DOCUMENT RESUME

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ABSTRACT

The Progress Check Booklet is designed to be used by the student working in the programed course to determine if he has mastered the concepts in the course booklets on: electrical current; voltage; resistance; measuring current and voltage in series circuits; relationships of current, voltage, and resistance; parellel circuits; combination circuits and voltage dividers, induction; relationships of current, counter EMF (electromotive force), and voltage in LR (inductive resistance) circuits; transformers; capacitance; series AC (alternating current) resistive-reactive circuits; series AC, RLC (inductive-resistive-capacitive) circuits and resonance; and parallel AC resistive-reactive circuits. Each progress check lesson consists of self-tests with the accompanying answers. Correct answers to all questions indicate to the student that he is ready to proceed to the next lesson. Appended are trigonometric tables and a summary of each of the modules. (Author/BP)

NAVEDTRA 34258-PC

BASIC ELECTRICITY AND ELECTRONICS

INDIVIDUALIZED LEARNING SYSTEM

PROGRESS CHECK MODULE

Progress Check Booklet

CHIEF OF NAVAL EDUCATION AND TRAINING

January 1974

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LESSON PROGRESS CHECKS

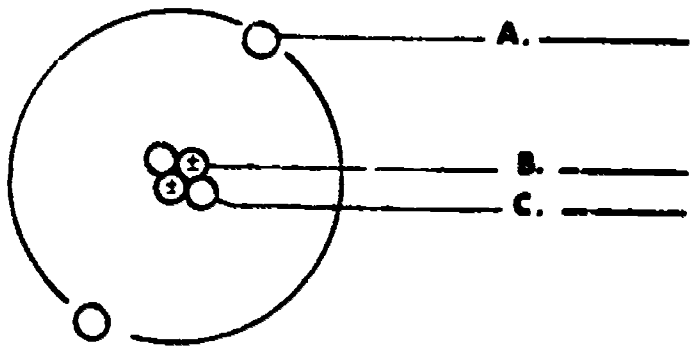
Record your answers in the spaces provided. When you have completed a lesson progress check, compare your answers to the correct answers. The correct answers are located at the end of each module along with blank pages for notes.

IF YOUR ANSWERS ARE ALL CORRECT, GO ON TO THE NEXT LESSON. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THAT LESSON UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRESS CHECK
LESSON I

Electricity and the Electron

1. Label the three particles indicated.



2. If a neutral atom contains 10 protons and 14 neutrons, it should contain:

____ a. 24 electrons.
____ b. 10 electrons.
____ c. 14 electrons.

3. The atomic particles which orbit the nucleus are:

____ a. protons.
____ b. neutrons.
____ c. electrons.

4. The nucleus of an atom is composed of:

____ a. electrons and neutrons.
____ b. protons and electrons.
____ c. protons, electrons, and neutrons.
____ d. neutrons and protons.

5. Protons and electrons normally are:

____ a. equal in number.
____ b. equal in size and weight.
____ c. found in the nucleus.

6. Electron movement is theoretical because:

____ a. the effects of electricity are unpredictable.
____ b. the existence of electricity is not positively known.
____ c. electron flow or movement cannot be directly observed.

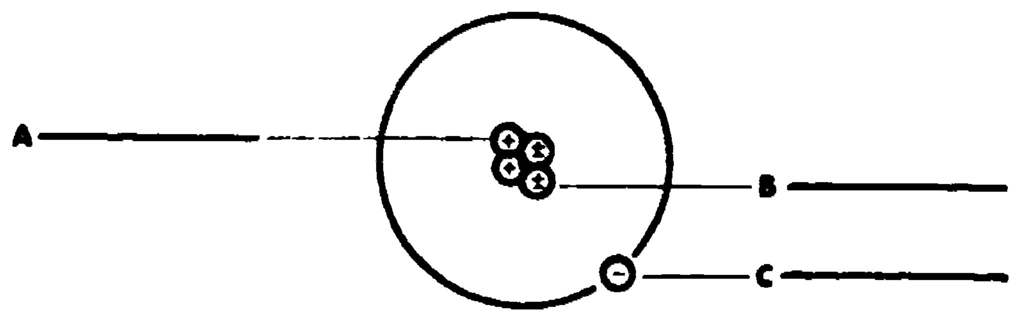
7. Which statement(s) is/are true?

____ a. The neutron is the lightest particle found in the atom.
____ b. Electricity is explained by the movement of protons.
____ c. The electron is the most mobile atomic particle.
____ d. All atoms have the same atomic structure and contain the same number of electrons, protons, and neutrons.
____ e. Atoms may differ from each other in the numbers of electrons, protons, and neutrons which make up their structure.

PROGRESS CHECK
LESSON II

Electron Movement

1. Label the atomic particles.



2. State the Law of Charged Bodies:

____

____

3. Match.

____ 1. two protons
____ 2. proton and electron
____ 3. (+) and (-)
____ 4. two electrons
____ 5. positive and negative
____ 6. (+) and (+)
____ 7. like charges
____ 8. unlike charges
____ 9. negative and negative
____ 10. positive and positive
____ 11. two neutrons

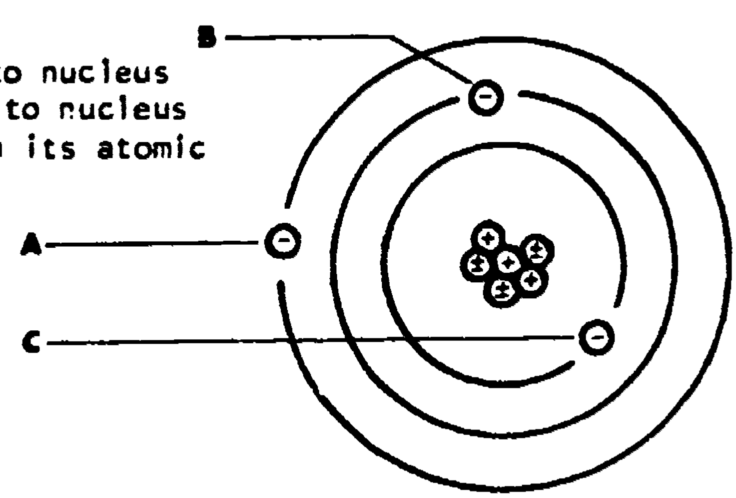
a. attraction

b. repulsion

c. neither

4. Match.

____ 1. weakest attraction to nucleus
____ 2. greatest attraction to nucleus
____ 3. easiest to free from its atomic orbit



5. Which correctly describes "random drift?'

____ a. the general movement of electrons in one direction through a wire.
____ b. the occasional straying of electrons from one nuclear orbit to another in the same atom.
____ c. the undirected movement of free electrons in a wire.
____ d. the haphazard movement of atoms in a wire.

6. Which correctly describes "free electrons?"

____ a. electrons which are no longer attached to an atom.
____ b. electrons which make up the outermost shell of an atom.
____ c. electrons which have become attached to another atom's nucleus.

7. When an electron is removed from a neutral atom the atom becomes a/an:

____ a. negative ion.
____ b. positive ion.
____ c. uncharged ion.
____ d. free ion.

8. The energy required to free an electron from it's parent atom is known as:

____ a. potential energy.
____ b. atomic energy.
____ c. ionization potential.
____ d. electromotive force.

Sound/Slide

Constructing a Simple Circuit

Self-Test
Module One - Lesson III

1. In the simple circuit, what device acts as the source?
   Answer ____________________

2. What device acts as the load?
   Answer ____________________

3. What is the function of the source?
   Answer ____________________

4. In a de-energized circuit, the switch is in the ________ position.
   open/closed.

5. The "blueprint" or plan used for constructing a simple circuit is called a ____________ diagram.

6. The negative terminal of a dry cell is the terminal ____________ of the cell.
   on the outer edge/in the center

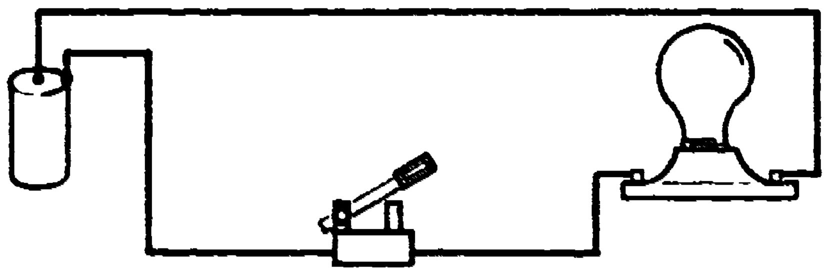
7. When wiring a circuit, the switch should be ________.
   open/closed.

1. a cell or battery; 2. a lamp; 3. provides the force that causes current to flow; 4. open; 5. schematic; 6. on the outer edge; 7. open

PROGRESS CHECK
LESSON III

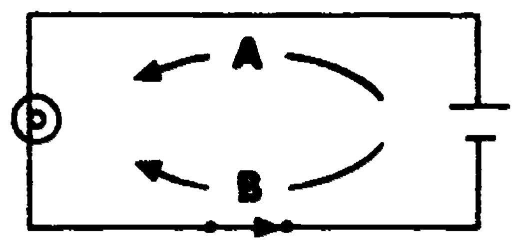
Current Flow

1. Draw a schematic of the circuit shown below.



2. Which arrow correctly shows the direction of current flow?

____

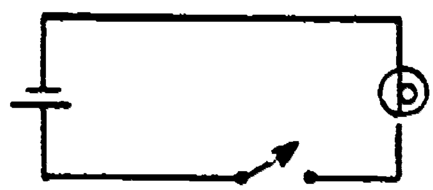


3. Which correctly describes electron current flow?

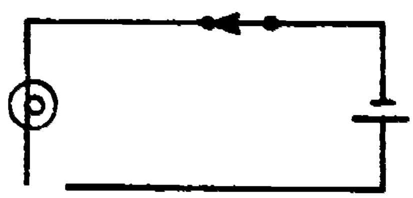
____ a. free electrons moving in one direction.
____ b. the directed drift of positive and negative charges through a wire.
____ c. the drifting of outermost electrons away from their atomic nuclei.
____ d. the random drift of electrons in a conductor.

4. In which circuit will current flow?

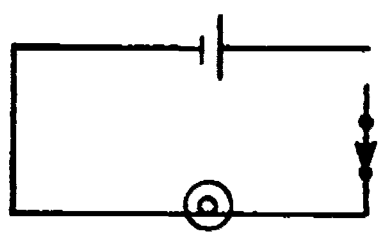
____ a.



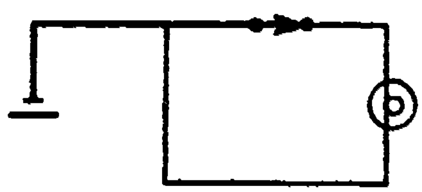
____ b.



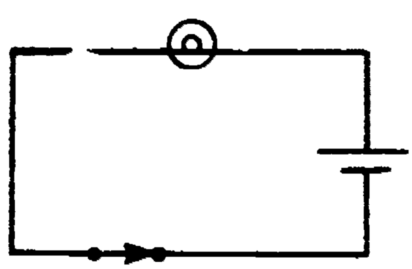
____ c.



____ d.



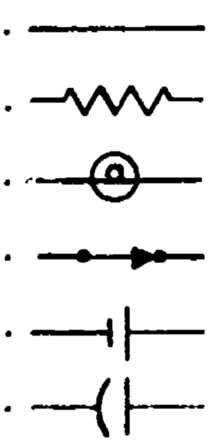
____ e.



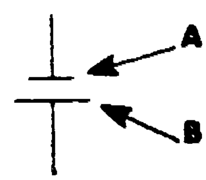
5. Match.

____ 1. cell
____ 2. switch
____ 3. lamp
____ 4. conductor

a.
b.
c.
d.
e.
f.



6. Which arrow points to the negative terminal? ____________



7. Which statement(s) is/are true?

____ a. Current will not flow in a circuit unless there is a complete path.
____ b. When a circuit is closed, there is an incomplete path.
____ c. A circuit is open when there is an incomplete path.
____ d. Current flow in a conductor is from positive to negative.

PROGRESS CHECK
LESSON IV

Measurement of Current

1. How many electrons constitute a coulomb of charge? ________

2. When two coulombs of charge pass a given point in one-half second, the current is:

____ a. 2 amperes.
____ b. 4 amperes.
____ c. 0.5 amperes.
____ d. 1 ampere.

3. Which formula is used to determine current flow?

____ a. $Q = \frac{t}{I}$

____ b. $I = \frac{Q}{t}$

____ c. $I = Q \times t$
____ d. $t = Q \times I$

4. Convert to scientific notation.

____ a. 210
____ b. 0.0431
____ c. 83,000
____ d. 0.001

5. Convert to decimal numbers.

____ a. 10^3
____ b. 10^{-1}
____ c. 10^{-3}
____ d. 10^5

6. Convert to amperes (use scientific notation).

____ a. 20 ma
____ b. 4 ma
____ c. 5 μa
____ d. 30 μa

7. Convert to microamperes (use scientific notation).

____ a. 0.003 a
____ b. 0.010 a
____ c. 0.000004 a
____ d. 0.000020 a

Sound/Slide

The Ammeter

Self-Test
Module One - Lesson V

1. The unit of measure for current is the ________________.
2. On an ammeter, the black terminal is ____________ and the red terminal is ______________.
3. What indicates that an ammeter is connected with incorrect polarity?
   Answer: ____
4. When an ammeter is to be connected into a circuit, the first step is
   ____.
5. When an ammeter is properly connected into a simple circuit, the meter is connected so that:
   a. only a small amount of the total current will pass through the meter.
   b. all of the current flowing in the circuit will pass through the meter.

   Answer: ____
6. A milliampere is equal to ________________ ampere(s).
7. The name for one millionth of an ampere is one ______________ ampere.
8. It is good practice to select a meter having a range ____________ than you expect to measure. greater/smaller

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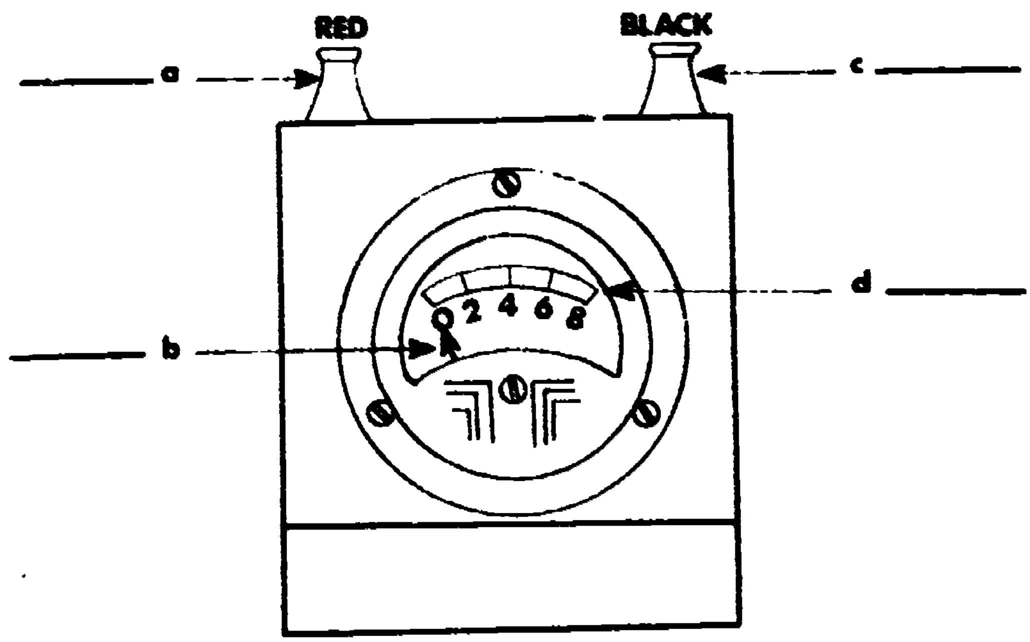
1. ampere; 2. negative, positive (in that order); 3. The pointer will deflect in the wrong direction; 4. de-energize the circuit; 5. b; 6. 1/1000; 7. micro; 8. greater

PROGRESS CHECK
LESSON V

The Ammeter

1. Label the parts of the ammeter.

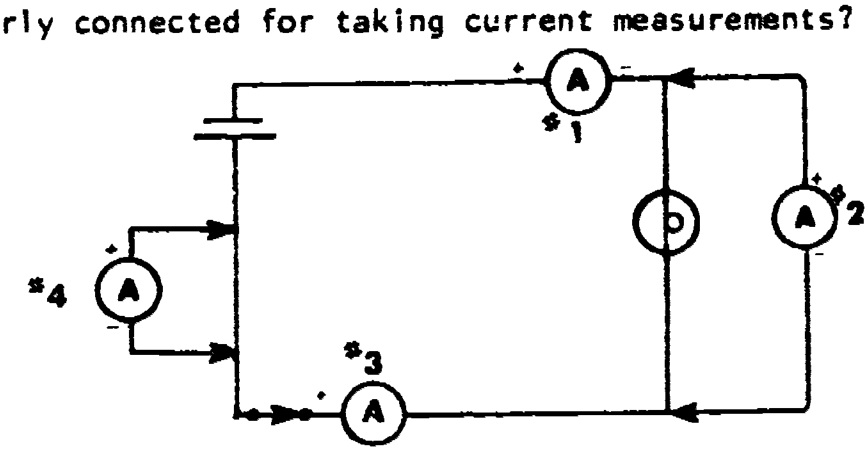


2. Which statement(s) is/are true?

____ a. The basic unit of electron current is the ampere.
____ b. When measuring current, the ammeter must be connected in parallel.
____ c. The ammeter is used to measure coulombs per second and is represented schematically by —(A)—
____ d. Polarity must be observed when connecting the ammeter into the circuit.
____ e. Current readings will be higher when the ammeter is connected near the negative terminal of the cell than when connected near the positive terminal.

3. Which meter is properly connected for taking current measurements?

____ a. Meter #1
____ b. Meter #2
____ c. Meter #3
____ d. Meter #4



4. Which correctly lists the steps for hooking up an ammeter and recording current?

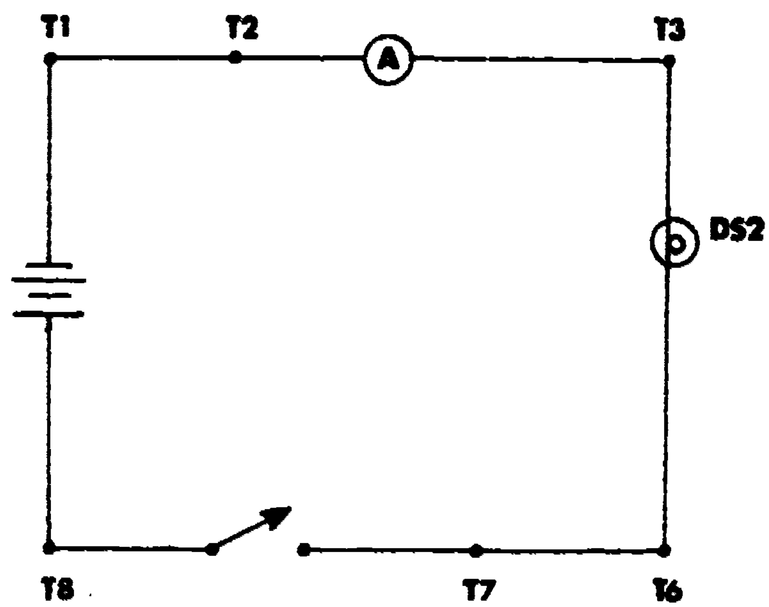
____ a. (1) Place switch in closed position.
(2) Break circuit and connect meter in series (observe polarity).
(3) Place switch in open position and take current reading.

____ b. (1) De-energize circuit.
(2) Connect leads, placing the meter in series and observing polarity.
(3) Energize circuit and take current reading.

____ c. both

____ d. neither

5. Build the circuit shown below. Then record the current in the blank below.



I = ____________________

PROGRESS CHECK ANSWERS
MODULE ONE

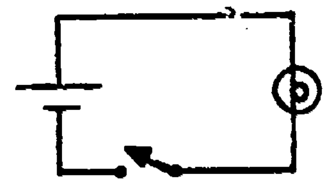
LESSON I

1. a. electron
   b. neutron
   c. proton
2. b
3. c
4. d
5. a
6. c
7. c, e

LESSON II

1. a. proton
   b. neutron
   c. electron
2. Like charges repel and unlike charges attract.
3. 1-b 7-b
   2-a 8-a
   3-a 9-b
   4-b 10-b
   5-a 11-c
   6-b
4. 1-a
   2-c
   3-a
5. c
6. a
7. b
8. c

LESSON III

1. 
2. b
3. a
4. e
5. 1-e
   2-d
   3-c
   4-a
6. a
7. a, c

LESSON IV

1. 6,250,000,000,000,000,000 or 6.25×10^{18} electrons
2. b
3. b
4. a. 2.1×10^{2}
   b. 4.31×10^{-2}
   c. 8.3×10^{4}
   d. 1×10^{-3}
5. a. 1000
   b. 0.1
   c. 0.001
   d. 100,000
6. a. 2×10^{-2}a
   b. 4×10^{-3}a
   c. 5×10^{-6}a
   d. 3×10^{-5}a
7. a. $3 \times 10^{3}\mu$a
   b. $1 \times 10^{4}\mu$a
   c. $4 \times 10^{0}\mu$a
   d. $2 \times 10^{1}\mu$a

LESSON V

1. a. positive termiral
   b. pointer (needle)
   c. negative terminal
   d. meter dial (scale)
2. a, c, and d
3. c
4. b
5. About 0.2 amps

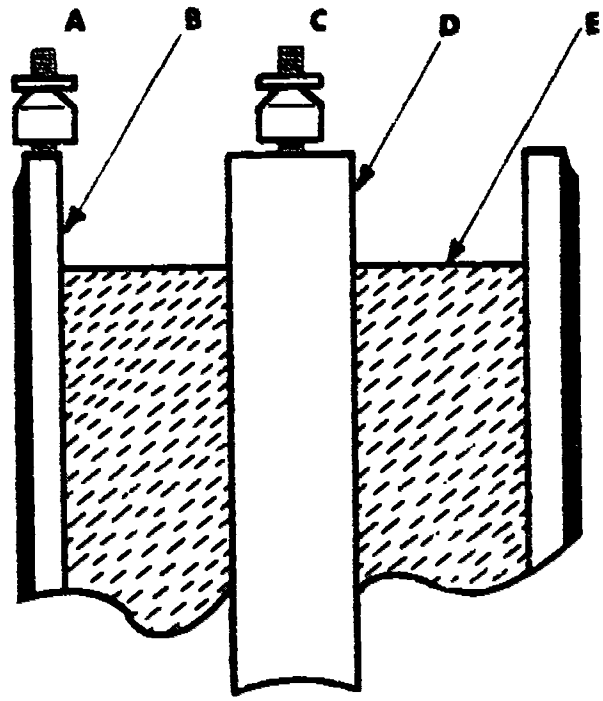
IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

MODULE TWO

PROGRESS CHECK
LESSON I

EMF From Chemical Action

1. Match.

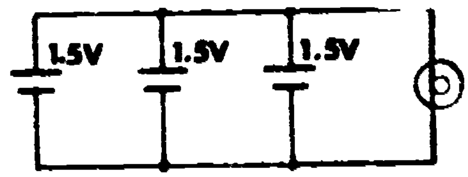


____ 1. carbon electrode
____ 2. negative terminal
____ 3. zinc electrode
____ 4. electrolyte
____ 5. positive terminal

2. Current flow inside a dry cell is from:

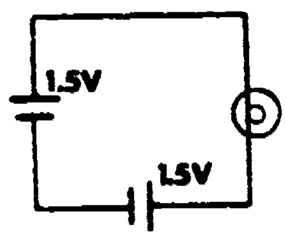
____ a. positive to negative
____ b. negative to positive.

3. Identify the kind of cell connection used in each circuit and the amount of voltage being applied to the lamp.

a. 

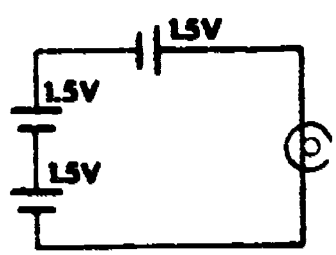
cell connection: ____

voltage at lamp: ____

b. 

cell connection: ____

voltage at lamp: ____

c. 

cell connection: ____

voltage at lamp: ____

4. Which statement(s) is/are true?

____ a. Terminals of the opposite polarity are connected together in a series aiding connection.
____ b. Terminals of the same polarity are connected together in a series opposing connection.
____ c. Both.
____ d. Neither.

5. Which statement(s) about electromotive force is/are true?

____ a. EMF is a force which tends to move electrons.
____ b. EMF is the same as voltage.
____ c. EMF is generated by the chemical energy released as a result of mechanical work on the cell.
____ d. EMF causes an accumulation of opposite charges on a cell's terminals.

6. Match.

____ 1. Voltage a. V
____ 2. Electromotive Force b. E
____ 3. Volt c. EMF

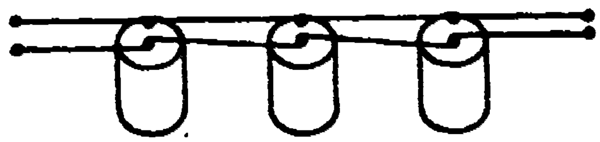
7. Match.

a. Series-aiding

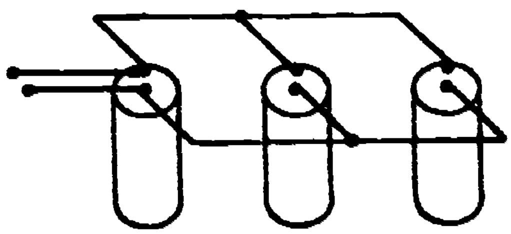
b. Series-opposing

c. Parallel

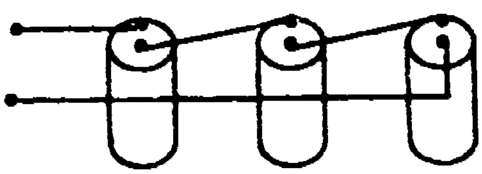
____ 1.



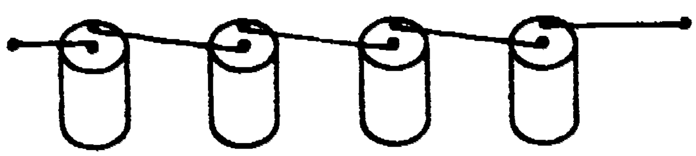
____ 2.



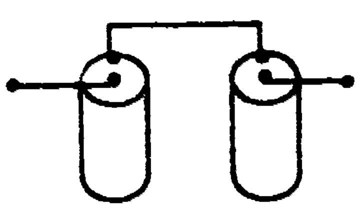
____ 3.



____ 4.



____ 5.



8. Convert to volts. (Use scientific notation.)

a. 10 mv ______________________ volts
b. 5 μv ______________________ volts
c. 4 kv ______________________ volts
d. 30 Mv ______________________ volts

9. Match.

____ 1. 3 μv		a. 0.005 v
____ 2. 5000 Kv		b. 30 μv
____ 3. 0.03 mv		c. 12 kv
____ 4. 5 mv		d. 5 Mv
____ 5. 0.000003 v		e. 0.003 mv
____ 6. 0.012 Mv		
____ 7. 12,000 v		

10. Convert values as indicated.

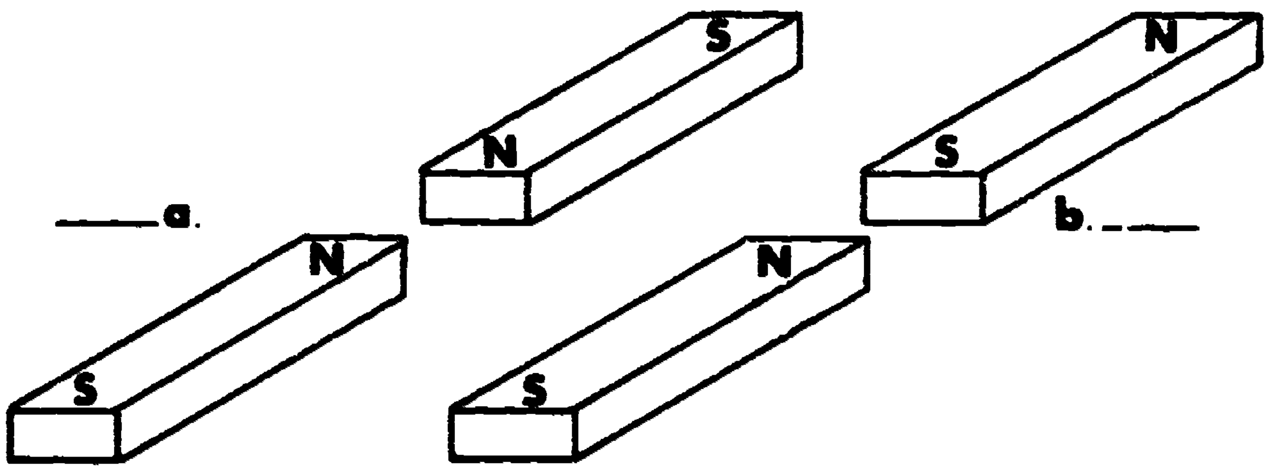
a. 5 volts to millivolts ______________________
b. 1 volt to microvolts ______________________
c. 4 millivolts to microvolts ______________________
d. 4 volts to kilovolts ______________________
e. 5×10^6 volts to megavolts ______________________
f. 3 megavolts to kilovolts ______________________
g. 1000 millivolts to volts ______________________
h. 1 microvolt to volts ______________________
i. 2 microvolts to millivolts ______________________
j. 3×10^4 kilovolts to megavolts ______________________
k. 1 kilovolt to megavolts ______________________

PROGRESS CHECK
LESSON II

Magnetism

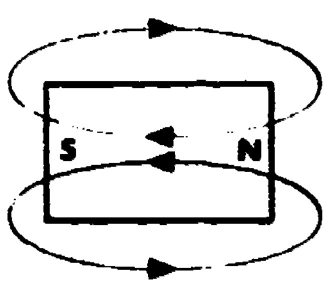
1. Which set of magnets will be attracted?

