept!*
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

**Additional resources:**

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “VIZ table for parallel RC circuit” in the Quantitative Reasoning section of the Questions chapter.
- Complete “LL and RL phasor diagrams” in the Quantitative Reasoning section of the Questions chapter.
- Run at least one simulation of a three-resistor current divider (circuit_002) using tshoot software, and show the final results.
  → Base each of your diagnostic tests on the application of some foundational concept of electric circuits (e.g. properties of series/parallel networks, Kirchhoff’s Laws, etc.)

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**Additional resources:**

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Simplified Tutorial chapter in its entirety.
- Complete “Power factor from wattmeter” in the Quantitative Reasoning section of the Questions chapter.
- Complete “AC generator horsepower” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Correcting an arbitrary load’s power factor” in the Quantitative Reasoning section of the Questions chapter.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Resonant pulse circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Series LC circuit calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find the Mistake(s)” in the Diagnostic Reasoning section of the Questions chapter.

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

- Read, outline, and reflect on the Full Tutorial chapter in its entirety.
- Complete “Explaining the meaning of calculations” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Series and parallel network impedances” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Series-parallel circuit tables” in the Quantitative Reasoning section of the Questions chapter.

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**Additional resources:**

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
  
  file wt_0069

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

- Complete “Voltage drop in an RC sub-network” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Induction motor model” in the Quantitative Reasoning section of the Questions chapter.
- Run at least one simulation of a loaded voltage divider (circuit_004) using tshoot software, and show the final results.
  → Base each of your diagnostic tests on the application of some foundational concept of electric circuits (e.g. properties of series/parallel networks, Kirchhoff’s Laws, etc.)

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Additional resources:

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the *Tutorial* chapter:
  - Composition of light
  - Fourier's Theorem
  - Time vs. frequency in circuits
  - Time-frequency relationships
  - Applications for frequency-domain analysis
- Run PicoScope software in its “Demo” mode and experiment with the spectrum analyzer feature:
  - Display the spectrum of a pure sine wave
  - Alter the frequency of that pure sine wave and note its effect on the spectrum display
  - Display the spectrum of a square wave
  - Display the spectrum of a triangle wave
- Complete “Amplifier test” in the *Conceptual Reasoning* section of the *Questions* chapter.
- Complete “Discerning even/odd harmonics from the time domain” in the *Diagnostic Reasoning* section of the *Questions* chapter.

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

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Signal coupling and cable separation
  → Electric field (capacitive) de-coupling
  → Magnetic field (inductive) de-coupling

- Examine and reflect on the Example: capacitive coupling within cable section of the Case Tutorial chapter, and answer the following questions:
  → Identify conditions that would maximize coupling between the aggressor and the victim
  → How would an open fault in the lamp affect the meter’s measurement, if at all?

- Examine and reflect on the Example: inductive coupling within cable section of the Case Tutorial chapter, and answer the following questions:
  → Identify conditions that would maximize coupling between the aggressor and the victim
  → How would an open fault in the lamp affect the meter’s measurement, if at all?

- Complete “Phantom voltage measurements” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Compressor system wiring” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Signal separation
  - Reactive filtering
  - Bode plots
  - LC resonant filters
  - Roll-off
  - Mechanical-electrical filters
  - Summary of filter types
  - Filtering complex signals

- Complete “Identifying (more) filter types” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Filter type and cutoff identifications” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Designing simple RC low-pass and high-pass filters” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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

- Read, outline, and reflect on the Wave screens section of the Historical References chapter.
- Complete “Square wave to sine wave” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Simple harmonic analyzer” in the Conceptual Reasoning section of the Questions chapter.
- Run at least one simulation of a band-pass filter (Circuit_010) using tshoot software, and show the final results.
  → Base each of your diagnostic tests on the application of some foundational concept of electric circuits (e.g. properties of series/parallel networks, Kirchhoff’s Laws, etc.)

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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Theory session 23

Oral Presentations

Today's class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, be graded on technical accuracy, and be followed by constructive criticism from the audience. You are allowed to bring notes for reference, but not allowed to read them to your audience. When you are chosen to present, you will have a brief period of time to gather your thoughts and set up for your presentation.

Your instructor will not provide answers to you prior to or during the presentation; you are solely responsible for any research, experimentation, and other actions necessary to adequately prepare for your presentation. If you inquire for help, the instructor may clarify what you will need to present on, and/or point you toward specific resources (e.g. “Try setting up a SPICE simulation”, “Try building a test circuit on your breadboard”, “Find and read the datasheet(s)”, “Research application notes written on this topic”, etc.), but do not expect them to give you answers or check your work because by this point in time you will have studied the necessary concepts to verify results for yourself, or at least to know where to go to find verification.

During your presentation the instructor and audience members are free to pose questions relevant to the graded objectives for your assigned problem. This may be done for the simple purpose of clarifying an unclear answer, or to probe for misconceptions.

The benefits of this exercise include honing your independent research skills, reinforcing your foundational knowledge of electronics, gaining confidence speaking to groups, and preparation for job interviews where being able to articulate your knowledge and solve realistic problems before a critical audience sets you apart from lesser-qualified candidates.

A problem will be randomly assigned to you from the options listed on the next several pages. No student will know which problem will be assigned to them until it is their turn to present, which means all students should be prepared to present on every problem shown. Furthermore, problems may contain unspecified parameters which will also be randomized at presentation time. Full credit will be given only for answers that are correct and logically supported by trusted principles and sources (e.g. Conservation of Energy, Ohm’s Law, datasheets, etc.).

