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Introduction to Electronics 110

New Brunswick

Department of Education
Educational Programs & Services Branch
2006

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Introduction to Electronics 110

Overview

Introduction to Electronics 110 introduces students to the skills and knowledge required to pursue post-secondary learning in electrical/electronics fields. This course is recognized as a Science or a Technology credit towards graduation. The course presents basic theory and circuitry including components such as resistors, inductors, capacitors, transformers and diodes.

Introduction to Electronics 110 will be of interest to students with a career objective at the technical or engineering levels of industry as well as those with a hobbyist interest.

Learning Activities

Students will build and test simple circuits to reinforce their knowledge of the theory presented and, in doing so, will build a firm base for further study and exploration of electronics. When available, industry/trades representatives should be invited to present to students in order to provide realistic applications of skills learned in this course.

Prerequisite

Grade 10 mathematics

Learning Resources

The textbook for this course is *Introduction to Electronics*, 4th Edition by Earl D. Gates, ISBN 0-7668-1698-2. This text is accompanied by a lab manual, IBSN 0-7668-1700-8. Both books are referenced throughout this course outline.

Additional information can be found in *Essentials of Electronics*, 2nd Edition by Frank D. Petruzella, ISBN 0-07-821048-8 and its accompanying activities manual (ISBN 0-07-821049-6) and instructor's manual (ISBN 0-07-821050-X).

Bridges career orientation software (www.bridges.ca)

WHSCC Choices for Life, Health and Safety (K-12)

Internet Access

Teachers may also refer to the corresponding online course, Introduction to Electronics 110. Students may be enrolled as a class to gain access to online content.

Suggested examples for additional assignments, worksheets, labs and enrichment activities are included in this document at Appendix A, Appendix B, Appendix C and Appendix D, respectively.

Additional kit based enrichment activities can be located at various electronics suppliers.

Labs

Lab materials recommended (one for every two students):

- Digital/analog trainer (XK-150)
- Digital multimeter (M3800)
- JW-1 jumper wire kit
- Component kit (see list in Appendix E)
- Four each C or D cells
- 22 gauge hook up wire
- Wire strippers
- Assorted magnets and iron filings

All lab materials are available from Munro Electronics and ABRA Electronics.

- Munro Electronics ; 1-506-635-1413; www.munroelectronics.com
- ABRA Electronics; 1-800-361-5237; www.abra-electronics.com

Additional lab resources for teacher demonstrations include:

- One oscilloscope (dual trace) for demonstrations
- One analog multimeter
- Electronics Workbench MultiSim ver.9 software
- One computer service tool kit

General Curriculum Outcomes

Upon the completion of this course, students will meet the following outcomes:

- **GCO 1** Students will be expected to demonstrate an understanding of the history and evolution of electronics and its social and cultural implications.
- **GCO 2** Students will be expected to identify career opportunities in electronics.
- **GCO 3** Students will be expected to demonstrate proficiency in the mathematical processes used in electronics.
- **GCO 4** Students will be expected to display safety consciousness in working with electronic equipment.
- **GCO 5** Students will be expected to demonstrate and apply an understanding of the basic theory of DC circuits and components.
- **GCO 6** Students will be expected to interpret and summarize the relationship between magnetism and electricity.
- **GCO 7** Students will be expected to demonstrate and apply an understanding of the basic theory of AC circuits and components.

Duration

90 hours

Course Code

1037630

INTRODUCTION TO ELECTRONICS 110

GCO 1 Demonstrate an understanding of the history and evolution of electronics and its social and cultural implications

Specific Curriculum Outcomes *Students will be expected to:*	**Suggestions for Teaching/Learning:**
• Become familiar with the progress made in the field of electricity/electronics and its impact on society.	The teacher introduces a timeline explaining development from the ancient Greeks discovering the static electricity caused by rubbing amber to the nanotechnology of today.
• Analyze ethical issues concerning present and future technological development in electronics.	The teacher initiates small group discussions of ethical impact upon society of technological development.
• Recognize their influence and personal responsibility in determining future developments.	The students analyze a new electronic product and discuss its cost, benefit to society, negative consequences, cultural significance, etc. In small groups students discuss future development of various consumer products. Students discuss the changes they have witnessed in their lifetimes with respect to telephone technology (or televisions, computers, video recording and play back equipment, audio recording and playback equipment, etc.) and what they predict this technology will look like in another twenty years? What trend(s) will future development follow? What impact will it have on society (both positive and negative)?

INTRODUCTION TO ELECTRONICS 110

GCO 1 Demonstrate an understanding of the history and evolution of electronics and its social and cultural implications

Suggestions for Learning/Assessment:	Resources:
During class and/or in small groups, students determine the extent to which students can critically evaluate the positive and negative effects of technological development in electronics. The students will complete Assignment # 1: History of Development in Electronics. The students will complete Assignment # 2: Ethics in Technology.	Gates, Earl D. *Introduction to Electronics.* 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages x to xii http://inventors.about.com/library/inventors/blelectric2.htm • Timeline of electricity/electronic inventions Appendix A • Assignment # 1: History of Development in Electronics • Assignment # 2: Ethics in Technology

INTRODUCTION TO ELECTRONICS 110
GCO 2 Identify career opportunities in electronics

Specific Curriculum Outcomes *Students will be expected to:*	**Suggestions for Teaching/Learning:**
• Understand the need for team work, effective communication and essential skills required for all jobs.	Working in small groups, students conduct informal research to determine conventional and new emerging career clusters in the electricity/electronics industry.
• Gain insight into the required and desirable academic and work experience skills needed to achieve a successful career in the electrical/electronics or related industries.	Using the Bridges program, individually or in teams, students research a minimum of three different careers where a minimum basic knowledge of electricity/electronics is required and complete individual career profiles.
• Recognize the importance of math and communication skills within the electrical/electronics and related industries.	The teacher organizes a field trip to a business that uses, manufactures or designs high-end electronic components/systems.
• Become familiar with the variety of career opportunities in electrical/electronics and related industries.	The teacher invites guest speakers from industry, Faculty of Engineering and trades colleges. Students prepare a list of interview questions prior to the visit focusing on working conditions, training, qualifications, salary, etc.
• Compare and contrast the training and taskings of technicians, technologists and professional engineers.	The teacher introduces *Employability Skills 2000+* as presented by the Conference Board of Canada.

GCO 2 Identify career opportunities in electronics

Suggestions for Learning/Assessment:	Resources:
During class and/or small group discussions, determine the extent to which students have critically evaluated the work environment, salary, skills, training and personal attributes pertinent to successful careers in the electricity/electronics field.	Gates, Earl D. *Introduction to Electronics*. 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages x to xii http://www.conferenceboard.ca/education/learning-tools/pdfs/esp2000.pdf • Conference Board of Canada: "Employability Skills 2000+" http://www23.hrdc-drhc.gc.ca/2001/e/generic/welcome.shtml • National Occupational Classification: Occupational Descriptions
The students complete Assignment # 3: Career Choices in Electricity/Electronics.	Appendix A • **Assignment # 3**: Career Choices in Electricity/Electronics Access to Internet and to Bridges program

INTRODUCTION TO ELECTRONICS 110
GCO 3 Demonstrate proficiency in the mathematical processes used in electronics

Specific Curriculum Outcomes: *Students will be expected to:*	**Suggestions for Teaching/Learning:**
• Use metric prefixes to describe large and small quantities and convert between prefixes where necessary to perform calculations.	Building upon students' prior knowledge of scientific notation and powers of ten, the teacher explains metric prefixes using the units of measurement common in electronics (amp, volt, ohm, etc.) and their conventional use in electronics. The teacher demonstrates conversions between metric prefixes. The teacher provides practice worksheets.
• Perform calculations using a scientific calculator.	Using the scientific calculator found on the computer desktop, demonstrate the key strokes required to solve problems using the exponent, inverse and parenthesis keys. The teacher provides practice worksheets.

INTRODUCTION TO ELECTRONICS 110
GCO 3 Demonstrate proficiency in the mathematical processes used in electronics

Suggestions for Learning/Assessment:	Resources:
The teacher prepares a test for students containing metric unit conversions and calculator problems, using applicable worksheets contained in the Appendices as a guide.	Gates, Earl D. *Introduction to Electronics.* 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages xiii to xv • Pages 13 and 14 Lab Manual for *Introduction to Electronics* • Lab 1-5: Unit Conversions Appendix B • **Worksheet # 1**: Calculator Practice

GCO 4 Display safety consciousness in working with electronic equipment

Specific Curriculum Outcomes: *Students will be expected to:*	**Suggestions for Teaching/Learning:**
• Identify safety procedures and common potential hazards in the lab and workplace.	The teacher leads a class discussion about personal injury and causes. Teacher presents accident prevention strategies.
• Demonstrate personal responsibility in the prevention of accidents and describe how accidents can be prevented.	In collaboration with the teacher, students develop a list of rules to be followed when working with live circuits in the lab.
• Demonstrate knowledge of immediate response procedures.	The students measure wet and dry body resistances with an analog multimeter and calculate corresponding lethal voltage/current levels using Ohm's Law. The teacher leads a class discussion about the statement, "It isn't the voltage that kills you, it's the current." The students create safety posters for the lab to illustrate safe working habits, accident prevention and immediate response procedures. The teacher can also choose from any of the activities listed in *WHSCC Choices for Life, Health and Safety (K-12);* Sections: E17 and E19 ***Note:*** *This material is best presented* <u>*after*</u> *students are taught the fundamental principles of electricity including Ohm's Law since, in order to understand the importance of electrical safety, a basic knowledge of current, voltage and resistance is required.*

INTRODUCTION TO ELECTRONICS 110
GCO 4 Display safety consciousness in working with electronic equipment

Suggestions for Learning/Assessment:	Resources:
Through on-going teacher, peer and self evaluation, students demonstrate an understanding of outcomes. The teacher observes student conduct while in the lab to determine their proficiency in preventing accidents and their adherence to lab safety rules. The teacher prepares a test for students on basic safety procedures, the physiology of electrical shock and immediate response procedures.	Gates, Earl D. *Introduction to Electronics.* 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages xvi to xvii WHSCC Choices for Life, Health and Safety (K-12) • Sections E17 and E19 http://www.allaboutcircuits.com/vol_1/chpt_3/1.html • "The Importance of Electrical Safety" • This is a highly recommended website that explains using Ohm's Law to calculate harmful levels of voltage and current.

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GCO 5 Demonstrate and apply an understanding of the basic theory of DC circuits and components

Specific Curriculum Outcomes: *Students will be expected to:*	Suggestions for Teaching/Learning:
• Identify the parts of the atom and understand the relationship between the valence shell and conductors, insulators and semiconductors.	The teacher provides a short review of basic atomic theory and introduces valence shells, conductors, insulators and semiconductors.
• State the definition of current, law of electrostatics and coulomb.	The teacher divides students into small groups to generate a quiz based upon students' prior knowledge and teacher's inclusive outline of points to be covered. As per Assignment # 4.
• Calculate current when given time and quantity of charge.	Explain current calculation using: $I = \frac{Q}{t}$
• State the definition of voltage and give examples of six energy sources that can be converted to electrical energy.	Explain current flow and voltage using a water pressure/flow analogy.
• Calculate total voltage and current rating of cells in series, parallel and series-parallel.	The teacher demonstrates energy conversions using photocells, crystal, dynamo and potato (or lemon) battery, etc. The teacher explains total voltage and current ratings of cells in series, parallel and series-parallel. The teacher demonstrates safe use of the multimeter and scales of measurement in DC voltage settings. The students complete battery lab.
• Using cell ratings, compute the lifespan of cells and batteries in a given load.	Using real life examples, the teacher demonstrates mathematical calculations for determining lifespan of batteries. Provide practice worksheets.

GCO 5 Demonstrate and apply an understanding of the basic theory of DC circuits and components

Suggestions for Learning/Assessment:	Resources:
Through on-going assessment, the teacher looks for consistent and correct usage of metric prefixes and units of measurement. The teacher observes students to determine correct usage of schematic symbols to represent components and circuits. The teacher checks for correct use of meters and safe working habits. The teacher prepares a test for students using applicable labs and worksheets contained in the Appendices as a guide. The teacher explains assignment # 4: Create Your Own Quiz - Atomic Theory Review (Teacher decides best questions or best complete quiz to be used for entire class.)	Gates, Earl D. *Introduction to Electronics.* 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages 3 to 13 and 17 to 27 http://www.allaboutcircuits.com/vol_1/chpt_3/9.html • "Safe Meter Usage" • This is a highly recommended resource detailing safe use of the multimeter. Lab Manual for *Introduction to Electronics* • Lab 1-1: Fundamentals of Electricity • Lab 1-2: Current • Lab 1-3: Voltage • Lab 1-6A: Connecting Cells and Batteries • Lab 1-6B: Connecting Cells and Batteries Appendix A • Assignment # 4: Create Your Own Quiz - Atomic Theory Review Appendix C • Lab 1-6C: Cell Configurations Appendix B • Worksheet # 2: Cell Ratings

GCO 5 Demonstrate and apply an understanding of the basic theory of DC circuits and components (continued)

Specific Curriculum Outcomes: *Students will be expected to:*	**Suggestions for Teaching/Learning:**
• Demonstrate an understanding of resistance as a characteristic of electrical circuits, short circuits and open circuits.	The teacher defines resistance, types of resistors, rheostats, and potentiometers. The teacher explains short and open circuits.
• Interpret colour codes of carbon composition resistors and calculate min and max tolerance.	The teacher demonstrates how to determine resistor value and calculate tolerance of resistors from the colour code. Provide practice worksheets. The students create their own mnemonic aid for the colour code.
• Calculate and measure total resistance in series, parallel and series-parallel.	The teacher demonstrates safe use of the multimeter and scales of measurement in ohmmeter settings. The teacher explains breadboards and their use in building temporary circuits. The students complete familiarization activity. The students decode resistors, confirm by measuring with an ohmmeter and indicate if the resistor falls within tolerance. The teacher illustrates how to solve for R_T in series, parallel and series-parallel. The students construct series, parallel and series-parallel resistor configurations and confirm calculated totals by measuring with an ohmmeter.

GCO 5 Demonstrate and apply an understanding of the basic theory of DC circuits and components (continued)

Suggestions for Learning/Assessment:	Resources:
The teacher prepares a test for students using applicable labs and worksheets contained in the Appendices as a guide. Through on-going assessment, the teacher checks for consistent and correct usage of metric prefixes and units of measurement. Through on-going assessment, the teacher checks for correct usage of schematic symbols to represent components and circuits. The teacher observes students to ensure correct use of meters and safe working habits are followed.	Gates, Earl D. *Introduction to Electronics*. 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages 3 to 13 and 17 to 27 Lab Manual for *Introduction to Electronics*: • Lab 1-4: Resistance • Lab 1-8: Resistors Colour Code • Lab 1-9: Resistors in Series • Lab 1-10: Resistors in Parallel • Lab 1-11: Resistors in Series-Parallel • Lab 1-12: Resistor Measurements • Lab 1-13: Resistor Measurements in Series • Lab 1-14: Resistor Measurements in Parallel • Lab 1-15: Resistor Measurements in Series-Parallel Appendix B • Worksheet # 3: Resistor Colour Code Appendix C • Familiarization Activity: XK-150 Trainer and Multimeter

INTRODUCTION TO ELECTRONICS 110
GCO 5 Demonstrate and apply an understanding of the basic theory of DC circuits and components (continued)

Specific Curriculum Outcomes: *Students will be expected to:*	**Suggestions for Teaching/Learning:**
• Discriminate between series, parallel and series-parallel circuits, and identify the common characteristics of each type of circuit.	The teacher explains the relationship between current, voltage and resistance as defined by Ohm's Law and demonstrate solving for an unknown quantity when any two are given.
• Interpret simple schematic diagrams including basic components.	The teacher provides practice worksheets.
• Analyze circuits with respect to Ohm's, Kirchoff's and Watt's Laws by applying each in mathematical computation.	The teacher explains the relationship between power, current and voltage as defined by Watt's Law and demonstrate solving for an unknown quantity when any two are given. The teacher provides practice worksheets. The teacher explains the two derivative formulae combining Ohm's and Watt's Laws. The teacher provides practice worksheets. The teacher explains schematics and use of symbols. The teacher explains series, parallel and series-parallel circuit analysis using Ohm' Law, Watt's Law and Kirchoff's Voltage and Current Laws. Demonstrate using a chart to collate data. The teacher provides practice worksheets. The teacher demonstrates safe use of the multimeter and scales of measurement in ammeter settings. The students construct series, parallel and series-parallel circuits, calculate all quantities, and confirm calculations by measuring with a multimeter.