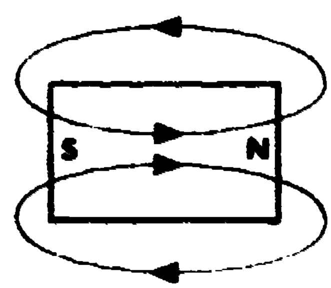
____ a. b. ____



2. Which diagram correctly shows the directional property of flux lines?

____ a. ____ b.



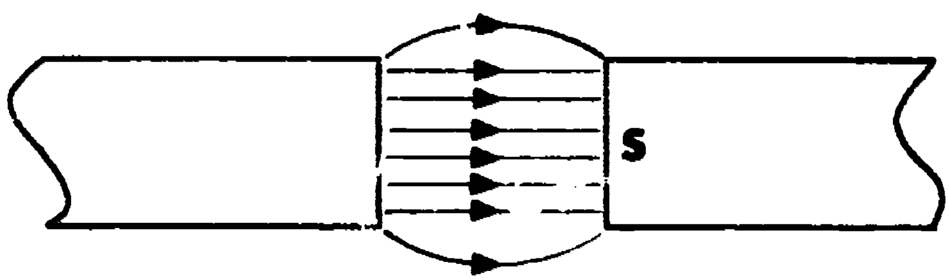


3. Which statement(s) is/are true?

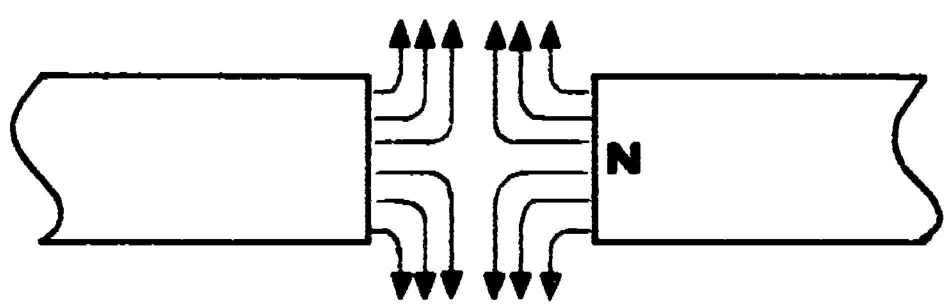
____ a. Opposite poles of a magnet have opposite magnetic polarity.
____ b. The force of magnetic attraction of a magnet is uniform throughout the magnet.
____ c. The magnetic attraction of a magnet is greatest at its center.
____ d. The magnetic force of a magnet is present only at its poles.
____ e. The magnetic force of a magnet surrounds the magnet in a field.

4. Label the unmarked bar magnets with N or S.

a.



b.



5. Which correctly states the Law of Magnetic Poles?

____ a. Lines of force repel each other.
____ b. Like magnetic poles repel; unlike poles attract.
____ c. Magnetic attraction will always be strongest at the poles.
____ d. Lines of magnetic force are polarized.

6. Which statement(s) is/are true?

____ a. The strength of a magnetic field at any point is indicated by the flux density.
____ b. Flux density for any magnet is greatest at its poles.
____ c. Flux density increases as distance from the poles increases.
____ d. A strong magnetic field contains few lines of flux.
____ e. The attraction for a piece of iron is strongest where the flux density is highest.

7. Around a magnet, the external lines of force:

____ a. leave the magnet from the north pole and enter the south pole.
____ b. often cross each other.
____ c. leave the magnet from the south pole and enter the north pole.
____ d. may be broken by a piece of iron shielding.

Sound/Slide

Electromagnetic Induction

Self-Test

Module Two - Lesson III

1. The left-hand rule is used to determine the direction of __________ flow in a generator.
2. When using the left-hand rule for generators, the thumb points in the direction of ____________, and the first finger in the direction of the ____________. The center finger will point in the direction of ____________.
3. If the field is moving rather than the conductor, the ____________ should point in the direction of ____________ motion of the conductor.
4. A magnetic field is always visualized as having a direction that is from ____________ to ____________.

1. current; 2. thrust or motion, field or flux, current flow (in that order); 3. thumb, relative; 4. north, south

PROGRESS CHECK
LESSON III

Electromagnetic Induction

1. Electromagnetic induction is:

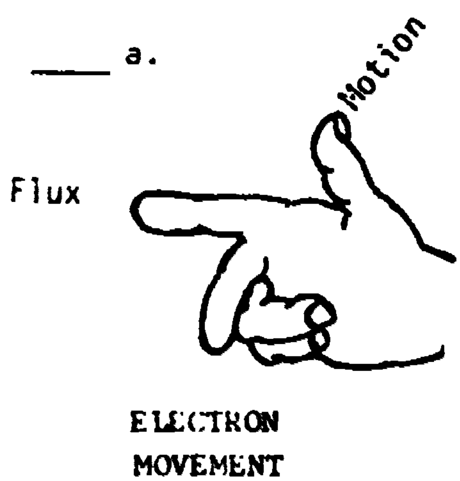
____ a. the process by which magnetism is produced by an electric current flowing through a conductor.
____ b. the generation of EMF caused by a difference in charge between two points.
____ c. the movement of electrons or current through a conductor.
____ d. the action which causes electron displacement in a conductor when lines of force move through it.

2. List the three factors that determine the amount of induced EMF.

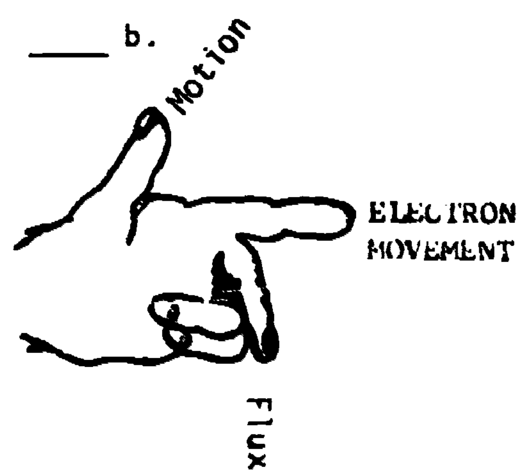
1) ____________________
2) ____________________
3) ____________________

3. Which correctly illustrates the Left-Hand Rule for Generators?

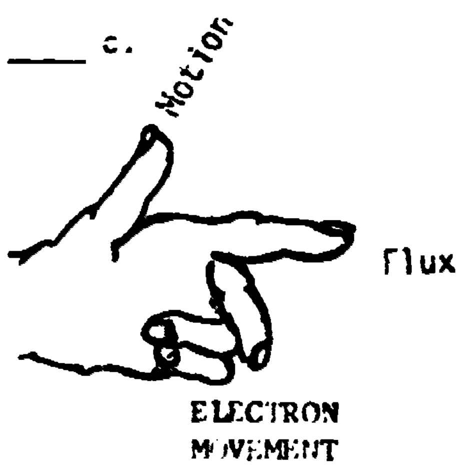
____ a.



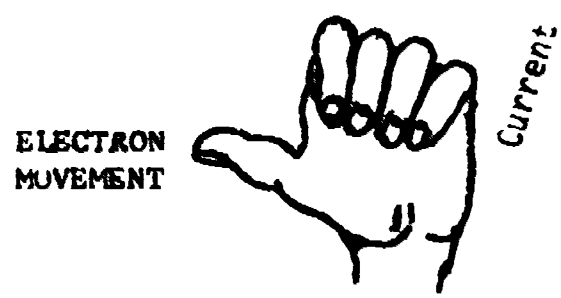
____ b.



____ c.

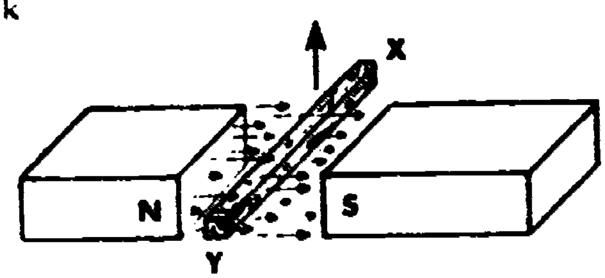


____ d.



4. Match.

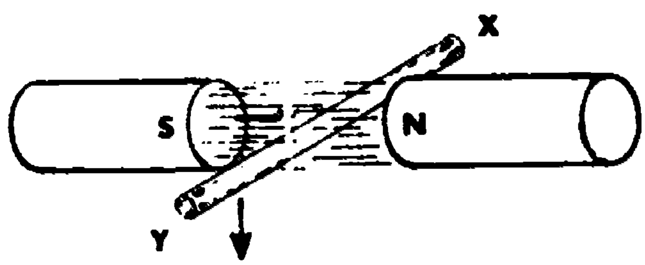
____ 1.



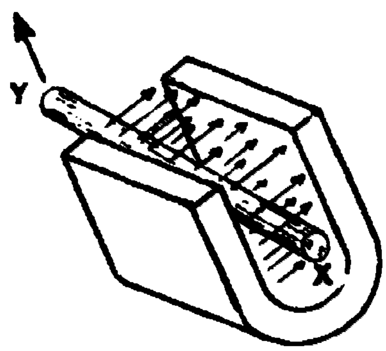
a. electron displacement toward X

b. electron displacement toward Y

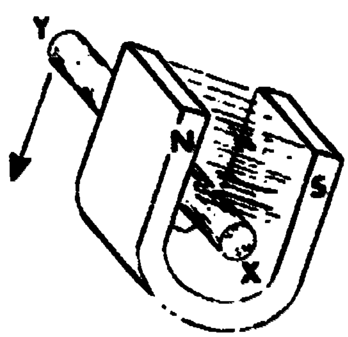
____ 2.



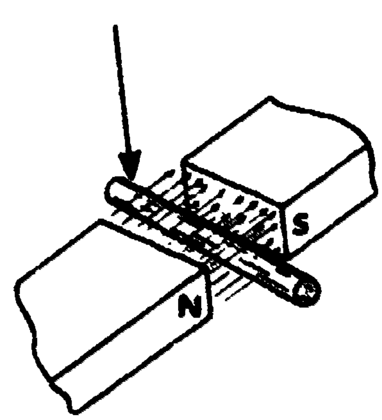
____ 3.



____ 4.

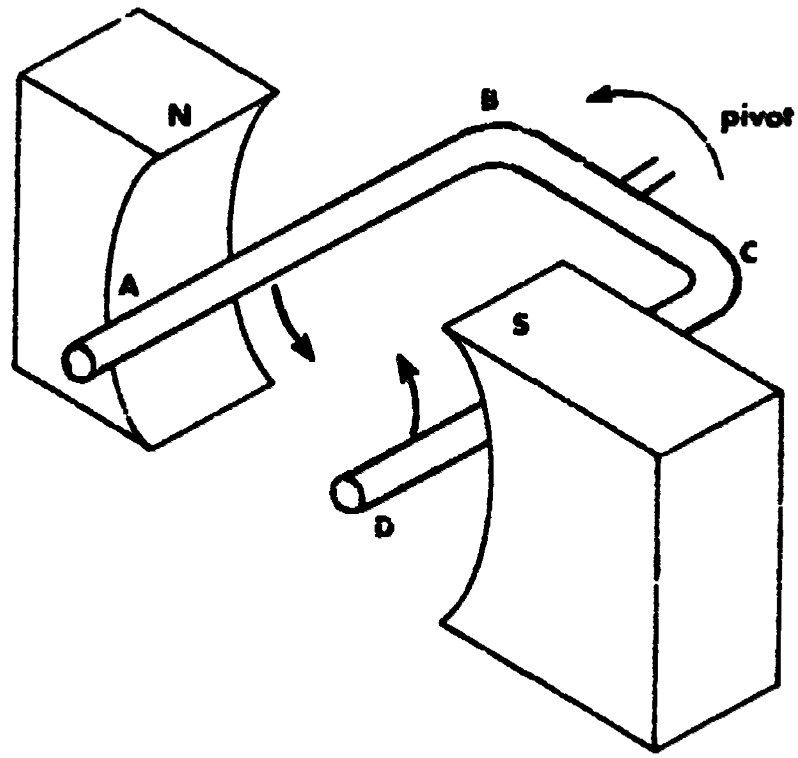


5. Label the polarity of the conductor.



6. Electrons will flow from:

____ a. A to B
____ b. B to A
____ c. C to B
____ d. D to C



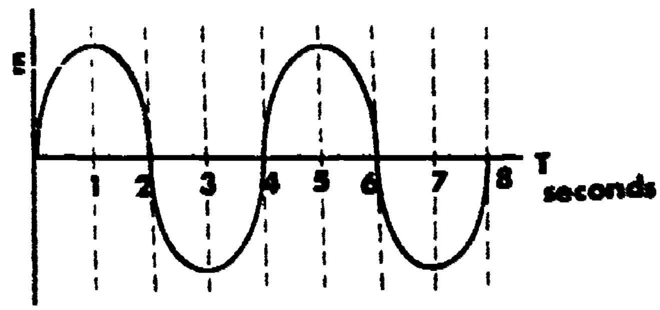
7. Which statement(s) is/are true?

____ a. Decreasing the speed of the conductor through the magnetic field results in more EMF.
____ b. A magnetic field is stronger if the flux density is increased.
____ c. If the strength of the magnetic field is increased, EMF will decrease.
____ d. If the number of turns of wire (or loops) in a magnetic field is increased, more EMF results.
____ e. EMF is greatest when the conductor is moving parallel to the lines of flux.

PROGRESS CHECK
LESSON IV

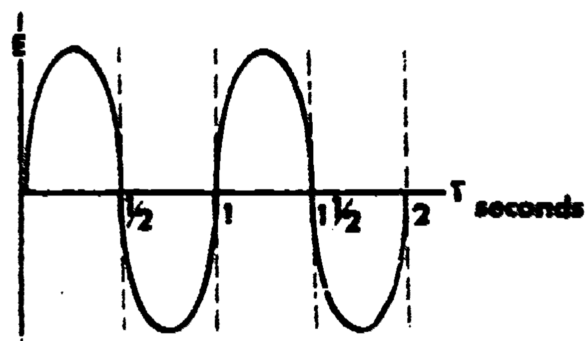
Generating AC Voltage

1. For the sine wave shown, how much time is required to complete one cycle?



____ a. 4 seconds
____ b. 8 seconds
____ c. 2 seconds
____ d. 6 seconds

2. What is the frequency of this sine wave?



____ a. 1 Hz.
____ b. 1/2 Hz.
____ c. 1 second.
____ d. 2 Hz.

3. If the time required to complete one cycle is 1 millisecond, the frequency of AC is:

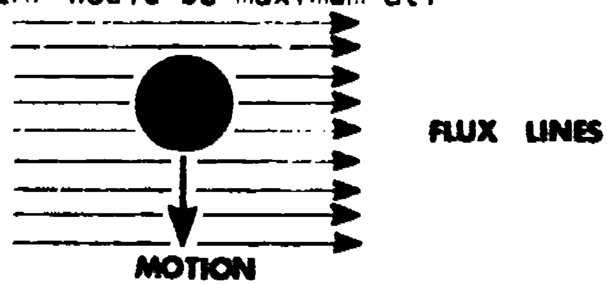
____ a. 10 Hz.
____ b. 100 Hz.
____ c. 1000 Hz.
____ d. 10,000 Hz.

4. List the two factors which determine the frequency of a generator.

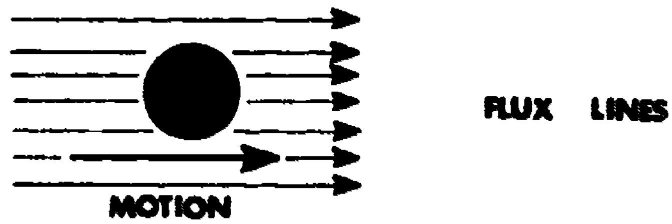
1) ________________________________
2) ________________________________

5. Induced EMF would be maximum at:

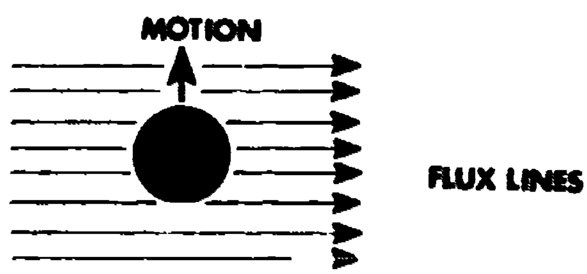
____ a.



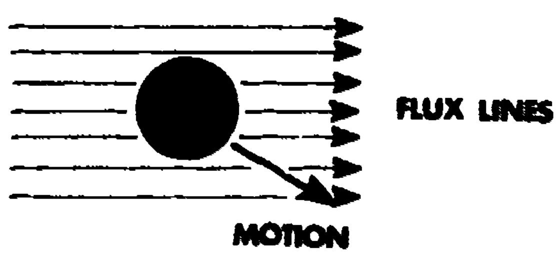
____ b.



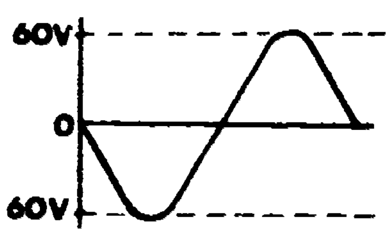
____ c.



____ d.



6. What is the peak-to-peak value of the sine wave shown?



peak-to-peak = __________

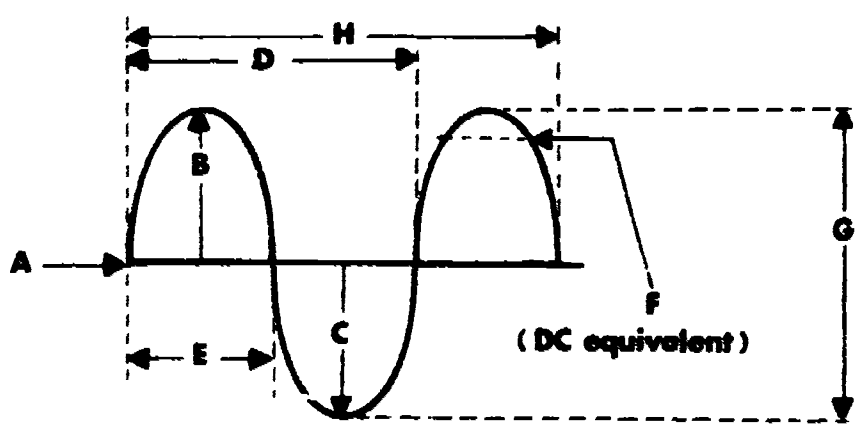
7. Which correctly describes a cycle?

____ a. one alternation
____ b. two alternations
____ c. three alternations
____ d. four alternations

8. Most AC meters are calibrated in:

____ a. average values.
____ b. peak-to-peak values.
____ c. effective values.
____ d. amplitude values.

9. Match the lettered parts of the graph to their appropriate terms.



____ 1. sine wave
____ 2. cycle
____ 3. alternation
____ 4. negative peak amplitude
____ 5. positive peak amplitude
____ 6. zero EMF
____ 7. effective value (RMS)
____ 8. peak to peak amplitude
____ 9. period

10. Which statement(s) is/are true?

____ a. The number of cycles per second is called the amplitude.
____ b. The peak value of a sine wave is the maximum positive or maximum negative value attained during one cycle.
____ c. One cycle of a sine wave is produced each time a simple AC generator rotates one complete revolution.
____ d. AC voltage values are usually expressed in effective values.

11. The symbols used to represent instantaneous values of current and voltage are:

____ a. I, E
____ b. r, e
____ c. i, e
____ d. i, r

Sound/Slide
AC-DC Generator Operation

Self-Test
Module Two - Lesson V

1. List the three requirements for electromagnetic induction to occur. There must be:
   a.
   b.
   c.

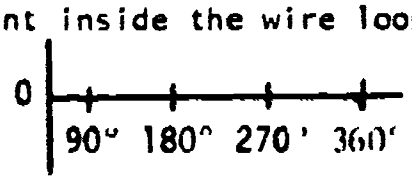
2. A generator is a device used to convert ___________ energy into ___________ energy.

3. An AC generator will have ___________ while a DC generator will have ___________.

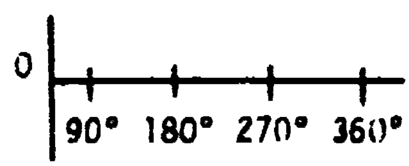
4. Inside the wire loops (coils) of either an AC or DC generator, the direction of current is ___________________________.
   constant/changing periodically

5. Draw a graph of the current inside the wire loops (coils) of a generator.

   a. for 90° rotation



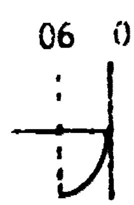
   b. for 270° rotation



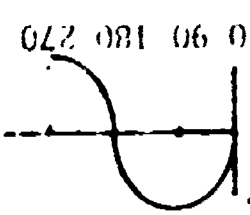
6. The current is maximum at:

   a. 0, 180°, and 360°
   b. 90°
   c. 90° and 270°

1. a. a conductor, b. a magnetic field, c. relative motion (in any order); 2. mechanical, electrical (in that order); 3. slip rings, a commutator (in that order); 4. changing periodically; 5. a.



b.

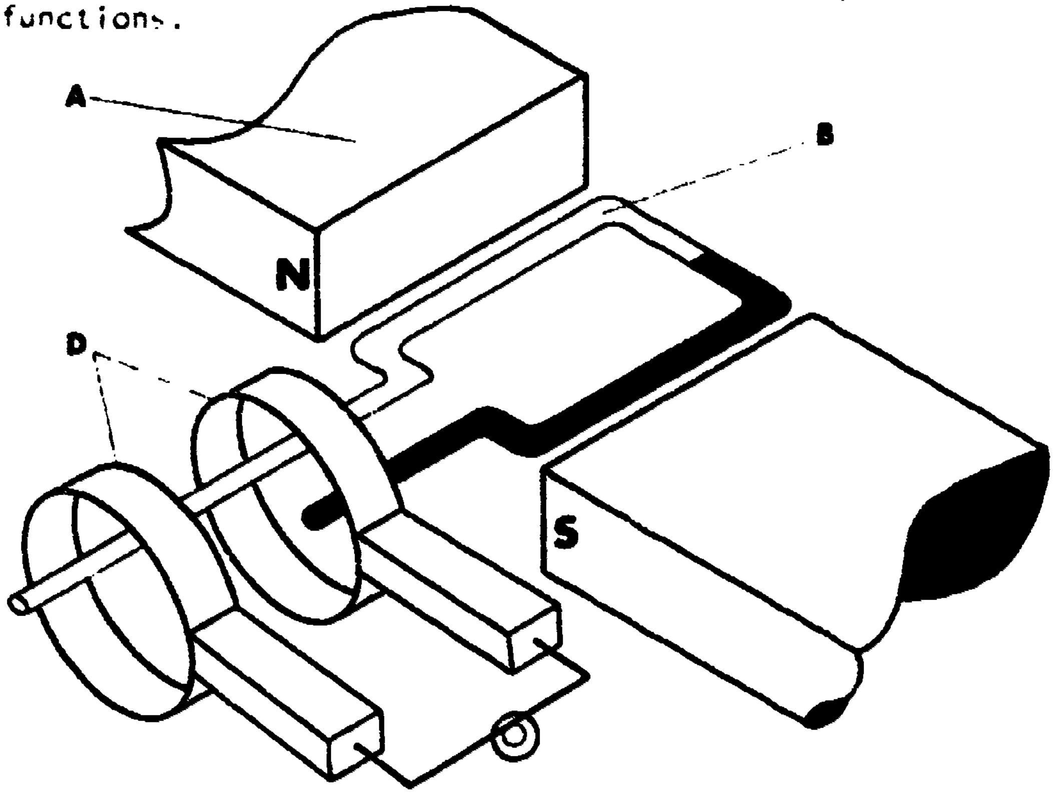


6. c

PROGRESS CHECK
LESSON V

Uses of AC and DC

1. Match the lettered parts in the diagram to their appropriate names or functions.



____ 1. armature
____ 2. slip rings
____ 3. brushes
____ 4. rotating loop
____ 5. creates lines-of-flux
____ 6. magnet

2. Another name for an AC generator is:

____ a. stator.
____ b. alternator.
____ c. commutator.
____ d. rotor.
____ e. CROW model.

3. The brushes that carry current from the slip rings to the outside circuit are usually made of:

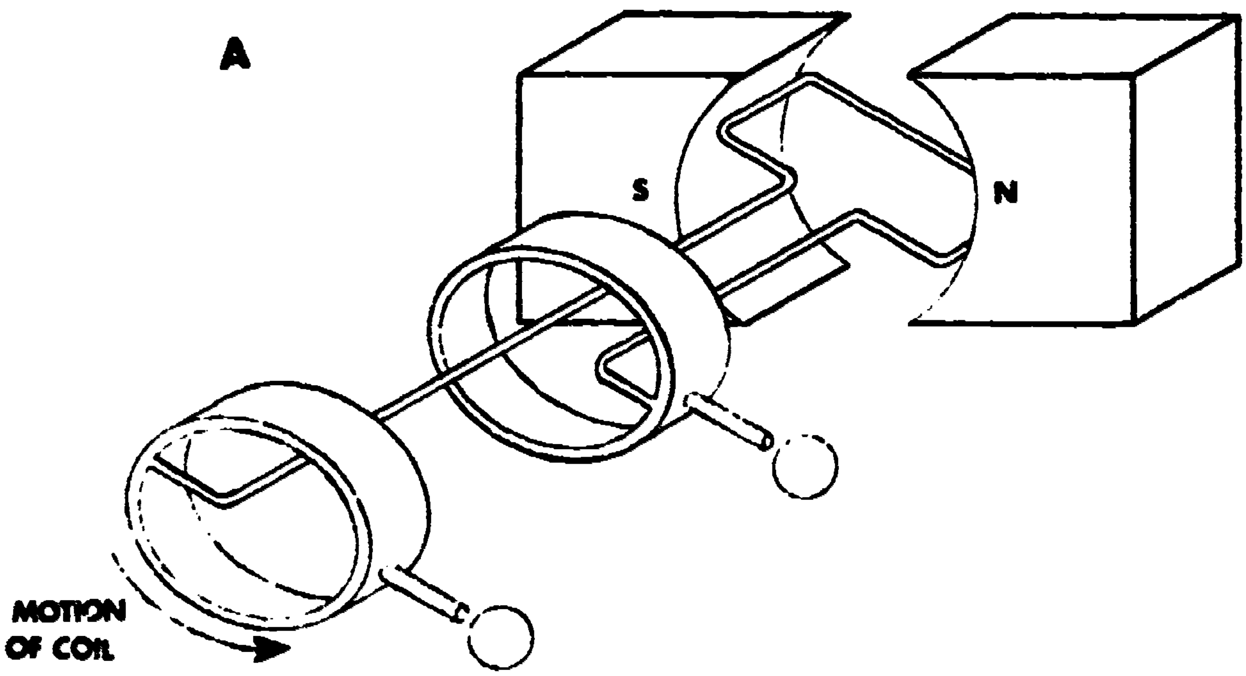
____ a. lead.
____ b. zinc.
____ c. copper.
____ d. carbon.