You are to regard your audience as technically adept (i.e. assuming everyone in attendance is familiar with the technical concepts and language; “skilled in the art”).
Note: all schematic diagrams for these problems are annotated with node numbers. These will be helpful when describing locations in the circuit for your audience, but they also serve as a cue on how to practice. Simply write a SPICE netlist using these node numbers, inserting component values of your choice, and then use SPICE to verify the results you calculate. Using SPICE, you may make as many versions of these circuits for practice as you would like! For example, the circuit of problem #1 may be converted into the following SPICE netlist (assuming $R_1 = 1.5 \, \text{k}\Omega$, $C_1 = 0.33 \, \mu\text{F}$, $L_1 = 500 \, \text{mH}$, and the source is 12 Volts AC at 500 Hz):

```
* Netlist
 v1 2 1 ac 12
 r1 2 0 1500
 c1 2 0 0.33e-6
 l1 1 0 500e-3
 .control
 set units=degrees
 .endc
 .ac lin 1 500 500
 .print ac vm(2) vp(2)
 .print ac vm(0,1) vp(0,1)
 .end
```

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Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

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<td>Power factor</td>
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<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
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<td>Fourier analysis</td>
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<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
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*One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem!* Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Problem #1
(Component values randomly chosen by instructor):

Grading

- [20%] Current magnitude and phase angle through resistor $R_1$ ($I_{R_1}$)
- [20%] Current magnitude and phase angle through capacitor $C_1$ ($I_{C_1}$)
- [20%] Current magnitude and phase angle through inductor $L_1$ ($I_{L_1}$)
- [20%] Voltage magnitude and phase angle between nodes 2 and 0 ($V_{2-0}$)
- [20%] Power factor

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2
(Component values randomly chosen by instructor):

Grading

- [20%] Current magnitude and phase angle through resistor $R_1$ ($I_{R1}$)
- [20%] Current magnitude and phase angle through capacitor $C_1$ ($I_{C1}$)
- [20%] Current magnitude and phase angle through inductor $L_1$ ($I_{L1}$)
- [20%] Total (source) current magnitude and phase angle ($I_{total}$)
- [20%] Power factor

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #3
(Component values randomly chosen by instructor):

Grading

- [20%] Voltage magnitude and phase angle across resistor $R_1$ ($V_{R1}$)
- [20%] Voltage magnitude and phase angle across capacitor $C_1$ ($V_{C1}$)
- [20%] Voltage magnitude and phase angle across inductor $L_1$ ($V_{L1}$)
- [20%] Total (source) current magnitude and phase angle ($I_{total}$)
- [20%] Power factor

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #4

Design a passive filter network meeting performance characteristics randomly chosen by instructor:

![Diagram of a filter network with input (V_in) and output (V_out) terminals.]

- Type of filter = (low-pass/high-pass)
- \( f_{\text{cutoff}} = \) ________ Ohms
- Using (inductor/capacitor)
- Minimum input impedance = ________ Ohms @ cut-off

Grading

- [20%] Proper pass characteristic (either low- or high-pass)
- [20%] Correct \( f_{\text{cutoff}} \) with component values chosen
- [20%] Predict effect(s) of resistor failing open
- [20%] Predict effect(s) of reactive component (L or C) failing open
- [20%] Calculate \( Z_{\text{in}} \) at \( f_{\text{cutoff}} \)

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #5
(Component values randomly chosen by instructor):

Grading

- [20%] Calculate resonant frequency with specified component values
- [20%] Voltage across $R_1$ ($V_{R1}$) at resonance
- [20%] Voltage across $C_1$ ($V_{C1}$) at resonance
- [20%] Voltage across $L_1$ ($V_{L1}$) at resonance
- [20%] Select new value for ____ to resonate at ______ Hz

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6

Demonstrate the measurement of signals in both the time and frequency domains. You may elect to do a live demonstration where you use real test equipment, or you may demonstrate this using a live computer simulation (e.g. Picoscope software in “demo” mode).

Grading

- [20%] Predict and then demonstrate how an (increase/decrease) in signal amplitude will affect both time- and frequency-domain views of a signal
- [20%] Predict and then demonstrate how an (increase/decrease) in fundamental signal frequency will affect both time- and frequency-domain views of a signal
- [20%] Predict and then demonstrate signal wave-shapes that contain both even and odd harmonics
- [20%] Predict and then demonstrate signal wave-shapes that contain only odd harmonics
- [20%] Predict and then demonstrate the harmonic frequency values for a _____ wave with a fundamental frequency of _____ Hz

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Theory session 24

The written exam will consist of the following types of questions and their related principles:

- (Question #1) Calculate voltages, currents, and impedances in a series AC circuit.  
  *Properties of series networks, Ohm’s Law, Kirchhoff’s Laws, AC phasors*

- (Question #2) Calculate voltages, currents, and impedances in a parallel AC circuit.  
  *Properties of parallel networks, Ohm’s Law, Kirchhoff’s Laws, AC phasors*

- (Question #3) Calculate voltages and currents in a series-parallel AC circuit.  
  *Capacitive reactance, inductive reactance, impedance, complex-number arithmetic, properties of series networks, properties of parallel networks, Ohm’s Law, Kirchhoff’s Laws*

- (Question #4) Calculate the power factor of an AC circuit.  
  *Capacitive reactance, inductive reactance, impedance, power factor, apparent power, reactive power, true power, Joule’s Law*

- (Question #5) Design and sketch a passive filter circuit with a specified cutoff frequency and characteristic.  
  *Filter circuit behavior, capacitive reactance, inductive reactance, resonance*

- (Question #6) Identify a passive filter circuit characteristic from its schematic diagram, and predict the effects of a component fault on that characteristic.  
  *Properties of series networks, properties of parallel networks, effects of opens vs. shorts, filter circuit behavior, capacitive reactance, inductive reactance*

- (Question #7 – REVIEW) Calculate voltage, current, resistance, and/or power in a simple circuit given necessary as well as extraneous parameters.  
  *Ohm’s Law, Joule’s Law, resistor 4-band color codes*

- (Question #8 – REVIEW) Identify voltage polarity given current direction, and current direction given voltage polarity, for both sources and loads. Also, identify sources versus loads given voltage polarity and current direction.  
  *Voltage, current, behavior of sources vs. loads*

- (Question #9 – REVIEW) Determine necessary resistor value to balance a bridge circuit, as well as calculate voltages and currents in that balanced bridge circuit.  
  *Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, properties of bridge networks*
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.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Full Tutorial chapter:
  - Loading effects
  - Winding polarity
  - Impedance transformation

- Complete “Gaulard and Gibbs transformer” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Autotransformer currents” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Testing transformer polarity” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Full Tutorial chapter in its entirety.
- Complete “Boost/buck transformer circuits” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Voltages between specified points” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find the mistake(s)” in the Diagnostic Reasoning section of the Questions chapter.