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GCO 5 Demonstrate and apply an understanding of the basic theory of DC circuits and components (continued)

Suggestions for Learning/Assessment:	Resources:
The teacher prepares a test for students using applicable labs and worksheets contained in the Appendices as a guide. Through on-going assessment, the teacher checks for consistent and correct usage of metric prefixes and units of measurement. Through on-going assessment, the teacher checks for correct usage of schematic symbols to represent components and circuits. The teacher observes students to ensure correct use of meters and safe working habits are followed.	Gates, Earl D. *Introduction to Electronics.* 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages 50 to 60 and 74 to 78 Lab Manual for *Introduction to Electronics*: • Lab 1-16: Ohm's Law • Lab 1-17: Power • Lab 1-18: Series DC Circuits • Lab 1-19: Parallel DC Circuits • Lab 1-20: Series-Parallel DC Circuits • Lab 1-21: Current in a Series Circuit • Lab 1-22: Voltage in a Series Circuit • Lab 1-23: Current in a Parallel Circuit • Lab 1-24: Voltage in a Parallel Circuit Appendix B • Worksheet # 4: Ohm's Law • Worksheet # 5: Watt's Law • Worksheet # 6: Ohm's and Watt's Laws Combined • Worksheet # 7: Series Circuits – Part One • Worksheet # 8: Series Circuits – Part Two • Worksheet # 9: Parallel Circuits – Part One • Worksheet # 10: Parallel Circuits – Part Two • Worksheet # 11: Series-Parallel Circuits – Part One • Worksheet # 12: Series-Parallel Circuits – Part Two

GCO 6 Interpret and summarize the relationship between magnetism and electricity

Specific Curriculum Outcomes: *Students will be expected to:*	Suggestions for Teaching/Learning:
• State the domain theory of magnetism and the properties and characteristics of magnetism. • Determine the purpose and operation of a relay. • Determine the purpose and operation of a solenoid. • Determine the purpose and operation of a generator. • Demonstrate an understanding of Faraday's Law. • Determine the purpose and operation of a motor.	The teacher provides magnets and iron filings to small groups of students. Students observe and record the characteristics of magnetic lines of flux and present findings to whole class. The teacher explains domain theory, types of magnets, characteristics of magnetism (reluctance, retentivity and permeability), magnetic induction and magnetic shielding. The student teams compete to build the strongest electromagnet and in doing so, verify the three variables that determine the strength of electromagnets and predict the direction of the North pole using the left-hand rule for coils. As per Lab 1-25A. The teacher demonstrates the operation of relays and solenoids, comparing and contrasting both. Teacher defines NO and NC contacts and SPST. SPDT, DPST and DPDT relay switches. The students complete Lab 1-25B: Relays. The teacher divides students into small groups to generate a quiz on magnetic theory. As per Assignment # 6. The teacher explains the operation of an AC generator, DC generator, Faraday's Law, the left-hand rule for generators and electric motors. The students conduct informal research on the operation of bicycle dynamos and could be assigned to build their own version. The students conduct informal research using the listed web sites as a starting point. The teacher provides materials and students build their own mini-motor from directions listed on the website, "A Motor in 10 Minutes" (re: Resources).

GCO 6 Interpret and summarize the relationship between magnetism and electricity

Suggestions for Learning/Assessment:	Resources:
The teacher prepares a test for students using applicable labs and worksheets contained in the Appendices as a guide. Through on-going assessment, the teacher checks for correct usage of schematic symbols to represent components and circuits. The teacher observes students to ensure correct use of meters and safe working habits are followed. The teacher explains assignment # 5: Create Your Own Quiz - Magnetic Theory (Teacher decides best questions or best complete quiz to be used for entire class.)	Gates, Earl D. *Introduction to Electronics.* 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • Pages 94 to 105 http://electronics.howstuffworks.com/relay.htm • "How Relays Work" http://home.howstuffworks.com/doorbell2.htm • "How Doorbells Work" http://www.wvic.com/how-gen-works.htm • "How An Electric Generator Works" http://www.gcsescience.com/pme21.htm • "Bicycle Dynamo Information" http://www.schoolscience.co.uk/content/5/physics/copper/copelech4pg1.html • "Electricity From Movement" http://electronics.howstuffworks.com/motor1.htm • "How Electric Motors Work" http://www.scitoys.com/scitoys/scitoys/electro/electro.html#motor • "A Motor in 10 Minutes" Lab Manual for *Introduction to Electronics* • Lab 1-25: Magnetism Appendix C • Lab 1-25A: Building an Electromagnet • Lab 1-25B: Relays Appendix A • Assignment # 5: Create Your Own Quiz - Magnetic Theory

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GCO 7 Demonstrate and apply an understanding of the basic theory of AC circuits and components

Specific Curriculum Outcomes: *Students will be expected to:*	**Suggestions for Teaching/Learning:**
• Demonstrate an understanding of basic AC voltage and current characteristics. • Perform calculations to determine peak-to-peak, peak and RMS (Effective) values for AC voltage and current. • Perform calculations to determine unknown quantities in AC resistive circuits using Ohm's and Watt's Laws. • Understand the theory of operation of inductors and their uses in AC circuits. • Calculate total inductance in series, parallel and series-parallel circuits. • Perform calculations to determine inductive reactance. • Understand the theory of operation of capacitors and their uses in AC circuits. • Calculate total capacitance in series, parallel and series-parallel circuits. • Perform calculations to determine capacitive reactance. • Perform calculations to determine inductive and capacitive reactance. • Understand the theory of the operation of transformers. • Perform calculations to determine turns ratio, number of turns, and voltage, current and power in the primary and secondary windings.	The teacher explains the use of an oscilloscope and shows students 112 V_{AC}, different DC voltages and signals of various frequencies. Using the oscilloscope, teacher explains peak-to-peak, peak, effective (RMS) value and frequency. The teacher demonstrates the calculations required to convert between peak, peak-to-peak and RMS values. Provide practice sheets. The teacher explains AC resistive circuits and demonstrates the use of Ohm's and Watt's Laws in solving for unknown values. Provide practice sheets. The students calculate power and current draw for different household appliances, lights, etc. Students determine loading on household circuits according to circuit breaker/fuse ratings. The teacher explains theory of inductors, their uses and Lenz's Law and demonstrates calculating total inductance in various configurations and calculating inductive reactance. Provide practice sheets. The students construct apparatus to test Lenz's Law and complete inductor lab. The teacher explains theory of capacitors and their uses, and demonstrates calculating total capacitance in various configurations and calculating capacitive reactance. Provide practice sheets. The students complete capacitor lab. The teacher explains theory of transformers and their uses, and demonstrates calculating turns ratio, number of turns and voltage, current and power in the primary and secondary windings. Provide practice sheets. The students complete transformer lab.

GCO 7 Demonstrate and apply an understanding of the basic theory of AC circuits and components

Suggestions for Learning/Assessment:	Resources:
The teacher prepares a test for students using applicable labs and worksheets contained in the Appendices as a guide. Through on-going assessment, the teacher checks for correct usage of schematic symbols to represent components and circuits. The teacher observes students to ensure correct use of meters and safe working habits are followed.	Gates, Earl D. *Introduction to Electronics.* 4th ed. DELMAR, Thompson Learning, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-5015 • ISBN 0-7668-1698-2 • AC Circuits - Pages 121 to 128 • Resistive AC Circuits - Pages 138 to 144 • Inductance – Pages 106 to 111 • Inductive AC Circuits – Pages 152 to 157 • Capacitance – Pages 112 to 118 • Capacitive AC Circuits - Pages 143 to 151 • Transformers – Pages 165 to 174 http://www.ndt-ed.org/TeachingResources/NDT_Tips/LenzLaw.htm • Lenz's Law Demonstration Apparatus Lab Manual for *Introduction to Electronics* • Lab 1-26: Inductance • Lab 1-27: Capacitance • Lab 1-28: Capacitor Application • Lab 2-1: Alternating Current • Lab 2-3: AC Measurements • Lab 2-6: Capacitors in AC Circuits • Lab 2-9: Inductors in AC Circuits • Lab 2-14: Transformers • Lab 2-15: Transformer Ratios Appendix B • Worksheet # 13: AC Conversions • Worksheet # 14: AC Resistive Circuits • Worksheet # 15: Inductor Configurations • Worksheet # 16: Inductive Reactance • Worksheet # 17: Capacitor Configurations • Worksheet # 18: Capacitive Reactance • Worksheet # 19: Transformers Appendix C • Lab 1-26A: Inductors • Lab 1-28A: Capacitors

APPENDICES

APPENDIX A

ASSIGNMENT # 1: HISTORY OF DEVELOPMENT IN ELECTRONICS

Choose and research one of the significant contributors* to the development of electricity/electronics as discussed in class. Your assignment should contain information about his or her life and times, a description of the discovery/work/invention and the science behind it, and the impact of the contribution.

OR

Research the ancient Egyptian (Babylon) battery. Your presentation should include a description of the battery, facts about its discovery, a critical analysis of its authenticity, and your opinion on the impact it would have had on our world of today if battery technology had been developed from this point in history instead of from the 1800's.

You can choose any of the following **presentation methods**:

1. A four hundred word essay (about two typewritten, double-spaced pages of text, not including diagrams or images)
2. A poster display on a full sheet of Bristol board
3. A PowerPoint presentation (15 slides minimum)
4. A 15 minute oral presentation to be delivered in class (delivery notes are to be passed in prior to your presentation)

IMPORTANT!! No matter which delivery method you choose, you **must** include a typewritten cover sheet and a bibliography page with citations of works consulted and works quoted using the MLA style. A very good reference for using the MLA style can be found at http://www.geocities.com/Athens/Oracle/4184/

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* Including, but not limited to, William Gilbert, Count Allesandro Volta, Georg Ohm, Andre Ampere, Guglielmo Marconi, Michael Faraday, Dr. Lee DeForest, H.C. Oersted, James Maxwell, James Watt and Heinrich Hertz.

ASSIGNMENT # 2: ETHICS IN TECHNOLOGY

Read and think about the following issues and write a minimum of one paragraph in response to each. There are no right or wrong answers; your responses should show that you have given careful thought to the issues.

1. A cell phone small enough for ants to use is obviously not a practical application of the newest nanotechnology. (At least not until they learn to talk!) So what is? Think along the lines of medical applications, communications, entertainment, etc. and describe practical purposes for tiny, yet complex, circuitry. Let your imagination run wild.

2. And... just because we **can** build a nanotechnology probe capable of human cell repair at the molecular level, **should** we be messing with creation? What are the possible consequences? Can our ethics keep up with the incredibly fast pace of technological progress?

3. A lot of R&D (research and development) in technology is government funded which is controversial because R&D dollars are sometimes being re-directed away from social programs. Should a country's government spend billions of dollars on expanding the technology required for space exploration or weapons building, for example, when some of its citizens do not have access to medical care or adequate housing?

4. Forty years ago, Gene Roddenberry, the writer/creator of the original Star Trek TV series, dreamed up many ahead-of-his-time devices like laser weapons and the flip-open communicator of "Beam me up, Scotty" fame that looks remarkably similar to the cell phones we use today. Do writers of science fiction foretell the future of technology? Or do they help to shape it? Would the cell phone look like it does today if we hadn't first seen Captain Kirk's communicator on TV many years ago?

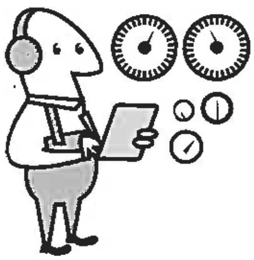
5. Most of the new cell phones in use today are equipped with GPS (Global Positioning System) which means that any time you use your cell phone, it is possible for someone to tell exactly where you are on the face of the planet. This is very useful if you are lost or hurt, for example, and need emergency services to respond to your distress call. GPS technology is also used in wrist bands for persons at high risk for being lost (Alzheimer's patients and children, for example) and can even be implanted into the body in microchips. This technology makes it is possible to never have another lost person or pet. But, what about personal freedoms and privacy? Do you want to be traceable at all times? Do the benefits outweigh the possible loss of freedom?

ASSIGNMENT # 3: CAREER CHOICES IN ELECTRICITY/ELECTRONICS

Name: ____________________ **Profession or Trade:** ______________
Due Date: __________________ **Teacher's Initials:** ________________

1. Choose a trade or profession that requires knowledge and skills in electricity/electronics. Get your teacher's approval of your choice.

2. Design a 20 slide (minimum) PowerPoint presentation on the trade or profession. Your presentation must include:



- an **introduction** slide,
- **information about the trade or profession** (such as typical tasks, education/certification required, where you can get training, expected salary, etc.),
- a **conclusion** slide, and
- a **bibliography** slide that lists all of the sites you visited to get information and pictures.

3. You can do most of your research in the **Bridges** program.

4. Remember, it's Power**Point** – not Power**Paragraph**. Information should be presented in point form. Spelling and grammar count! Animations, sounds and slide transitions are required but must be part of a good design that enhances the information rather than being an annoying distraction. Backgrounds and font styles must be the same throughout the presentation.

5. Links to websites can be installed by clicking on the **Slide Show** menu and then on **Action Buttons**.

6. If you need a refresher on how to use PowerPoint, visit the tutorial located at www.actden.com/pp/index.htm.

7. Save your work often!

8. Your presentation will be marked on the following criteria. Maximum point score is 42.

Criteria	*Needs Developing (0 marks)*	*Developing (2 marks)*	*Competent (4 marks)*	*Highly Competent (6 marks)*
Focus-Content (Information)	Presentation is confusing and needs more information	Ideas are scattered and need further development	Developed ideas and essentially accurate information	Sophisticated, substantial, well-developed ideas
Organization (Overall order, flow, and transitions)	Details and examples show confused organization; hard to follow	Details and examples show incorrect organization	Information in logical order	Information is presented in effective order; transitions help presentation flow smoothly
Introduction	Introduction is not apparent	Introduction is vague	Introduction contains a focus	Introduction has a sharp, distinct focus
Conclusion	Conclusion is not apparent	The closing slide attempts to summarize and draw a conclusion	The closing slide summarizes and draws a conclusion	The closing slide summarizes and draws a clear and effective conclusion
Slide Show - Layout and Presentation	Too many extras (e.g. transitions). Message not the most important characteristic	Too many 'added extras' which detract from the message. Some organization shown	Organization apparent and appealing	A high degree of originality, organization and eye appeal
Citations	No way to check validity of information.	Some information, photos and graphics do not use proper MLA citations.	Sources are documented. Possible to check on the accuracy of information.	All sources of information are clearly identified and credited using MLA citations throughout.
Graphics, Sound and/or Animation	The graphics, sounds, and/or animations are unrelated to the content. Graphics do not enhance understanding of the content, or are distracting decorations that create a busy feeling and detract from the content.	Some of the graphics, sounds, and/or animations seem unrelated to the topic/theme and do not enhance the overall concepts. Images are too large/small in size. Images are poorly cropped or the colour/resolution is fuzzy.	The graphics, sound/and or animation visually depict material and assist the audience in understanding the flow of information or content. Images are proper size, resolution	The graphics, sound and/or animation assist in presenting an overall theme and make visual connections that enhance understanding of concept, ideas and relationships. All images are proper size and resolution, and enhance the content. There is a consistent visual theme.