4. Which statement(s) is/are true?

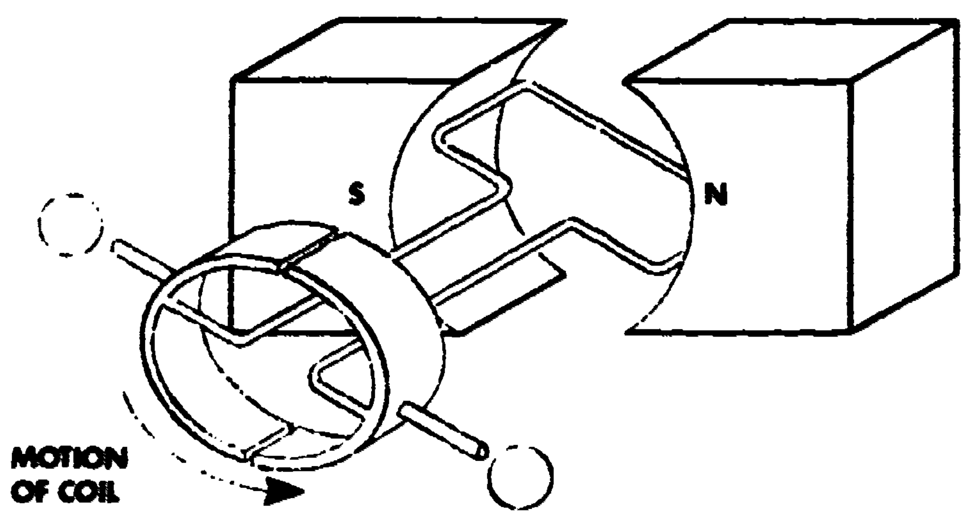
____ a. A commutator is a switching device.
____ b. Slip rings are normally made of copper.
____ c. A commutator is used to change DC to AC.
____ d. Slip rings are used in a DC generator.

5. Label the polarity of the brushes.

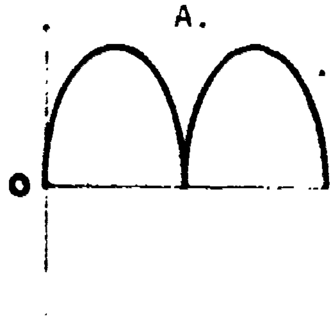
A

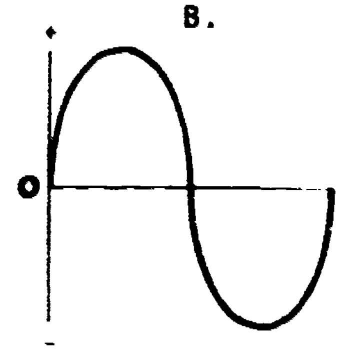


B



6. Which diagram shows the output waveform taken from a commutator?



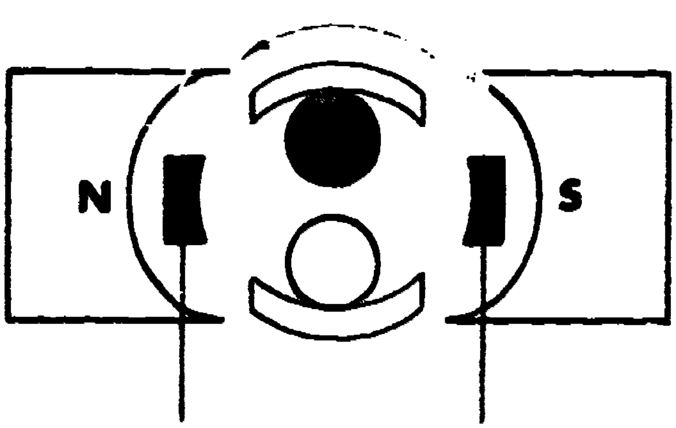


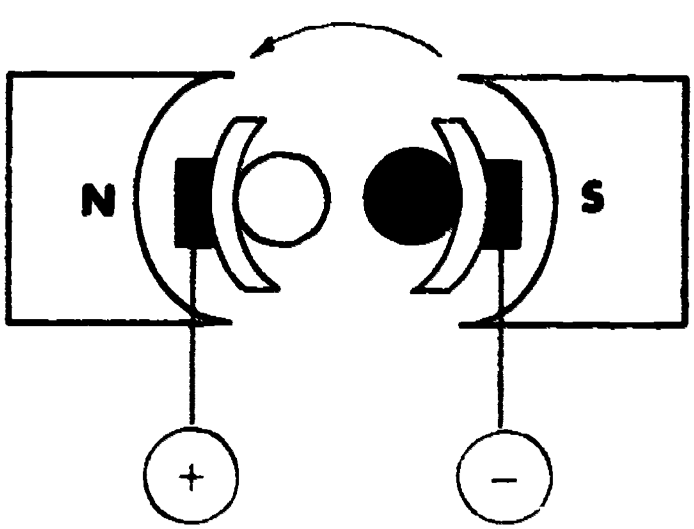
7. Match.

____ 1.	usually used for transmission over great distances with low loss of energy	a. AC
____ 2.	the output generated does not vary in direction	
____ 3.	generator has its contact ring divided into segments (commutator)	b. DC
____ 4.	generator has slip ring which transmits EMF to the load	
____ 5.	voltage may be increased or decreased in value with a low loss of energy	

8. In what position of the commutator would induced EMF be maximum.

____ A. ____ B.





Sound/Slide
Voltage Measurement - The DC Voltmeter

Self-Test
Module Two - Lesson VI

1. When a meter is said to be "polarity sensitive," it ____________ (does/does not) make a difference which lead is connected to the positive or negative side of the source.

2. DC voltmeters ____________ (are/are not) "polarity sensitive."

3. The red lead should be connected to the ____________ (negative/positive/either) side of the source.

4. A voltmeter is connected in ____________ (series/parallel) with the component across which voltage is to be measured.

5. When measuring the voltage across the load, the voltmeter is connected so that:

   a. all of the current flowing through the load flows through the meter.
   b. a small part of the current is passed through the meter.

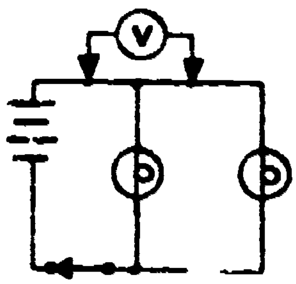
1. does; 2. are; 3. positive; 4. parallel; 5. b

PROGRESS CHECK
LESSON VI

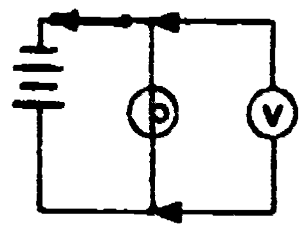
Measuring Voltage

1. Which schematic shows the voltmeter correctly installed?

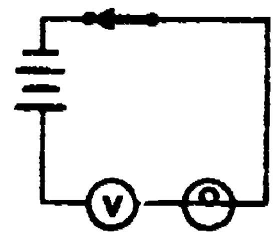
____ A.



____ B.



____ C.

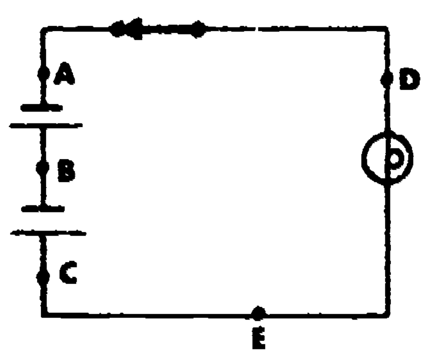


2. To measure DC voltages, a voltmeter must be connected:

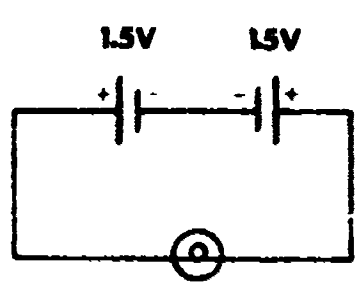
____ a. in series with the load being measured.
____ b. in parallel across the component or source to be measured.
____ c. across a potential difference.
____ d. with its red lead to the negative side of component being measured and black lead to the positive side.

3. Between what points can voltage be measured?

____ a. A and B
____ b. A and D
____ c. B and C
____ d. A and C
____ e. C and E
____ f. D and E



4. What is the potential difference across the lamp?



____ volts

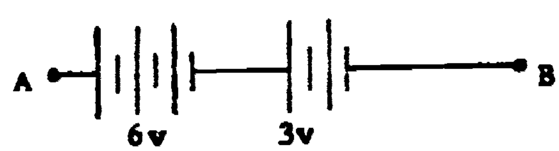
5. Which statement(s) is/are true?

____ a. Voltage can be measured only across a potential difference.
____ b. A difference in potential exists where EMF is generated and where energy is used by the load.
____ c. The schematic symbol of a voltmeter is 

____ d. Polarity must be observed when measuring DC voltage.
____ e. A voltage drop occurs where EMF is generated.
____ f. A voltage rise occurs at the voltage source.

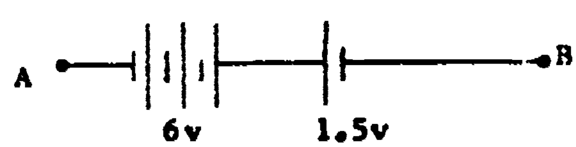
6. To which point in the diagram would the negative terminal of the voltmeter be connected? (Circle your answer.)

7. What is the total EMF produced by the two batteries?



EMF = ____ volts

8. What is the potential difference between points A and B?

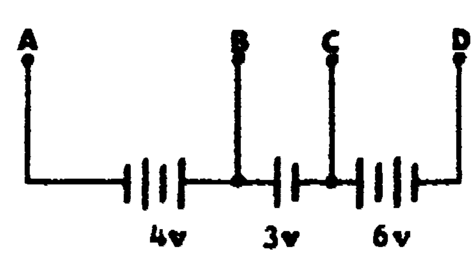


____ a. 6 volts
____ b. 4.5 volts
____ c. 7.5 volts
____ d. 1.5 volts

9. Complete the table:

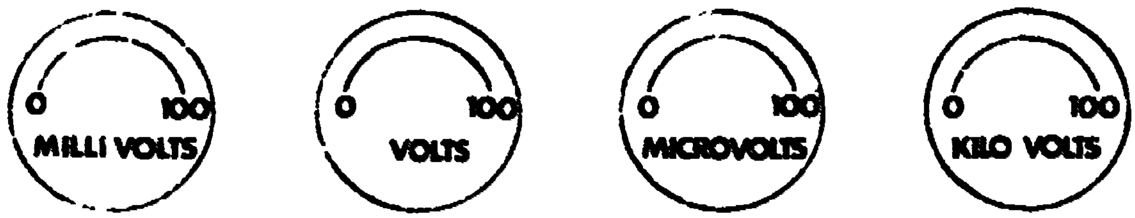
Voltage between:

AB	BC	CD	AD

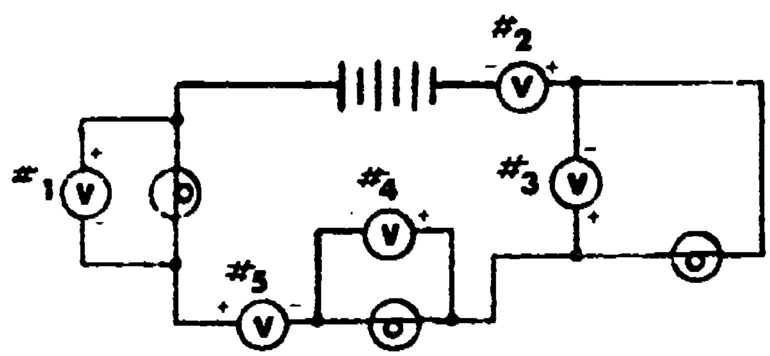


10. Which of these meters would be most useful for measuring 0.000070 volts?

____ a. ____ b. ____ c. ____ d.



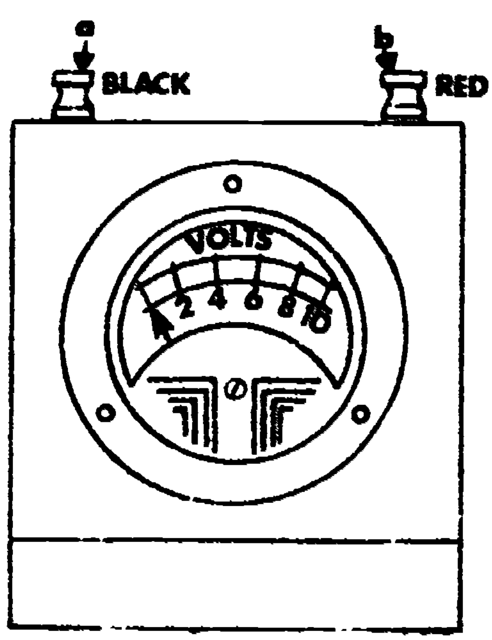
11. Which meter(s) is/are correctly connected for measuring DC voltage?



____ a. meter #1
____ b. meter #2
____ c. meter #3
____ d. meter #4
____ e. meter #5

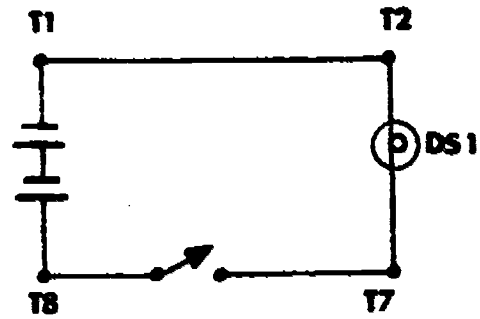
12. Label the polarity of the voltmeter terminals.

____ a.



b. ____

13. Using PB 0-1, build a simple circuit according to the schematic below.



Energize the circuit, then measure and record voltage:
a. at the source (between T1 and T8). _____ volts
b. across the load. ____ volts
c. across the closed switch. ____ volts

De-energize the circuit, then measure and record voltage:
d. at the source (between T1 and T8). ____ volts
e. across the load. ____ volts
f. across the open switch. ____ volts

PROGRESS CHECK ANSWERS
MODULE TWO

LESSON I

1. 1-d
   2-a
   3-b
   4-e
   5-c
2. a
3. a. parallel, 1.5 volts
   b. series, 0 volts (opposing)
   c. series, 4.5 volts (aiding)
4. a, b, c
5. a, d
6. 1-b
   2-c
   3-a
7. 1-c
   2-c
   3-a
   4-a
   5-b
8. a. 1×10^{-2} v
   b. 5×10^{-6} v
   c. 4×10^{3} v
   d. 3×10^{7} v
9. 1-e
   2-d
   3-b
   4-a
   5-e
   6-c
   7-c

LESSON I (Cont'd)

10. a. 5,000 or 5×10^{3} mv
    b. 1,000,000 or 1×10^{6} μv
    c. 4,000 or 4×10^{3} μv
    d. 0.004 or 4×10^{-3} kv
    e. 5 Mv
    f. 3,000 or 3×10^{3} kv
    g. 1 v
    h. 0.000001 or 1×10^{-6} v
    i. 0.002 or 2×10^{-3} mv
    j. 30 Mv
    k. 0.001 or 1×10^{-3} Mv

LESSON II

1. b
2. a
3. a, f
4. a. N
   b. N
5. b
6. a. b, e
7. a

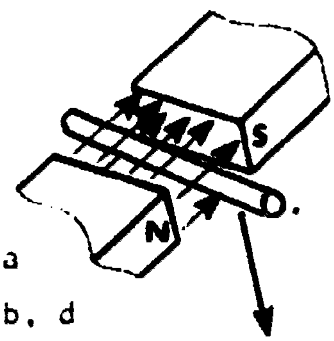
LESSON III

1. d
2. 1) strength of magnetic field
   2) speed of relative motion between conductor and magnetic field
   3) length of conductor in magnetic field
3. c

LESSON III (Cont'd)

4. 1-b
   2-b
   3-a
   4-b

5.



6. a

7. b, d

LESSON IV

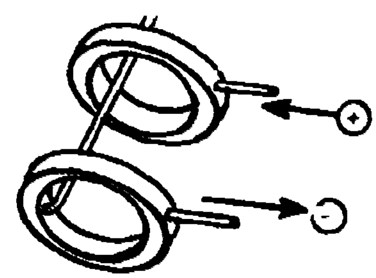
1. a
2. a
3. c
4. 1) the speed of rotation of the armature (coil of wire)
   2) the number of pairs of magnet'c poles in the generator
5. a, c
6. 120 volts
7. b
8. c
9. 1-H
   2-D
   3-E
   4-C
   5-E
   6-A
   7-F
   8-G
   9-D

LESSON IV (Cont'd)

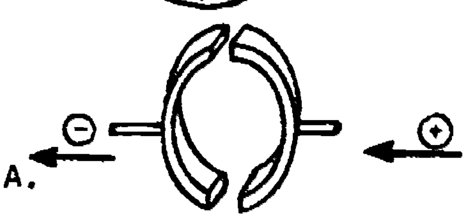
10. b, c, d
11. c

LESSON V

1. 1-B
   2-D
   3-C
   4-B
   5-A
   6-A
2. b
3. ..
4. a, b
5. A.



   B.



6. A.
7. 1-a
   2-b
   3-b
   4-a
   5-a
8. B

LESSON VI

1. B
2. b, c
3. a, c, d, f
4. 0 v
5. a, b, c, d, f
6. A
7. 9 volts
8. b
9.

AB	BC	CD	AD
4v	3v	6v	5v

10. c
11. a, c
12. a. (-)
    b. (+)
13. a. 3 volts (approximate)
    b. 3 volts (approximate)
    c. zero volts
    d. 3 volts (approximate)
    e. zero volts
    f. 3 volts

IF YOUR ANSWERS ARE ALL CORRECT, TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE TEST.

PROGRESS CHECK
LESSON 1

Characteristics of Resistance

1. List three factors that determine the resistance of a conductor.

   (1) ______________________________________
   (2) ______________________________________
   (3) ______________________________________

2. Which is the poorest conductor?

   ____ a. gold
   ____ b. copper
   ____ c. aluminum
   ____ d. carbon
   ____ e. silver

3. A material is a conductor because:

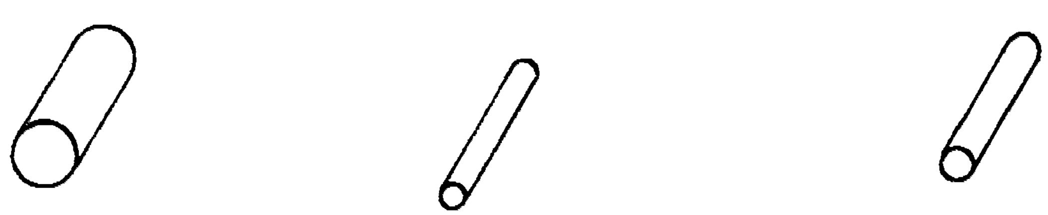
   ____ a. its atoms can easily accept and give up electrons.
   ____ b. its atoms do not readily accept or give up electrons.

4. Define resistance. ______________________________________
   ____

5. The letter abbreviation for resistance is ________ and its unit of measurement symbol is __________.

6. Which section of copper wire has the most resistance?

   ____ a. ____ b. ____ c.



7. Which statement(s) is/are true?

____ a. Resistance is a measure of the amount of current flow in a conductor.
____ b. All materials offer some amount of opposition to electron flow.
____ c. The more resistance a material has, the smaller the current it will conduct.
____ d. The atomic structure of a material has very little effect on its resistance.

8. $33\ k = 33 \times 10^3 =$ ________________ (in basic units).

9. 1.0×10^3 kilohms equals one ________________.

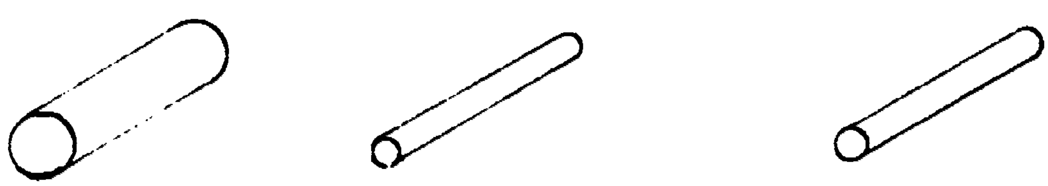
10. Which is true?

____ a. 500,000 ohms equals 50 Megohms.
____ b. Ohms divided by 1000 equal Megohms.
____ c. Ohms divided by 1000 equal kilohms.
____ d. 0.5 Megohms equals 500 kilohms.

11. If the length of a conductor is halved, what is the effect on its resistance? ____________________

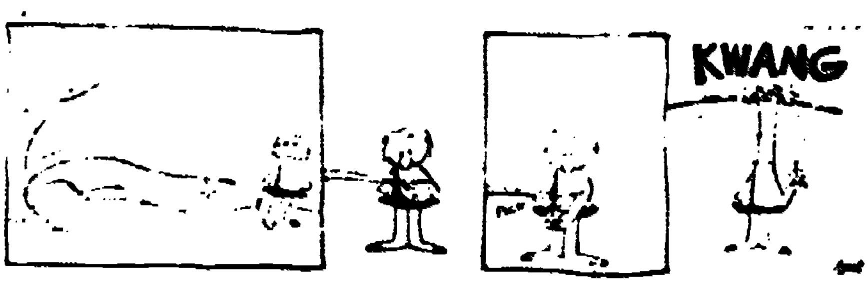
12. Which section of silver conductor has the least resistance?

____ a. ____ b. ____ c.



13. Which statement(s) is/are true?

____ a. The greater the cross-sectional area of a conductor, the smaller the resistance.
____ b. The greater the cross-sectional area of a wire, the higher the resistance.
____ c. An insulator is a material which aids electron flow.
____ d. Rubber, glass, and porcelain are examples of poor conductors.
____ e. Non-conductors have a low resistance.
____ f. Good insulators have a high resistance.
____ g. The unit of measure for resistance is the ampere.



If you don't know what it does don't fool with it!

PROGRESS CHECK
LESSON II

Resistors

1. Resistors are usually classified according to:

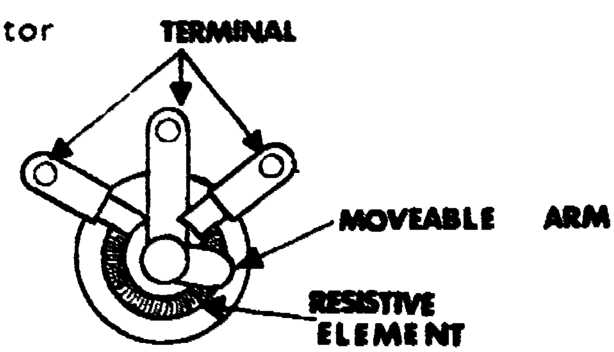
____ a. the materials used for their resistance elements.
____ b. their ohmic value or amount of resistance they possess.
____ c. whether their resistance value is fixed or can be varied.
____ d. their physical size.

2. Which statement(s) is/are true?

____ a. The value of a fixed resistor is set and cannot be varied.
____ b. Potentiometers and rheostats are classified as fixed resistors.
____ c. More than one resistance value can be obtained from a tapped resistor; however, each of these values is fixed.
____ d. The maximum resistance value of a tapped resistor depends on the number of taps or connections that it has.

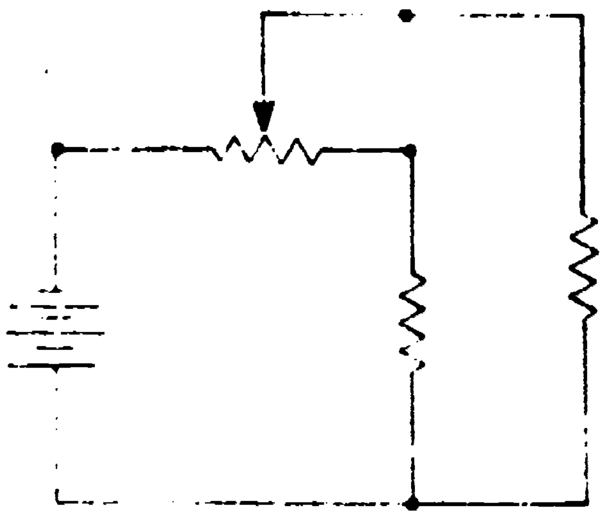
3. This illustration shows a:

____ a. rheostat
____ b. potentiometer
____ c. sliding contact resistor
____ d. tapped resistor

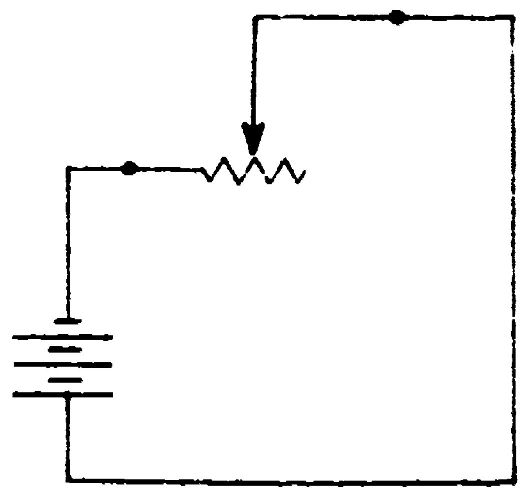


4. Which circuit shows a rheostat?

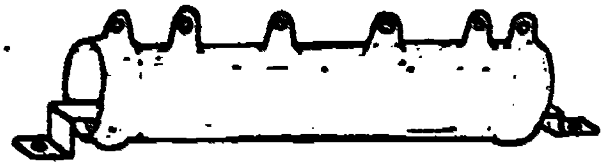
____ A.



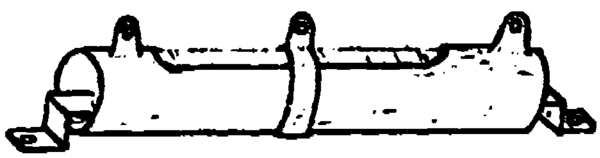
____ B.

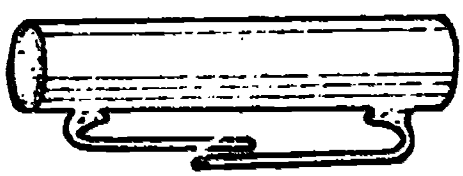


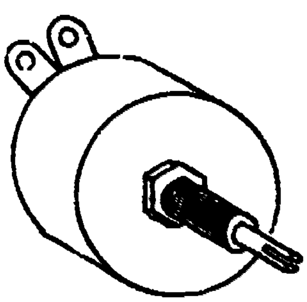
5. Draw the schematic symbol for each of the resistors illustrated.

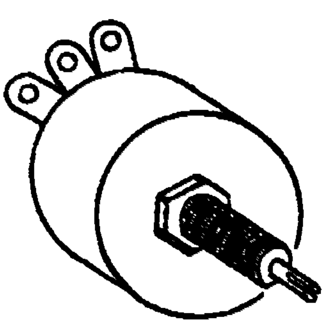
a. 

b. 

c. 

d. 

e. 

f. 

6. Match.

____ 1. inexpensive and easy to manufacture	a. carbon resistors
____ 2. ohmic values tend to change with age	b. wire-wound resistors
____ 3. expensive to manufacture	
____ 4. able to carry large amounts of current without damage	
____ 5. low current handling capabilities	
____ 6. highly accurate resistance values	
____ 7. ohmic values not highly accurate; wide tolerance range	
____ 8. resistance values very stable over long periods of time	

7. Which statement(s) is/are true?

____ a. Resistor value refers to the number of ohms of resistance a resistor has.

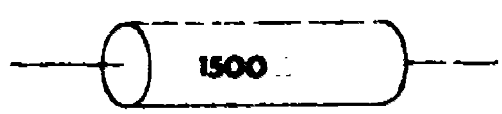
____ b. Resistance is a physical property.

____ c. It is possible to tell the resistance value of a resistor from its physical size.

____ d. Resistors with greater cross-sectional area have greater resistance.

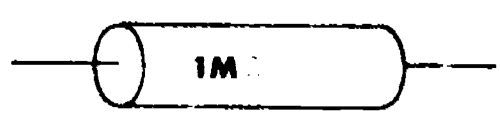
8. Which resistor has the most resistance?

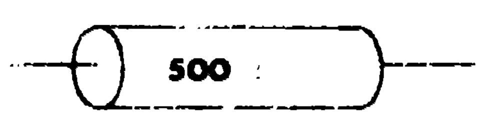
____ a.



____ b.

____ c.





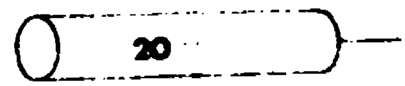
____ d.

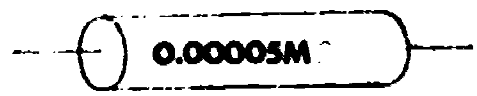
9. The wattage rating of a resistor:

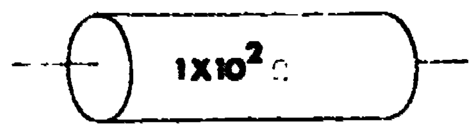
____ a. determines a resistors ohmic value.
____ b. determines the maximum current a resistor can safely carry.
____ c. refers to the amount of resistance possessed by a resistor.
____ d. is determined by the resistor's physical size.