**NOTE:** there are many calculations required to perform phasor analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. **Unless and until you can do the problem(s) on your own, you have not yet learned the concept!**
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Explaining the meaning of calculations” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Three parallel current sources” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find the mistakes” in the Diagnostic Reasoning section of the Questions chapter.

NOTE: there are many calculations required to perform phasor analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. Unless and until you can do the problem(s) on your own, you have not yet learned the concept!
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Examine and reflect on the Example: wye-wound versus delta-wound motors section of the Case Tutorial chapter, and answer the following questions:
  → Identify which parameters are different between these two electric motors of equal horsepower, when energized by identical three-phase sources.
  → Identify how each of the phase voltages and currents may be calculated from the given information (100 HP, $V_{line} = 460$ V).
- 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.

NOTE: there are many calculations required to perform polyphase circuit analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. Unless and until you can do the problem(s) on your own, you have not yet learned the concept!
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- The Gallery chapter of the SPICE Modeling of Power Circuits learning module contains circuit examples complete with computer-generated analyses useful as practice problems. Using SPICE, you may modify these simulations for the purpose of generating your own practice problems and solutions!
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Prototype electrical power transmission system section of the Historical References chapter.
- Complete “Similar voltages and currents” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Balanced Delta source and Delta load” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Three-phase versus single-phase power transmission” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- The Gallery chapter of the SPICE Modeling of Power Circuits learning module contains circuit examples complete with computer-generated analyses useful as practice problems. Using SPICE, you may modify these simulations for the purpose of generating your own practice problems and solutions!

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

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Wye-Wye transformer bank
  - Delta-Delta transformer bank
  - Wye-Delta transformer bank
  - Delta-Wye transformer bank

- Complete “480 Volts to 208 Volts” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Balanced Delta source and Wye load with transformers” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Failed transformer winding” in the Diagnostic Reasoning section of the Questions chapter.

**NOTE:** there are many calculations required to perform polyphase circuit analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. *Unless and until you can do the problem(s) on your own, you have not yet learned the concept!*

- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following section of the Tutorial chapter:
  - Wiring from phasor diagrams
- Complete “Sketching winding connections” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Load calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find the mistake(s)” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Moving wire and magnet” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Poles and speed and frequency” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of faults in manually-regulated generator” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “9-lead Wye motor connections” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Motor power based on PT and CT measurements” 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.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, be graded on technical accuracy, and be followed by constructive criticism from the audience. You are allowed to bring notes for reference, but not allowed to read them to your audience. When you are chosen to present, you will have a brief period of time to gather your thoughts and set up for your presentation.

*Your instructor will not provide answers to you prior to or during the presentation; you are solely responsible for any research, experimentation, and other actions necessary to adequately prepare for your presentation. If you inquire for help, the instructor may clarify what you will need to present on, and/or point you toward specific resources (e.g. “Try setting up a SPICE simulation”, “Try building a test circuit on your breadboard”, “Find and read the datasheet(s)”, “Research application notes written on this topic”, etc.), but do not expect them to give you answers or check your work because by this point in time you will have studied the necessary concepts to verify results for yourself, or at least to know where to go to find verification.*

During your presentation the instructor and audience members are free to pose questions relevant to the graded objectives for your assigned problem. This may be done for the simple purpose of clarifying an unclear answer, or to probe for misconceptions.

The benefits of this exercise include honing your independent research skills, reinforcing your foundational knowledge of electronics, gaining confidence speaking to groups, and preparation for job interviews where being able to articulate your knowledge and solve realistic problems before a critical audience sets you apart from lesser-qualified candidates.

A problem will be randomly assigned to you from the options listed on the next several pages. No student will know which problem will be assigned to them until it is their turn to present, which means all students should be prepared to present on *every* problem shown. Furthermore, problems may contain unspecified parameters which will also be randomized at presentation time. Full credit will be given only for answers that are correct *and* logically supported by trusted principles and sources (e.g. Conservation of Energy, Ohm’s Law, datasheets, etc.).

You are to regard your audience as technically adept (i.e. assuming everyone in attendance is familiar with the technical concepts and language; “skilled in the art”).
Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Concept</th>
<th>Related Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation of Energy</td>
<td>Amplitude, period, frequency</td>
</tr>
<tr>
<td>Behavior of sources vs. loads</td>
<td>$R$ vs. $X$ vs. $Z$</td>
</tr>
<tr>
<td>Ohm’s Law</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Joule’s Law</td>
<td>Power factor</td>
</tr>
<tr>
<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
<tr>
<td>Properties of series networks</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
</tr>
<tr>
<td>Kirchhoff’s Voltage Law</td>
<td>Behavior of transformers</td>
</tr>
<tr>
<td>Kirchhoff’s Current Law</td>
<td>Properties of wye networks</td>
</tr>
<tr>
<td>Maximum Power Transfer Theorem</td>
<td>Properties of delta networks</td>
</tr>
<tr>
<td>Superposition Theorem</td>
<td></td>
</tr>
<tr>
<td>Thévenin’s and Norton’s Theorems</td>
<td></td>
</tr>
<tr>
<td>Electric fields and capacitance</td>
<td></td>
</tr>
<tr>
<td>Magnetic fields and inductance</td>
<td></td>
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<tr>
<td>Inverse-exponential growth/decay</td>
<td></td>
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<tr>
<td>Conduction in semiconductors</td>
<td></td>
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<tr>
<td>Behavior of PN junctions</td>
<td></td>
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<tr>
<td>Behavior of BJTs</td>
<td></td>
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<tr>
<td>Behavior of FETs</td>
<td></td>
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<tr>
<td>Sinking vs. sourcing current</td>
<td></td>
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<tr>
<td>Behavior of thyristors</td>
<td></td>
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<tr>
<td>Switch/gate circuits and Boolean</td>
<td></td>
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<tr>
<td>Switch/gate circuits and truth tables</td>
<td></td>
</tr>
<tr>
<td>Logic voltage levels</td>
<td></td>
</tr>
<tr>
<td>DeMorgan’s Theorem</td>
<td></td>
</tr>
</tbody>
</table>