ASSIGNMENT # 3:
CAREER CHOICES IN ELECTRICITY/ELECTRONICS

Using the ***Bridges*** program, research three different trades/professions where a minimum basic knowledge of electricity/electronics is required. Complete individual career profile essays on each which include:

- an **introduction** that gives a basic description of the trade/profession,
- **information about the trade** such as typical tasks, education/certification required, where you can get training, expected salary,
- a **conclusion** that indicates current employment opportunity status and outlook for the trade/profession.

A minimum of three paragraphs is required, type-written and double-spaced. The data submitted in the information paragraph may be bulleted. Use the same format for all three trades/professions.

ASSIGNMENT # 4: CREATE YOUR OWN QUIZ – ATOMIC THEORY REVIEW

Due Date:

Quiz Date:

Each assigned team will design a quiz for the class on atomic theory which tests for an understanding of all of the key points listed below.

The quiz must include a minimum of three sections. Each section will be of different questioning types (multiple choice, fill in the blank, word match, draw and label a diagram, etc.) You must also include a separate answer key.

The best and fairest quiz will be selected to be photocopied and given to the entire class. You will not know which team 'won' until you see the quiz. You may find yourself taking the same quiz that your team wrote!

Key Points:

- Definitions of atom, ion, nucleus, shells, proton, neutron, electron, atomic number, valence shells, insulator, conductor, and semi-conductor.
- Model of an atom showing location of particles and their charges.

ASSIGNMENT # 5: CREATE YOUR OWN QUIZ – MAGNETIC THEORY

Due Date:

Quiz Date:

Each assigned team will design a quiz for the class on magnetic theory which tests for an understanding of all of the key points listed below.

The quiz must include a minimum of three sections. Each section will be of different questioning types (multiple choice, fill in the blank, word match, draw and label a diagram, etc.) You must also include a separate answer key.

The best and fairest quiz will be selected to be photocopied and given to the entire class. You will not know which team 'won' until you see the quiz. You may find yourself taking the same quiz that your team wrote!

Key Points:

- Definitions of magnet, artificial magnet, permanent magnet, temporary magnet, electromagnet, retentivity, reluctance, permeability, relay, solenoid, NO and NC contacts.
- Explain domain theory, magnetic induction and magnetic shielding.
- List the factors that determine strength of an electromagnet.

ASSIGNMENT # 6: CREATE YOUR OWN QUIZ – SEMICONDUCTOR THEORY

Due Date:

Quiz Date:

Each assigned team will design a quiz for the class on semiconductor theory which tests for an understanding of all of the key points listed below.

The quiz must include a minimum of three sections. Each section will be of different questioning types (multiple choice, fill in the blank, word match, draw and label a diagram, etc.) You must also include a separate answer key.

The best and fairest quiz will be selected to be photocopied and given to the entire class. You will not know which team 'won' until you see the quiz. You may find yourself taking the same quiz that your team wrote!

Key Points:

- Definitions of intrinsic and extrinsic materials, covalent bonding, doping, pentavalent and trivalent materials, negative temperature coefficient, majority and minority carriers, electron-hole pairs, N-type and P-type materials, PN junction diodes and LED's.
- Explain/draw and label full and half wave rectifiers.
- Explain why current limiting resistors are required for diode circuits.
- Draw and label schematic symbols for diodes, LED's, and NPN and PNP transistors.

APPENDIX B

WORKSHEET # 1: CALCULATOR PRACTICE

Use your calculator to perform the following operations. If required, round your answers to five decimal places. Write your answers in the spaces provided.

1. $\frac{1}{467} =$ ________________ (Use inverse key.)

2. $\frac{1}{0.000289} =$ ________________ (Use inverse key.)

3. $\frac{1}{0.00421} + \frac{1}{27.9} =$ ________________ (Use inverse key.)

4. $3.47 \times 10^{6} + 629 \times 10^{3} =$ ________________ (Use exponent key.)

5. $\frac{27.9 \times 10^{-3}}{4.35 \times 10^{6}} =$ ________________ (Use exponent key.)

6. $18 \times 10^{-6} \times 22.9 \times 10^{9} =$ ________________ (Use exponent key.)

7. $\frac{1}{4.73 \times 10^{3}} =$ ________________ (Use inverse and exponent keys.)

8. $\frac{1}{1.23 \times 10^{3}} + \frac{1}{4.56 \times 10^{3}} =$ ________________ (Use inverse and exponent keys.)

9. $\frac{1}{4.78} - \left[\frac{1}{8.92} + \frac{1}{12.5}\right] =$ ________________ (Use inverse and parenthesis keys.)

10. $\dfrac{1}{\frac{1}{2.46 \times 10^{3}} - \left[\frac{1}{129 \times 10^{6}} + \frac{1}{356 \times 10^{3}}\right]} =$ ________________

(Use inverse, exponent and parenthesis keys.)

ANSWERS

1. $\frac{1}{467}$ = **0.00214**

2. $\frac{1}{0.000289}$ = **3460.20761**

3. $\frac{1}{0.00421} + \frac{1}{27.9}$ = **237.56553**

4. $3.47 \times 10^6 + 629 \times 10^3$ = **4 099 000**

5. $\frac{27.9\times10^{-3}}{4.35\times10^{6}}$ = **6.41379**

6. $18 \times 10^{-6} \times 22.9 \times 10^9$ = **412 200**

7. $\frac{1}{4.73\times10^{3}}$ = **0.00021**

8. $\frac{1}{1.23\times10^{3}} + \frac{1}{4.56\times10^{3}}$ = **0.00103**

9. $\frac{1}{4.78} - \left[\frac{1}{8.92} + \frac{1}{12.5}\right]$ = **0.01710**

10. $\dfrac{1}{\frac{1}{2.46\times10^{3}} - \left[\frac{1}{129\times10^{6}} + \frac{1}{356\times10^{3}}\right]}$ = **2477.16473**

WORKSHEET # 2: CELL RATINGS

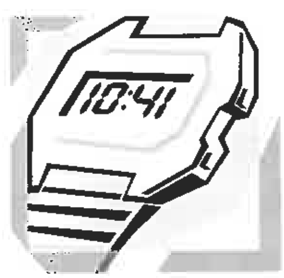
1. What is the maximum current a cell rated at 1500 mA-hr can supply for 5 hours?

2. How long can a cell rated at 700 mA-hr provide 10 mA of current?

3. Max's flashlight draws 200 mA of current and uses a single AA cell to operate. Max buys a cell rated at 1800 mA-hr. How long will his flashlight work?

4. Max decides to buy better quality cells for his flashlight and chooses one with a 2400 mA-hr rating. How long will his flashlight work with this more expensive cell?

5. Schmo finds a new watch in his cereal box that draws 2.5 mA of current during normal use but draws 200 mA when the alarm rings. The watch came with a cell rated at 500 mA-hr. If Schmo doesn't use the alarm, how long will his watch run after he turns it on?



6. When silly Schmo tries to turn on his new watch for the first time, he accidentally turns on the alarm instead. How long does Schmo have to figure out how to turn off the alarm before it drains the battery?

ANSWERS

1. $$\frac{1500\ mA-hr}{5\ hr} = 300\ mA$$

The cell can supply **300 mA** for **5** hours.

2. $$\frac{700\ mA-hr}{10\ mA} = 70\ hr$$

The cell can provide 10 mA for **70 hours**.

3. $$\frac{1800\ mA-hr}{200\ mA} = 9\ hr$$

Max's flashlight will work for **9 hours**.

4. $$\frac{2400\ mA-hr}{200\ mA} = 12\ hr$$

Max's flashlight will work for **12 hours** with the more expensive cell.

5. $$\frac{500\ mA-hr}{2.5\ mA} = 200\ hr$$

Schmo's watch will run for **200 hours** or 8 **days** and 8 hours.

6. $$\frac{500\ mA-hr}{200\ mA} = 2.5\ hr$$

Schmo has **2.5 hours** to figure out how to turn off the alarm before it drains the battery. (Moral of the story: always read the instructions first!)

WORKSHEET # 3: RESISTOR COLOUR CODE

VALUE	COLOUR CODE			
20 KΩ ± 5%	Red	Black	Orange	Gold
3.4 Ω ± 2%				
100 KΩ ± 10%				
0.73 Ω ± 1%				
8.7 MΩ ± 20%				
910 Ω ± 5%				
47 MΩ ± 10%				
820 MΩ ± 20%				
550 KΩ ± 5%				
4.7 KΩ ± 2%				
16 Ω ± 1%				

COLOUR CODE	VALUE	TOLERANCE RANGE
Yellow, yellow, yellow, red	**440 KΩ ± 2 %**	**431.2 KΩ to 448.8 KΩ**
Red, blue, brown, silver		
Brown, black, red, gold		
Gray, blue, silver, brown		
Orange, green, orange, red		
Violet, violet, violet, no colour		
White, yellow, black, gold		
Gray, brown, green, red		
Red, orange, yellow, gold		
Green, yellow, gold, brown		
Gray, gray, red, no colour		

ANSWERS

VALUE	COLOUR CODE			
20 KΩ ± 5%	**Red**	**Black**	**Orange**	**Gold**
3.4 Ω ± 2%	*Orange*	*Yellow*	*Gold*	*Red*
100 KΩ ± 10%	*Brown*	*Black*	*Brown*	*Silver*
0.73 Ω ± 1%	*Violet*	*Orange*	*Silver*	*Brown*
8.7 MΩ ± 20%	*Gray*	*Violet*	*Green*	*No colour*
910 Ω ± 5%	*White*	*Brown*	*Brown*	*Gold*
47 MΩ ± 10%	*Yellow*	*Violet*	*Blue*	*Silver*
820 MΩ ± 20%	*Gray*	*Red*	*Violet*	*No colour*
550 KΩ ± 5%	*Green*	*Green*	*Yellow*	*Gold*
4.7 KΩ ± 2%	*Yellow*	*Violet*	*Red*	*Red*
16 Ω ± 1%	*Brown*	*Blue*	*Black*	*Brown*

COLOUR CODE	VALUE	TOLERANCE RANGE
Yellow, yellow, yellow, red	**440 KΩ ± 2 %**	**431.2 KΩ to 448.8 KΩ**
Red, blue, brown, silver	*260 Ω ± 10%*	*234 Ω to 286Ω*
Brown, black, red, gold	*1 KΩ ± 5%*	*950 Ω to 1.05 KΩ*
Gray, blue, silver, brown	*0.86 Ω ± 1%*	*0.8514 Ω to 0.8686 Ω*
Orange, green, orange, red	*35 KΩ ± 2%*	*34.3 KΩ to 35.7 KΩ*
Violet, violet, violet, no colour	*770 MΩ ± 20%*	*616 MΩ to 924 MΩ*
White, yellow, black, gold	*94 Ω ± 5%*	*89.3 Ω to 98.7 Ω*
Gray, brown, green, red	*8.1 MΩ ± 2%*	*7.938 MΩ to 8.262 MΩ*
Red, orange, yellow, gold	*230 KΩ ± 5%*	*218.5 KΩ to 241.5 KΩ*
Green, yellow, gold, brown	*5.4 Ω ± 1%*	*5.346 Ω to 5.454 Ω*
Gray, gray, red, no colour	*8.8 KΩ ± 20%*	*7.04 KΩ to 10.56 KΩ*

WORKSHEET # 4: OHM'S LAW

1. I_T = 100 mA E_T = ? R_T = 100 Ω E_T = ________________
2. I_T = 1.8 mA E_T = ? R_T = 54 KΩ E_T = ________________
3. I_T = ? E_T = 250 V R_T = 500 Ω I_T = ________________
4. I_T = ? E_T = 50V R_T = 7.6 MΩ I_T = ________________
5. I_T = 2 A E_T = 100 V R_T = ? R_T = ________________
6. I_T = 46.3 mA E_T = 50 V R_T = ? R_T = ________________
7. I_T = 100 µA E_T = ? R_T = 100 Ω E_T = ________________
8. I_T = 928 mA E_T = 10 V R_T = ? R_T = ________________
9. I_T = ? E_T = 120 V R_T = 100 KΩ I_T = ________________
10. I_T = 29 mA E_T = ? R_T = 12.3 KΩ E_T = ________________

ANSWERS

1. I_T = 100 mA E_T = ? R_T = 100 Ω E_T = **10 V**
2. I_T = 1.8 mA E_T = ? R_T = 54 KΩ E_T = **97.2 V**
3. I_T = ? E_T = 250 V R_T = 500 Ω I_T = **500 mA**
4. I_T = ? E_T = 50V R_T = 7.6 MΩ I_T = **6.58 µA**
5. I_T = 2 A E_T = 100 V R_T = ? R_T = **50 Ω**
6. I_T = 46.3 mA E_T = 50 V R_T = ? R_T = **1.08 KΩ**
7. I_T = 100 µA E_T = ? R_T = 100 Ω E_T = **10 mV**
8. I_T = 928 mA E_T = 10 V R_T = ? R_T = **10.8 Ω**
9. I_T = ? E_T = 120 V R_T = 100 KΩ I_T = **1.2 mA**
10. I_T = 29 mA E_T = ? R_T = 12.3 KΩ E_T = **357 V**

WORKSHEET # 5: WATT'S LAW

1. P_T = 1 W	I_T = ?	E_T = 10 V	I_T = ________
2. P_T = 500 mW	I_T = ?	E_T = 100 V	I_T = ________
3. P_T = ?	I_T = 784 µA	E_T = 50 V	P_T = ________
4. P_T = ?	I_T = 400 mA	E_T = 10 V	P_T = ________
5. P_T = 2 W	I_T = 100 A	E_T = ?	E_T = ________
6. P_T = 500 mW	I_T = 28 mA	E_T = ?	E_T = ________
7. P_T = 4 W	I_T = 100 mA	E_T = ?	E_T = ________
8. P_T = 3.5 KW	I_T = ?	E_T = 240 V	I_T = ________
9. P_T = ?	I_T = 30 A	E_T = 300 V	P_T = ________
10. P_T = 10 W	I_T = ?	E_T = 120 V	I_T = ________

ANSWERS

1. P_T = 1 W	I_T = ?	E_T = 10 V	I_T = **100 mA**
2. P_T = 500 mW	I_T = ?	E_T = 100 V	I_T = **5 mA**
3. P_T = ?	I_T = 784 µA	E_T = 50 V	P_T = **39.2 mW**
4. P_T = ?	I_T = 400 mA	E_T = 10 V	P_T = **4 W**
5. P_T = 2 W	I_T = 100 A	E_T = ?	E_T = **20 mV**
6. P_T = 500 mW	I_T = 28 mA	E_T = ?	E_T = **17.9 V**
7. P_T = 4 W	I_T = 100 mA	E_T = ?	E_T = **40 V**
8. P_T = 3.5 KW	I_T = ?	E_T = 240 V	I_T = **14.6 A**
9. P_T = ?	I_T = 30 A	E_T = 300 V	P_T = **9 KW**
10. P_T = 10 W	I_T = ?	E_T = 120 V	I_T = **83.3 mA**

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WORKSHEET # 6: OHM'S AND WATT'S LAWS COMBINED

1. P_T = 10 W E_T = 10 V R_T = ? R_T = ____________

2. P_T = 642 mW E_T = 120 V R_T = ? R_T = ____________

3. P_T = 10 W E_T = ? R_T = 75 Ω E_T = ____________

4. P_T = 250 W E_T = ? R_T = 2.2 KΩ E_T = ____________

5. P_T = ? E_T = 355 mV R_T = 8 Ω P_T = ____________

6. P_T = ? E_T = 150 V R_T = 4 KΩ P_T = ____________

7. P_T = 10 W I_T = 5 mA R_T = ? R_T = ____________

8. P_T = 42.7 mW I_T = 870 µA R_T = ? R_T = ____________

9. P_T = 150 W I_T = ? R_T = 1 KΩ I_T = ____________

10. P_T = 1.9 mW I_T = ? R_T = 770 Ω I_T = ____________

11. P_T = ? I_T = 5 mA R_T = 470 Ω P_T = ____________

12. P_T = ? I_T = 3.6 A R_T = 5 MΩ P_T = ____________

ANSWERS

1. P_T = 10 W E_T = 10 V R_T = ? R_T = **10 Ω**

2. P_T = 642 mW E_T = 120 V R_T = ? R_T = **22.4 KΩ**

3. P_T = 10 W E_T = ? R_T = 75 Ω E_T = **27.4 V**

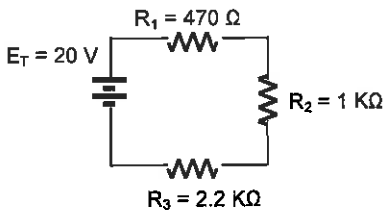
4. P_T = 250 W E_T = ? R_T = 2.2 KΩ E_T = **742 V**