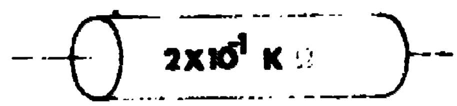
10. Match.

____ 1. highest ohmic value
____ 2. highest wattage rating

a.


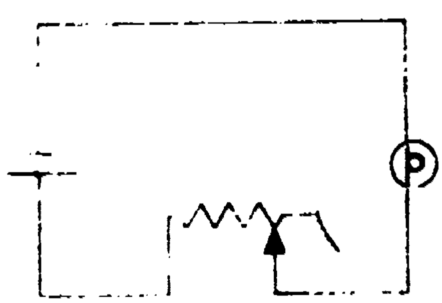
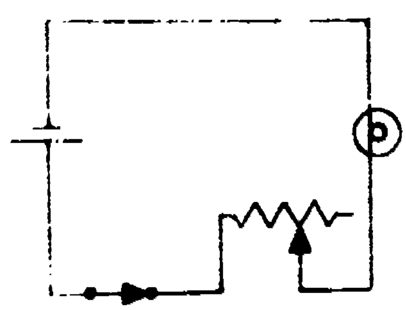
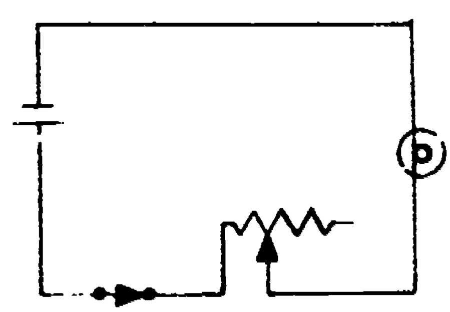
b.


c.


d.


11. In which circuit would the lamp burn brightest?

____ a. ____ b. ____ c.

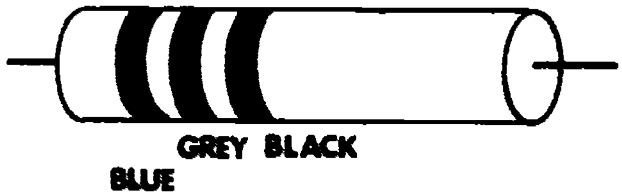




PROGRESS CHECK
LESSON III

Resistor Identification

1. What is the ohmic value of the resistor represented by the diagram shown?

____ a. 57 ohms
____ b. 68 ohms
____ c. 570 ohms
____ d. 680 ohms

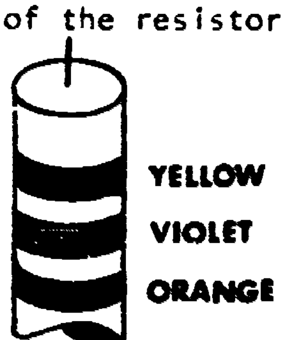


2. A resistor is coded with four color bands. The first band is green, the second is blue, the third is orange and the fourth is gold. What is the resistance of this resistor?

____ a. 45 Kohms
____ b. 56 Kohms
____ c. 67 Kohms
____ d. 560 Kohms

3. What is the ohmic value of the resistor illustrated by the drawing shown?

____ a. 36 Kohms
____ b. 47 Kohms
____ c. 360 Kohms
____ d. 470 Kohms

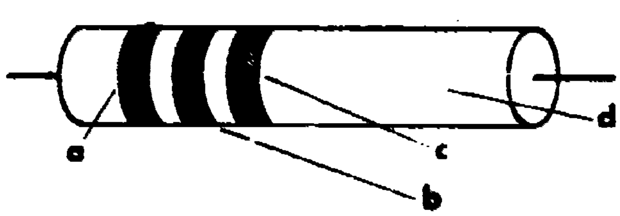


4. What is the ohmic value of a resistor whose first color band is orange, second band is orange, and third band is green?

____ a. 2.2 Megohms
____ b. 2.3 Megohms
____ c. 3.2 Megohms
____ d. 3.3 Megohms

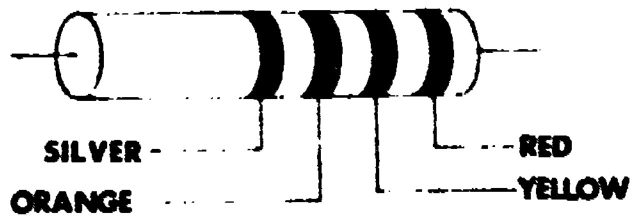
5. Which band indicates the first significant figure?

____ a.
____ b.
____ c.
____ d.



6. The tolerance of this resistor is:

____ a. 1%
____ b. 5%
____ c. 10
____ d. 20%

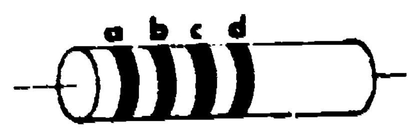


7. Which is the correct sequence of color bands on a 24 Kohm resistor with a tolerance of 10%?

____ a. yellow, red, orange, silver.
____ b. silver, red, yellow, orange.
____ c. red, yellow, orange, gold.
____ d. red, yellow, orange, silver.

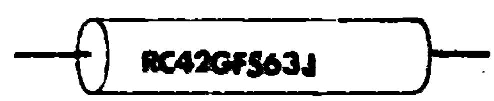
8. Color band "b" on the resistor below indicates the:

____ a. first significant figure
____ b. second significant figure
____ c. multiplier
____ d. tolerance



9. What is the resistance of the resistor illustrated in figure #1?

____ a. 5.63 ohms
____ b. 56 kohms
____ c. 56.3 ohms
____ d. 563 ohms

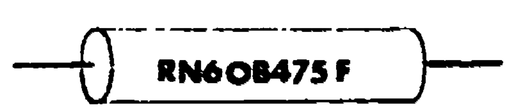


10. What is the magnitude of resistance offered by a resistor that has the designation "RC22B104K"?

____ a. 100 kohms
____ b. 10 kohms
____ c. 10.4 kohms
____ d. 22.1 kohms

11. What is the resistance of this resistor?

____ a. 475 kohms
____ b. 4.7 megohms
____ c. 47.5 ohms
____ d. 475 ohms



PROGRESS CHECK
LESSON IV

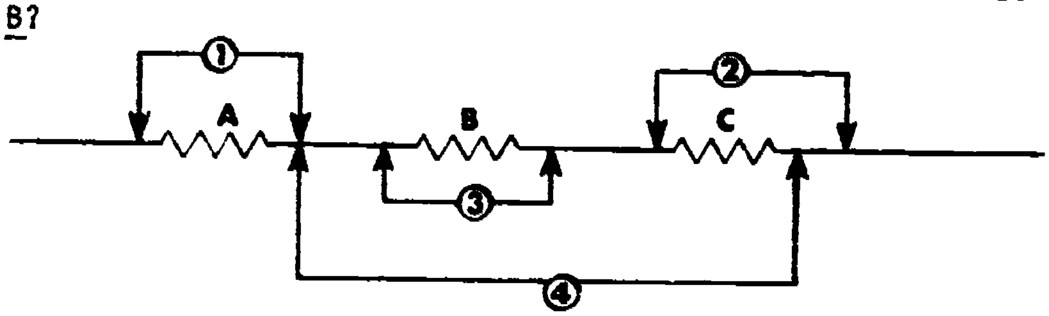
The Ohmmeter

1. The principle function of an ohmmeter is to measure the magnitude of:

_____ a. current
_____ b. resistance
_____ c. voltage
_____ d. conductance

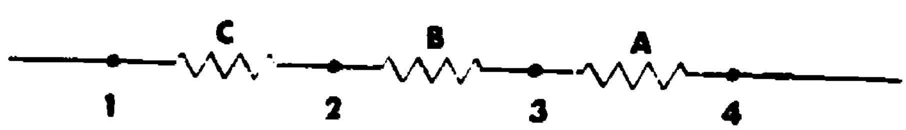
2. In the schematic shown, which ohmmeter will indicate the resistance of resistor B?

_____ a. #1
_____ b. #2
_____ c. #3
_____ d. #4



3. On the diagram shown, an ohmmeter must be connected between points __________ to measure the combined resistance of resistors A and B.

_____ a. 1 and 4
_____ b. 2 and 3
_____ c. 2 and 4
_____ d. 1 and 3



4. When resistance is measured using the ohms function of a multimeter, minimum resistance values will be indicated when the meter pointer is at the __________ portion of the ohms scale.

_____ a. linear portion
_____ b. extreme left
_____ c. extreme right
_____ d. center

5. When resistance is measured with a multimeter, the scale is such that maximum resistance is indicated at the __________.

_____ a. extreme right
_____ b. extreme left
_____ c. linear portion
_____ d. center

6. When measuring a 100 Kohm resistor, the pointer on the ohmmeter scale indicates 10. In what position is the range selector?

    ____ a. R x 10
    ____ b. R x 100
    ____ c. R x 1,000
    ____ d. R x 10,000

7. What will the pointer indicate on an Ohmmeter scale if the range selector is set to R x 10,000 and the resistor being measured is 5.6 Megohms?

    ____ a. 0.56
    ____ b. 5.6
    ____ c. 56
    ____ d. 560

8. The pointer of an ohmmeter indicating mid-scale, with the range selector in the R x 100 position, will ____________ when the range selector is moved to the R x 10,000 position.

    ____ a. move toward infinity
    ____ b. not move
    ____ c. move toward zero

PROGRESS CHECK ANSWERS

MODULE THREE

LESSON I

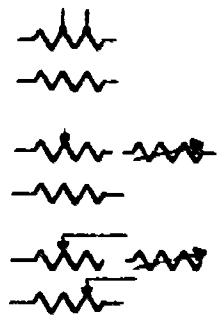
1. (1) type of material used (atomic structure of a material)
   (2) length of conductor
   (3) cross-sectional area of conductor
2. d
3. a
4. Resistance is the property of a material that opposes current flow.
5. R, ..
6. b
7. b, c
8. 33,000..
9. megohm
10. c, d
11. Resistance will be halved
12. a
13. a, d, f

LESSON II

1. a, c
2. a, c
3. b
4. B

LESSON II (Cont'd)

5. a.
   b.
   c.
   d.
   e.
   f.



6. 1. a
   2. a
   3. b
   4. b
   5. a
   6. b
   7. a
   8. b
7. a, b
8. c
9. b, d
10. 1. d
    2. c
11. c

LESSON III

1. b
2. b
3. b
4. d

LESSON III (Cont'd)

5. a
6. c
7. d
8. b
9. b
10. a
11. b

LESSON IV

1. b
2. c
3. c
4. c
5. b
6. d
7. d
8. c

IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

Measuring Current in a Series Circuit

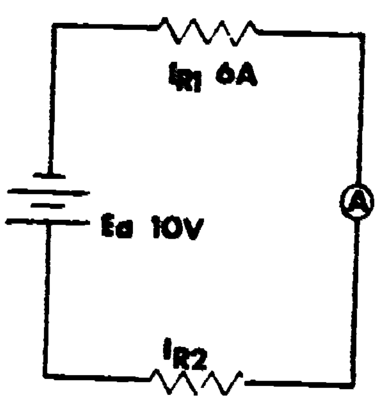
1. State the correct definition of a series circuit.

____

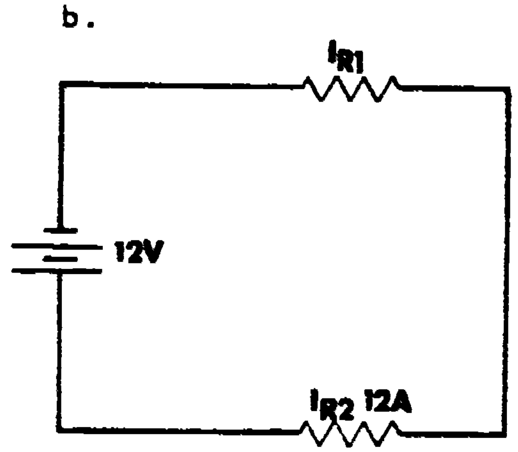
____

2. Compute and record indicated values of circuit current.

a.



b.



a. I_{R2} ____________________

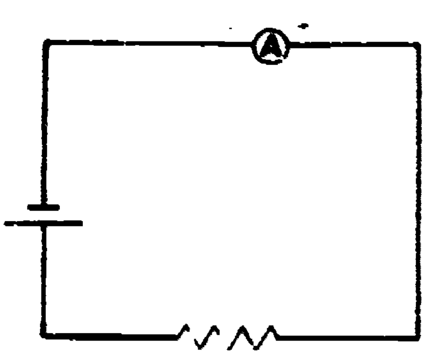
b. I_{R1} ____________________

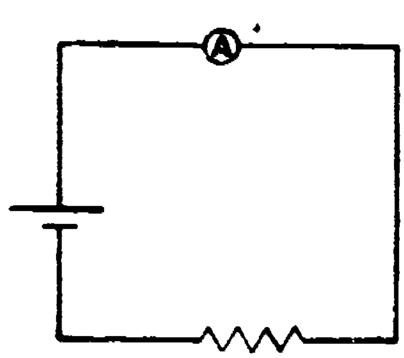
3. Which schematic shows the meter correctly installed for measuring current?

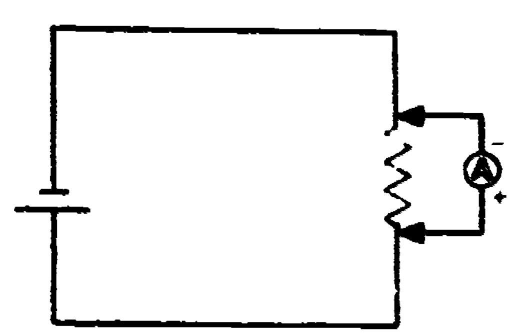
____ a.

____ b.

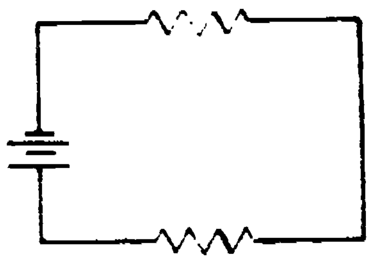
____ c.

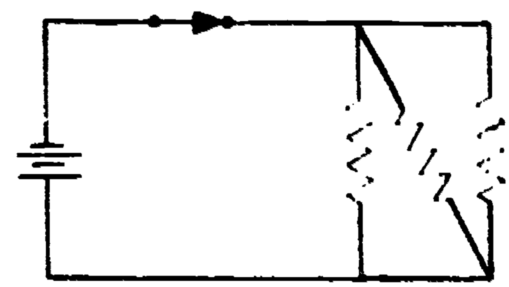


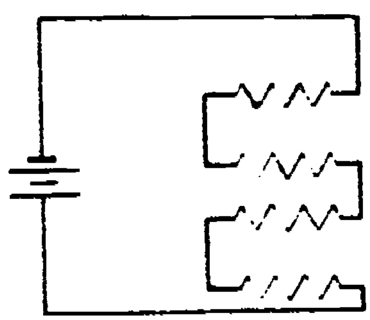


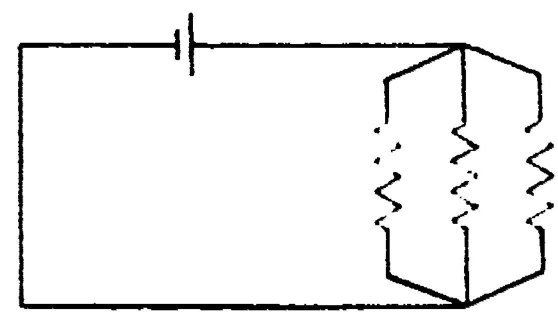


4. Match the schematics to their appropriate characteristics.

a. 

b. 

c. 

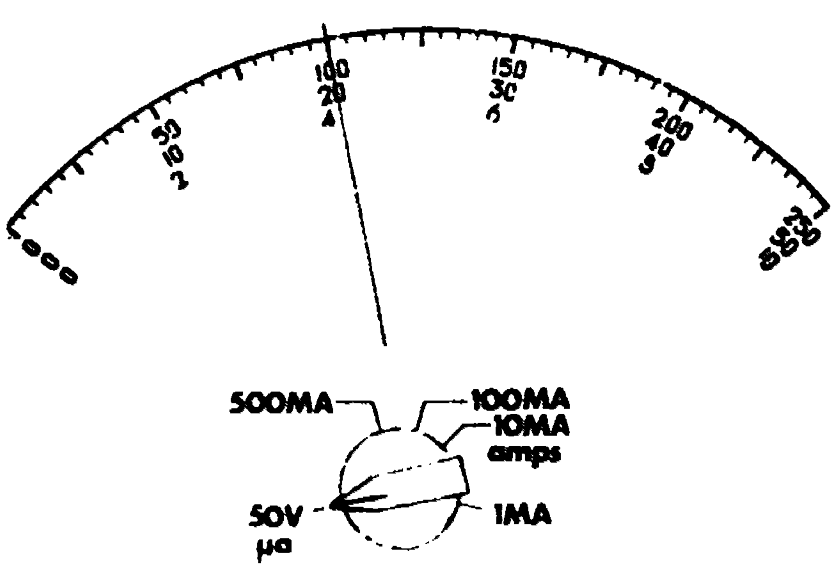
d. 

____ 1. more than one path for current flow
____ 2. series circuit
____ 3. parallel circuit
____ 4. only one path for current flow

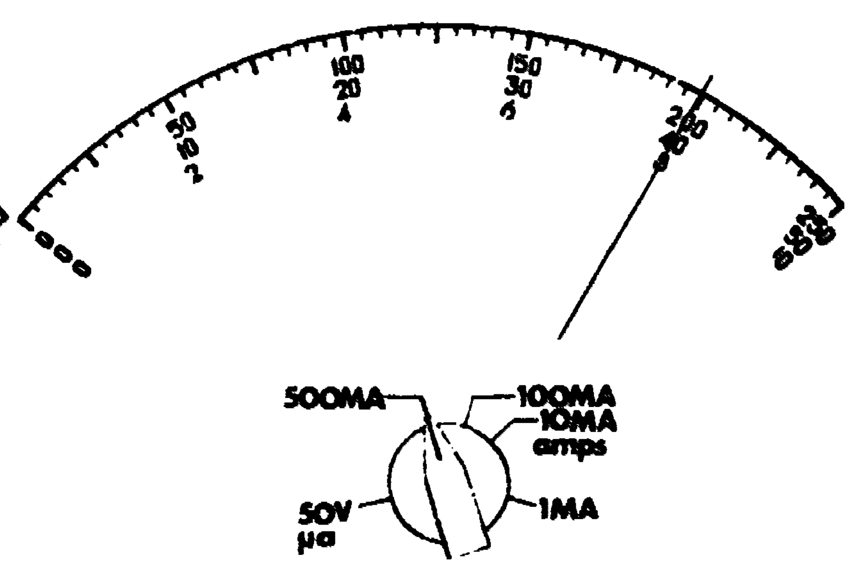
5 To measure direct current on any scale, except the 50 micro amp scale, the meter function switch must be in the ______________ position.

6. Which illustration indicates a current value of 20 ..amps?

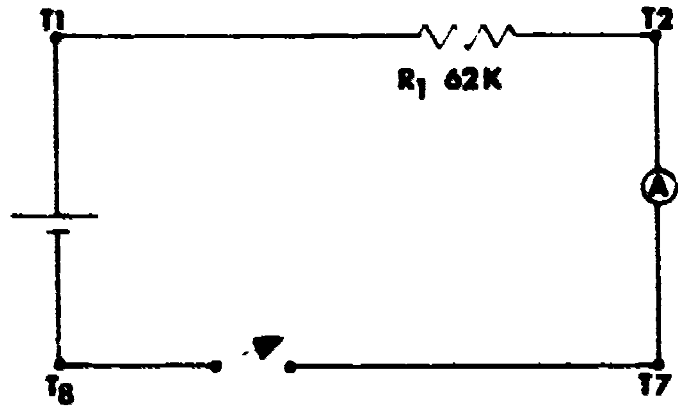
____ a.



b.

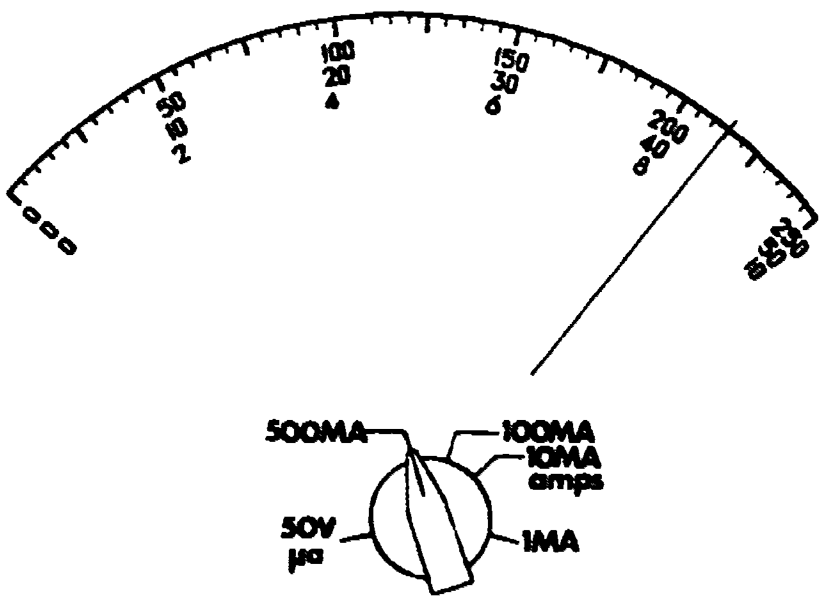


7. Using Practice Board 0-1, a 62 k resistor, and one dry cell, construct a series circuit as indicated by the schematic and close the switch, then measure and record circuit current.

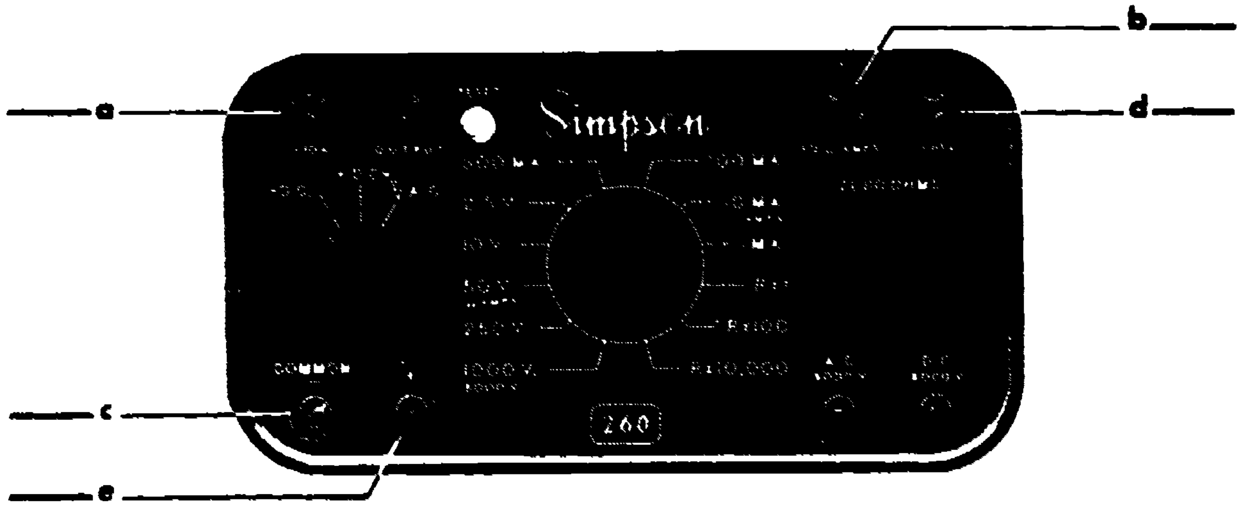


8. What is the current reading indicated below?

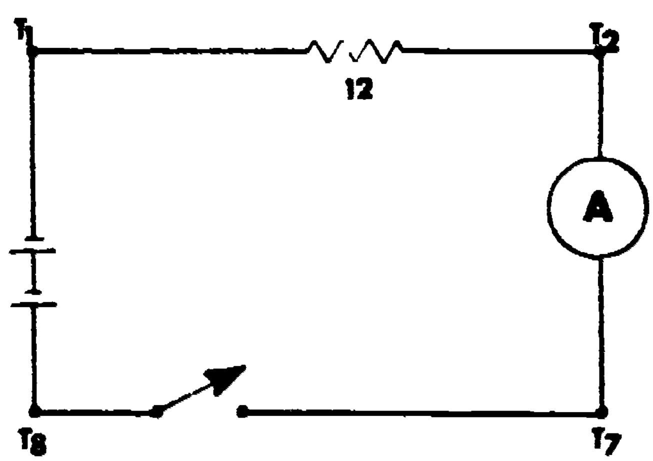
____ a. 40 ma
____ b. 430 ma
____ c. 230 ma
____ d. 80 ma



9. On the illustration below, check the arrows which point to the jacks used when making current measurements in the ranges of 0-1 ma, 10 ma, 100 ma, 500 ma.



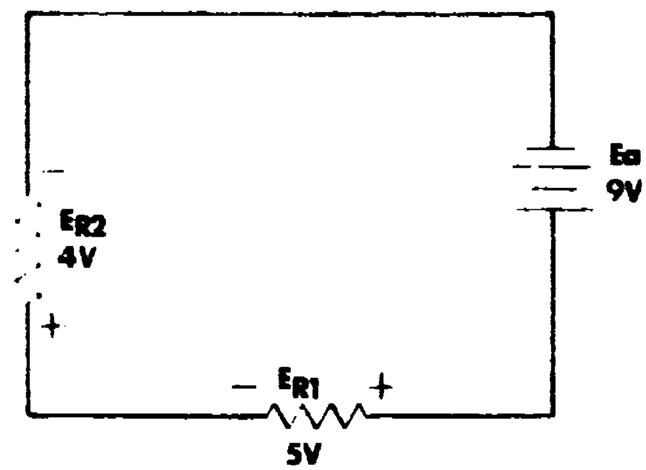
10. Modify the series circuit you constructed for question #7 as shown below and close the switch, then measure and record circuit current.



PROGRESS CHECK
LESSON 11

Voltage in a Series Circuit

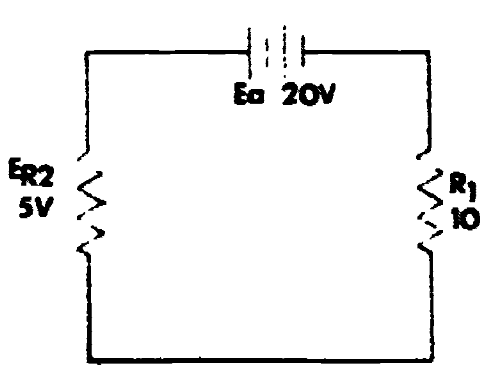
1. Study the schematic, then check the statement(s) that is/are true.

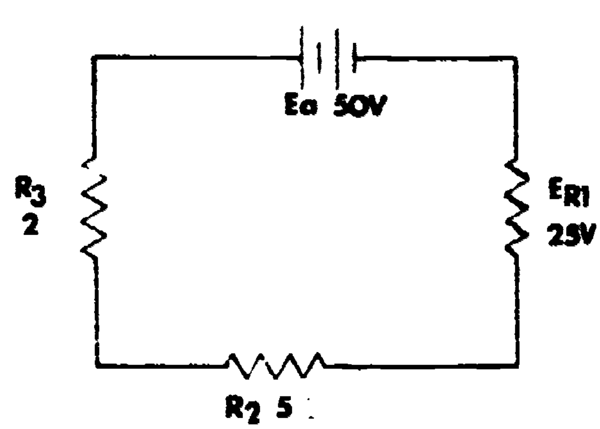


____ a. The voltage rise is equal to the sum of the voltage drops.
____ b. The total voltage dropped is 13 volts.
____ c. The voltage drop across R1 is greater than the voltage drop across R2.
____ d. The voltage rise at the source is 4 volts.
____ e. The total applied voltage is 18 volts.
____ f. The rise in potential is 9 volts.
____ g. The polarities indicated for both voltage drops are correct.
____ h. The polarity indicated for E_{R1} is correct.

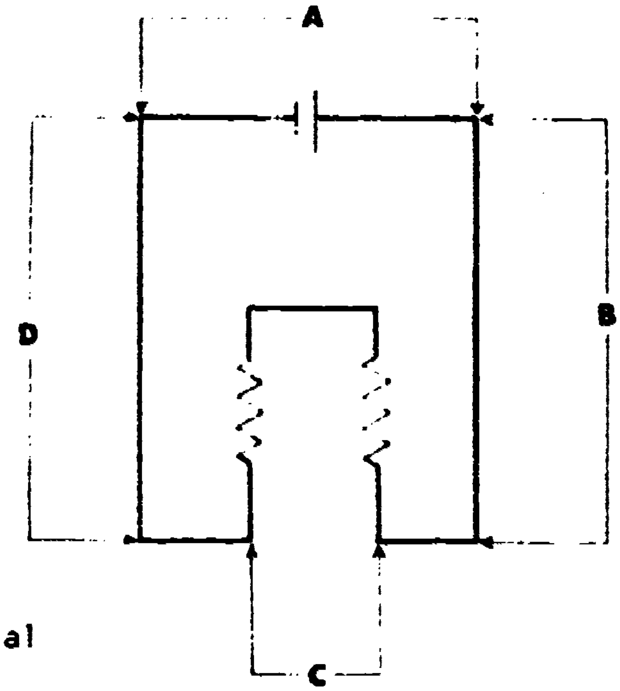
2. Select the resistor in each schematic that will have the largest voltage drop.