One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem! Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Problem #1
(Component values randomly chosen by instructor):

- $V_{\text{source}} = \underline{\text{_______}}$
- $R_{\text{load}} = \underline{\text{_______}}$
- $N_p$ (primary turns) = $\underline{\text{_______}}$
- $N_s$ (secondary turns) = $\underline{\text{_______}}$

Note: the instructor will choose component values simple enough that you will not need an electronic calculator to obtain exact solutions. For this reason, you will not be permitted to use any calculating device when analyzing this circuit! This prohibition of calculating devices is typical during technical interviews for electronics technician jobs.

Grading
- [20%] Current magnitude through primary winding ($I_p$)
- [20%] Current magnitude through secondary winding ($I_s$)
- [20%] Voltage magnitude across load ($V_{\text{load}}$)
- [20%] Power delivered by source ($P_{\text{source}}$)
- [20%] Effect(s) of _____ failing open

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2
(Source voltages and terminal polarities randomly chosen by instructor):

Grading

- [20%] Properly position each source vector on the graph
- [20%] Calculate $V_{total}$ using a calculator
- [20%] Properly sketch $V_{total}$ vector on the graph
- [20%] Re-sketch diagram for source ___ failing (0 Volts)
- [20%] Re-calculate $V_{total}$ for source ___ failing (0 Volts)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #3

(Instructor will randomly choose two of the following – $I_{line}, I_{phase}$ (source or load), $V_{line}, V_{phase}$ (source or load), $R_{phase}$ (load), $P_{total}$):

Grading

[20% each] Calculate five of the unspecified parameters (student’s choice)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #4

(Instructor will randomly choose two of the following – $I_{line}$, $I_{phase}$ (source or load), $V_{line}$, $V_{phase}$ (source or load), $R_{phase}$ (load), $P_{total}$):

Grading

○ [20% each] Calculate five of the unspecified parameters (student’s choice)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5
(Instructor will randomly choose $V_{line}$ and either $I_{line}$, $I_{phase}$, or $P_{motor}$ for each of the two motors):

Grading

- [20%] Calculate first unspecified parameter of the Wye motor
- [20%] Calculate second unspecified parameter of the Wye motor
- [20%] Calculate first unspecified parameter of the Delta motor
- [20%] Calculate second unspecified parameter of the Delta motor
- [20%] Calculate total power for both motors ($P_{total}$)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6

(ABC line voltage and transformer turns ratio randomly chosen by instructor, as well as whether the primaries will be Wye or Delta, and whether the secondaries will be Wye or Delta):

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
</table>

\[ \text{Diagram of transformer windings} \]

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
</table>

Grading

- [20%] Proper connections from primary windings to ABC lines
- [20%] Proper connections from secondary windings to XYZ lines
- [20%] XYZ line voltage magnitude
- [20%] Primary winding voltage magnitude
- [20%] Secondary winding voltage magnitude

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
The *written exam* will consist of the following types of questions and their related principles:

- **(Question #1)** Calculate voltages, currents, and/or powers in a transformer circuit  
  *Transformer behavior, Ohm’s Law, Joule’s Law*

- **(Question #2)** Calculate voltage, current, resistance, and/or power in a balanced three-phase AC circuit  
  *Properties of wye-connected networks, properties of delta-connected networks*

- **(Question #3)** Sketch connections to make a three-phase transformer bank from three separate transformers, given phasor diagrams of primary and secondary voltages.  
  *Transformer behavior, properties of wye-connected networks, properties of delta-connected networks, phasor diagrams*

- **(Question #4)** Calculate current, horsepower, and/or power factor for an AC electric motor, either single-phase or three-phase.  
  *Power factor, Joule’s Law, properties of wye-connected networks, properties of delta-connected networks*

- **(Question #5)** Sketch phasor diagrams of AC quantities in simple circuits.  
  *Ohm’s Law, properties of series networks, properties of parallel networks, Kirchhoff’s Laws, complex-number arithmetic, AC phasors, phasor diagrams, power factor*

- **(Question #6)** Determine possible faults in a simple AC motor or generator circuit.  
  *Effects of opens vs. shorts, properties of wye-connected networks, properties of delta-connected networks, AC induction motor behavior, AC generator behavior*

- **(Question #7 – REVIEW)** Design and sketch an unloaded voltage divider network given required voltage and/or current values.  
  *Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, properties of series networks*

- **(Question #8 – REVIEW)** Calculate voltages, currents, and/or power dissipations in a circuit containing multiple sources.  
  *Properties of series and parallel networks, behaviors of sources and loads, Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, Maximum Power Transfer Theorem, Superposition Theorem, Thévenin’s Theorem, Norton’s Theorem*