5. P_T = ? E_T = 355 mV R_T = 8 Ω P_T = **15.8 mW**

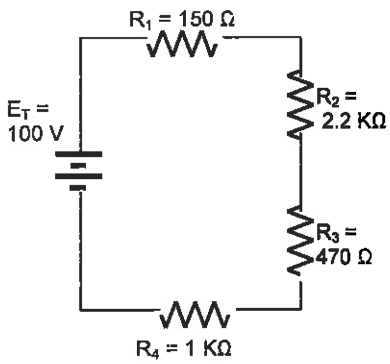
6.	P_T = ?	E_T = 150 V	R_T = 4 KΩ	P_T = **5.63 W**
7.	P_T = 10 W	I_T = 5 mA	R_T = ?	R_T = **400 KΩ**
8.	P_T = 42.7 mW	I_T = 870 μA	R_T = ?	R_T = **56.4 KΩ**
9.	P_T = 150 W	I_T = ?	R_T = 1 KΩ	I_T = **387 mA**
10.	P_T = 1.9 mW	I_T = ?	R_T = 770 Ω	I_T = **1.57 mA**
11.	P_T = ?	I_T = 5 mA	R_T = 470 Ω	P_T = **11.8 mW**
12.	P_T = ?	I_T = 3.6 A	R_T = 5 MΩ	P_T = **64.8 MW**

WORKSHEET # 7: SERIES CIRCUITS - PART ONE

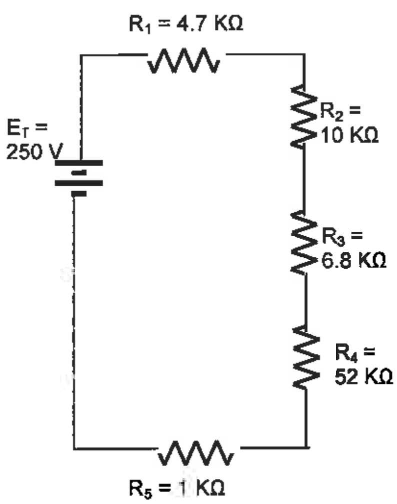
Solve for all unknown values in the following circuits. Round each answer to three significant figures and use metric prefixes where possible. Do not use rounded values in calculations. Each answer **must** include the correct metric prefix and unit of measurement to be considered correct.



	R	I	E	P
R_1	470 Ω			
R_2	1 KΩ			
R_3	2.2 KΩ			
Totals			20 V	



	R	I	E	P
R_1	150 Ω			
R_2	2.2 KΩ			
R_3	470 Ω			
R_4	1 KΩ			
Totals			100 V	



	R	I	E	P
R_1	4.7 KΩ			
R_2	10 KΩ			
R_3	6.8 KΩ			
R_4	52 KΩ			
R_5	1 KΩ			
Totals			250 V	

ANSWERS

	R	I	E	P
R_1	470 Ω	5.45 mA	2.56 V	14 mW
R_2	1 KΩ	5.45 mA	5.45 V	29.7 mW
R_3	2.2 KΩ	5.45 mA	12 V	65.3 mW
Totals	3.67 KΩ	5.45 mA	20 V	109 mW

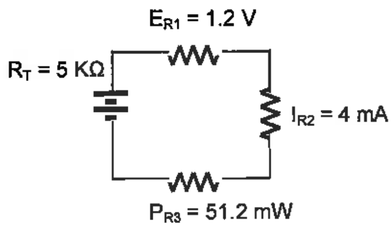
	R	I	E	P
R_1	150 Ω	26.2 mA	3.93 V	103 mW
R_2	2.2 KΩ	26.2 mA	57.6 V	1.51 W
R_3	470 Ω	26.2 mA	12.3 V	322 mW
R_4	1 KΩ	26.2 mA	26.2 V	685 mW
Totals	3.82 KΩ	26.2 mA	100 V	2.62 W

	R	I	E	P
R_1	4.7 KΩ	3.36 mA	15.8 V	52.9 mW
R_2	10 KΩ	3.36 mA	33.6 V	113 mW
R_3	6.8 KΩ	3.36 mA	22.8 V	76.6 mW
R_4	52 KΩ	3.36 mA	174 V	586 mW
R_5	1 KΩ	3.36 mA	3.36 V	11.3 mW
Totals	74.5 KΩ	3.36 mA	250 V	839 mW

WORKSHEET # 8: SERIES CIRCUITS - PART TWO

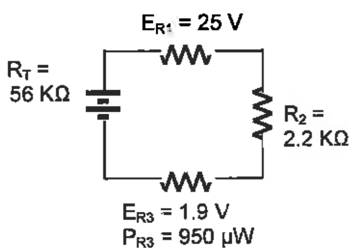
Solve for all unknown values in the following circuits. Round each answer to three significant figures and use metric prefixes where possible. Do not use rounded values in calculations. Each answer must include the correct metric prefix and unit of measurement to be considered correct.

1.



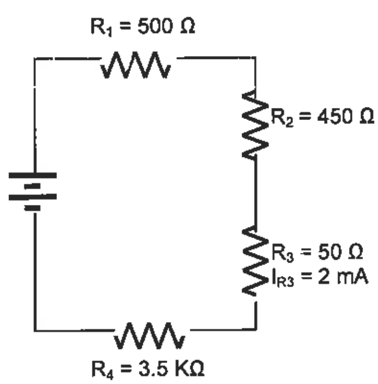
	R	I	E	P
R_1			1.2 V	
R_2		4 mA		
R_3				51.2 mW
Totals	5 KΩ			

2.



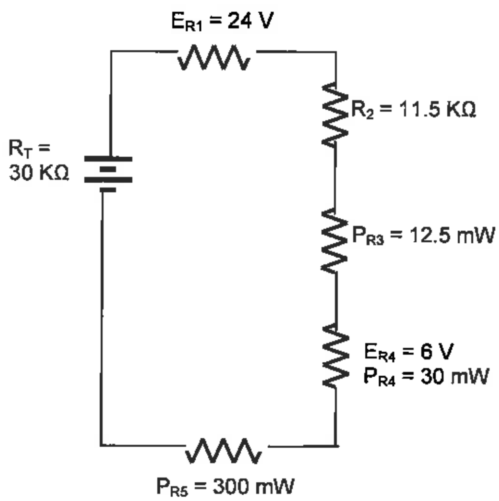
	R	I	E	P
R_1				
R_2				
R_3				
Totals				

3.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
Totals				

4.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
R_5				
Totals				

ANSWERS

1.

	R	I	E	P
R_1	300 Ω	4 mA	1.2 V	4.8 mW
R_2	1.5 KΩ	4 mA	6 V	24 mW
R_3	3.2 KΩ	4 mA	12.8 V	51.2 mW
Totals	5 KΩ	4 mA	20 V	80 mW

2.

	R	I	E	P
R_1	50 KΩ	5 µA	25 V	12.5 mW
R_2	2.2 KΩ	5 µA	1.1 V	550 µW
R_3	3.8 KΩ	5 µA	1.9 V	950 µW
Totals	56 KΩ	5 µA	28 V	14 mW

3.

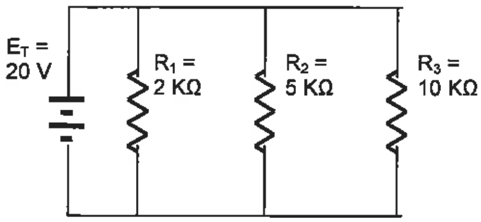
	R	I	E	P
R_1	500 Ω	2 mA	1 V	2 mW
R_2	450 Ω	2 mA	900 mV	1.8 mW
R_3	50 Ω	2 mA	100 mV	200 µW
R_4	3.5 KΩ	2 mA	7 V	14 mW
Totals	4.5 KΩ	2 mA	9 V	18 mW

4.

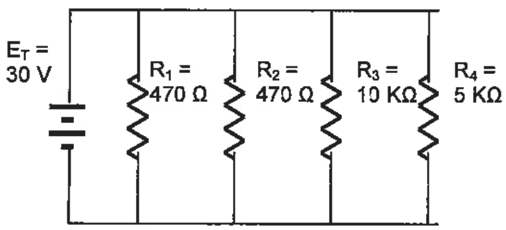
	R	I	E	P
R_1	4.8 KΩ	5 mA	24 V	120 mW
R_2	11.2 KΩ	5 mA	57.5 V	288 mW
R_3	500 Ω	5 mA	2.5 V	12.5 mW
R_4	1.2 KΩ	5 mA	6 V	30 mW
R_5	12 KΩ	5 mA	60 V	300 mW
Totals	30 KΩ	5 mA	150 V	750 mW

WORKSHEET # 9: PARALLEL CIRCUITS - PART ONE

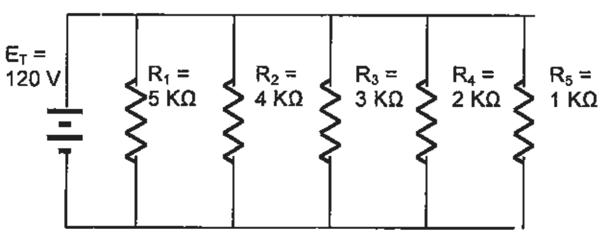
Solve for all unknown values in the following circuits. Round each answer to three significant figures and use metric prefixes where possible. Do not use rounded values in calculations. Each answer **must** include the correct metric prefix and unit of measurement to be considered correct.



	R	I	E	P
R_1	2 KΩ			
R_2	5 KΩ			
R_3	10 KΩ			
Totals			20 V	



	R	I	E	P
R_1	470 Ω			
R_2	470 Ω			
R_3	10 KΩ			
R_4	5 KΩ			
Totals			30 V	



	R	I	E	P
R_1	5 KΩ			
R_2	4 KΩ			
R_3	3 KΩ			
R_4	2 KΩ			
R_5	1 KΩ			
Totals			120 V	

ANSWERS

	R	I	E	P
R_1	2 KΩ	10 mA	20 V	200 mW
R_2	5 KΩ	4 mA	20 V	80 mW
R_3	10 KΩ	2 mA	20 V	40 mW
Totals	1.25 KΩ	16 mA	20 V	320 mW

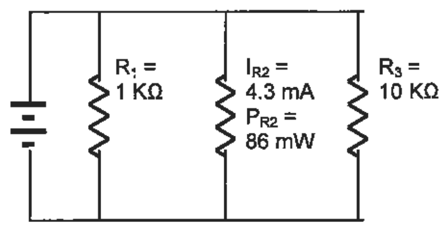
	R	I	E	P
R_1	470 Ω	63.8 mA	30 V	1.91 W
R_2	470 Ω	63.8 mA	30 V	1.91 W
R_3	10 KΩ	3 mA	30 V	90 mW
R_4	5 KΩ	6 mA	30 V	180 mW
Totals	220 Ω	137 mA	30 V	4.1 W

	R	I	E	P
R_1	5 KΩ	24 mA	120 V	2.88 W
R_2	4 KΩ	30 mA	120 V	3.6 W
R_3	3 KΩ	40 mA	120 V	4.8 W
R_4	2 KΩ	60 mA	120 V	7.2 W
R_5	1 KΩ	120 mA	120 V	14.4 W
Totals	438 Ω	274 mA	120 V	32.9 W

WORKSHEET # 10: PARALLEL CIRCUITS - PART TWO

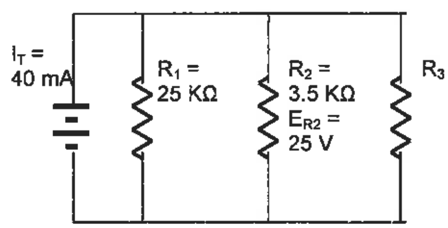
Solve for all unknown values in the following circuits. Round each answer to three significant figures and use metric prefixes where possible. Do not use rounded values in calculations. Each answer must include the correct metric prefix and unit of measurement to be considered correct.

1.



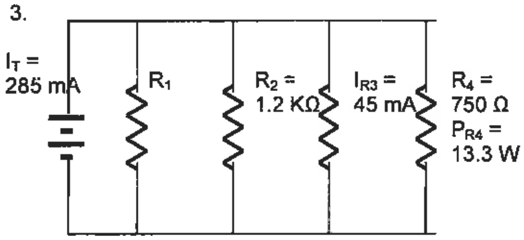
	R	I	E	P
R_1	1 KΩ			
R_2		4.3 mA		86 mW
R_3	10 KΩ			
Totals				

2.



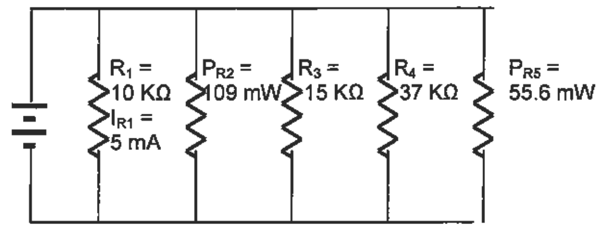
	R	I	E	P
R_1				
R_2				
R_3				
Totals				

3.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
Totals				

4.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
R_5				
Totals				

ANSWERS

1.

	R	I	E	P
R_1	1 KΩ	20 mA	20 V	400 mW
R_2	4.65 KΩ	4.3 mA	20 V	86 mW
R_3	10 KΩ	2 mA	20 V	40 mW
Totals	760 Ω	26.3 mA	20 V	526 mW

2.

	R	I	E	P
R_1	25 KΩ	1 mA	25 V	25 mW
R_2	3.5 KΩ	7.14 mA	25 V	179 mW
R_3	785 Ω	31.9 mA	25 V	796 mW
Totals	625 Ω	40 mA	25 V	1 W

3.

	R	I	E	P
R_1	4.23 KΩ	23.6 mA	100 V	2.36 W
R_2	1.2 KΩ	83.2 mA	100 V	8.31 W
R_3	2.22 KΩ	45 mA	100 V	4.49 W
R_4	750 Ω	133 mA	100 V	13.3 W
Totals	350 Ω	285 mA	100 V	28.5 W

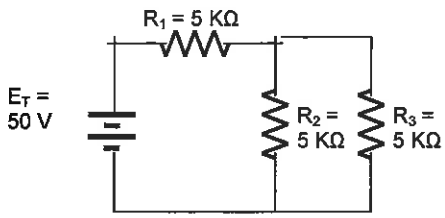
4.

	R	I	E	P
R_1	10 KΩ	5 mA	50 V	250 mW
R_2	22.9 KΩ	2.18 mA	50 V	109 mW
R_3	15 KΩ	3.33 mA	50 V	167 mW
R_4	37 KΩ	1.35 mA	50 V	67.6 mW
R_5	45 KΩ	1.11 mA	50 V	55.6 mW
Totals	3.85 KΩ	13 mA	50 V	649 mW

WORKSHEET # 11: SERIES-PARALLEL CIRCUITS – PART ONE

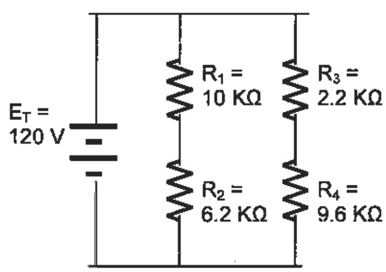
Solve for all unknown values in the following circuits. Round each answer to three significant figures and use metric prefixes where possible. Do not use rounded values in calculations. Each answer **must** include the correct metric prefix and unit of measurement to be considered correct.

1.