____ a. ____ b.





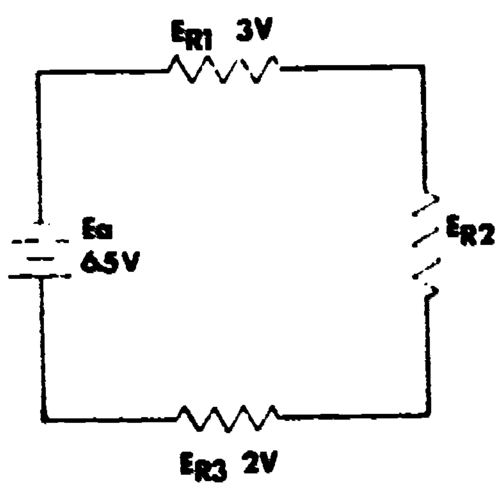
3. Match lettered arrows on schematic to corresponding voltage concepts.



____ 1. voltage rise
____ 2. "0" difference in potential
____ 3. voltage drop

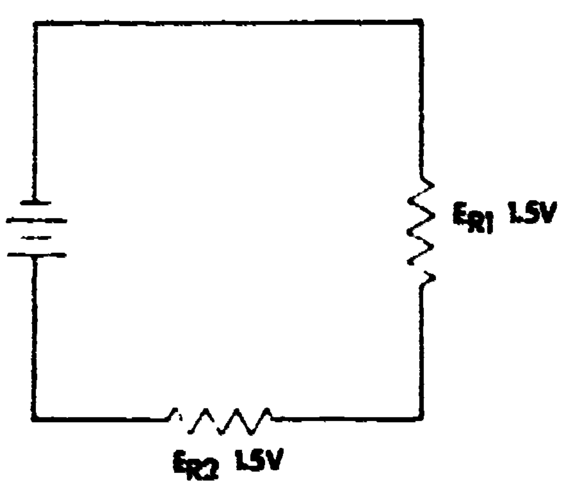
4. Compute and record the correct amount of total voltage rise or drop in each schematic.

a.



voltage drop ______

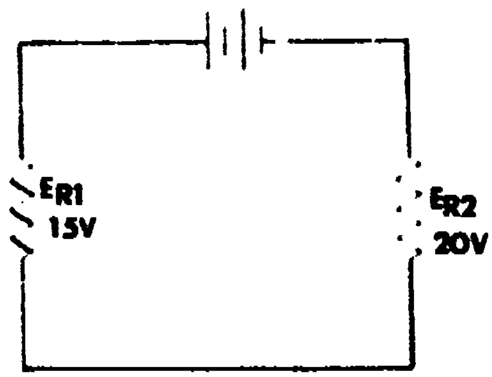
b.



voltage rise ______

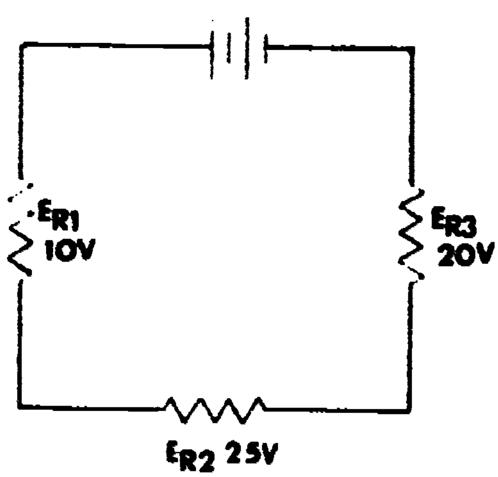
5. Compute and record the source voltage (E_a) in each schematic.

a.



E_a = ______

b.



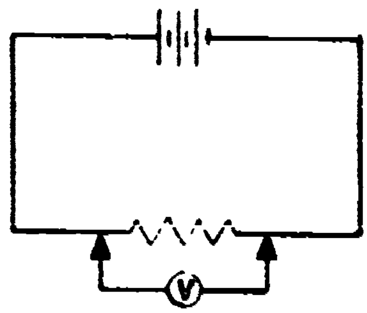
E_a = ______

PROGRESS CHECK
LESSON III

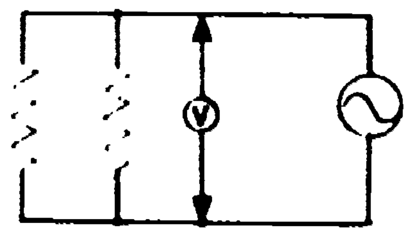
The Multimeter as a Voltmeter

1. Match.

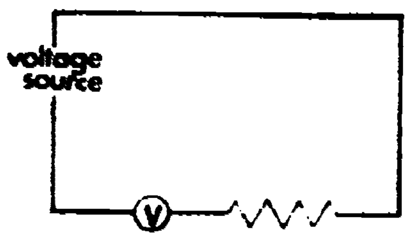
____ 1.



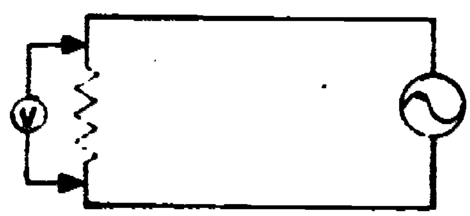
____ 2.



____ 3.



____ 4.



a. AC voltage meter connection

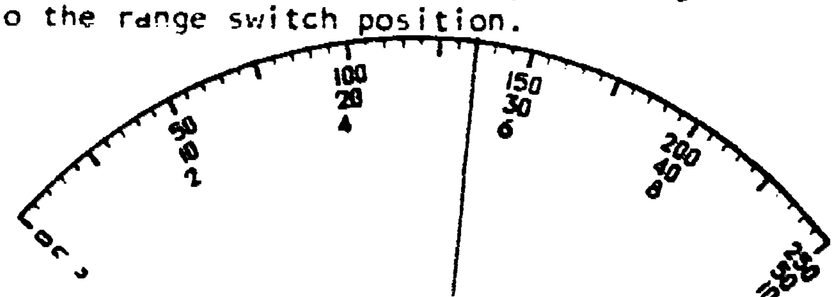
b. DC voltage meter connection

c. incorrect voltmeter connection (AC or DC)

2. Check the statement(s) that is/are true.

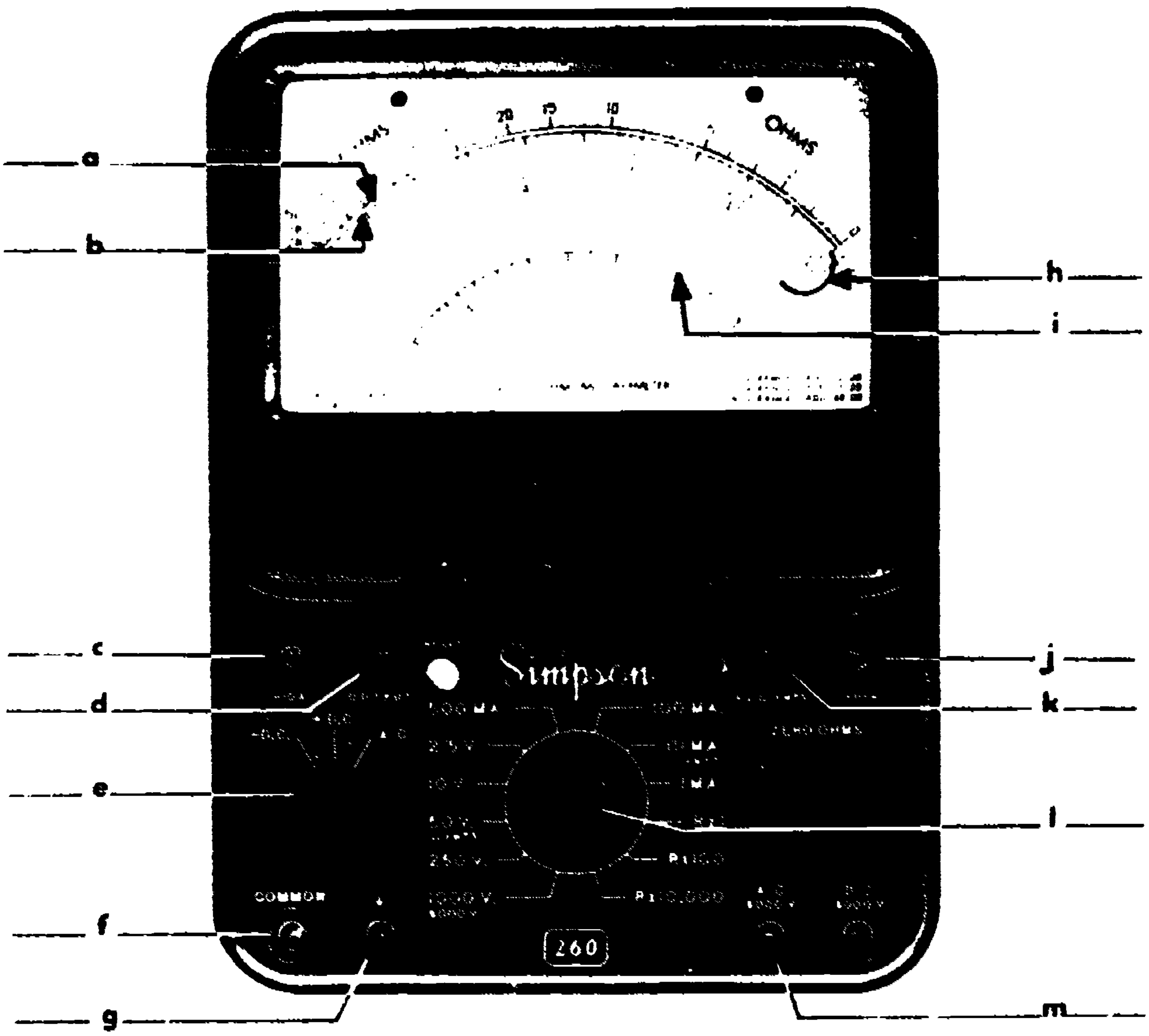
____ a. When measuring voltage with a multimeter, the function switch must always be in the +DC position.
____ b. When reading DC voltage, polarity must be observed.
____ c. When measuring DC voltage with a multimeter, correct meter connection will cause pointer deflection to the left of zero.
____ d. Meter polarity of the Simpson 260 can be changed by moving the function switch to either <u>+DC</u> or <u>-DC</u>.
____ e. Meter polarity of the Simpson 260 can <u>only</u> be changed by removing the test leads from the circuit and reversing them.

3. Interpret the meter DC scale below by matching the indicated voltage to the range switch position.



Range-Switch Position		DC Voltage
____ 1. 10 v		a. 540 volts
____ 2. 50 v		b. 135 volts
____ 3. 2.5 v		c. 27 volts
____ 4. 250 v		d. 1.35 volts
____ 5. 1000 v		e. 5.4 volts

4. Check the lettered parts and scales of the multimeter that are used for measuring DC voltage.



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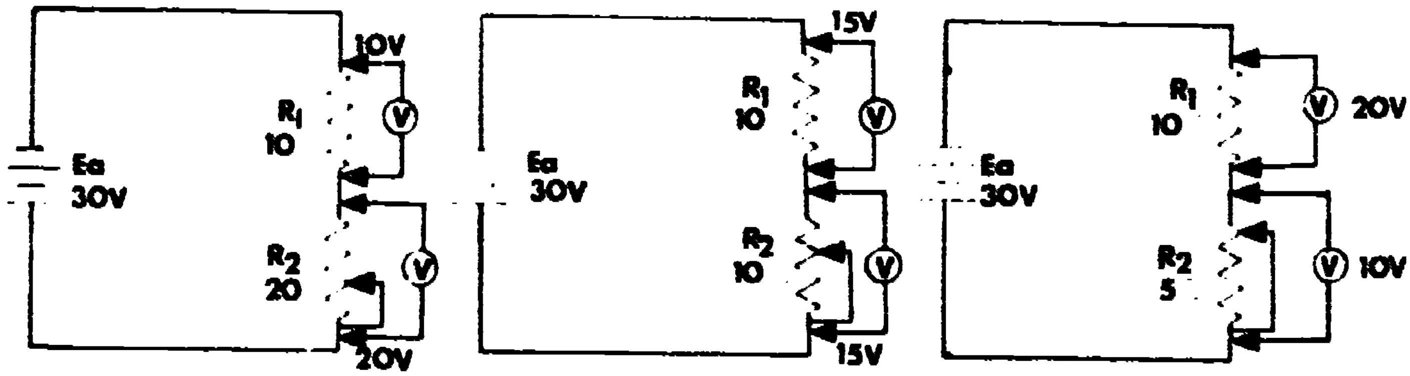
5. The diagram below illustrates a circuit with a variable resistor, a fixed resistor, and a source connected in series. The variable resistor is shown at three different settings.



Check the statement(s) that is/are true.

____ a. The largest voltage drop will take place across the least resistance.

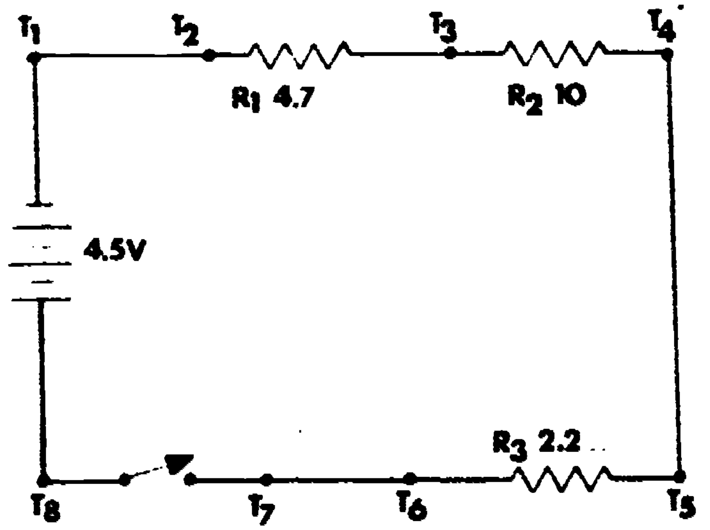
____ b. The voltage drop across the variable resistor is always greatest.

____ c. The voltage drop across the variable resistor will become greater or smaller as the resistance goes up or down.

____ d. The voltage dropped across a fixed resistor always remains the same.

____ e. The sum of the voltage drops always equals the applied voltage.

6. Using Practice Board 0-1 and components drawn from the material center, construct a series circuit as indicated by the schematic.



Energize the circuit then measure and record DC voltage at the points indicated below.

a. Test points T2 to T3. ____________________
b. Test points T3 to T4. ____________________
c. Test points T5 to T6. ____________________
d. Test points T7 to T8. ____________________
e. Test points T1 to T8. ____________________

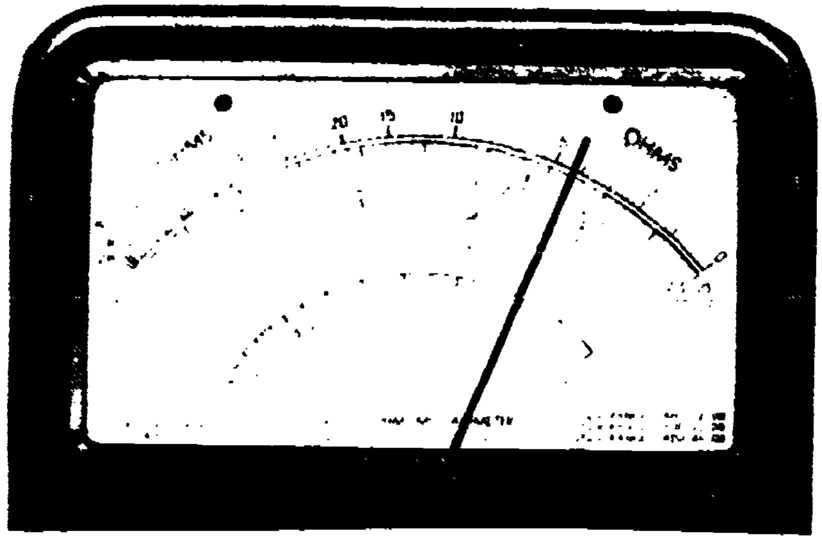
Open the switch and measure and record voltage at:

f. Test points T7 to T8. ____________________

7. Check the statement(s) that is/are true.

____ a. Polarity does not have to be observed when measuring AC voltage.
____ b. When measuring AC voltage with a multimeter the function switch is not used.
____ c. The black DC arc on the Simpson 260 is used for measuring AC voltages.
____ d. The figures directly below the scale marked 2.5 VAC only on the Simpson 260 are used for measuring AC voltages 2.5 v or less.
____ e. The figures above the red AC arc on the Simpson 260 are used for measuring AC voltages.

8. Interpret the meter reading and record the indicated AC voltage for each range switch position.



Range Switch Position	Meter Reading
a. 10 v	_____ volts AC
b. 50 v	_____ volts AC
c. 2.5 v	_____ volts AC
d. 250 v	_____ volts AC
e. 1000 v	_____ volts AC

PROGRESS CHECK ANSWERS

MODULE FOUR

LESSON I

1. Only one path for current flow.
2. a. 6 amps
   b. 12 amps
3. a
4. 1-b and d
   2-a and c
   3-b and d
   4-a and c
5. +DC or -DC
6. a
7. Approximately 25 ıamps
8. b
9. c, e
10. Approximately 250 milliamps

LESSON II

1. a, c, f, g, h
2. a. R1
   b. R1
3. 1. a
   2. b and d
   3. c
4. a. 6.5 v (drop)
   b. 3 v (rise)

LESSON II (Cont'd)

5. a. 35 v
   b. 55 v

LESSON III

1. 1. b
   2. a
   3. c
   4. a
2. b, d
3. 1. e
   2. c
   3. d
   4. b
   5. a
4. b, e, f, g, h, l
5. c, e
6. Approximately
   a. 1.25 v
   b. 2.6 v
   c. 0.6 v
   d. 0 v
   e. 4.5 v
   f. 4.5 v
7. a, d, e
8. a. 7.5 VAC
   b. 37.5 VAC
   c. 1.9 VAC
   d. 187.5 VAC
   e. 750 VAC

IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

Voltage, Current, and Resistance

1. A circuit that has only one path for current flow is a/an ______________ circuit.

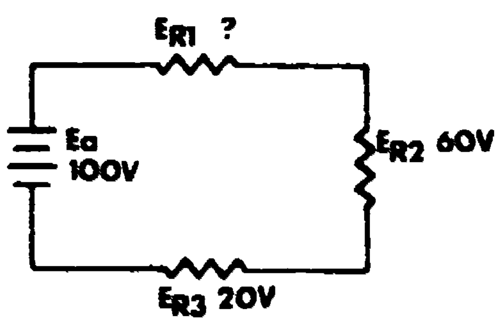
    _____ a. open
    _____ b. series
    _____ c. short
    _____ d. parallel

2. If circuit resistance is physically changed to a higher value, and the applied voltage remains unchanged, circuit current will:

    _____ a. increase.
    _____ b. decrease.
    _____ c. remain the same.
    _____ d. increase by the square.

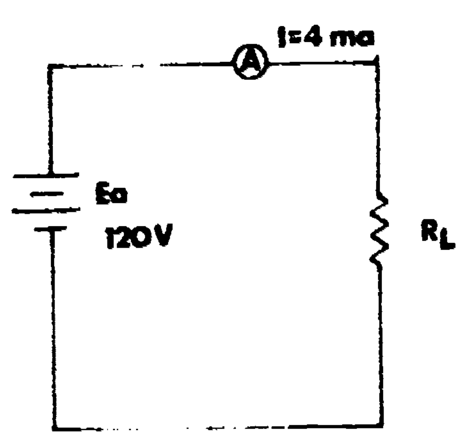
3. What is the value of E_{R1} in the diagram shown below?

    _____ a. 180 v
    _____ b. 100 v
    _____ c. 80 v
    _____ d. 20 v



4. If the value of voltage applied to a circuit is physically doubled while circuit resistance is unchanged, circuit current will:

    _____ a. decrease by four times.
    _____ b. double.
    _____ c. remain the same.
    _____ d. increase by four times.



5. Physically reducing a circuits applied voltage to half of its original value will cause the circuit current to be:

____ a. halved.
____ b. doubled.
____ c. tripled.
____ d. quadrupled.

6. The statement, "Circuit current is directly proportional to the applied voltage and inversely proportional to circuit resistance," is known as:

____ a. Kirchhoff's Law.
____ b. Joule's Law.
____ c. Ohm's Law.
____ d. Weber's Theory.

7. Physically decreasing circuit resistance will cause circuit current to:

____ a. increase by square.
____ b. decrease.
____ c. increase.
____ d. remain unchanged.

PROGRESS CHECK
LESSON II

Ohm's Law Formula

1. Converting chemical energy to electrical energy within a source describes a:

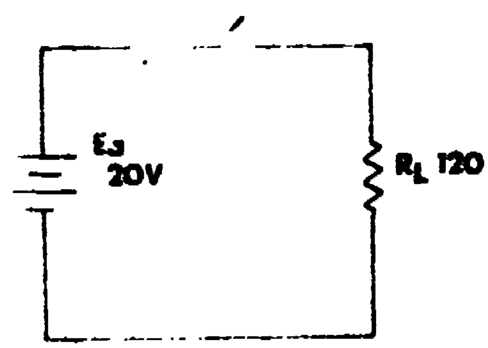
____ a. fall in potential.
____ b. rise in potential.
____ c. voltage drop.
____ d. power transfer.

2. What is the value of the voltage drop across a 30-ohm resistor that has 2 amps of current flowing through it?

____ a. 0.06 volts
____ b. 15 volts
____ c. 60 volts
____ d. 120 volts

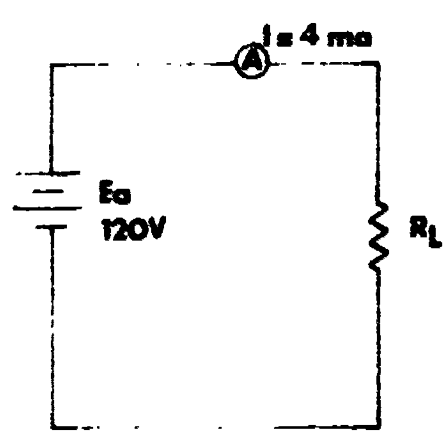
3. What is the value of current?

____ a. 1.66 ma
____ b. 16.6 ma
____ c. 166 ma
____ d. 1.66 a



4. What is the value of the load resistance?

____ a. 300 ohms
____ b. 480 ohms
____ c. 30 kohms
____ d. 48 kohms



5. What is the voltage drop across a 1 kohm resistor that has 2 ma of current flowing through it?

____ a. 2 v
____ b. 2 v
____ c. 2 v
____ d. 0.5 Mv

6. Which of the following mathematically expresses Ohm's Law?

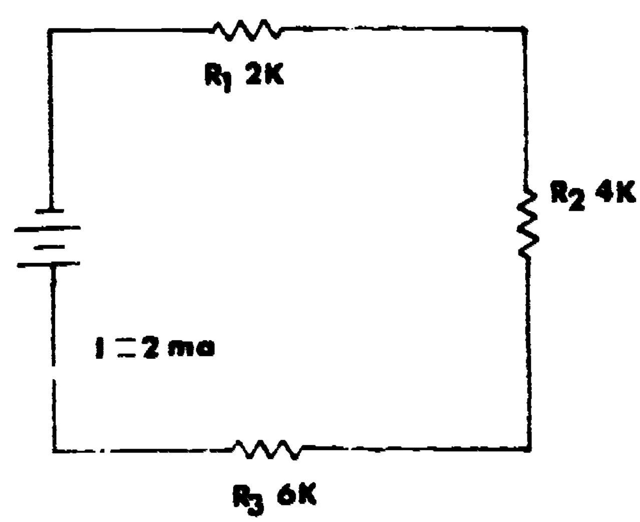
____ a. $I = \frac{E}{R}$
____ b. $P - IE$
____ c. $W = FD$
____ d. $P = \frac{W}{T}$

7. Which of the following accurately describes the conversion from electrical energy to heat energy within a resistance?

____ a. voltage drop
____ b. current loss
____ c. rise in potential
____ d. power loss

8. What is the value of source voltage in the circuit diagram shown below?

____ a. 6 v
____ b. 8 v
____ c. 12 v
____ d. 24 V

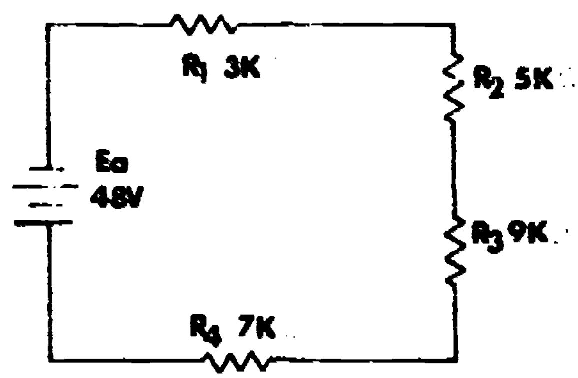


9. 50 volts, applied across a resistor, causes 5 amps of current to flow. What is the value of the resistor?

_____ a. 10 ohms.
_____ b. 25 ohms.
_____ c. 250 ohms.
_____ d. 2.5 kohms.

10. What is the value of total current in the diagram below?

_____ a. 2 ma
_____ b. 5 ma
_____ c. 2 a
_____ d. 5 a

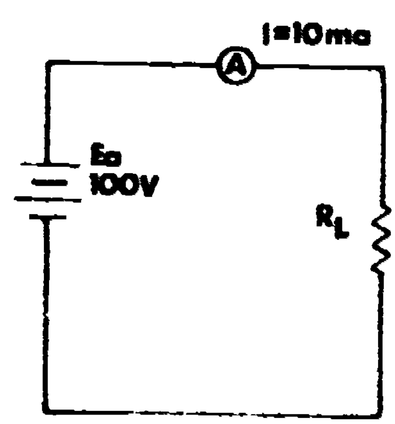


11. What is the value of current flow if a 40-ohm resistor is connected across a 20-volt battery?

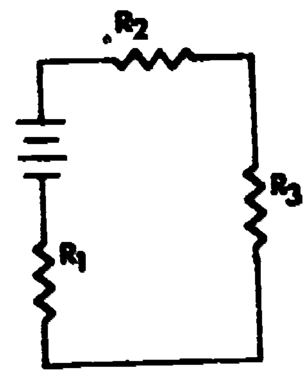
_____ a. 0.2 a
_____ b. 0.5 a
_____ c. 2 a
_____ d. 5 a

12. What is the value of the load resistor in the diagram shown below?

_____ a. 10 ohms.
_____ b. 100 ohms.
_____ c. 1 kohm.
_____ d. 10 kohms.

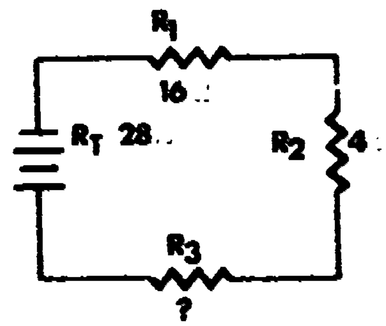


13. Which of the following is a characteristic of the circuit represented by the diagram shown?



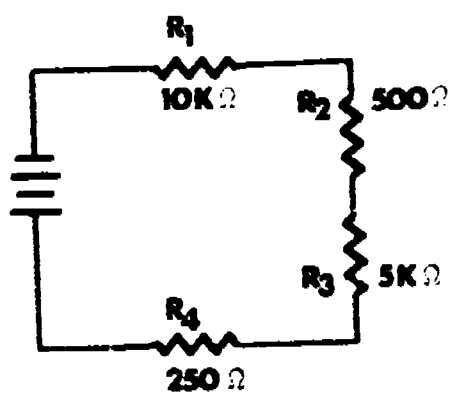
____ a. Voltage drops are equal.
____ b. Total resistance is smaller than the smallest resistor.
____ c. Total current is the sum of individual currents.
____ d. Total resistance is greater than the largest resistor.