- **(Question #9 – REVIEW)** Design and sketch a circuit exhibiting a specified time delay for inverse-exponential growth or decay of voltage or current.  
  *Properties of series and parallel networks, capacitor behavior, inductor behavior, inverse exponential calculations*
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Read, outline, and reflect on the Mercury arc rectifiers section of the Historical References chapter.
- Complete “Terminal block construction of a bridge rectifier” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Peak rectified voltage” in the Quantitative Reasoning section of the Questions chapter.
- Complete “How not to connect an oscilloscope to a rectifier” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- Full-wave bridge rectifier with ideal diodes section of the Animations chapter.
- Full-wave bridge rectifier with real diodes section of the Animations chapter.
- The Gallery chapter of the SPICE Modeling of Semiconductor Circuits learning module contains circuit examples complete with computer-generated analyses useful as practice problems. Using SPICE, you may modify these simulations for the purpose of generating your own practice problems and solutions!
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Full Tutorial chapter in its entirety.
- Read, outline, and reflect on the John Bardeen’s and Walter Brattain’s transistor patent section of the Historical References chapter.
- Complete “Controlling and controlled currents” in the Conceptual Reasoning section of the Questions chapter.
- Complete “BJT circuit calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faults in test circuit” in the Diagnostic Reasoning section of the Questions chapter.

**NOTE:** there are many calculations required to perform transistor circuit analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. Unless and until you can do the problem(s) on your own, you have not yet learned the concept!
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

**Additional resources:**

- The Gallery chapter of the SPICE Modeling of Semiconductor Circuits learning module contains circuit examples complete with computer-generated analyses useful as practice problems. Using SPICE, you may modify these simulations for the purpose of generating your own practice problems and solutions!
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Manual voltage regulation” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Zener current with varying load resistance” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of faults in a series voltage regulator” in the Diagnostic Reasoning section of the Questions chapter.

NOTE: there are many calculations required to perform transistor circuit analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. Unless and until you can do the problem(s) on your own, you have not yet learned the concept!
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Satellite electronics” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Transistor without a heat sink” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find the mistake(s)” in the Diagnostic Reasoning section of the Questions chapter.

**NOTE:** there are many calculations required to perform heat-transfer analysis, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. *Unless and until you can do the problem(s) on your own, you have not yet learned the concept!*
- Carefully organize all your numerical results so you do not lose track of each number’s meaning. A good way to do this is to thoroughly annotate the circuit diagram with all calculated voltages and currents, including voltage polarities and current directions. This gives context to your mathematical work.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Watch the flip-book animation shown in the Comparator generating PWM waveform section of the Animations chapter.
- Complete “Comparator output waveform” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Duty cycle and power calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Identifying possible faults in a motor speed controller” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Bright/Royer externally-excited inverter circuits” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Converter efficiency” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Tracing fault current” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Complete “Early three-phase inverter design” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Voltmeter discrepancy” in the Conceptual Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the **Tutorial** chapter:
  - Matching source and load voltages
  - Capacitor and inductor review
  - Simple step-down converter
  - Buck converter
  - Boost converter

- Complete “Buck converter regulation” in the **Conceptual Reasoning** section of the **Questions** chapter.

- Complete “Converter efficiency calculations” in the **Quantitative Reasoning** section of the **Questions** chapter.

- Complete “Faults in a buck converter” in the **Diagnostic Reasoning** section of the **Questions** chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Inverting converter
  - Cuk converter
  - Flyback converter
  - Forward converter
- Complete “24 Volt spotlight” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Dying battery source” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Identifying possible root-cause faults” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Battery UPS circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Soft-start time delay” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Component faults in a limited regulator circuit” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Oral Presentations

Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, be graded on technical accuracy, and be followed by constructive criticism from the audience. You are allowed to bring notes for reference, but not allowed to read them to your audience. When you are chosen to present, you will have a brief period of time to gather your thoughts and set up for your presentation.

Your instructor will not provide answers to you prior to or during the presentation; you are solely responsible for any research, experimentation, and other actions necessary to adequately prepare for your presentation. If you inquire for help, the instructor may clarify what you will need to present on, and/or point you toward specific resources (e.g. “Try setting up a SPICE simulation”, “Try building a test circuit on your breadboard”, “Find and read the datasheet(s)”, “Research application notes written on this topic”, etc.), but do not expect them to give you answers or check your work because by this point in time you will have studied the necessary concepts to verify results for yourself, or at least to know where to go to find verification.

During your presentation the instructor and audience members are free to pose questions relevant to the graded objectives for your assigned problem. This may be done for the simple purpose of clarifying an unclear answer, or to probe for misconceptions.

The benefits of this exercise include honing your independent research skills, reinforcing your foundational knowledge of electronics, gaining confidence speaking to groups, and preparation for job interviews where being able to articulate your knowledge and solve realistic problems before a critical audience sets you apart from lesser-qualified candidates.

A problem will be randomly assigned to you from the options listed on the next several pages. No student will know which problem will be assigned to them until it is their turn to present, which means all students should be prepared to present on every problem shown. Furthermore, problems may contain unspecified parameters which will also be randomized at presentation time. Full credit will be given only for answers that are correct and logically supported by trusted principles and sources (e.g. Conservation of Energy, Ohm’s Law, datasheets, etc.).

You are to regard your audience as technically adept (i.e. assuming everyone in attendance is familiar with the technical concepts and language; “skilled in the art”).