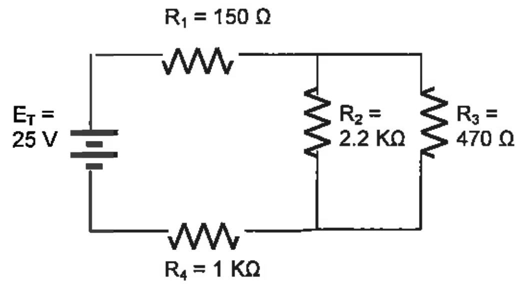
	R	I	E	P
R_1				
R_2				
R_3				
Totals				

2.



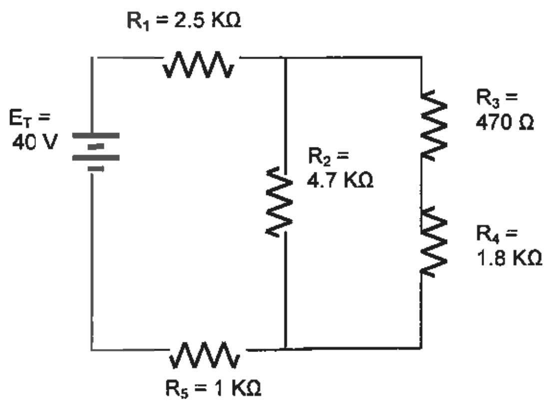
	R	I	E	P
R_1				
R_2				
R_3				
R_4				
Totals				

3.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
Totals				

4.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
R_5				
Totals				

ANSWERS

1.

	R	I	E	P
R_1	5 KΩ	6.67 mA	33.3 V	222 mW
R_2	5 KΩ	3.33 mA	16.7 V	55.6 mW
R_3	5 KΩ	3.33 mA	16.7 V	55.6 mW
Totals	7.5 KΩ	6.67 mA	50 V	333 mW

2.

	R	I	E	P
R_1	10 KΩ	7.41 mA	74.1 V	549 mW
R_2	6.2 KΩ	7.41 mA	45.9 V	340 mW
R_3	2.2 KΩ	10.2 mA	22.4 V	228 mW
R_4	9.6 KΩ	10.2 mA	97.6 V	993 mW
Totals	6.83 KΩ	17.6 mA	120 V	2.11 W

3.

	R	I	E	P
R_1	150 Ω	16.3 mA	2.44 V	39.7 mW
R_2	2.2 KΩ	2.86 mA	6.3 V	18 mW
R_3	470 Ω	13.4 mA	6.3 V	84.4 mW
R_4	1 KΩ	16.3 mA	16.3 V	264 mW
Totals	1.54 KΩ	16.3 mA	25 V	407 mW

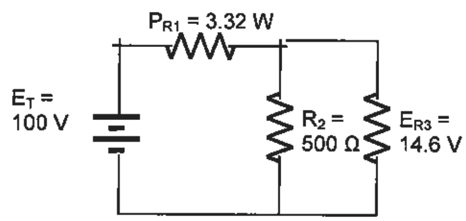
4.

	R	I	E	P
R_1	2.5 KΩ	7.95 mA	19.9 V	158 mW
R_2	4.7 KΩ	2.59 mA	12.2 V	31.5 mW
R_3	470 Ω	5.36 mA	2.52 V	13.5 mW
R_4	1.8 KΩ	5.36 mA	9.65 V	51.7 mW
R_5	1 KΩ	7.95 mA	7.95 V	63.2 mW
Totals	5.03 KΩ	7.95 mA	40 V	318 mW

WORKSHEET # 12: SERIES-PARALLEL CIRCUITS – PART TWO

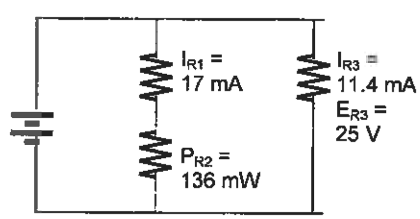
Solve for all unknown values in the following circuits. Round each answer to three significant figures and use metric prefixes where possible. Do not use rounded values in calculations. Each answer **must** include the correct metric prefix and unit of measurement to be considered correct

1.



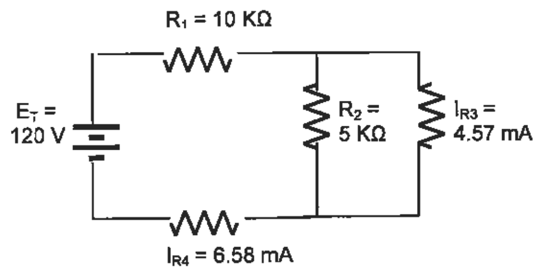
	R	I	E	P
R_1				
R_2				
R_3				
Totals				

2.



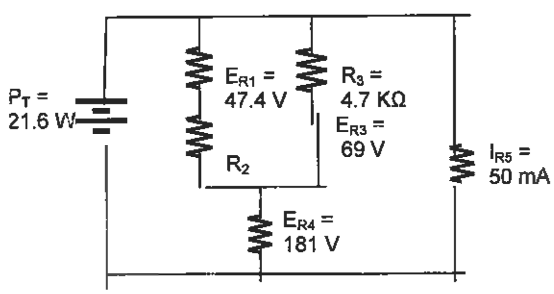
	R	I	E	P
R_1				
R_2				
R_3				
Totals				

3.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
Totals				

4.



	R	I	E	P
R_1				
R_2				
R_3				
R_4				
R_5				
Totals				

ANSWERS

1.

	R	I	E	P
R_1	2.2 KΩ	38.9 mA	85.4 V	**3.32 W**
R_2	**500 Ω**	29.2 mA	14.6 V	426 mW
R_3	1.51 KΩ	9.68 mA	**14.6 V**	141 mW
Totals	2.57 KΩ	38.9 mA	**100 V**	3.89 W

2.

	R	I	E	P
R_1	1 KΩ	**17 mA**	17 V	289 mW
R_2	471 Ω	17 mA	8 V	**136 mW**
R_3	2.19 KΩ	**11.4 mA**	**25 V**	285 mW
Totals	880 Ω	28.4 mA	25 V	710 mW

3.

	R	I	E	P
R_1	**10 KΩ**	6.58 mA	65.8 V	433 mW
R_2	**5 KΩ**	2.01 mA	10.1 V	20.4 mW
R_3	2.22 KΩ	**4.57 mA**	10.1 V	46.4 mW
R_4	6.71 KΩ	**6.58 mA**	44.2 V	291 mW
Totals	18.2 KΩ	6.58 mA	**120 V**	790 mW

4.

	R	I	E	P
R_1	2.18 KΩ	21.7 mA	**47.4 V**	1.03 W
R_2	995 Ω	21.7 mA	21.6 V	469 mW
R_3	**4.7 KΩ**	14.7 mA	**69 V**	1.01 W
R_4	4.97 KΩ	36.4 mA	**181 V**	6.59 W
R_5	5 KΩ	**50 mA**	250 V	12.5 W
Totals	2.89 KΩ	86.4 mA	250 V	**21.6 W**

WORKSHEET # 13: AC CONVERSIONS

1. What is the peak-to-peak value of a current sine wave that reaches a maximum positive alternation of 1.52 mA?

2. What is the peak value of an AC voltage with a peak-to-peak value of 120 V?

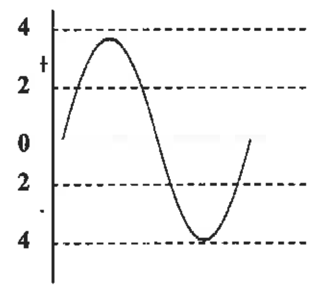
3. An AC voltage has a peak value of 42 V. What is its effective value?

4. An AC current has a peak value of 100 mA. What is its RMS value?

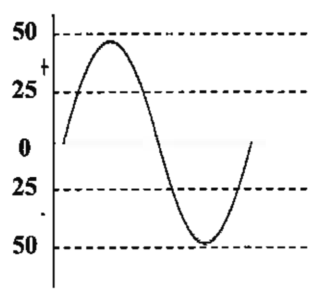
5. What is the peak-to-peak value of an AC current of 2.4 A?

6. What is the peak-to-peak value of an AC voltage of 50 V?

7. In the diagram below, what are the RMS, peak and peak-to-peak values of the current sine wave displayed, given that each vertical division on the oscilloscope equals 2 mA?



8. In the diagram below, what are the RMS, peak and peak-to-peak values of the voltage sine wave displayed, given that each vertical division on the oscilloscope equals 25 V?



ANSWERS

1. $I_{PP} = I_P \times 2$ $\quad I_{PP} = 1.52\text{ mA} \times 2$ $\quad I_{PP} = 3.04\text{ mA}$

The peak-to-peak value of a current sine wave that reaches a maximum positive alternation of 1.52 mA is 3.04 mA.

2. $E_P = \frac{E_{PP}}{2}$ $\quad E_P = \frac{120\text{ V}}{2}$ $\quad E_P = 60\text{ V}$

The peak value of an AC voltage with a peak-to-peak value of 120 V is 60 V.

3. $E_{RMS} = E_P \times 0.707$ $\quad E_{RMS} = 42\text{ V} \times 0.707$ $\quad E_{RMS} = 29.694\text{ V}$

An AC voltage with a peak value of 42 V has an effective value of 29.7 V.

4. $I_{RMS} = I_P \times 0.707$ $\quad I_{RMS} = 100\text{ mA} \times 0.707$ $\quad I_{RMS} = 70.7\text{ mA}$

An AC current with a peak value of 100 mA has an RMS value of 70.7 mA.

5. $I_{RMS} = I_P \times 0.707$ $\quad 2.4\text{ A} = I_P \times 0.707$ $\quad \frac{2.4\text{ A}}{0.707} = \frac{I_P \times \cancel{0.707}}{\cancel{0.707}}$

$\frac{2.4\text{ A}}{0.707} = I_P$ $\quad 3.394625\text{ A} = I_P$

$I_{PP} = I_P \times 2$ $\quad I_{PP} = 3.394625\text{ A} \times 2$ $\quad I_{PP} = 6.78925\text{ A}$

The peak-to-peak value of an AC current of 2.4 A is 6.79 A.

6. $E_{RMS} = E_P \times 0.707$ $\quad 50\text{ V} = E_P \times 0.707$ $\quad \frac{50\text{ V}}{0.707} = \frac{E_P \times \cancel{0.707}}{\cancel{0.707}}$

$\frac{50\text{ V}}{0.707} = E_P$ $\quad 70.721357\text{ V} = E_P$

$E_{PP} = E_P \times 2$ $\quad E_{PP} = 70.721357\text{ V} \times 2$ $\quad E_{PP} = 141.4427\text{ V}$

The peak-to-peak value of an AC voltage of 50 V is 141 V.

7. $I_P = 4\text{ mA}$ $\quad I_{PP} = 8\text{ mA}$

$I_{RMS} = I_P \times 0.707$ $\quad I_{RMS} = 4\text{ mA} \times 0.707$ $\quad I_{RMS} = 2.828\text{ mA}$

The RMS value is 2.83 mA, the peak value is 4 mA and the peak-to-peak value is 8 mA.

8. $E_P = 50\text{ V}$ $\quad E_{PP} = 100\text{ V}$

$E_{RMS} = E_P \times 0.707$ $\quad E_{RMS} = 50\text{ V} \times 0.707$ $\quad E_{RMS} = 35.35\text{ V}$

The RMS value is 35.4 V, the peak value is 50 V and the peak-to-peak value is 100 V.

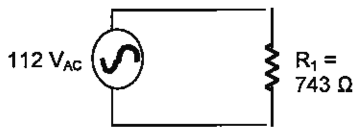
WORKSHEET # 14: AC RESISTIVE CIRCUITS

1. What are the effective voltage drops across two resistors, 2.2 KΩ and 5 KΩ, connected in series with 30 V_{AC} applied?

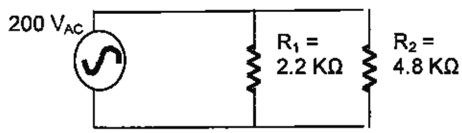
2. What is the effective current value in a circuit having a source of 120 V_{AC} and a resistive load of 1.2 KΩ?

3. Find the effective current value for each of the following circuits:

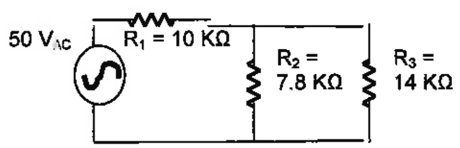
a.



b.



c.



ANSWERS

1. I_T = 4.166667 mA $\quad$ E_{R1} = 4.166667 mA x 2.2 KΩ = **9.17 V** $\quad$ E_{R2} = 4.166667 mA x 5 KΩ = **20.8 V**

2. 100 mA

3. 148 mA

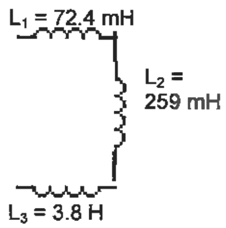
4. 133 mA

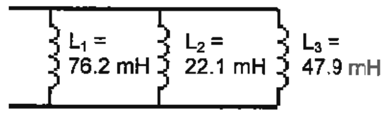
5. 3.33 mA

WORKSHEET # 15: INDUCTOR CONFIGURATIONS

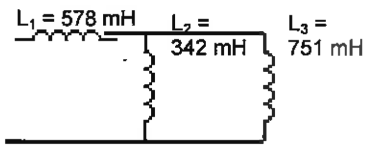
Find the L_T of the following inductor configurations.

1.

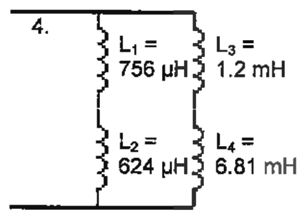




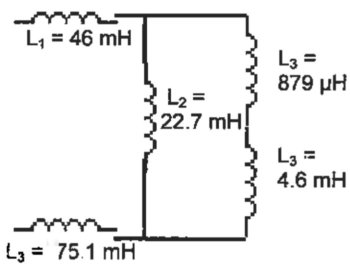
3.



4.



5.