14. What is the resistance of R3?



____ a. 8 ohms
____ b. 12 ohms
____ c. 18 ohms
____ d. 20 ohms

15. What is the value of R_T?



____ a. 765 kohms
____ b. 15.5 kohms
____ c. 15.75 kohms
____ d. 765 Kohms

PROGRESS CHECK
LESSON III

Power

1. The amount of work done per unit time describes:

____ a. current.
____ b. voltage.
____ c. resistance.
____ d. power.

2. How much power is dissipated by a circuit that has a 75-volt source and a current flow of 5 ma?

____ a. 375 w
____ b. 3.75 w
____ c. 0.375 w
____ d. 37.5 w

3. Which of the following correctly expresses the relationship that exists between power, work and time?

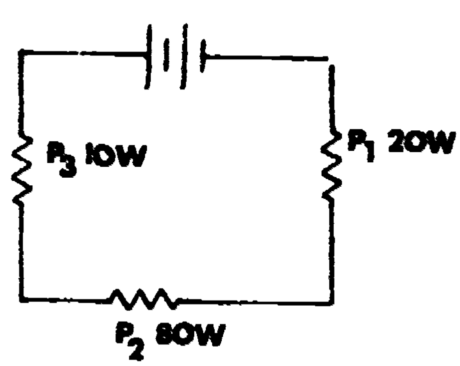
____ a. $P = \frac{W}{T}$

____ b. $P = \frac{T}{W}$

____ c. $P = W \times T$
____ d. $P = W + T$

4. In the circuit represented by the diagram below, how much power is supplied by the source?

____ a. 6.15 w
____ b. 16.6 w
____ c. 110 w
____ d. 160 w



5. Electrical power can be expressed as:

____ a. force per unit area.
____ b. coulombs per unit time.
____ c. work per unit time.
____ d. joules per coulomb.

6. How much power is dissipated by a circuit that has a 440-volt source and a total resistance of 880 ohms?

____ a. 110 w
____ b. 220 w
____ c. 440 w
____ d. 880 w

7. How much power is dissipated by a circuit containing 6 K ohms of resistance when 2 ma of current is flowing?

____ a. 2.4 mw
____ b. 24 mw
____ c. 1.2 w
____ d. 12 w

PROGRESS CHECK
LESSON IV

Internal Resistance

1. When a load is placed across a source, what causes the decrease in terminal voltage?

    ____ a. the internal resistance of the source.
    ____ b. the physical size of the source.
    ____ c. the power dissipated by the load.
    ____ d. the physical size of the load resistance.

2. Internal resistance is an opposition to current and will cause ________ (more/less) voltage to be present across the load.

3. As circuit current increases, the voltage drop across the internal resistance will ______________ (increase/decrease).

4. Increasing the load resistance will result in ________ (more/less) circuit current and therefore ________ (more/less) voltage dropped across the internal resistance.

5. All sources of EMF contain a certain amount of resistance. This opposition to current flow is called:

    ____ a. terminal resistance.
    ____ b. internal resistance.
    ____ c. load resistance.
    ____ d. circuit resistance.

6. Internal resistance of a source ________ (can/cannot) be measured with an ohmmeter.

PROGRESS CHECK
LESSON V

Troubleshooting Series Circuits

1. A shorted component in a series circuit will ________ total resistance.

   ____ a. cause an increase in
   ____ b. cause a decrease in
   ____ c. have no effect on
   ____ d. always double

2. What effect will an open have on total resistance of a series circuit?

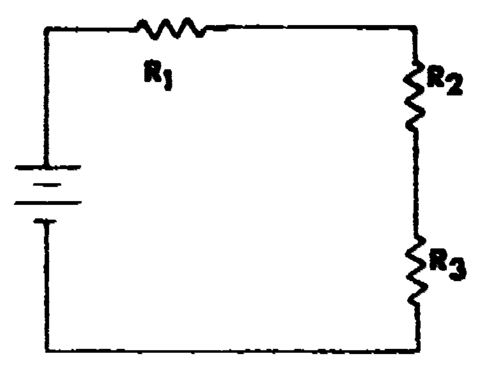
   ____ a. Total resistance will increase to infinity.
   ____ b. Total resistance will always double.
   ____ c. Total resistance will always decrease to zero.
   ____ d. Total resistance will decrease to a smaller value.

3. In a series circuit a shorted component will cause:

   ____ a. a decrease in circuit current
   ____ b. an increase in total resistance
   ____ c. a decrease in all voltage drops
   ____ d. an increase in circuit current

4. In the circuit represented by the diagram shown, a short across R-3 will cause a/an.

   ____ a. increase in total resistance.
   ____ b. decrease in total circuit current.
   ____ c. decrease in the voltage drops across E_{R1} and E_{R2}.
   ____ d. increase in the voltage drops across E_{R1} and E_{R2}.



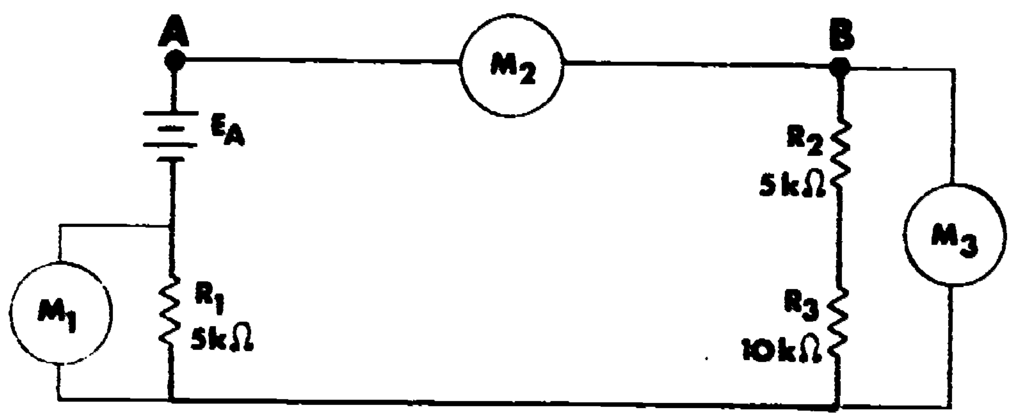
5. What effect does an open have on circuit current?

_____ a. It will cause current to decrease to 0.
_____ b. It will cause current to exactly double.
_____ c. It will cause current to increase at a linear rate.
_____ d. It will cause current to decrease to half its original value.

6. Determine the trouble in the circuit represented by the diagram shown by comparing the abnormal with the normal measurements.

_____ a. point A grounded
_____ b. R1 open
_____ c. R3 open
_____ d. point B grounded

	NORMAL CIRCUIT MEASUREMENTS	ABNORMAL CIRCUIT MEASUREMENTS
E_a	200 v	200 v
M1	50 v	0
M2	10 ma	0
M3	150 v	200 v



PROGRESS CHECK ANSWERS

MODULE FIVE

LESSON I

1. b
2. b
3. d
4. b
5. a
6. c
7. c

LESSON II

1. b
2. c
3. c
4. c
5. c
6. a
7. a
8. d
9. a
10. a
11. b
12. d
13. d
14. a
15. c

LESSON III

1. d
2. c
3. a
4. c
5. c
6. b
7. b

LESSON IV

1. a
2. less
3. increase
4. less; less
5. b
6. cannot

LESSON V

1. b
2. a
3. d
4. d
5. a
6. c

IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

Rules for Voltage and Current

1. A parallel circuit is one in which:

____ a. the currents through each branch are equal.
____ b. there is more than one current path connected to a common voltage source.
____ c. the voltage drops across each component are different.
____ d. there is only one path for current flow.

2. Which statement below expresses the relationship between source voltage and the voltage drops across each branch of a parallel circuit?

____ a. Sour ltage increases as any branch voltage drop decreases.
____ b. The voltage drop across each branch is equal to source voltage.
____ c. The voltage drop across each branch increases as the source voltage decreases.
____ d. Source voltage is the sum of the voltage drops across each branch.

3. Which of the following equations is the mathematical expression for total voltage in a parallel circuit?

____ a. $E_T = E_1 \times E_2 \times \ldots \times E_n$
____ b. $E_T = E_1 + E_2 + \ldots + E_n$
____ c. $E_T = E_1 = E_2 = \ldots = E_n$
____ d. $E_T = E_1 - E_2 - \ldots - E_n$

4. Which of the following equations would be used to determine total current in a parallel circuit?

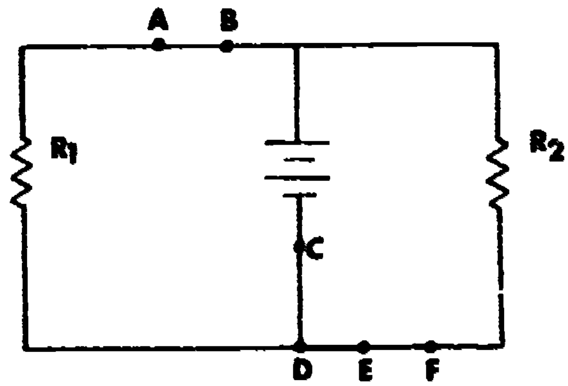
____ a. $I_T = I_1 = I_2 = \ldots = I_n$
____ b. $I_T = I_1 - I_2 - \ldots - I_n$
____ c. $I_T = I_1 + I_2 + \ldots + I_n$
____ d. $I_T = I_1 \times I_2 \times \ldots \times I_n$

5. In a parallel circuit, current through each branch is inversely proportional to:

_____ a. the number of branches.
_____ b. the source voltage.
_____ c. total circuit current.
_____ d. the branch resistance.

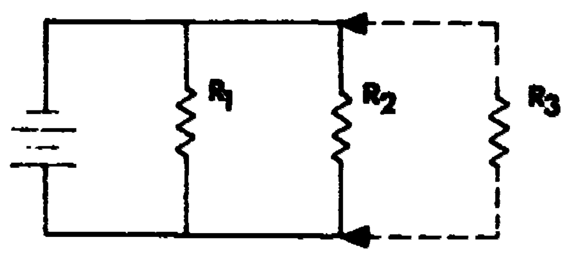
6. Between what two points of the circuit represented by this diagram should an ammeter be inserted to measure total circuit current?

_____ a. A and B
_____ b. C and D
_____ c. D and E
_____ d. E and F



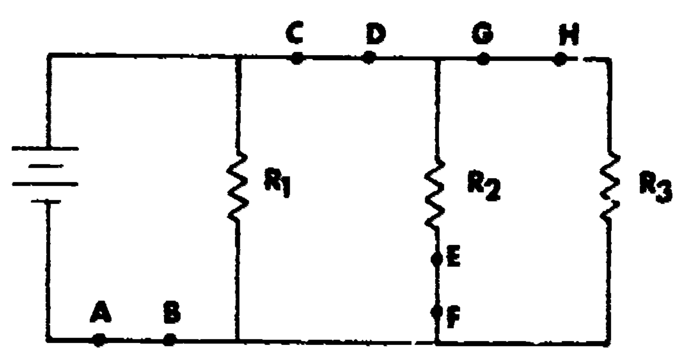
7. When R3 is added to the circuit diagram shown below, the current through R1 will:

_____ a. increase.
_____ b. decrease by half.
_____ c. decrease by the square.
_____ d. not change.



8. In the circuit represented by the diagram shown below, between what two points should an ammeter be inserted to measure the combined branch currents of R2 and R3?

_____ a. G and H
_____ b. E and F
_____ c. C and D
_____ d. A and B

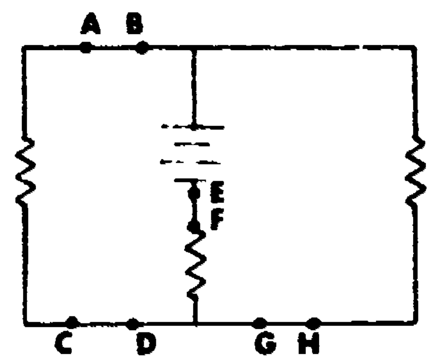


9. What will happen to the total current in a parallel circuit when another resistor is connected in parallel?

____ a. Current will always triple.
____ b. Current will decrease.
____ c. Current will not change.
____ d. Current will increase.

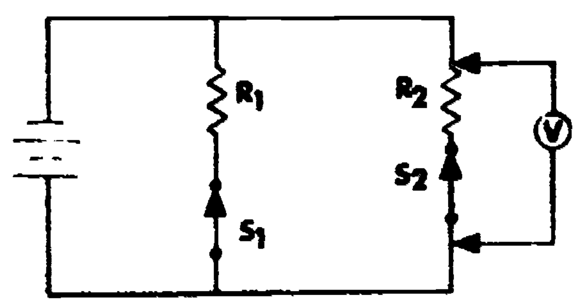
10. In the circuit represented by the schematic shown below, between what two points would a fuse be placed to protect all circuit components?

____ a. A and B
____ b. C and D
____ c. E and F
____ d. G and H



11. In the circuit represented by the diagram shown below, if S2 is opened, the voltmeter reading will:

____ a. increase.
____ b. decrease.
____ c. drop to zero.
____ d. remain steady.

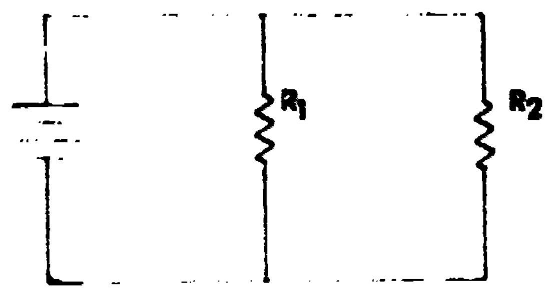


PROGRESS CHECK
LESSON II

Rules for Resistance and Power

1. In the circuit below, if resistor R2 is replaced with one of greater resistance, the:

____ a. total circuit resistance will decrease.
____ b. current flow through R1 will increase.
____ c. voltage drop across R2 will increase.
____ d. power dissipated by R1 will remain the same.



2. Which of the following equations is used to determine the total resistance of a two-branch parallel circuit?

____ a. $R_T = R1 - R2$

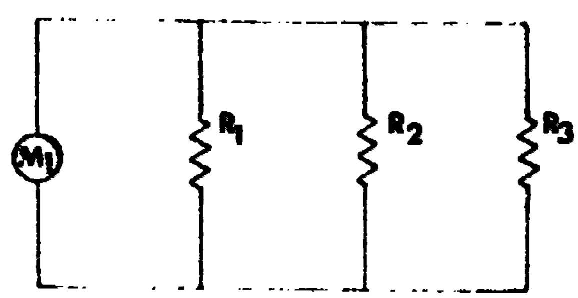
____ b. $R_T = R1 + R2$

____ c. $R_T = \frac{R1 \times R2}{R1 + R2}$

____ d. $R_T = \frac{R1 + R2}{R1 \times R2}$

3. In the circuit represented by the diagram shown, if R1 is disconnected from the circuit, the indication on ohmmeter M1 will:

____ a. increase.
____ b. decrease.
____ c. drop to 0.
____ d. increase to infinity.



4. If a third current path is added to a two-branch parallel circuit, the total resistance of the circuit will be:

____ a. less than it was before the current path was added.
____ b. greater than it was before the current path was added.
____ c. the same as it was before the current path was added.
____ d. equal to the resistance of the additional current path.

5. Which of the following expressions could be used to determine the total resistance of a parallel circuit containing resistors of equal value?

____ a. $R_T = \frac{R}{n}$

____ b. $R_T = \frac{R1 \times R2}{R1 \times R2}$

____ c. $R_T = \frac{R1 + R2}{R1 + R2}$

____ d. $R_T = \frac{R1 + R2}{n}$

6. Which of the following expressions could be used to solve for total power of a parallel circuit when the power dissipated by each branch resistor is known?

____ a. $P_T = I^2E_T$

____ b. $P_T = P_1 + P_2 + \ldots + P_n$

____ c. $P_T = P_1 \times P_2 \times \ldots \times P_n$

____ d. $P_T = \frac{P}{n}$

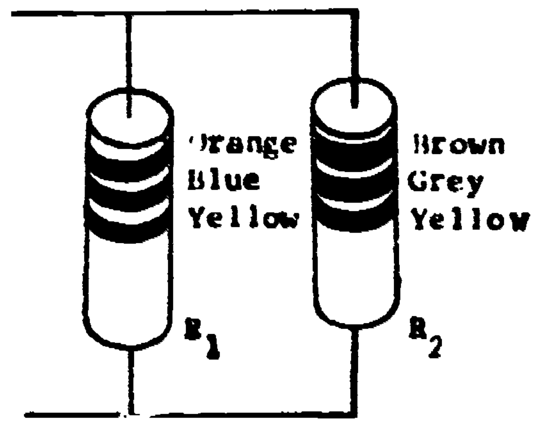
7. Which of the below resistors has the same resistance as the equivalent resistance of R1 and R2?

____ a.

____ b.

____ c.

____ d.

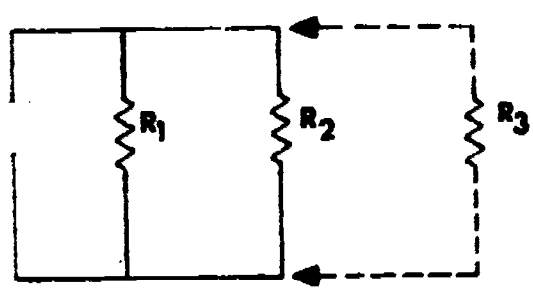


8. Which of the following describes the relationship between the equivalent resistance and the individual branch resistance of a parallel circuit? Equivalent resistance will always be:

____ a. greater than the largest branch resistance.
____ b. smaller than the smallest branch resistance.
____ c. equal to the sum of the branch resistance.
____ d. equal to the smallest branch resistance.

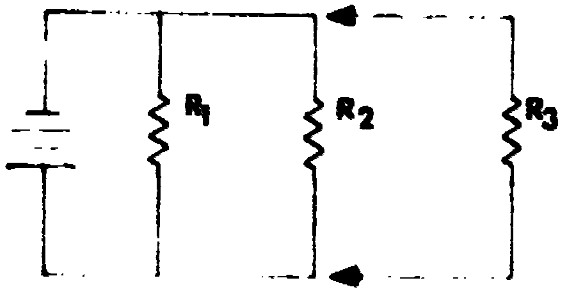
9. In the circuit represented by the diagram shown below, what will happen to the equivalent resistance when R3 is connected?

____ a. increase
____ b. decrease
____ c. double
____ d. not change



10. In the circuit diagram shown below, the total power dissipated by the circuit when R3 is connected will:

____ a. double.
____ b. not change.
____ c. increase.
____ d. decrease.



11. In a three-branch parallel circuit, the equivalent resistance of any two of the branches will always be:

____ a. the same as the total resistance of the circuit.
____ b. less than the total resistance of the circuit.
____ c. greater than the total resistance of the circuit.
____ d. equal to the equivalent resistance of any other two branches.

12. A circuit consists of two resistors, equal in ohmic value, connected in parallel. What is the total resistance?

____ a. one-half the value of one resistor
____ b. one-half the sum of the resistors
____ c. the sum of the resistors
____ d. the same as the value of one resistor

13. What is the value of the equivalent resistance of a three-branch parallel circuit that contains resistors of 20 ohms, 30 ohms, and 60 ohms?

____ a. 0.1
____ b. 0.6
____ c. 10
____ d. 110

PROGRESS CHECK
LESSON III

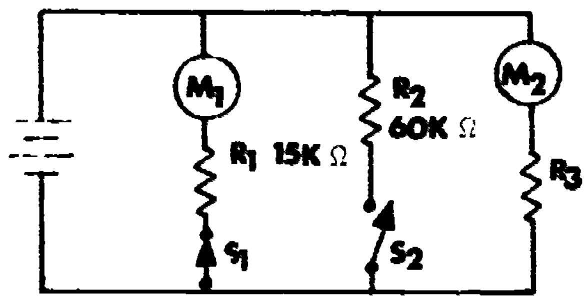
Variational Analysis

1. What will happen to the total current in a parallel circuit when another resistor is connected in parallel?

____ a. Current will always triple.
____ b. Current will decrease.
____ c. Current will not change.
____ d. Current will increase.

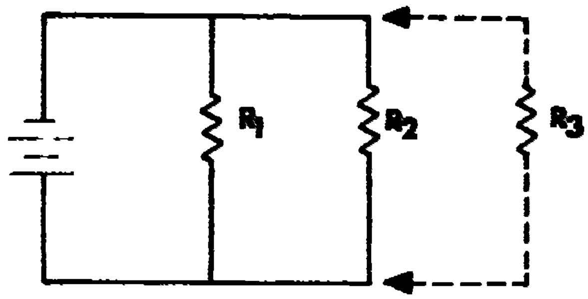
2. If S2 is closed and S1 is opened, the indication on M1 will ____________ and M2 will ______________.

____ a. increase/decrease
____ b. decrease/increase
____ c. remain steady/increase
____ d. decrease/remain steady



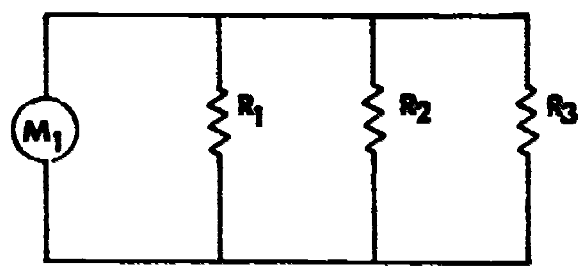
3. When R3 is added to the circuit diagram shown below, the current through R1 will:

____ a. increase.
____ b. decrease by half.
____ c. decrease by the square.
____ d. not change.



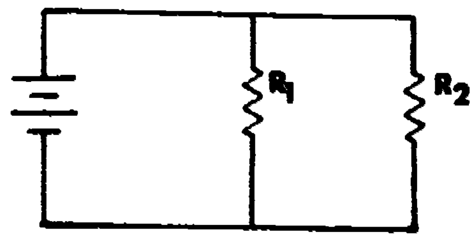
4. If R1 is disconnected from the circuit, the indication on ohmmeter M1 will:

____ a. increase.
____ b. decrease.
____ c. drop to zero.
____ d. increase to infinity.



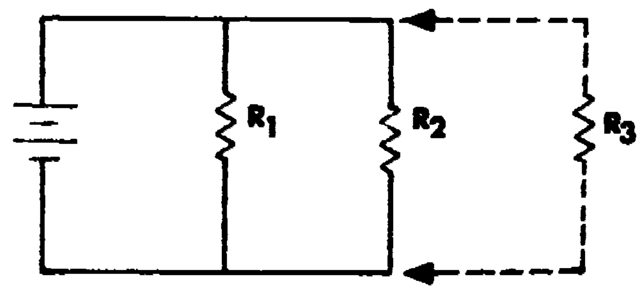
5. If resistor R2 is increased in value, which of the following is correct?

____ a. Total circuit resistance will decrease.
____ b. The current flow through R1 will increase.
____ c. The voltage drop across R2 will increase.
____ d. The power dissipated by R1 will remain the same.



6. What will happen to the equivalent resistance when R3 is connected?

____ a. increase
____ b. decrease
____ c. double
____ d. not change



7. The total power dissipated when R3 is connected will:

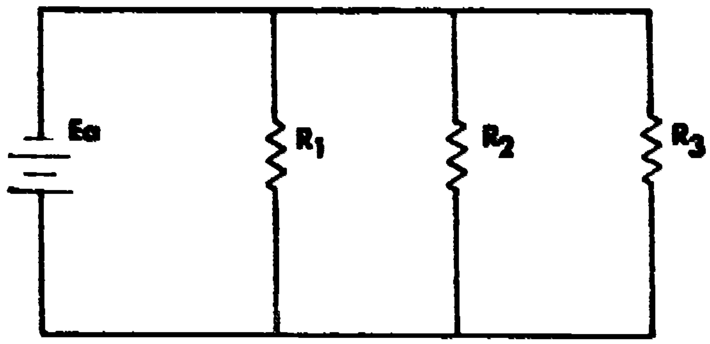
____ a. double.
____ b. not change.
____ c. increase.
____ d. decrease.

8. What effect will an open in one branch of a parallel circuit have on total circuit current?

____ a. An open will cause circuit current to increase.
____ b. An open will cause circuit current to double.
____ c. An open will cause circuit current to decrease.
____ d. An open does not effect circuit current.

9. Decreasing source voltage will cause I_{R3} to:

____ a. remain constant.
____ b. increase.
____ c. decrease.
____ d. stop.



10. Increasing E_a in a parallel circuit causes the current through each branch to ________________ proportionally.

PROGRESS CHECK
LESSON IV

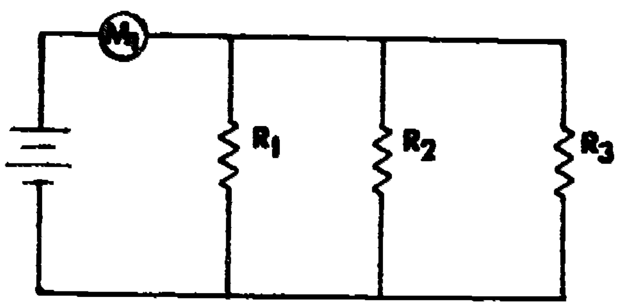
Troubleshooting Parallel Circuits

1. An open in any branch of a parallel circuit will cause total circuit current to:

____ a. increase.
____ b. decrease.
____ c. remain unchanged.
____ d. cease flowing.

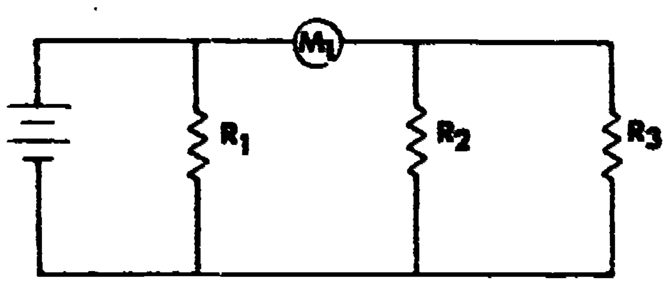
2. In the circuit diagram shown below, if R1 opens, the reading on M1 will ____________.

____ a. decrease to zero
____ b. decrease by the value of I_1
____ c. increase by the value of I_1
____ d. not change



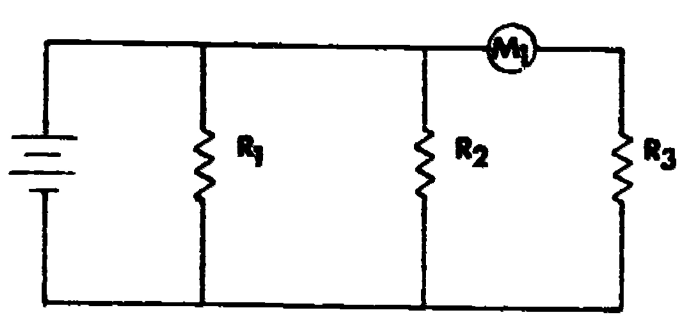
3. In the circuit represented by the diagram shown, if R1 shorts the indication on ammeter M1 will:

____ a. decrease.
____ b. drop to zero.
____ c. increase.
____ d. remain steady.



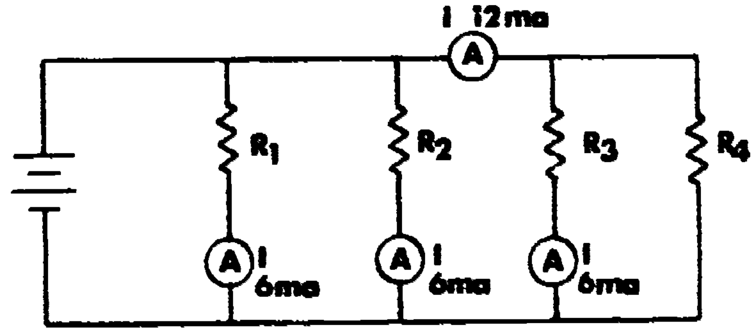
4. In the circuit represented by the diagram shown, if R1 opens, the indication on ammeter M1 will:

____ a. increase.
____ b. remain steady.
____ c. decrease.
____ d. drop to zero.



5. In the circuit diagram shown below, if R2 opens, what value of current will flow through R4?

____ a. 0
____ b. 6 ma
____ c. 8 ma
____ d. 12 ma

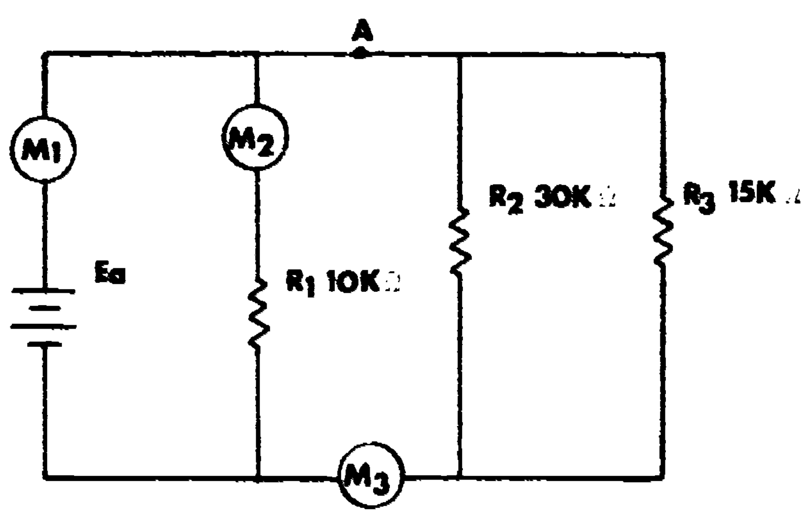


6. An open in any branch of a parallel circuit will:

____ a. have no effect on any other branch.
____ b. cause total circuit current to increase.
____ c. decrease total resistance.
____ d. increase the power supplied to the circuit.