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Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Conservation of Energy</th>
<th>Amplitude, period, frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior of sources vs. loads</td>
<td>$R$ vs. $X$ vs. $Z$</td>
</tr>
<tr>
<td>Ohm’s Law</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Joule’s Law</td>
<td>Power factor</td>
</tr>
<tr>
<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
<tr>
<td>Properties of series networks</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
</tr>
<tr>
<td>Kirchhoff’s Voltage Law</td>
<td>Behavior of transformers</td>
</tr>
<tr>
<td>Kirchhoff’s Current Law</td>
<td>Properties of wye networks</td>
</tr>
<tr>
<td>Maximum Power Transfer Theorem</td>
<td>Properties of delta networks</td>
</tr>
<tr>
<td>Superposition Theorem</td>
<td>Heat transfer</td>
</tr>
<tr>
<td>Thévenin’s and Norton’s Theorems</td>
<td>Pulse-width modulation</td>
</tr>
<tr>
<td>Electric fields and capacitance</td>
<td></td>
</tr>
<tr>
<td>Magnetic fields and inductance</td>
<td></td>
</tr>
<tr>
<td>Inverse-exponential growth/decay</td>
<td></td>
</tr>
<tr>
<td>Conduction in semiconductors</td>
<td></td>
</tr>
<tr>
<td>Behavior of PN junctions</td>
<td></td>
</tr>
<tr>
<td>Behavior of BJTs</td>
<td></td>
</tr>
<tr>
<td>Behavior of FETs</td>
<td></td>
</tr>
<tr>
<td>Sinking vs. sourcing current</td>
<td></td>
</tr>
<tr>
<td>Behavior of thyristors</td>
<td></td>
</tr>
<tr>
<td>Switch/gate circuits and Boolean</td>
<td></td>
</tr>
<tr>
<td>Switch/gate circuits and truth tables</td>
<td></td>
</tr>
<tr>
<td>Logic voltage levels</td>
<td></td>
</tr>
<tr>
<td>DeMorgan’s Theorem</td>
<td></td>
</tr>
</tbody>
</table>

One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem! Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Problem #1
(Component values randomly chosen by instructor, including the \( \beta \) value of \( Q_1 \))

Grading
- [20%] Current magnitude and direction through resistor \( R_C \) (\( I_{RC} \))
- [20%] Current magnitude and direction through node 3 (\( I_3 \))
- [20%] All current magnitudes and directions entering and exiting node 0
- [20%] Voltage magnitude and polarity between nodes 1 and 3 (\( V_{1-3} \))
- [20%] Voltage magnitude and polarity across resistor \( R_B \) (\( V_{RB} \))

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2
(Component values randomly chosen by instructor, including Zener breakdown voltage rating of $D_1$)

Note: the instructor will choose component values simple enough that you will not need an electronic calculator to obtain exact solutions. For this reason, you will not be permitted to use any calculating device when analyzing this circuit! This prohibition of calculating devices is typical during technical interviews for electronics technician jobs.

Grading

- [20%] Current magnitude and direction through diode $D_1$ ($I_{D_1}$)
- [20%] Current magnitude and direction through node 1 ($I_1$)
- [20%] All current magnitudes and directions entering and exiting node 2
- [20%] Voltage magnitude and polarity between nodes 1 and 2 ($V_{1-2}$)
- [20%] Voltage magnitude and polarity across resistor $R_{load}$ ($V_{load}$)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Grading

- [20%] All current directions when transistor is in the “on” state
- [20%] All voltage polarities when transistor is in the “on” state
- [20%] All current directions when transistor is in the “off” state
- [20%] All voltage polarities when transistor is in the “off” state
- [20%] Energy efficiency if $V_{source} = \text{____}$, $I_{source} = \text{____}$, $V_{load} = \text{____}$, and $I_{load} = \text{____}$

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Grading

- [20%] All current directions when transistor is in the “on” state
- [20%] All voltage polarities when transistor is in the “on” state
- [20%] All current directions when transistor is in the “off” state
- [20%] All voltage polarities when transistor is in the “off” state
- [20%] $I_{load}$ if $V_{source} =$ ____ , $I_{source} =$ ____ , $V_{load} =$ ____ , and Efficiency = ____

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5

Grading

○ [20%] All current directions when transistor is in the “on” state
○ [20%] All voltage polarities when transistor is in the “on” state
○ [20%] All current directions when transistor is in the “off” state
○ [20%] All voltage polarities when transistor is in the “off” state
○ [20%] Energy efficiency if $V_{\text{source}} = \ldots$, $I_{\text{source}} = \ldots$, $V_{\text{load}} = \ldots$, and $I_{\text{load}} = \ldots$

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6
(Component values randomly chosen by instructor, including the turns of each transformer winding)

Grading

- [20%] Current magnitude and direction through load ($I_{load}$)
- [20%] Current directions through rectifier network during one half-cycle of the AC source
- [20%] Current directions through rectifier network during other half-cycle of the AC source
- [20%] Peak voltage magnitude across load ($V_{load \text{ pk}}$)
- [20%] RMS voltage magnitude at transformer secondary winding ($V_{sec}$)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
The written exam will consist of the following types of questions and their related principles:

- **(Question #1)** Predict voltages and/or currents in a single- or three-phase AC-DC rectifier circuit. 
  *Ohm’s Law, Kirchhoff’s Voltage Law, diode behavior, rectifier circuit behavior, RMS versus peak AC quantities, properties of wye-connected networks, properties of delta-connected networks*

- **(Question #2)** Calculate voltages, currents, and/or power dissipations in a BJT or FET switching circuit. 
  *Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, properties of series and parallel networks, BJT behavior, FET behavior*

- **(Question #3)** Design and sketch a circuit using either a BJT or an FET to switch DC power to a load. 
  *BJT behavior, FET behavior, behavior of sources and loads, Kirchhoff’s Laws, properties of series and parallel networks*

- **(Question #4)** Calculate temperatures, voltages, currents, and/or power dissipations for a power semiconductor component heat sink given all the necessary parameters. 
  *Thermal resistance, Joule’s Law*

- **(Question #5)** Determine voltages and currents for a switching power-conversion circuit. 
  *Behavior of sources vs. loads, capacitor behavior, inductor behavior, BJT behavior, FET behavior, diode behavior, KVL, KCL, efficiency*

- **(Question #6)** Determine possible faults in a semiconductor power control circuit. 
  *Effects of opens vs. shorts, BJT behavior, FET behavior, thyristor behavior, rectifier circuits, PWM power control, switch-mode DC-DC power converters, DC-AC power converters*