ANSWERS

1. The total inductance of this configuration is **4.13 H.**
2. The total inductance of this configuration is **12.6 mH.**
3. The total inductance of this configuration is **813 mH.**
   (L_A = 234.9881 mH)
4. The total inductance of this configuration is **1.18 mH.**
   (L_A = 1.38 mH and L_B = 8.01 mH)
5. The total inductance of this configuration is **126 mH.**
   (L_A = 5.479 mH and L_B = 4.413687 mH)

<u>**WORKSHEET # 16: INDUCTIVE REACTANCE**</u>

1. Find the inductive reactance of a 825 µH inductor at:

   a. 450 Hz
   b. 2 KHz
   c. 97.5 KHz

2. Find the inductive reactance of a 450 mH inductor at:

   a. 450 Hz
   b. 2 KHz
   c. 97.5 KHz

3. What is the effect of increasing the frequency on the resulting inductive reactance? Why?

4. What is the effect of increasing the size of the inductor on the resulting inductive reactance? Why?

5. Find the inductive reactance of three 800 µH inductors in series at 1.8 KHz.

6. Find the inductive reactance of three 800 µH inductors in parallel at 1.8 KHz.

7. How much current flows in a circuit with an inductive reactance of 200 Ω when 50 V_{AC} at 50 Hz is applied?

8. What voltage must be applied to a circuit having an inductive reactance of 975 Ω to cause 25.6 mA of current?

9. What is the inductive reactance of a circuit with 480 mA of current and 72 V_{AC} applied?

ANSWERS

1. a. $X_L = 2\pi f L$

$= (2\pi)(450 \text{ Hz})(825\ \mu\text{H})$

$= 2.33263\ \Omega$

The inductive reactance is 2.33 Ω

b. $X_L = 2\pi f L$

$= (2\pi)(2 \text{ KHz})(825\ \mu\text{H})$

$= 10.36726\ \Omega$

The inductive reactance is 10.4 Ω

c. $X_L = 2\pi f L$

$= (2\pi)(97.5 \text{ KHz})(825\ \mu\text{H})$

$= 505.40372\ \Omega$

The inductive reactance is 505 Ω

2. a. $X_L = 2\pi f L$

$= (2\pi)(450 \text{ Hz})(450 \text{ mH})$

$= 1272.345\ \Omega$

The inductive reactance is 1.27 KΩ

b. $X_L = 2\pi f L$

$= (2\pi)(2 \text{ KHz})(450 \text{ mH})$

$= 5654.867\ \Omega$

The inductive reactance is 5.65 KΩ

c. $X_L = 2\pi f L$

$= (2\pi)(97.5 \text{ KHz})(450 \text{ mH})$

$= 275674.755\ \Omega$

The inductive reactance is 276 KΩ

3. The inductive reactance **increases** because it is directly proportional to frequency.

4. The inductive reactance **increases** because it is directly proportional to the amount of inductance.

5. $L_T = L_1 + L_2 + L_3$

$= 800\ \mu\text{H} + 800\ \mu\text{H} + 800\ \mu\text{H}$

$= 2400\ \mu\text{H}$

$= 2.4 \text{ mH}$

$X_L = 2\pi f L$

$= (2\pi)(1.8 \text{ KHz})(2.4 \text{ mH})$

$= 27.14336\ \Omega$

The inductive reactance is 27.1 Ω

6. $L_T = \dfrac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$

$= \dfrac{1}{\frac{1}{800\ \mu H} + \frac{1}{800\ \mu H} + \frac{1}{800\ \mu H}}$

$= 266.6666\ \mu H$

$X_L = 2\pi f L$

$= (2\pi)(1.8\ KHz)(266.6666\ \mu H)$

$= 3.015928\ \Omega$

The inductive reactance is 3.02 Ω

7. $I = \dfrac{E}{X_L} = \dfrac{50\ V_{AC}}{200\ \Omega} = 250\ mA$ **The current in this circuit is 250 mA**

8. $I = \dfrac{E}{X_L}$ $E = I \times X_L = 25.6\ mA \times 975\ \Omega = 24.96\ V_{AC}$

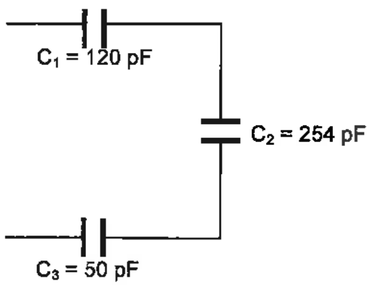
The voltage applied to this circuit is 25 V_{AC}

9. $I = \dfrac{E}{X_L}$ $X_L = \dfrac{E}{I} = \dfrac{72\ V_{AC}}{480\ mA} = 150\ \Omega$ **The inductive reactance of this circuit is 250 Ω**

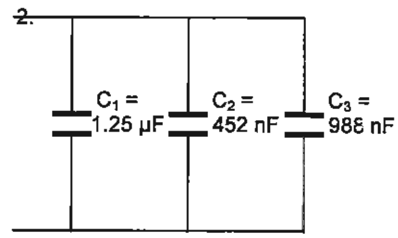
WORKSHEET # 17: CAPACITOR CONFIGURATIONS

Find the C_T of the following capacitor configurations.

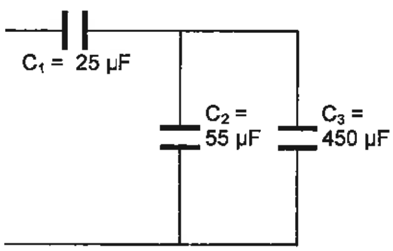
1.



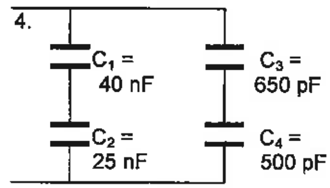
2.



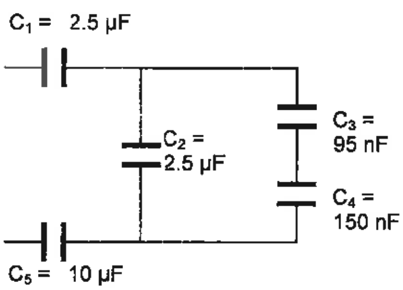
3.



4.



5.



ANSWERS

1. The total capacitance of this configuration is **31 pF**.
2. The total capacitance of this configuration is **2.69 µF**.
3. The total capacitance of this configuration is **23.8 µF**. (C_A = 505 µF)
4. The total capacitance of this configuration is **15.7 nF**. (C_A = 15.38462 nF and C_B = 282.608696 pF)
5. The total capacitance of this configuration is **1.12 µF**. (C_A = 58.16327 nF and C_B = 2.558163 µF)

WORKSHEET # 18: CAPACITIVE REACTANCE

1. Find the capacitive reactance of a 450 pF capacitor at:
    a. 50 Hz
    b. 2 KHz
    c. 15 KHz

2. Find the capacitive reactance of a 12 μF capacitor at:
    a. 50 Hz
    b. 2 KHz
    c. 15 KHz

3. What is the effect of increasing the frequency on the resulting capacitive reactance? Why?

4. What is the effect of increasing the size of the capacitor on the resulting capacitive reactance? Why?

5. Find the capacitive reactance of three 800 μF capacitors in series at 400 Hz.

6. Find the capacitive reactance of three 800 μF capacitors in parallel at 400 Hz.

7. How much current flows in a circuit with a capacitive reactance of 48 KΩ when 50 V_{AC} at 50 Hz is applied?

8. What voltage must be applied to a circuit having a capacitive reactance of 500 Ω to cause 25.6 mA of current?

9. What is the capacitive reactance of a circuit with 875 μA of current and 890 mV_{AC} applied?

ANSWERS

1. a. $X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(50\ Hz)(450\ pF)}$

$= 7073.55302\ \Omega$

The capacitive reactance is 7.07 KΩ

b. $X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(2\ KHz)(450\ pF)}$

$= 176.83883\ \Omega$

The capacitive reactance is 177 Ω

c. $X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(10\ KHz)(450\ pF)}$

$= 35.36777\ \Omega$

The capacitive reactance is 35.4 Ω

2. a. $X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(50\ Hz)(12\ \mu F)}$

$= 265.258238\ \Omega$

The capacitive reactance is 265 Ω

b. $X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(2\ KHz)(12\ \mu F)}$

$= 6.631456\ \Omega$

The capacitive reactance is 6.63 Ω

c. $X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(10\ KHz)(12\ \mu F)}$

$= 1.32629\ \Omega$

The capacitive reactance is 1.33 Ω

3. The capacitive reactance **decreases** because it is inversely proportional to frequency.
4. The capacitive reactance **decreases** because it is inversely proportional to the amount of capacitance.

5. $C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$

$= \frac{1}{\frac{1}{800\ \mu F} + \frac{1}{800\ \mu F} + \frac{1}{800\ \mu F}}$

$= 266.66667\ \mu F$

$X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(400\ Hz)(266.66667\ \mu F)}$

$= 1.492078\ \Omega$

The inductive reactance is 1.49 Ω

6. $C_T = C_1 + C_2 + C_3$

$= 800\ \mu F + 800\ \mu F + 800\ \mu F$

$= 2.4\ nF$

$X_C = \frac{1}{2\pi f C}$

$= \frac{1}{(2\pi)(400\ Hz)(2.4\ nF)}$

$= 165786.39905\ \Omega$

The inductive reactance is 166 MΩ

7. $I = \frac{E}{X_C} \quad = \frac{50\ V_{AC}}{48\ K\Omega} \quad = 0.0010416667\ A$

The current in this circuit is 1.04 mA

8. $I = \frac{E}{X_C} \quad E = I \times X_C \quad = 25.6\ mA \times 500\ \Omega \quad = 12.8\ V_{AC}$

The voltage applied to this circuit is 12.8 V_{AC}

9. $I = \frac{E}{X_C} \quad X_C = \frac{E}{I} \quad = \frac{890\ mV_{AC}}{875\ \mu A} \quad = 1017.14286\ \Omega$

The inductive reactance of this circuit is 1.02 KΩ

WORKSHEET # 19: TRANSFORMERS

1. What is the turns ratio of a transformer having 2275 turns on the primary winding and 15 925 turns on the secondary winding? What kind of transformer is it?

2. What is the turns ratio of a transformer having 23 760 turns on the primary winding and 17 820 turns on the secondary winding? What kind of transformer is it?

3. A transformer has a turns ratio of 5 with 15 000 turns on the secondary winding. How many turns are on the primary winding? What kind of transformer is it?

4. A transformer has a turns ratio of 0.25 with 2400 turns on the primary winding. How many turns are on the secondary winding? What kind of transformer is it?

5. A transformer has a turns ratio of 1 with 1225 turns on the primary winding. How many turns are on the secondary winding? What kind of transformer is it?

6. A transformer with a turns ratio of 7 has 10 V_{AC} applied. What is E_S?

7. A transformer with a turns ratio of 0.625 has an I_S of 420 mA. What is I_P?

8. What is the P_S of a transformer with an E_P of 50 V_{AC} and an I_P of 2 mA?

9. Solve for all unknown values for a transformer with a turns ratio of 9, N_P = 36 300, P_S = 4.4 W and E_P = 220 V_{AC}.

	PRIMARY	SECONDARY
N		
E		
I		
P		

10. Solve for all unknown values for a transformer with a turns ratio of 0.04, N_S = 130, I_S = 23 mA and E_S = 2.4 V_{AC}.

	PRIMARY	SECONDARY
N		
E		
I		
P		

ANSWERS

1. Turns ratio = $\frac{N_S}{N_P} = \frac{15\,925}{2275} = 7$

   The turns ratio is 7. The transformer is a step-up.

2. Turns ratio = $\frac{N_S}{N_P} = \frac{17\,820}{23\,760} = 0.75$

   The turns ratio is 0.75. The transformer is a step-down.

3. Turns ratio = $\frac{N_S}{N_P}$ $\quad N_P = \frac{N_S}{\text{turns ratio}} = \frac{15\,000}{5} = 3000$

   There are 3000 turns on the primary. The transformer is a step-up.

4. Turns ratio = $\frac{N_S}{N_P}$

   $N_S = N_P \times \text{turns ratio}$
   $= 2400 \times 0.25$
   $= 600$

   There are 600 turns on the secondary. The transformer is a step-down.

5. Turns ratio = $\frac{N_S}{N_P}$

   $N_S = N_P \times \text{turns ratio}$
   $= 1225 \times 1$
   $= 1225$

   There are 1225 turns on the secondary. The transformer is an isolation type.

6. $E_S = E_P \times \text{turns ratio}$
   $= 10\ V_{AC} \times 7$
   $= 70\ V_{AC}$

   The voltage felt across the secondary winding of this transformer is 70 V_{AC}.

7. $I_S = \frac{I_P}{\text{turns ratio}}$

   $I_P = I_S \times \text{turns ratio}$
   $= 420\text{ mA} \times 0.625$
   $= 262.5\text{ mA}$

   The current in the primary winding is 263 mA.

8. $P_P = I_P \times E_P$
   $= 2\text{ mA} \times 50\ V_{AC}$
   $= 100\text{ mW}$

   $P_S = P_P$
   $P_S = 100\text{ mW}$

   The power in the secondary winding is 100 mW.

9.

	PRIMARY	SECONDARY
N	36 300	326 700
E	220 V_{AC}	1980 V_{AC}
I	20 mA	2.22 mA
P	4.4 W	4.4 W

$P_P = P_S$
$P_P = 4.4\ W$

$I_P = \frac{P_P}{E_P} = \frac{4.4\ W}{220\ V_{AC}} = 20\ mA$

$E_S = E_P \times \text{turns ratio}$
$= 220\ V_{AC} \times 9$
$= 1980\ V_{AC}$

$I_S = \frac{I_P}{\text{turns ratio}} = \frac{20\ mA}{9} = 2.22\ mA$

$N_S = N_P \times \text{turns ratio}$
$= 36\ 300 \times 9$
$= 326\ 700$

10.

	PRIMARY	SECONDARY
N	3250	130
E	60 V_{AC}	2.4 V_{AC}
I	920 µA	23 mA
P	55.2 mW	55.2 mW

$N_P = \frac{N_S}{\text{turns ratio}} = \frac{130}{0.04} = 3250$

$E_P = \frac{E_S}{\text{turns ratio}} = \frac{2.4\ V_{AC}}{0.04} = 60\ V_{AC}$

$I_P = I_S \times \text{turns ratio}$
$= 23\ mA \times 0.04$
$= 920\ \mu A$

$P_P = I_P \times E_P$
$= 920\ \mu A \times 60\ V_{AC}$
$= 55.2\ mW$

$P_S = P_P$
$P_S = 55.2\ mW$

APPENDIX C

LAB 1-6C: CELL CONFIGURATIONS

Objective: To predict by calculation and confirm by measurement the total voltage of cells in series, parallel and series-parallel configurations.

Materials/Equipment Required: four C or D cells, 22 gauge hook up wire, wire strippers, masking tape, Multimeter

Procedure:

1. Label each cell as A, B, C and D using small pieces of masking tape.
2. Using the multimeter, measure and record each cell's voltage in the data table provided. Be sure to place the red lead on the anode and the black lead on the cathode, and to use the lowest possible scale for accuracy.

Series Configurations

3. Draw the schematic for cells A and B connected in series indicating the cathode and anode of the battery (combined cells).
4. From the measurements taken in Step 2, calculate and record E_T for this configuration, showing your equation, in the space provided.
5. Using small pieces of masking tape to hold hook up wire in place, connect the cells in series.
6. Using the multimeter, measure the battery voltage and record it in the space provided.
7. Repeat Steps 3 to 6 for cells B, C and D in series.

Parallel Configurations

8. Draw the schematic for cells C and D connected in parallel indicating the cathode and anode of the battery.
9. From the measurements taken in Step 2, calculate and record E_T for this configuration, showing your equation, in the space provided.
10. Using small pieces of masking tape to hold hook up wire in place, connect the cells in parallel.
11. Using the multimeter, measure the battery voltage and record it in the space provided.
12. Repeat Steps 8 to 11 for cells A, B and C in parallel.

Series-Parallel Configurations

13. Draw the schematic for two parallel strings of two cells in series. One string is to have cells A and B in series. The other string is to have cells C and D in series.
14. From the measurements taken in Step 2, calculate and record E_T for this configuration, showing your equation, in the space provided.
15. Using small pieces of masking tape to hold hook up wire in place, connect the cells in series-parallel.
16. Using the multimeter, measure the battery voltage and record it in the space provided.

Conclusion

17. Write three conclusions/observations concerning cell configurations proven by this lab.

Data Summary:

Cell A	Cell B	Cell C	Cell D

Cells A and B in series

Schematic:

Calculation of E_T: Measurement of E_T:

Cells B, C and D in series

Schematic:

Calculation of E_T: Measurement of E_T:

Cells C and D in parallel

Schematic:

Calculation of E_T: Measurement of E_T:

Cells A, B and C in parallel

Schematic:

Calculation of E_T: Measurement of E_T:

Cells A, B, C and D in series-parallel

Schematic:

Calculation of E_T: Measurement of E_T:

Conclusions:

1.
2.
3.

FAMILIARIZATION ACTIVITY

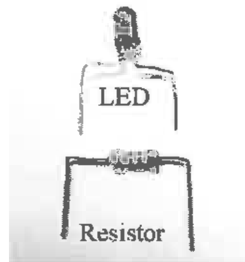
Objectives: Familiarization with the XK-150 Digital/Analog Trainer and M-3800 multimeter by completing the following activities:

a. set up and measure the variable power supply for specified voltages, and

b. build and test simple LED (Light Emitting Diode) circuits.

Materials and Equipment Required:

XK-150 Digital/Analog Trainer
M-3800 multimeter
22 gauge jumper wire (red and black)
Two Light Emitting Diodes (LED's), of any colour
Two resistor with colour bands of red, red, red, gold.
(The resistor body colour does not matter.)



Procedure:

PART A

☐ 1. Make sure the trainer is turned **OFF** but plugged into the wall supply.