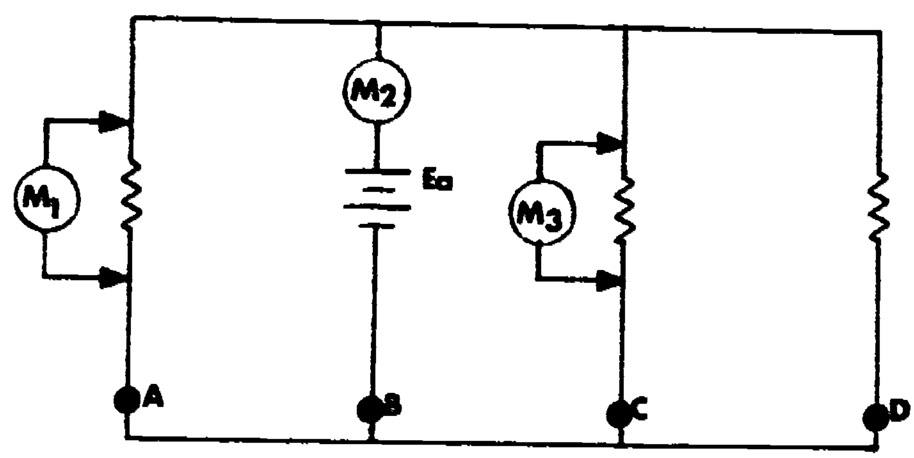
7. By comparing abnormal with normal measurements, determine the trouble in the circuit represented by the diagram.

		NORMAL CIRCUIT MEASUREMENTS	ABNORMAL CIRCUIT MEASUREMENTS
____ a.	open at point A		
____ b.	R1 open	E_a 30 v	30 v
____ c.	R2 open	M1 6 ma	5 ma
____ d.	R3 open	M2 3 ma	3 ma
		M3 3 ma	2 ma



8. By comparing the abnormal with the normal measurements, determine the trouble in the circuit represented by the diagram.

		NORMAL CIRCUIT MEASUREMENTS	ABNORMAL CIRCUIT MEASUREMENTS
____ a.	point A open	E_a 50 v	50 v
____ b.	point B open	M1 50 v	50 v
____ c.	point C open	M2 8 ma	6 ma
____ d.	point D open	M3 50 v	0



PROGRESS CHECK ANSWERS

MODULE SIX

LESSON I

1. b
2. b
3. c
4. c
5. d
6. b
7. d
8. c
9. d
10. c
11. d

LESSON II

1. d
2. c
3. a
4. a
5. a
6. b
7. c
8. b
9. b
10. c
11. c

LESSON II (Cont'd)

12. a
13. c

LESSON III

1. d
2. d
3. d
4. a
5. d
6. b
7. c
8. c
9. c
10. increase

LESSON IV

1. b
2. b
3. b
4. b
5. b
6. a
7. c
8. c

IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON 1

Solving Complex Circuits

1. Which formula below correctly expresses the total power dissipated in a series-parallel circuit?

____ a. $P_T = I^2E$

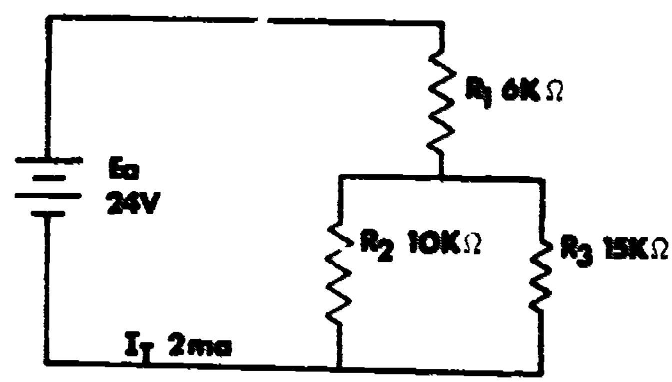
____ b. $P_T = IR$

____ c. $P_T = P1 + P2 + P3 + \ldots + Pn$

____ d. $P_T = \frac{P1 \times P2}{P1 + P2}$

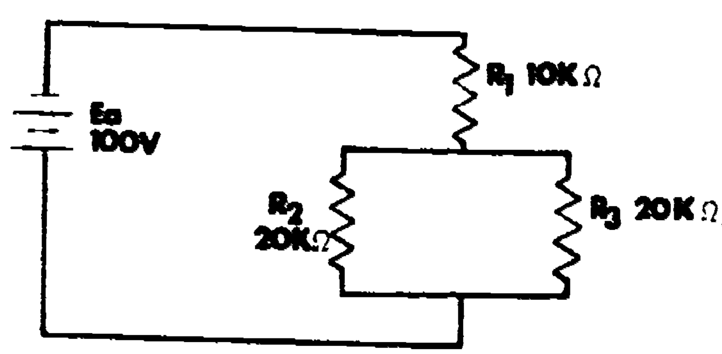
2. What is the total power dissipated?

____ a. 36 mw
____ b. 48 mw
____ c. 60 mw
____ d. 72 mw



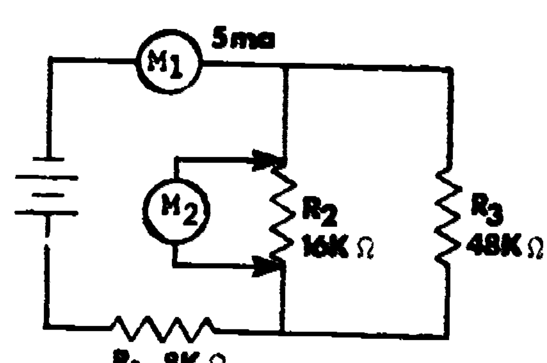
3. What is the value of total circuit current?

____ a. 2.5 ma
____ b. 5 ma
____ c. 10 ma
____ d. 15 ma



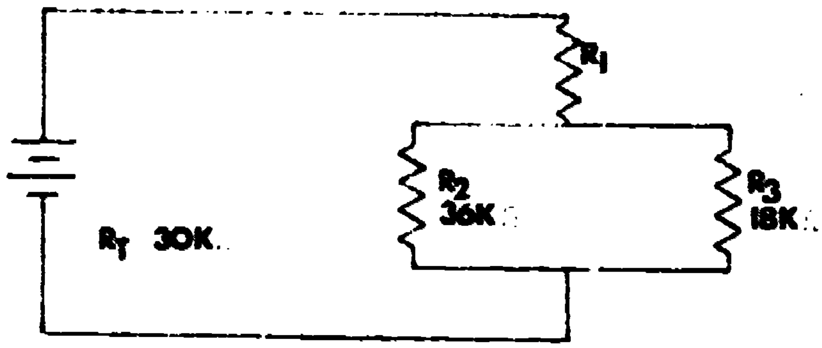
4. Voltmeter M2 will indicate:

____ a. 40 volts
____ b. 60 volts
____ c. 100 volts
____ d. 360 volts



5. What is the resistance of R1?

____ a. 9 kilohms
____ b. 18 kilohms
____ c. 27 kilohms
____ d. 36 kilohms



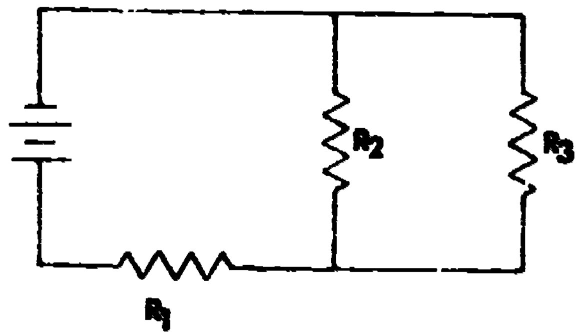
6. Which of the following expressions shows the correct relationship between total and individual resistance for the circuit represented by the diagram?

____ a. $R_T = R1 + \frac{R2 \times R3}{R2 + R3}$

____ b. $R_T = R1 - \frac{R2 + R3}{R2 + R3}$

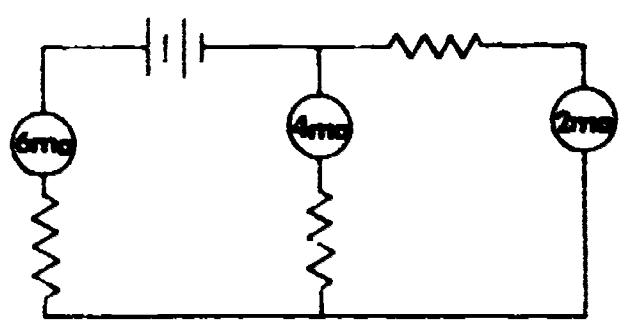
____ c. $R_T = \frac{R1 \times (R2 + R3)}{R1 + (R2 + R3)}$

____ d. $R_T = \frac{R1 + (R2 \times R3)}{R1 \times (R2 + R3)}$



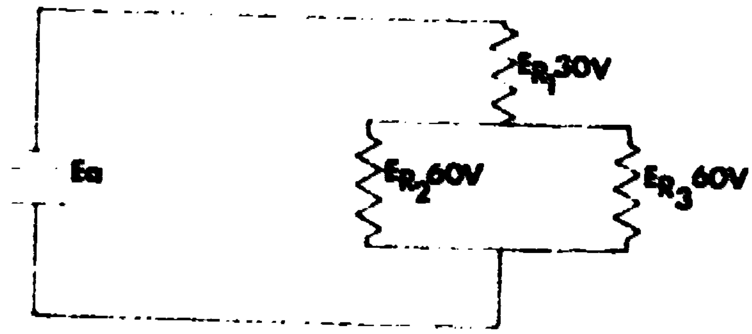
7. What is the total circuit current?

____ a. 6 ma
____ b. 8 ma
____ c. 10 ma
____ d. 12 ma



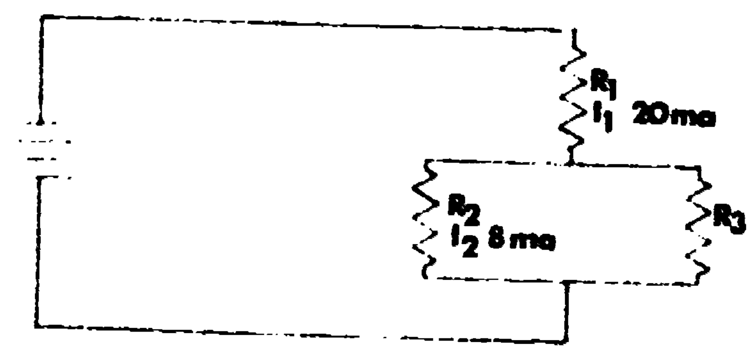
8. What is the value of source voltage?

____ a. 30 volts
____ b. 90 volts
____ c. 120 volts
____ d. 150 volts



9. What is the value of the current flowing through R3?

____ a. 8 ma
____ b. 10 ma
____ c. 12 ma
____ d. 28 ma



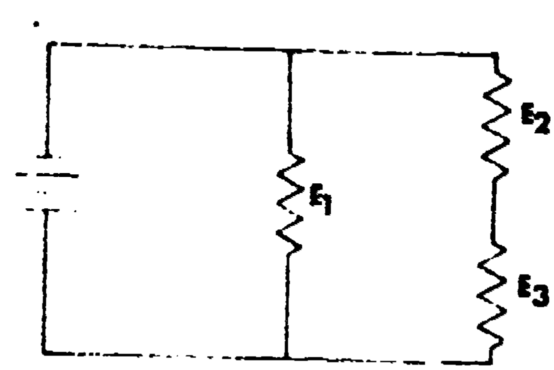
10. Which of the following expressions is a correct statement of Kirchhoff's Voltage Law for the circuit represented by the diagram shown below?

____ a. $E_T = E_1 = (E_2 + E_3)$

____ b. $E_T = E_1 = E_2 = E_3$

____ c. $E_T = E_1 + E_2 = E_3$

____ d. $E_T = E_1 + (E_2 = E_3)$



11. "A circuit that has more than one current path and more than one series voltage drop," describes which figure?

____ a. 1
____ b. 2
____ c. 3
____ d. 4


FIG.1

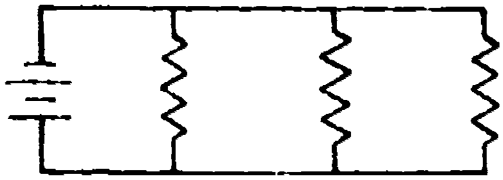


FIG.2

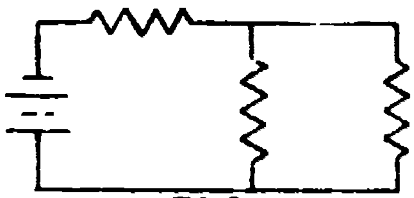


FIG.3

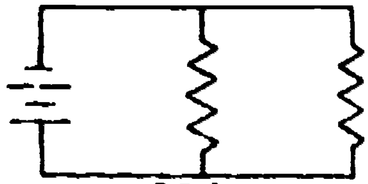
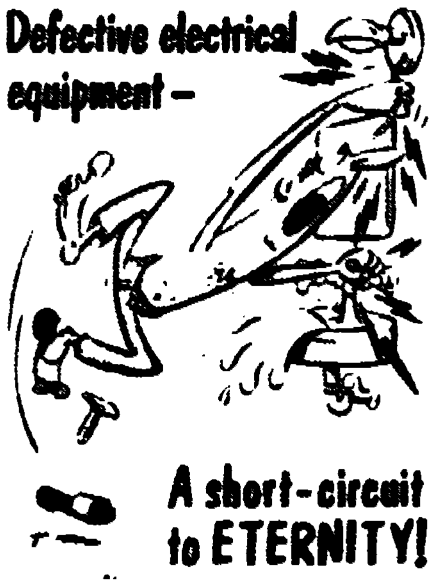


FIG.4



PROGRESS CHECK
LESSON II

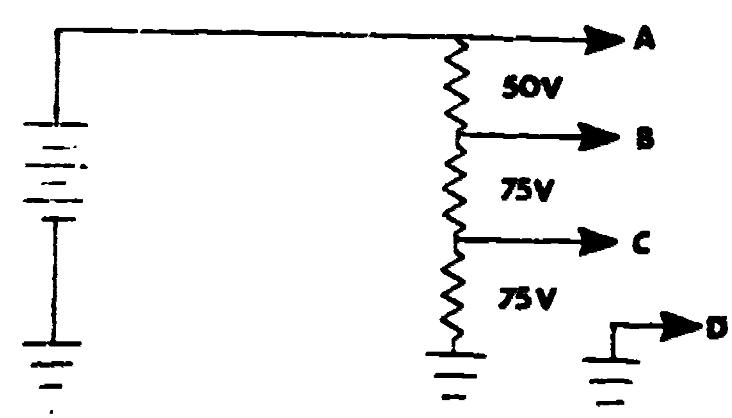
Voltage Reference

1. "An arbitrarily chosen point to which all other points are compared" is a description of a:

____ a. positive ground.
____ b. negative ground point.
____ c. reference point.
____ d. (none of the above)

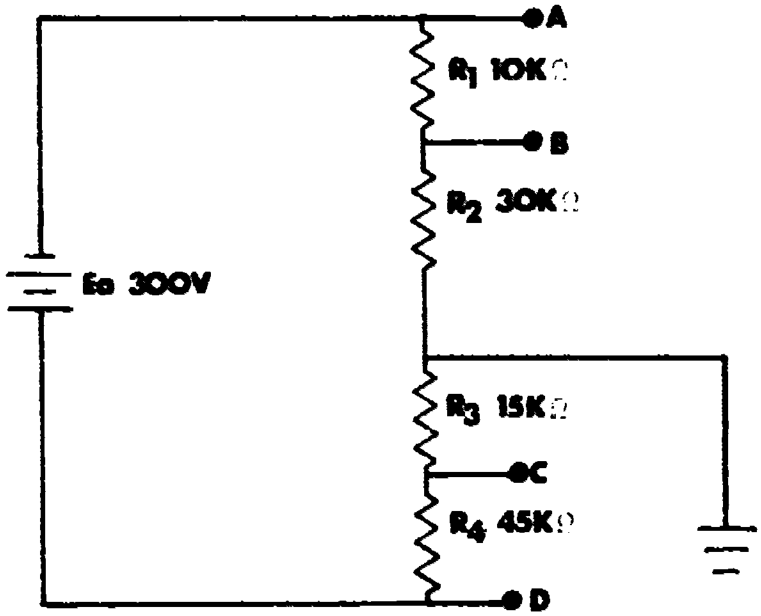
2. Making use of various reference points, match:

____ 1. Point A is--	a 125 volts positive in reference to point C.
____ 2. Point B is--	b. 75 volts negative in reference to point B
____ 3. Point C is--	c. 150 volts positive in reference to point D
____ 4. Point D is--	d. 200 volts negative in reference to Point A.



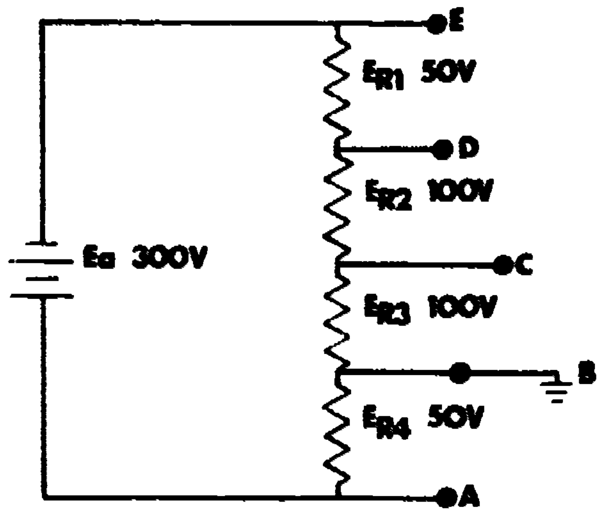
3. What is the polarity and the value of voltage at terminal B with respect to ground?

____ a. + 30 volts
____ b. - 45 volts
____ c. - 90 volts
____ d. -120 volts



4. What is the magnitude and polarity of the voltage at point D with respect to ground?

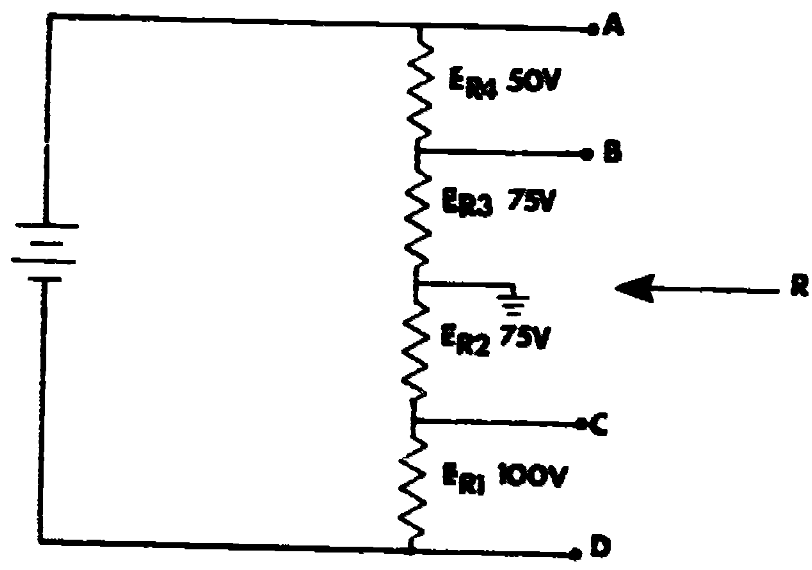
____ a. -100 volts
____ b. -200 volts
____ c. +200 volts
____ d. +100 volts



5. What is the polarity of the voltage at Point A with respect to R?

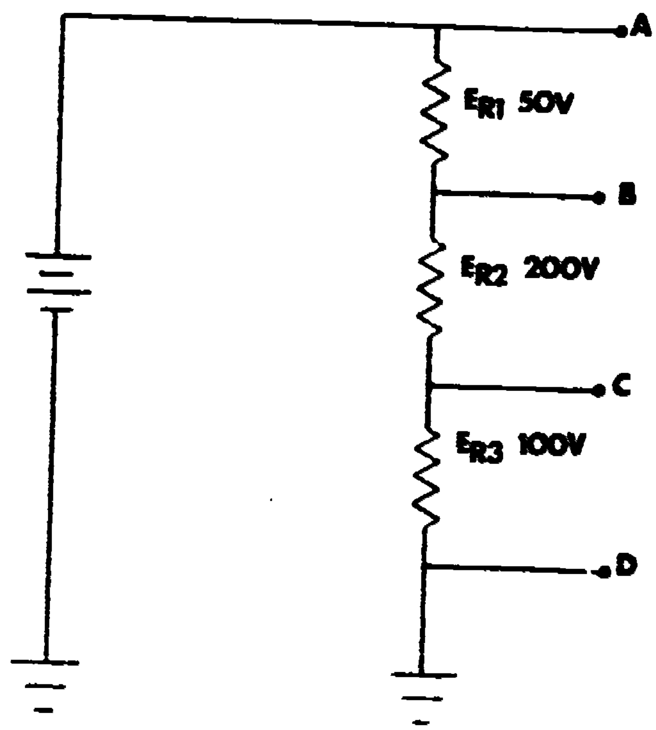
____ a. positive

____ b. negative



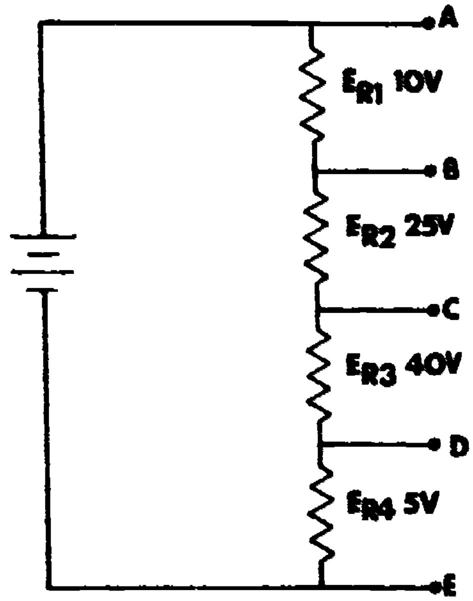
6. What is the potential and polarity at point B with respect to A?

____ a. + 50 volts
____ b. +200 volts
____ c. - 50 volts
____ d. +300 volts



7. What is the polarity and magnitude of the voltage at point E with respect to point B?

____ a. -35 volts
____ b. +40 volts
____ c. +65 volts
____ d. -70 volts



PROGRESS CHECK
LESSON III

Voltage Dividers

1. Which feature of a voltage divider enables it to supply voltages of positive and/or negative polarity?

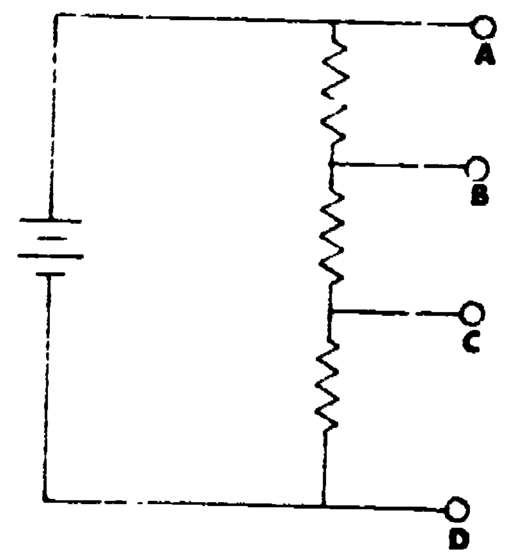
____ a. number of series resistors.
____ b. size of resistors used.
____ c. location of reference point.
____ d. number of loads attached.

2. What is the polarity of point C with respect to Point B?

____ a. negative

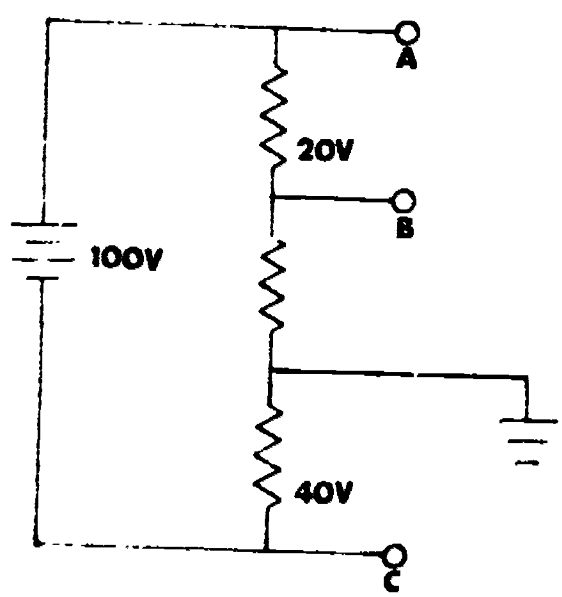
____ b. positive

____ c. no polarity can be assigned



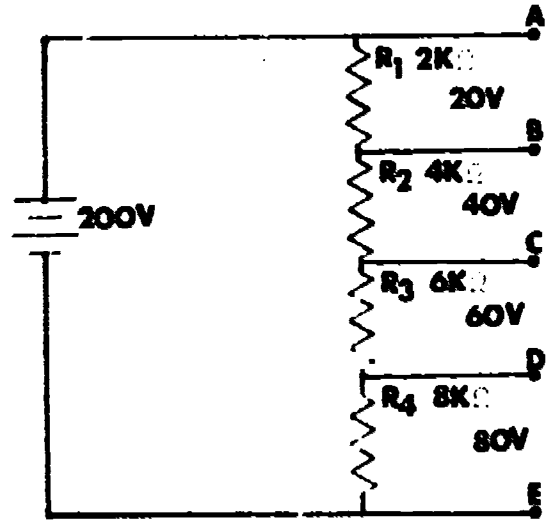
3. What is the magnitude and polarity of point A with respect to ground?

____ a. negative 40 volts
____ b. positive 60 volts
____ c. negative 60 volts
____ d. positive 20 volts



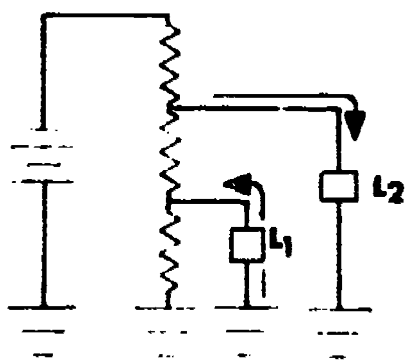
4. What is the polarity and voltage at terminal C with respect to point A?

____ a. -40 v
____ b. +60 v
____ c. -60 v
____ d. -200 v

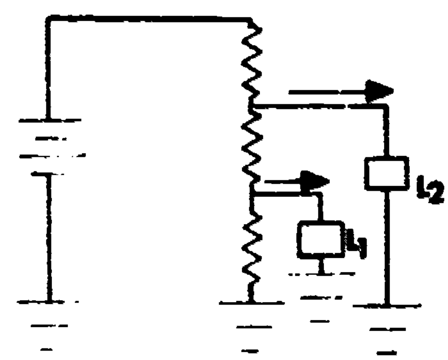


5. Which of the following diagrams shows the correct direction of current flow, using the electron theory of current flow?

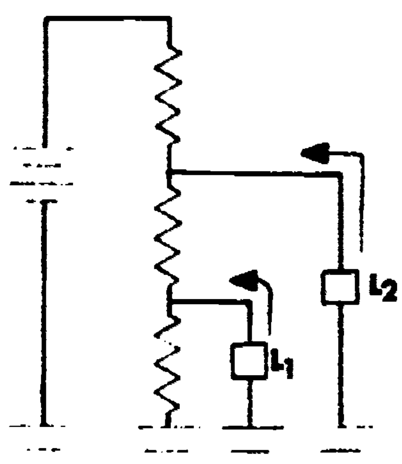
____ a.



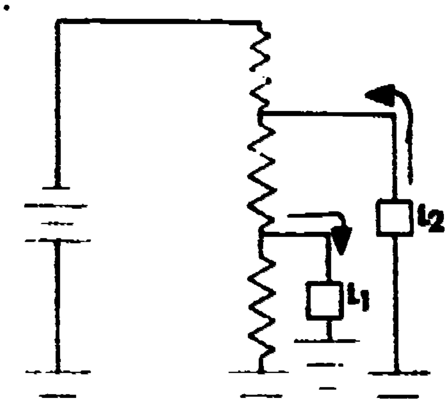
____ b.