- **(Question #7 – REVIEW)** Identify voltage polarity given current direction, and current direction given voltage polarity, for both sources and loads. Also, identify sources versus loads given voltage polarity and current direction. 
  *Voltage, current, behavior of sources vs. loads*

- **(Question #8 – REVIEW)** Qualitatively predict voltage, current, and power changes in a series or parallel resistor circuit resulting from one component change. 
  *Properties of series and parallel networks, effects of opens vs. shorts, behavior of sources and loads, properties of voltage sources, properties of current sources*

- **(Question #9 – REVIEW)** Calculate voltages, currents, and/or powers in a transformer circuit. 
  *Transformer behavior, Ohm’s Law, Joule’s Law*
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Boolean expressions from gate circuits” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Boolean expressions from relay circuits” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Circuits from three-input truth tables” in the Quantitative Reasoning section of the Questions chapter.
- Run at least one simulation of a combinational logic controlled motor circuit (Circuit_009) using tshoot software, and show the final results.

**NOTE:** there are many steps required to translate between truth tables, Boolean expressions, and logic circuits, and therefore many places one can make mistakes. Here are some proven strategies for success:

- Work through the representative example problems shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. *Unless and until you can do the problem(s) on your own, you have not yet learned the concept!*

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

**Additional resources:**

- tshoot circuit troubleshooting simulation software in the “no-fault” mode (tshoot -nofault), particularly circuit_009.
- file wt_0244
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “74HC147 encoder” in the Conceptual Reasoning section of the Questions chapter.
- Complete “5-line to 32-line decoder” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted encoder circuit” in the Diagnostic Reasoning section of the Questions chapter.
- Complete “Another faulted encoder circuit” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “74HC151 mux” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Arbitrary SOP expression” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted concentrator circuit” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Read, outline, and reflect on the Digital pulse criteria section of the Derivations and Technical References chapter.
- Complete “Wrong way siren circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Timing diagram for an enabled SR latch” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Sound-controlled lamp” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Timing diagram for another simple shift register” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Frequency divider design” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Sequential tail-light blinker” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Full Tutorial chapter in its entirety.
- Complete “Counter circuit identification” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Frequency division” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Counter with faulted gate” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the “Relating I/O status to virtual elements” subsection of the “Ladder Diagram (LD) programming” section of the Full Tutorial chapter.
- Read, outline, and reflect on the “Ladder diagram counters” subsection of the “Ladder Diagram (LD) programming” section of the Full Tutorial chapter.
- Complete “Determining bit statuses from switch conditions” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Determining necessary switch conditions for bit statuses” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Motor start-up limit counter” in the Conceptual Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the “Ladder diagram timers” subsection of the “Ladder Diagram (LD) programming” section of the Full Tutorial chapter.
- Complete “Determining color highlighting from switch conditions” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Determining bit statuses from color highlighting” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Sequenced-start conveyor belts” in the Conceptual Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Examine and reflect on the Oscilloscope, cable, and signal generator section of the Case Tutorial chapter, and answer the following questions:
  → Identify all waveform imperfections captured in the oscillographs
  → Comment on the effects wrought by each cabling alteration
- Complete “Two crosstalk scenarios” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Evaluating set-up and hold times” in the Quantitative Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Texas Instruments What Is a High-Speed Eye Diagram? slideshow document in your EETREF collection, and answer the following questions:
  → What is an eye diagram useful for?
  → Identify some of the relevant properties of an eye diagram.
  → Explain why the transmitted and received signal eye diagrams do not look the same.
- Locate the Tektronix tutorial Fundamentals of Signal Integrity in your EETREF collection, and read all sections appropriate to answering the following questions:
  → Explain what it means for a digital signal to have good integrity.
  → Explain the significance of “setup” and “hold” times for digital circuits.
  → How does edge speed relate to signal harmonics?
  → Identify some common causes of poor signal integrity and how to identify them using test equipment.
- Complete “The Soul of a New Machine” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Simultaneous crosstalk” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Measuring jitter using an eye diagram” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Pulse waveform oscillographs” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Oral Presentations

Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, be graded on technical accuracy, and be followed by constructive criticism from the audience. You are allowed to bring notes for reference, but not allowed to read them to your audience. When you are chosen to present, you will have a brief period of time to gather your thoughts and set up for your presentation.

Your instructor will not provide answers to you prior to or during the presentation; you are solely responsible for any research, experimentation, and other actions necessary to adequately prepare for your presentation. If you inquire for help, the instructor may clarify what you will need to present on, and/or point you toward specific resources (e.g. “Try setting up a SPICE simulation”, “Try building a test circuit on your breadboard”, “Find and read the datasheet(s)”, “Research application notes written on this topic”, etc.), but do not expect them to give you answers or check your work because by this point in time you will have studied the necessary concepts to verify results for yourself, or at least to know where to go to find verification.

During your presentation the instructor and audience members are free to pose questions relevant to the graded objectives for your assigned problem. This may be done for the simple purpose of clarifying an unclear answer, or to probe for misconceptions.

The benefits of this exercise include honing your independent research skills, reinforcing your foundational knowledge of electronics, gaining confidence speaking to groups, and preparation for job interviews where being able to articulate your knowledge and solve realistic problems before a critical audience sets you apart from lesser-qualified candidates.

A problem will be randomly assigned to you from the options listed on the next several pages. No student will know which problem will be assigned to them until it is their turn to present, which means all students should be prepared to present on every problem shown. Furthermore, problems may contain unspecified parameters which will also be randomized at presentation time. Full credit will be given only for answers that are correct and logically supported by trusted principles and sources (e.g. Conservation of Energy, Ohm’s Law, datasheets, etc.).