☐ 2. Make sure the multimeter is turned **OFF**. Insert the black meter lead into the **COM** jack of the meter and the red meter lead into the **V/Ω** jack. Set the multimeter to the **200 DCV** scale.

☐ 3. Insert the red meter lead into the hole on top of the red binding post of the power supply.

☐ 4. Insert the black meter lead into the hole on the top of the black binding post of the power supply.

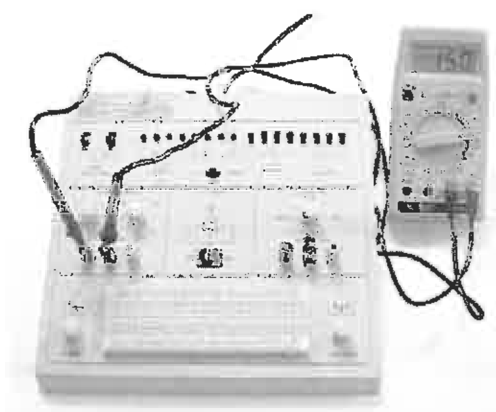
☐ 5. Rotate the positive power supply control to its full counter-clockwise position (OFF).

☐ 6. Turn **ON** both the multimeter and the trainer.

☐ 7. You should read approximately 1.2 V on the meter. The power supply does not turn all the way down to 0 V.

☐ 8. Slowly rotate the control knob to its full clockwise position while observing the reading on the meter. You should read about 18 V.

☐ 9. Adjust the power supply to have an output of 10.0 V.

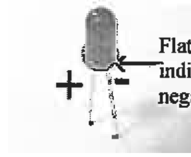


☐ 10. Turn the meter scale to **20 DCV** and observe the meter reading. The measurement is accurate to two decimal places.

☐ 11. Turn the meter scale to **1000 DCV** and observe the reading. The measurement is only accurate to the nearest whole volt.

☐ 12. Turn the meter scale back to **20 DCV** and adjust the power supply to 2.20 V.

☐ 13. Momentarily turn the multimeter switch to the **2 DCV** scale and observe the reading. Since the maximum voltage for the scale has been exceeded, the meter shows a ***1*** on the far left of the display. DO NOT overload the meter for any longer than it takes to observe the overload reading.



☐ 14. Turn **OFF** both the meter and the trainer. Remove the meter leads from the trainer and turn the power supply down to its full counter-clockwise position.

PART B:

☐ 1. Loosen the cap on the red and black binding posts.

☐ 2. Insert a 4" length of black jumper wire through the hole in the black binding post and tighten the cap. Insert the other end of the wire into hole ***20-a***.

☐ 3. Insert a 4" length of red jumper wire through the hole in the red binding post and tighten the cap. Insert the other end of the wire into hole ***1-a***.

☐ 4. Insert one end of the resistor into hole ***1-b*** and the other end into hole ***10-b***.

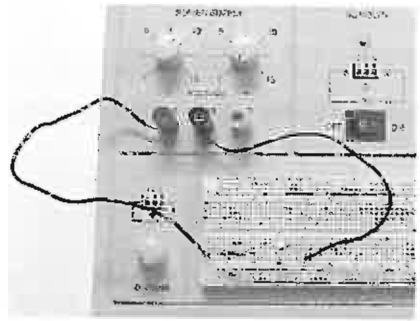


DIAGRAM A

☐ 5. Insert the negative end of the LED into hole ***20-c*** and the positive end into hole ***10-c***. Your set up should look like DIAGRAM A.

> The diode and the resistor are in series. They are connected, end to end, in row ***10*** since the holes ***a*** to ***e*** are the same electrical point.

☐ 6. Switch the multimeter to the **20 DCV** scale. Turn **ON** both the trainer and the multimeter.

☐ 7. Set the power supply to 5 V. The LED should be lit. If it does not light, turn off the equipment and check all of your connections. Make sure the leads of the LED are not reversed.

☐ 8. Measure the voltage across holes ***1-a*** and ***20-a*** by touching the red meter lead to the bare wire going into hole ***1-a*** and touching the black meter lead to the bare wire going into hole ***20-a***. (The tips of the meter leads are too big to insert into the holes. Forcing them in will damage the breadboard! The measurement is just as accurate by touching the bare wires instead.)

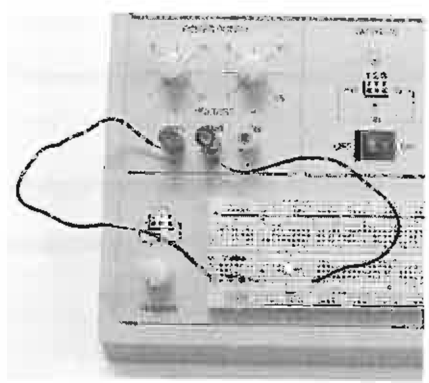


DIAGRAM B

☐ 9. Measure the voltage across the resistor. It should be approximately 3.3 V.

□ 10. Measure the voltage across the diode. It should be approximately 1.7 V.

□ 11. Turn **OFF** both the meter and the trainer.

□ 12. Insert the other resistor in holes ***1-e*** and ***10e***. Your set-up should look like DIAGRAM B.

> The two resistors are now connected in parallel. Both left sides are connected in row *1* and both right sides are connected in row *10*.

□ 13. Switch the multimeter to the **20 DCV** scale. Turn **ON** both the trainer and the multimeter.

□ 14. Set the power supply to 5 V. The LED should be lit. If it does not light, turn off the equipment and check all of your connections. Make sure the leads of the LED are not reversed.

□ 15. Measure the voltage across each resistor. The measurements will be the same (approximately 3.2 V) because the resistors are in parallel.

□ 16. Turn **OFF** both the meter and the trainer.

□ 17. Move the black jumper wire to hole ***30-a***.

□ 18. Insert a second diode in series in the circuit by inserting the positive lead of the diode into hole ***20-d*** and the negative lead in hole ***30-d***. Your set-up should look like DIAGRAM C.

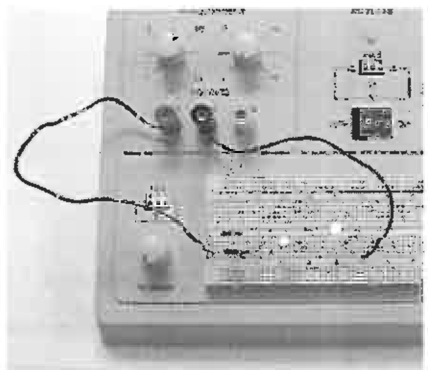


DIAGRAM C

> The two resistors are connected in parallel and the two diodes are in series.

□ 19. Switch the multimeter to the **20 DCV** scale. Turn **ON** both the trainer and the multimeter.

□ 20. Measure the voltage across the resistors. It should be approximately 1.4 V.

□ 21. Measure the voltage across both diodes. It should be approximately 3.6 V with each individually measuring about 1.8 V.

□ 22. Turn the trainer OFF and disassemble the circuit.

LAB # 1-25A: BUILDING AN ELECTROMAGNET

Objective: To build the strongest electromagnet possible from the materials given.

Materials/Equipment Required:

- two C or D cells
- wire strippers
- iron nails
- 22 gauge hook up wire (2 meters)
- masking tape
- paperclips or metal washers

Procedure:

1. Using only materials listed, construct an electromagnet and test its strength by determining how many paperclips or metals washers it can pick up.

2. Experiment with different cell configurations, wire-wrapping techniques and cores to strengthen your magnet.

3. Record your best number of paperclips and/or washers. (Note: You may have to prove this number in head-to-head competition!)

4. Using the left-hand rule for coils, determine and mark the North pole. Check with another team to verify attraction and repulsion of their electromagnet.

5. After the competition, disassemble your electromagnet.

6. Check for retentivity of magnetism in the nail. Bang it on a hard surface and re-check for retained magnetism.

7. Complete questions below.

Questions

1. Write out the steps you took to improve the strength of your electromagnet and the results.

2. What are the three factors that determine the strength of an electromagnet?

3. Describe the left-hand rule for coils.

4. Why did the nail retain magnetism?

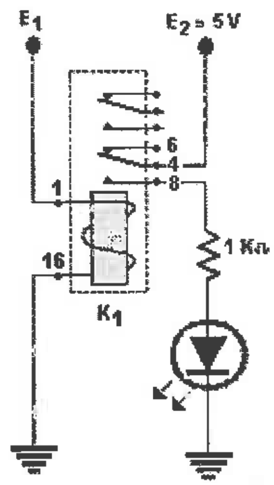
5. Why does striking the nail cause it to loose its magnetism?

LAB 1-25B: RELAYS

Objective: To observe the operation of a relay in a circuit.

Materials/Equipment Required: protoboard with power supply LED (any colour) DPDT relay (OMRON G5V-2) hook up wire 1 KΩ resistor

Procedure:



1. Construct the circuit shown to the right on your protoboard using the variable positive DC supply for E_1 and a regulated 5V supply for E_2. (The regulated 5V supply is located in the upper right quarter of your trainer.) Insert the relay so that it straddles the bridge between the two groupings of connection points. You can use the grounding post from the trainer's generator for the LED circuit's ground. Make sure the LED's negative side is connected to ground.

2. Start with the DC voltage supply turned all the way down to its lowest voltage. Slowly turn up the voltage until the relay pulls-in (energizes and causes the LED to light). If you listen closely, you may be able to hear the relay energize. You should repeat this step a few times to get the average voltage.

3. Measure and record the pull-in voltage across the relay coil.

4. Slowly turn down the voltage until the relay drops-out (de-energizes and causes the switch to open). Again, repeat this a few times to get the average voltage.

5. Measure and record the drop-out voltage across the relay coil.

6. Rebuild and test the circuit using the NC contacts of K_1.

Data:

Pull-in voltage:

Drop-out voltage:

Questions:

1. How does using the NC contacts in step 6 differ from using the NO contacts?
2. Describe the construction and operation of a DPDT relay.
3. Describe two basic, practical applications for relays: one using the NO contacts and one using the NC contacts.

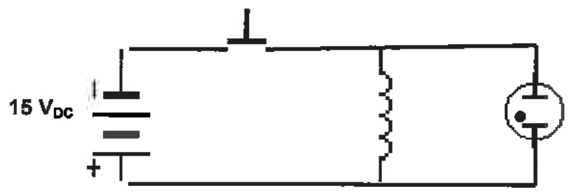
LAB 1-26A: INDUCTORS

Objective: To observe the operation of an inductor in a circuit.

Materials/Equipment Required: protoboard with power supply hook up wire neon lamp push button switch 112 V_{AC} step-down transformer

Procedure:

1. Construct the following circuit on your protoboard using the primary winding of the transformer as the inductor.



2. Depress the switch and release it. The neon lamp should light when the circuit is opened.

Questions

1. Explain why the lamp lights when the switch is opened.

2. Explain what would happen if the neon lamp was replaced with a spark plug.

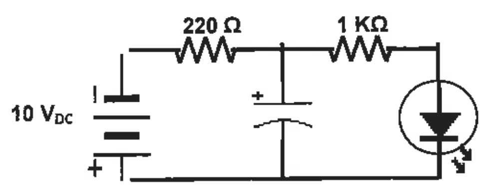
LAB 1-28A: CAPACITORS

Objective: To observe the operation of a capacitor in a circuit.

Materials/Equipment Required: protoboard with power supply hook up wire LED 220 Ω resistor 1 KΩ resistor 1000 µF capacitor

Procedure:

1. Construct the following circuit on your protoboard. Make sure to observe the correct polarity for both the LED and the capacitor.



2. Turn the trainer ON for a few seconds and then turn it OFF. Observe that the LED remains lit for a few seconds after the circuit power is turned off.

Questions

1. Explain why the LED stays lit after the trainer is turned off.

2. How does a capacitor store electrical energy?

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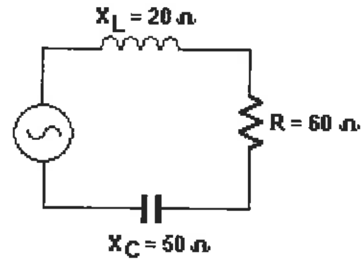
Calculating Impedance Using Vector Addition



The combined opposition to alternating current caused by inductance, capacitance and resistance is known as **impedance** (Z). Circuits having all three characteristics are known as LCR circuits. For this examination of calculating impedance, we will consider only series LCR circuits.

You may remember seeing the memory aid **ELI the ICE man** in this unit. The **ELI** reminds us that voltage (E) leads current (I) through an inductor (L). The **ICE** reminds us that current (I) leads voltage (E) through a capacitor (C). Therefore, there is a 180° phase difference between the current through inductors and capacitors in an LCR circuit. The current through resistors however, is in phase with the applied voltage.

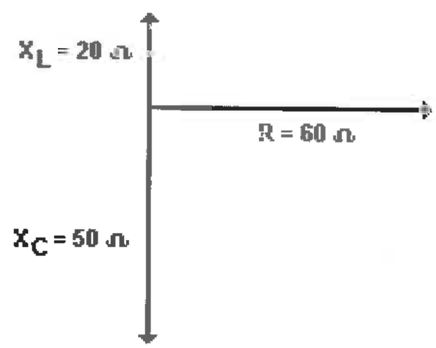
A vector diagram shows the magnitude and the direction of a quantity simultaneously. The following vector diagram is of the three oppositions in the above LCR circuit.

Because X_L and X_C are 180° out of phase, to find the net reactance, X_{NET}, of the circuit is simply a matter of subtraction:

$$X_{NET} = X_C - X_L$$

$$X_{NET} = 50\ \Omega - 20\ \Omega$$

$$X_{NET} = 30\ \Omega$$



The net reactance of the circuit is capacitive in characteristic since there is a greater value of X_C in the circuit than X_L. This means that the X_{NET} value is drawn in the X_C direction.

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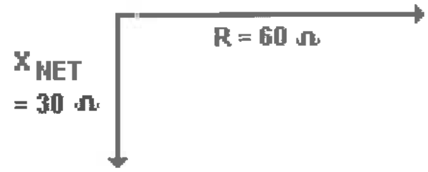
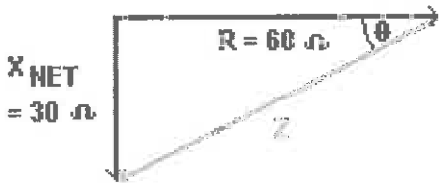
The redrawn vector diagram is shown using the X_{NET} value.





When you know any two sides of a right angle triangle, you can use Pythagorean's Theorem to calculate the third side. This will solve for the magnitude of the circuit impedance.

$$Z^2 = R^2 + X_{NET}^2$$

$$Z = \sqrt{R^2 + X_{NET}^2}$$

$$Z = \sqrt{60\,\Omega^2 + 30\,\Omega^2}$$

$$Z = \sqrt{4500}$$

$$Z = 67.082039\,\Omega$$

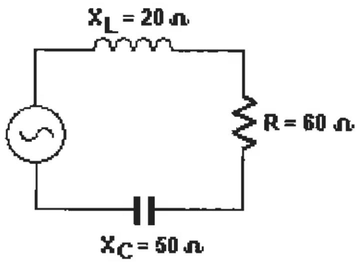
The phase angle of the series circuit (angle θ) is the angle whose tangent equals X_{NET} divided by R. The angle is negative in this example since the circuit's characteristic is capacitive. To find the angle, we apply the tan formula as follows:

$$\tan\theta = \frac{\text{opposite side}}{\text{adjacent side}} \quad \text{or} \quad \tan\theta = \frac{X_{NET}}{R}$$

$$\tan\theta = \frac{-30\,\Omega}{60\,\Omega}$$

$$\tan\theta = -0.5$$

$$\angle\theta = -26.6^{\circ}$$



Now, looking at our example circuit again, if we give I_T a value of 522 mA, since we know that current is common in a series circuit, the value of the current is the same for each of the components.

With this value, we can calculate each of the voltage drops around the circuit.