You are to regard your audience as technically adept (i.e. assuming everyone in attendance is familiar with the technical concepts and language; “skilled in the art”).

file wt_0248
### Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Conservation of Energy</th>
<th>Amplitude, period, frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior of sources vs. loads</td>
<td>$R$ vs. $X$ vs. $Z$</td>
</tr>
<tr>
<td>Ohm’s Law</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Joule’s Law</td>
<td>Power factor</td>
</tr>
<tr>
<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
<tr>
<td>Properties of series networks</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
</tr>
<tr>
<td>Kirchhoff’s Voltage Law</td>
<td>Behavior of transformers</td>
</tr>
<tr>
<td>Kirchhoff’s Current Law</td>
<td>Properties of wye networks</td>
</tr>
<tr>
<td>Maximum Power Transfer Theorem</td>
<td>Properties of delta networks</td>
</tr>
<tr>
<td>Superposition Theorem</td>
<td>Heat transfer</td>
</tr>
<tr>
<td>Thévenin’s and Norton’s Theorems</td>
<td>Pulse-width modulation</td>
</tr>
<tr>
<td>Electric fields and capacitance</td>
<td>Transmission lines</td>
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<tr>
<td>Magnetic fields and inductance</td>
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<tr>
<td>Inverse-exponential growth/decay</td>
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<tr>
<td>Conduction in semiconductors</td>
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<td>Behavior of PN junctions</td>
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<td>Behavior of BJTs</td>
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<td>Behavior of FETs</td>
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<td>Sinking vs. sourcing current</td>
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<td>Behavior of thyristors</td>
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<td>Switch/gate circuits and Boolean</td>
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<tr>
<td>Switch/gate circuits and truth tables</td>
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<td>Logic voltage levels</td>
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<tr>
<td>DeMorgan’s Theorem</td>
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</table>

*One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem! Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.*
Problem #1

Write a Boolean expression and sketch both a logic gate and a relay ladder-logic circuit diagram to implement the following truth table:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>0</td>
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</tr>
</tbody>
</table>

Grading

- [20%] Boolean expression matches truth table
- [20%] Logic gate diagram implements Boolean expression
- [20%] Relay ladder logic diagram implements Boolean expression
- [20%] Effect on truth table if ____ fails (high/low) in the gate circuit
- [20%] Effect on truth table if ____ fails (open/shorted) in the relay circuit

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #2
Sketch a timing diagram showing the output states of this circuit given an initial count value of ___ and the Up/Down control line in the (high/low) state, for eight cycles of the clock pulse:

Grading
- [20%] Output states for the first four clock pulses
- [20%] Output states for the second four clock pulses
- [20%] Effect on count sequence if ___ fails with (high/low) output
- [20%] Effect on count sequence if ___ fails with (high/low) output
- [20%] Identify if this is a synchronous or asynchronous circuit

Note: full credit given only for answers that are correct and logically supported by trusted principles.
**Problem #3**

Complete a schematic diagram for this binary “up” counter so that it counts from zero to ___ and then returns to zero after the next clock pulse. The instructor will randomly choose whether this counter has a *synchronous* or *asynchronous* clear input:

Grading

- [20%] Modulus value of the complete counter circuit
- [20%] Complete count sequence starting from a value of ___
- [20%] Additional circuitry correct for truncating the count sequence
- [20%] Enable input properly connected to allow counting
- [20%] Clear signal frequency if clock frequency is ___ Hz

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #4

Sketch a DC motor start/stop control circuit using an SR latch and two pushbutton switches (NO or NC), with a transistor interposing between the latch IC and the high-current motor. Assume the use of a CMOS latch IC.

Grading

- [20%] SR latch never enters the “invalid” state with just one pushbutton pressed at any time
- [20%] Pressing “Start” switch sets the latch and pressing “Stop” switch resets the latch
- [20%] Proper pullup/pulldown resistors
- [20%] Correct driving signal to power transistor
- [20%] Correct controlled current direction for power transistor

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5

Sketch a ladder diagram (LD) program for this Koyo CLICK PLC to control the starting and stopping of an electric motor, as well as the wires necessary to connect the PLC to start and stop switches and a transistor to switch DC power to the motor. Note the part number of this PLC, which will be important for your circuit design! Feel free to add components if needed:

Grading

- [10%] Proper wiring between Start switch and the PLC
- [10%] Proper wiring between Stop switch and the PLC
- [10%] Proper wiring between PLC and transistor
- [10%] Proper wiring between motor and transistor
- [10%] Proper wiring to power the PLC processor itself
- [20%] Program activates output Y3 when “Start” input energized
- [20%] Program de-activates output Y3 when “Stop” input energized
- [10%] Program latches output Y3 in its last state when both switches unpressed

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6

Complete a timing diagram for this circuit (instructor sketches all states during the “initial” period):

Grading

- [10% per time period] All output states correct

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Theory session 60

The written exam will consist of the following types of questions and their related principles:

- (Question #1) Determine logic states within a combinational logic circuit.
  Logic function truth tables, logic levels in TTL and CMOS circuits, effects of opens vs. shorts

- (Question #2) Sketch a latch or flip-flop circuit to fulfill a specified function.
  Latch behavior, flip-flop behavior, timing diagrams, pull-up and pull-down resistor function

- (Question #3) Evaluate digital timing diagrams for adequate signal integrity.
  Timing diagrams, AC quantities, switch bounce, oscilloscope display interpretation, eye diagram interpretation, resonance, propagation delay, set-up time, hold time, logic levels in TTL and CMOS circuits.

- (Question #4) Determine possible faults in a combinational logic gate or relay ladder logic circuit.
  Logic function truth tables, properties of series and parallel networks, effects of opens vs. shorts, relay behavior

- (Question #5) Determine possible faults in a latch or flip-flop circuit.
  Logic function truth tables, latch behavior, flip-flop behavior, effects of opens vs. shorts, timing diagrams