$E_{XL} = I \times X_L$	$E_{XC} = I \times X_C$	$E_R = I \times X_L$
$E_{XL} = 522\text{ mA} \times 20\ \Omega$	$E_{XC} = 522\text{ mA} \times 50\ \Omega$	$E_R = 522\text{ mA} \times 60\ \Omega$
$E_{XL} = 10.44\ V_{AC}$	$E_{XC} = 26.1\ V_{AC}$	$E_R = 31.32\ V_{AC}$

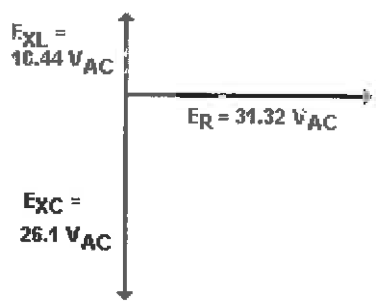
From Kirchoff's Voltage Law, we know that the sum of the voltage drops in any closed loop equals the applied voltage. BUT, since we're looking at an LCR circuit here, we must find their vectored sum.

To find the vector sum of the voltage drops, first sketch the vector diagram and find E_{XNET}.

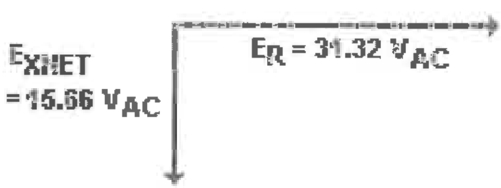
$E_{XNET} = E_{XC} - E_{XL}$

$E_{XNET} = 26.1\ V_{AC} - 10.44\ V_{AC}$

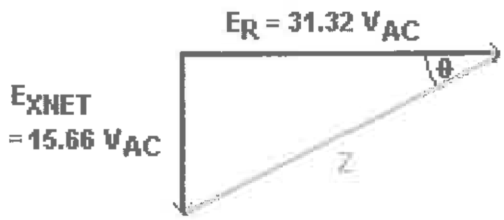
$E_{XNET} = 15.66\ V_{AC}$



Then redraw the vector diagram with the calculated E_{XNET} value:



Find the vector sum by using Pythagorean's Theorem:



$$Z^2 = E_R^2 + E_{XNET}^2$$

$$Z = \sqrt{E_R^2 + E_{XNET}^2}$$

$$Z = \sqrt{31.32\ V_{AC}^2 + 15.66\ V_{AC}^2}$$

$$Z = \sqrt{1226.178}$$

$$Z = 35.0168$$

The applied voltage is **35 V_{AC}**.

Find angle θ by using the tan formula:

$$\tan\theta = \frac{\text{opposite side}}{\text{adjacent side}} \quad \text{or} \quad \tan\theta = \frac{E_{XNET}}{E_R}$$

$$\tan\theta = \frac{-15.66\ V_{AC}}{31.32\ V_{AC}}$$

$$\tan\theta = -0.5$$

$$\angle\theta = -26.6^{o}$$

As you've probably noticed, it is the same angle we calculated earlier because the ratios are identical.

Since this circuit's overall reactance is capacitive, and in a capacitive circuit current leads voltage (**ELI** the **ICE** man), we know that the applied voltage of 35 V_{AC} lags the current by 26.6°.

In a series circuit, the reference is the current since current is common in series. That explains the negative angle. And while we're here, solving for parallel LCR circuits is similar except, you guessed it, voltage is common and the total current is the vectored sum of the branch currents.

Impedance is defined as the ratio of the applied effective voltage (E) to the effective current (I) in the circuit. As a formula:

$$Z = \frac{E}{I}$$

This formula should be very familiar to you since it is similar to the Ohm's Law formula with the **Z** substituted for the **R** in Ohm's Law.

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Once you know any two of the quantities, finding the third is as simple as using this formula. In the example shown, it wasn't really necessary to calculate the applied voltages with vectors, it was shown just to reinforce the concept (and because adding vectors is fun!). With the current value, we could have solved for the applied voltage once we had calculated Z and angle θ back on the second page.

$$Z = \frac{E}{I}$$

$$E = Z \times I$$

$$E = 67.082039\,\Omega \times 522\text{ mA}$$

$$E = 35.0168\ V_{AC}$$

The negative angle tells us that the applied voltage of 35 V_{AC} lags the current by 26.6°. Problem solved!

To sum up, to solve for all quantities in a **series LCR circuit**, either the total impedance or the applied voltage must be added by vector addition, depending upon which quantity you are given. Current is common and is the reference point for the resulting angle. With any two quantities, you can use the impedance formula to find the third.

For **parallel LCR circuits**, voltage is the common reference point, and impedance or the branch currents must be added by vectoring. Again with any two quantities, you can solve for the third with the impedance formula.

Series-parallel LCR circuits are solved by using redrawn equivalent circuits and the applicable method, either series or parallel.

One last point, when the inductive reactance and the capacitive reactance in a circuit are equal ($X_L = X_C$), the circuit is said to be at **resonance**. Because they cancel each other out, the circuit becomes purely resistive and draws the most current. The reactances become equal at one specific frequency which is known as the circuit's **resonant frequency**.

At resonant frequency, the energy stored in the circuit's capacitors equals the energy stored in the inductors but the maximums for each happen at alternate half cycles in the alternating current. The result is that the during the half cycle when the inductors magnetic field is collapsing, the counter emf produced charges the capacitor to its full amount. During the next half cycle, the capacitor's discharge builds the maximum magnetic field around the inductor. This passing back of forth of energy is known as **oscillation**. While it would seem that the energy transferred could be perpetual, there is a slight loss, or **damping**, during the oscillations. To prevent damping and sustain oscillation, the circuit requires a constant supply of AC energy from the source.

Circuits that are designed to oscillate at a specific resonant frequency are known as **oscillators**. When you tune a radio to a specific frequency, you are varying inductors and capacitors in the antenna circuit of the radio to their resonant frequency which is the carrier frequency of the radio station. The radio waves cause the antenna circuit to oscillate and the signal is strengthened (maximum current is produced at resonance) before being "decoded" by the subsequent radio circuits. That is why you can still hear a weak signal when a radio is tuned slightly above or below the resonant (station) frequency – maximum current is not yet reached.

Resonant frequency (f_o) is calculated by a formula that is derived from $X_L = X_C$ because, as just stated, at resonance the reactances are equal in magnitude. The formula for calculating the resonant frequency of a circuit is:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

To determine the resonant frequency of a circuit, the value of the total circuit inductance or the value of the total circuit capacitance, you simply manipulate the equation to isolate the unknown and use your calculator to do the rest. Remember that, at resonance a circuit is purely resistive and the voltage and current are in phase.

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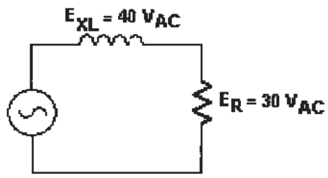
APPENDIX D

Problems

1. Determine the applied voltage and the phase angle of the following circuit. Does the voltage lead or lag the current? (Hint: There is no capacitor in the circuit so $X_C = 0\ \Omega$.)

3 marks

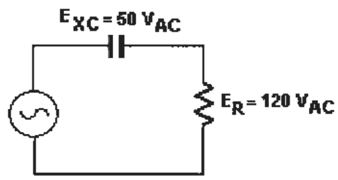


The applied voltage of ________ V_{AC}

leads/lags the current by _______°.

2. Determine the applied voltage and the phase angle of the following circuit. Does the voltage lead or lag the current?

3 marks

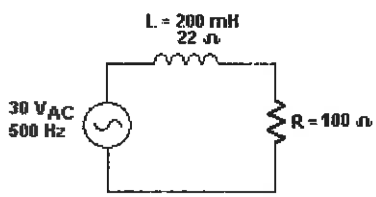


The applied voltage of ________ V_{AC}

leads/lags the current by _______°.

3. Determine the impedance, phase angle and effective current of the following circuit. The internal resistance of the inductor is 22 Ω. (Hint: The internal resistance of the coil must be used to determine the total resistance of the circuit.)

4 marks

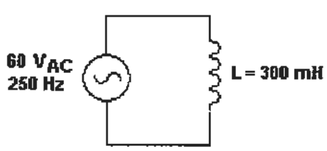


The applied voltage of leads/lags the current by _______°.

Z = __________ Ω   I = __________

4. A 300 mH Inductor draws 120 mA when it is connected to a 60 V_{AC}, 250 Hz source. Determine the reactance and the resistance of the inductor.

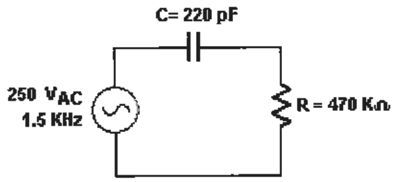
2 marks



X_L = _________ Ω   R = _________ Ω

5. Determine the impedance, phase angle and effective current of the following circuit:

4 marks

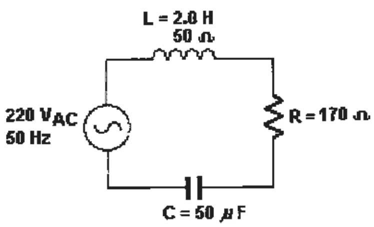


The applied voltage of leads/lags the current by _______°.

Z = ________ Ω   I = ________

6. Determine the impedance, phase angle and effective current of the following circuit:

4 marks

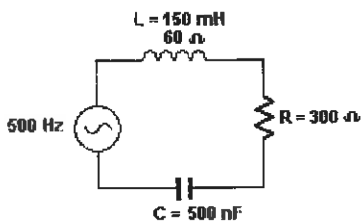


The applied voltage of leads/lags the current by _______°.

Z = ________ Ω   I = ________

7. Determine the impedance, phase angle and source voltage of the following circuit that draws 250 mA:

4 marks



The applied voltage of ________ V_{AC} leads/lags the current by ________°

Z = ________ Ω

8. Determine the resonant frequency of a series antenna circuit which has a resistance of 20 Ω, an inductance of 280 μH and a capacitance of 70 pF.

2 marks

9. What inductance must be placed in series with a 20 μF capacitor to produce a circuit with a resonant frequency of 3.0 KHz?

3 marks

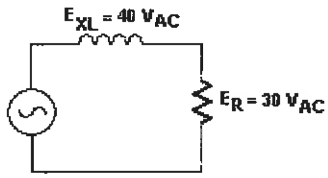
10. What capacitance must be placed in series with a 500 μH inductor to produce a circuit with a resonant frequency of 1.5 MHz?

3 marks

Answers to Problems

1. Determine the applied voltage and the phase angle of the following circuit. Does the voltage lead or lag the current? (Hint: There is no capacitor in the circuit so $X_C = 0\ \Omega$.)

3 marks

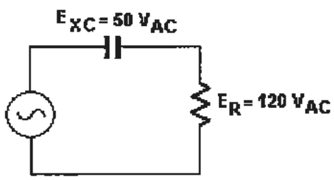


The applied voltage of __50_ V_{AC}

leads/~~lags~~ the current by _**53.1**__°.

2. Determine the applied voltage and the phase angle of the following circuit. Does the voltage lead or lag the current?

3 marks

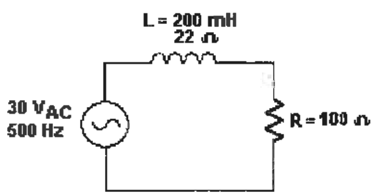


The applied voltage of __130__ V_{AC}

~~leads~~/lags the current by __**22.6**_°.

3. Determine the impedance, phase angle and effective current of the following circuit. The internal resistance of the inductor is 22 Ω. (Hint: The internal resistance of the coil must be used to determine the total resistance of the circuit.)

4 marks



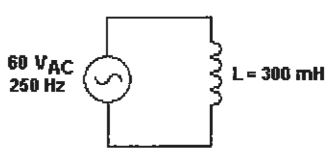
The applied voltage of **leads/~~lags~~** the current by _**79**_°.

Z = __640_ Ω

I = _**46.9 mA**__

4. A 300 mH inductor draws 120 mA when it is connected to a 60 V_{AC}, 250 Hz source. Determine the reactance and the resistance of the inductor.

2 marks

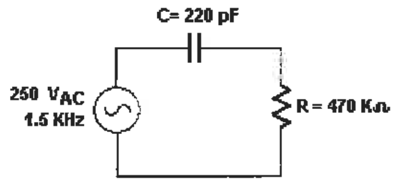


X_L = __**471**_ Ω

R = __**168**__ Ω

5. Determine the impedance, phase angle and effective current of the following circuit:

4 marks

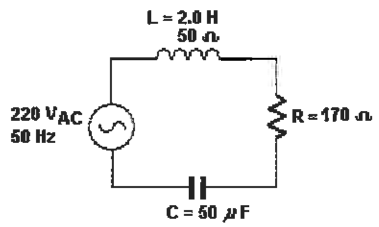


The applied voltage ~~leads~~/**lags** the current by _45.7_°.

Z = __673__ Ω   I = __371 μA__

6. Determine the impedance, phase angle and effective current of the following circuit:

4 marks

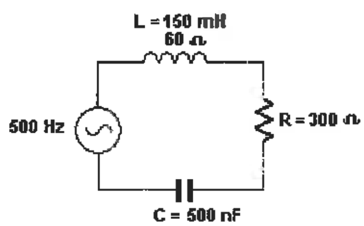


The applied voltage of **leads**/~~lags~~ the current by _68.7_°.

Z = _606__ Ω   I = _363 mA__

7. Determine the impedance, phase angle and source voltage of the following circuit that draws 250 mA:

4 marks



The applied voltage of _99_ V_{AC} ~~leads~~/**lags** the current by _24.6__°.

Z = _396__ Ω

8. Determine the resonant frequency of a series antenna circuit which has a resistance of 20 Ω, an inductance of 280 μH and a capacitance of 70 pF.   2 marks

1.14 MHz

9. What inductance must be placed in series with a 20 μF capacitor to produce a circuit with a resonant frequency of 3.0 KHz?   3 marks

141 μH

10. What capacitance must be placed in series with a 500 μH inductor to produce a circuit with a resonant frequency of 1.5 MHz?   3 marks

22.5 pF

Suggested Component Kit

(Prices shown do not include quantity discount.)

Qty	Part No	Description	Price	Subtot	1-12	1-13	1-14	1-16	1-21	1-22	1-23	1-24	1-25B	1-26A	1-28	1-28A	2-15
		Pre-Assembled Component Kits															
1	LED-5R	LED; 5mm, red	0.12	$0.12									X				
1	LED-5G	LED; 5 mm, green	0.11	$0.11									X				
1	LED-5Y	LED; 5 mm, yellow	0.11	$0.11									X				
2	R1/2-220	Resistor, 1/2 watt, 220 Ω	0.05	$0.10												X	
2	R1/2-470	Resistor, 1/2 watt, 470 Ω	0.05	$0.10	X	X	X	X	X	X	X	X					
2	R1/2-1K	Resistor, 1/2 watt, 1 KΩ	0.05	$0.10	X	X	X	X	X	X	X	X	X			X	
2	R1/2-2.2K	Resistor, 1/2 watt, 2.2 KΩ	0.05	$0.10	X	X	X	X	X	X	X	X					
2	R1/2-4.7K	Resistor, 1/2 watt, 4.7 KΩ	0.05	$0.10	X	X	X	X	X	X	X	X					
2	R1/2-10K	Resistor, 1/2 watt, 10 KΩ	0.05	$0.10	X	X	X	X	X	X	X	X					
1	OMRON G5V-2	5 VDC, DPDT	1.99	$1.99									X				
1	NO-110	Pushbutton Switch; NC	0.49	$0.49										X			
1	36HN010	110 VAC Neon Indicator	5.99	$5.99										X			
1	TRF-120	Transformer, Open Frame, 115V I/P	6.99	$6.99										X			X
1	TSW-130	Toggle Switch; SPDT (On-On)	1.89	$1.89											X		
1	470R50	Electrolytic Radial Capacitor; 470 µF	0.29	$0.29											X		
1	1000R16	Electrolytic Radial Capacitor; 1000 µF	0.35	$0.35												X	
1	35L300C	Indicator Lamp; 5 V	1.99	$1.99											X		
			Kit Total	$21.02													