____ c.

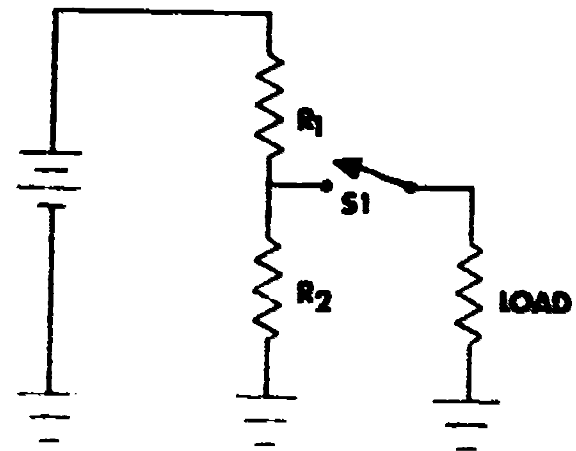


____ d.



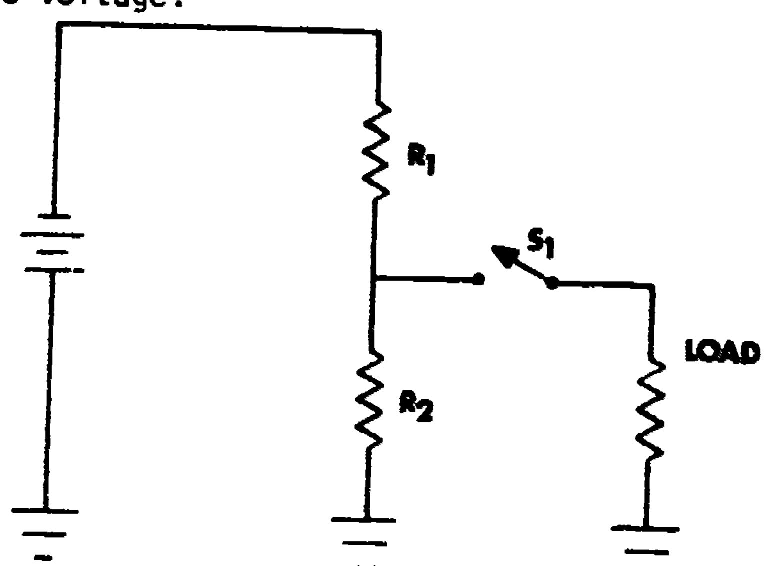
6. What effect will closing <u>S1</u> have on total circuit current?

_____ a. Total circuit current will decrease.
_____ b. Total circuit current will increase.
_____ c. Total circuit current will double.
_____ d. Total circuit current will not change.



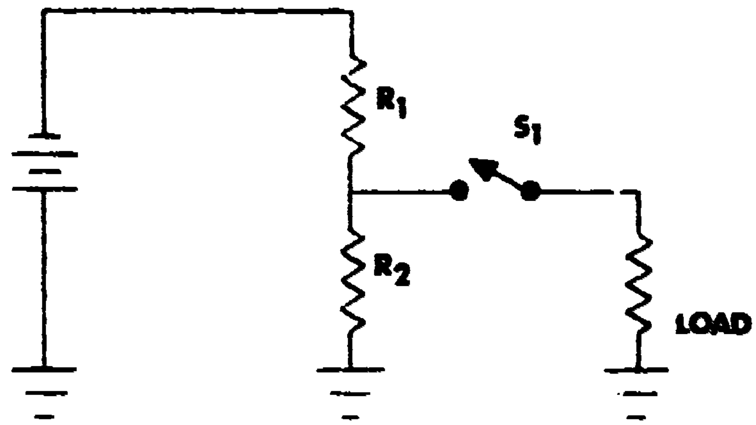
7. Closing <u>S1</u> will cause the voltage across <u>R2</u> to:

_____ a. decrease.
_____ b. increase.
_____ c. increase to source voltage.
_____ d. not change.



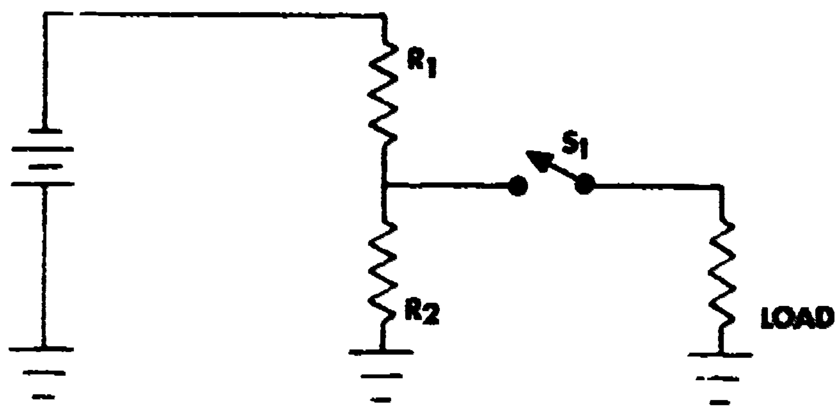
8. What effect will closing S1 have on total resistance?

____ a. increase
____ b. not change
____ c. decrease
____ d. increase to infinity



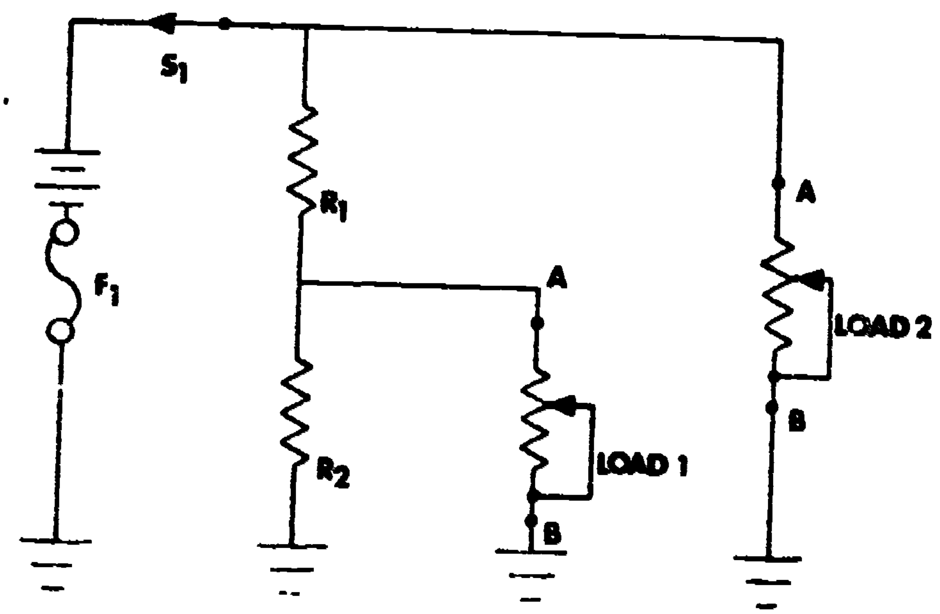
9. What effect will opening S1 have on the voltage dropped across R1?

____ a. increase
____ b. not change
____ c. increase to source voltage
____ d. decrease

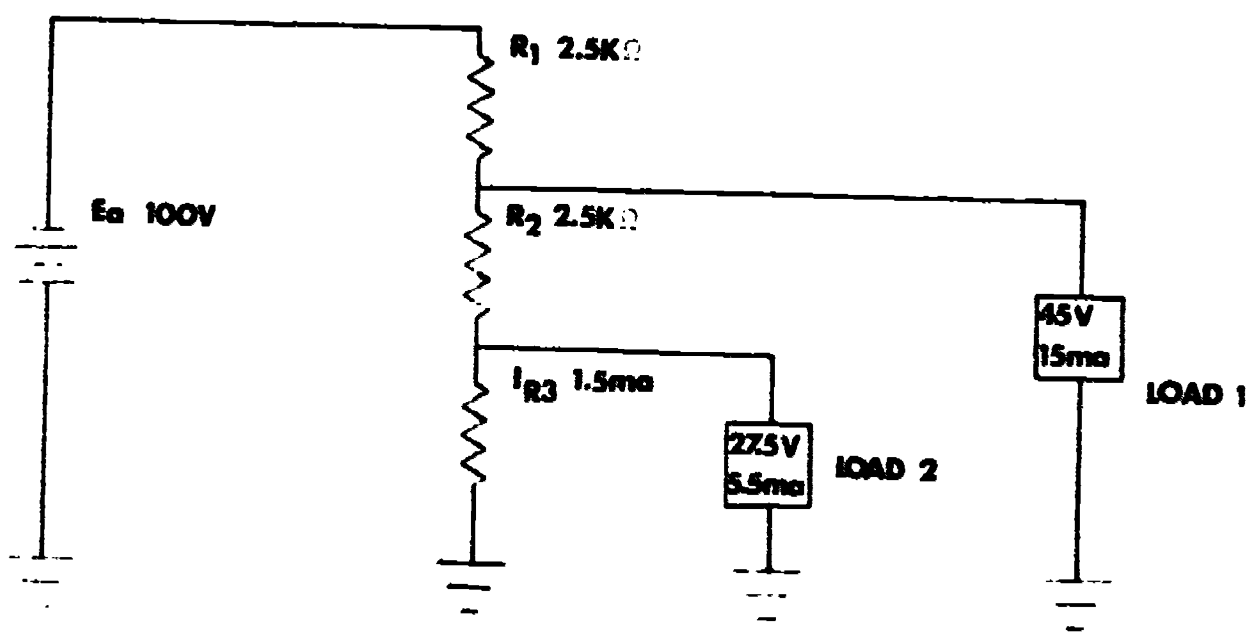


10. Moving the arm of load 1 to point A will cause E_{R1} to:

____ a. double.
____ b. increase.
____ c. decrease.
____ d. stay the same.



11. Solve.



a. I_T = ____
b. R_T = ____
c. E_{R1} = ____
d. E_{R2} = ____
e. I_{R2} = ____
f. E_{R3} = ____
g. R_3 = ____

PROGRESS CHECK ANSWERS

MODULE SEVEN

LESSON I

1. c
2. b
3. b
4. b
5. b
6. a
7. a
8. b
9. c
10. a
11. c

LESSON II

1. c
2. 1-a
   2-c
   3-b
   4-d
3. c
4. b
5. a
6. c
7. d

LESSON III

1. c
2. a
3. b
4. c
5. c
6. b
7. a
8. c
9. d
10. b
11. a. 22 ma
    b. 4.5 kΩ
    c. 55 v
    d. 17.5 v
    e. 7 ma
    f. 27.5 v
    g. 18.3 kΩ

IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

<u>Electromagnets</u>

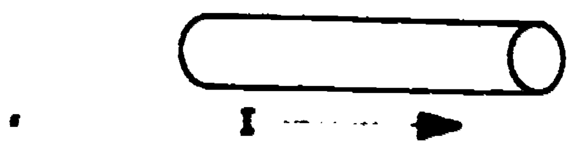
1. Write the definition of electromagnetism.

____

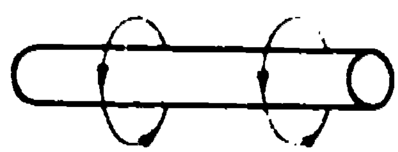
____

____

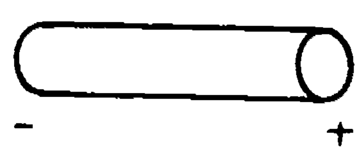
2. In the following sketch, indicate by arrows the direction of the lines of force.



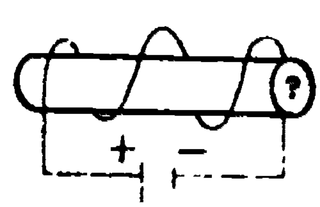
3. In the following sketch, indicate by an arrow the direction of current flow.



4. In the following sketch, indicate by arrows the direction of current flow and lines of force.



5. Is the pole marked with a question mark a North or South pole?



6. State in your own words the two primary purposes for using a relay.

   1. ____

   2. ____

      ____

      ____

PROGRESS CHECK
LESSON 11

Inductors and Flux Density

1. Match the statement in A to the drawings in B.

A

____ 1. has higher permeability

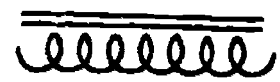
____ 2. has higher reluctance

____ 3. has less permeability

____ 4. has less reluctance

B

a. 

b. 

2. List the five factors that affect flux density in an inductor.

Directly Proportional (Any order.)

a. ____________________

b. ____________________

c. ____________________

d. ____________________

Inversely Proportional

e. ____________________

PROGRESS CHECK
LESSON III

Inducing a Voltage

1. Three factors are necessary to generate an EMF by magnetic induction. List the three factors. (Any order.)

   a. ____________________
   b. ____________________
   c. ____________________

2. The magnetic field generated by a current-carrying conductor originates:

   ____ a. along the skin area of the conductor.
   ____ b. in the immediate area around the conductor.
   ____ c. instantaneously throughout the conductor.
   ____ d. in the center of the conductor.

3. When a circuit is first energized, the magnetic field:

   ____ a. expands.
   ____ b. collapses.

4. With the field moving outward, the conductor moves ____________ in relation to it.

5. Relative motion exists in a current-carrying conductor due to the ____________ and ____________ field.

6. The EMF induced in a conductor due to a changing magnetic field ____________ the current that causes it.

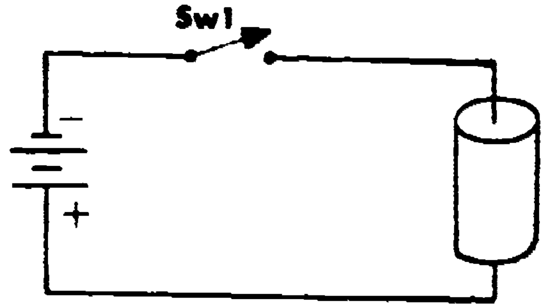
7. The induced EMF opposes circuit EMF. This induced EMF is called ____________ EMF.

8. The induced EMF is of ____________ value after current reaches a steady value.

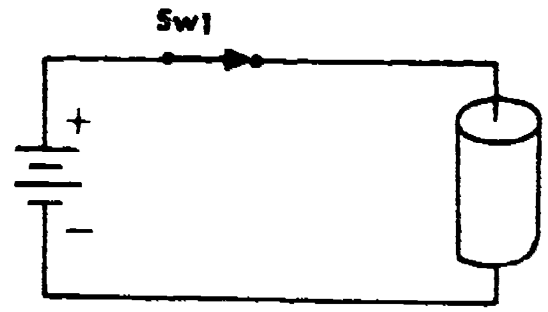
9. When current is in a steady state and the circuit is opened, the __________ starts to collapse.

10. When the magnetic field is collapsing, the CEMF is in such a direction that it attempts to __________ current flow.

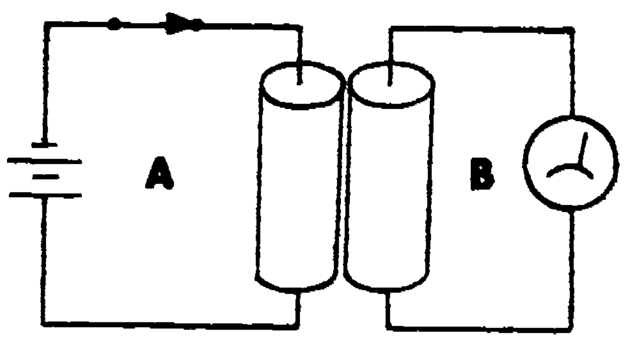
11. On the schematic, indicate (with polarity signs) the polarity of CEMF at the instant SW1 is closed.



12. On the schematic, indicate (with signs) the polarity of CEMF at the instant SW1 is opened.



13. Indicate the polarity of induced EMF in circuit B when circuit A is first energized.



14. Which of the statements below is known as Lenz's Law?

____ a. The sum of the voltage drops around a series circuit will equal source voltage.
____ b. The direction of the voltage drops is such as to add to source voltage.
____ c. The polarity of the voltage drops is such that when added to source voltage, the sum is zero.
____ d. The polarity of the induced EMF is such that it tends to set up a current flow that opposes the original current.

15. CEMF is present in a circuit only when circuit current is __________.

16. A source that will supply a continuously changing value of E and I is a/an ____________ source.

PROGRESS CHECK
LESSON IV

Induction and Inductance

1. Inductance is the property of a circuit that opposes any change in circuit ___________.

2. A change in circuit current produces a/an _______________ that opposes this change.

3. Lenz's Law is the basis for explaining the property of ________.

4. The voltage produced by the property of inductance is called _________.

5. The opposition felt by a changing current is due to circuit _____________.

6. The CEMF present in a circuit due to inductance ___________ the source current.

7. Inductance is symbolized by the letter L and is measured in:

   ____ a. farads.
   ____ b. henrys.
   ____ c. ohms.
   ____ d. mhos.

8. Very small units of inductance are normally expressed as _________ henrys or __________ henrys.

9. To find L_T of a three-branch parallel inductive circuit, the formula ______________ would be used.

10. In parallel, total inductance is always ___________ the smallest inductance.

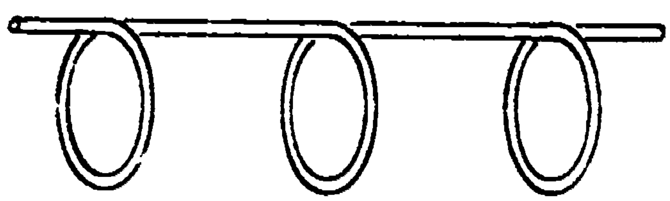
11. In a series circuit, total inductance is found by ____________ the individual values of inductance.

12. A parallel inductive circuit with one inductor of 10 mh and one of 25 mh would have an L_T of ________________ mh.

13. A series inductive circuit with five inductors of 3, 17, 25, 30 and 50 mh would have an L_T of _____________ mh.

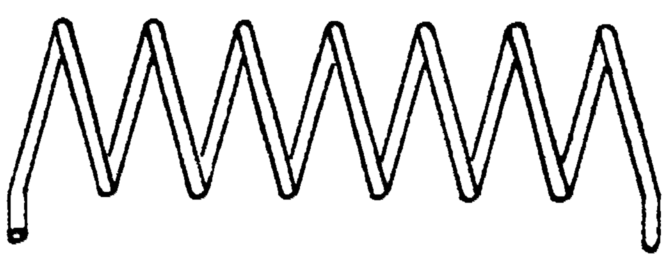
14. Which of the below diagrams would exhibit the greatest amount of inductance?

____ a.

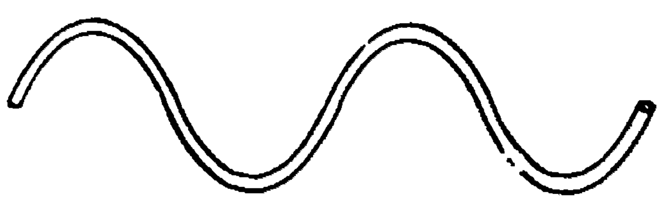


____ b.

____ c.



____ d.



15. List three physical means available for increasing the magnetic field strength of an inductor.

    a. ______________________________
    b. ______________________________
    c. ______________________________

16. To determine the direction of the inductive magnetic field, you would use the ____________ for coils.

17. Inserting a core into a coil will create a greater concentration of ________________.

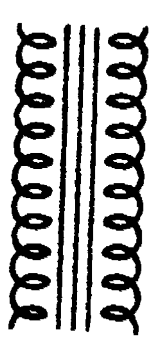
18. Inductance _____________ be affected by increasing current through the coil.

19. List three physical means of increasing induction between two coils.

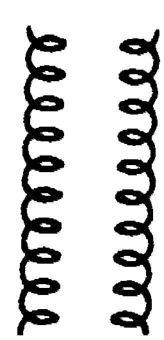
    a. ______________________________
    b. ______________________________
    c. ______________________________

20. Two coils positioned at right angles will exhibit ____________ mutual inductance.

21. Coefficient of coupling will be greatest between which of the coil pairs below?



A ____



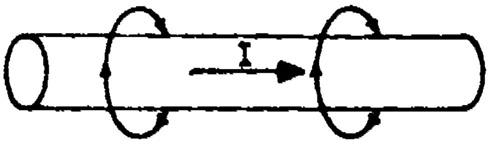
B ____

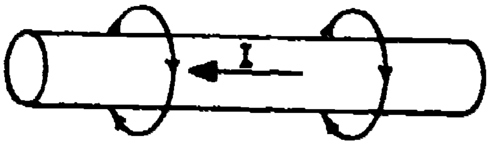
PROGRESS CHECK ANSWERS

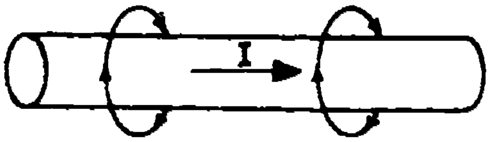
MODULE EIGHT

LESSON I

1. Electromagnetism is the production of a magnetic field by current flow through a conductor.

2. 

3. 

4. 

\- +

5. South

6. 1. remote control of circuits without the necessity of running great lengths of high-current wiring.
   2. decrease safety hazards involved in physically controlling high power circuits.

LESSON II

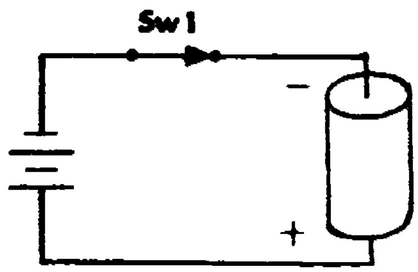
1. 1-b
   2-a
   3-a
   4-b

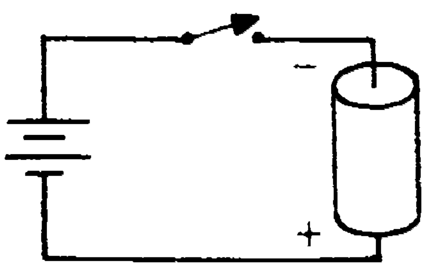
LESSON II (Cont'd)

2. a. permeability
   b. number of turns
   c. cross-sectional area of the core
   d. current flow through the coil
   e. length of core

   in any order

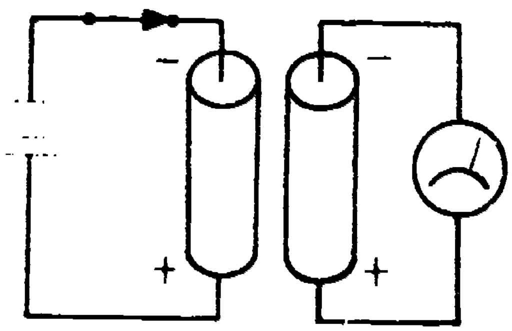
LESSON III

1. a. motion
   b. flux
   c. conductor
2. d
3. a
4. inward
5. expanding
   collapsing
6. opposes
7. counter
8. zero
9. magnetic field
10. sustain
11. 

12. 

LESSON III (Cont'd)

13.



14. d
15. changing
16. alternating

LESSON IV

1. current
2. voltage or CEMF
3. inductance
4. CEMF
5. inductance
6. opposes
7. b
8. milli
   micro (either order)
9. $L_T = \dfrac{1}{\frac{1}{L1} + \frac{1}{L2} + \frac{1}{L3}}$
10. less than
11. adding
12. 7.1 mh

LESSON IV (Cont'd)

13. 125 mh
14. c
15. a. increasing turns in coil
    b. decreasing space between turns
    c. inserting iron core
16. left-hand rule
17. lines of flux
18. will not
19. a. decrease space between coils
    b. use high permeability core material
    c. increase coil turns
20. zero or no
21. a.

IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY NOW TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

Rise and Decay of Current and Voltage

1. In a DC LR circuit, when the circuit is first energized, voltage drop is ______________ across the inductor.

2. At the instant the circuit is energized, circuit current is ______________ and E_R is ______________.

3. After five time constants, voltage drop across the resistor is ______________ and circuit current is ______________.

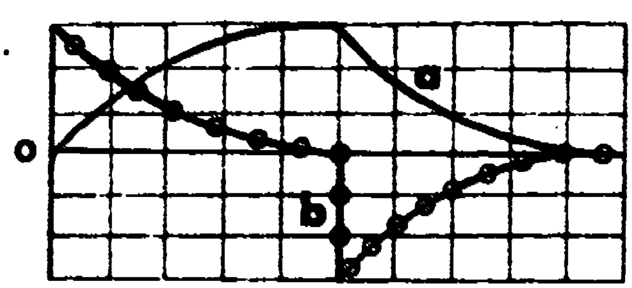
4. When current has stabilized (five time constants), voltage drop across the inductor is ______________.

5. As circuit current is increasing, energy is being stored in a/an ______________ field about the coil.

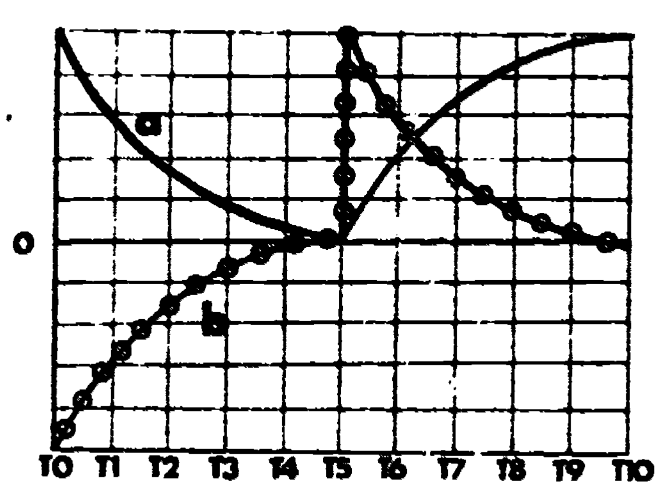
6. Removing the source and shorting the LR branch will cause the magnetic field to ______________ and current will flow in the ______________ direction.

7. Which of the graphs below correctly indicates CEMF, E_L, E_R and I at T5 when the switch is opened?

____ a.



____ b.



Curve a = I and E_R

Curve b = CEMF and E_L

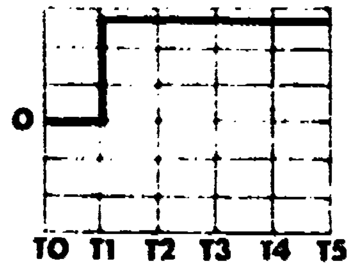
8. On the growth and decay graph, the horizontal base represents ______________.

9. The purpose of the graph is to pictorially represent the values of voltage and current in reference to ______________.

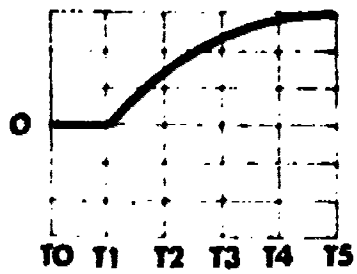
10. The vertical base of the graph represents circuit values of E and I in either a ____________ or ____________ direction.

11. Which graph represents current in a DC circuit containing only resistance when the switch is closed at T1?

____ a.



____ b.



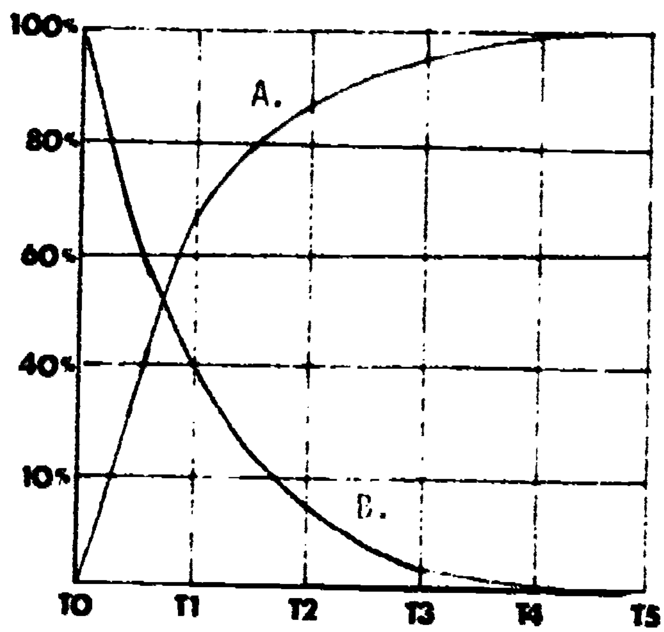
12. Current is slower to reach its maximum value in a circuit containing inductance due to the ________ generated by the inductor.

13. The ____________ of the LR circuit is greatest at T1 due to the rate of change of current being greatest at this instant.

14. The polarity of the CEMF always ____________ the source EMF during current rise.

15. When a circuit is first de-energized, the value of ____________ or ________________________ is maximum.

16. What values are represented by the graph below when a DC LR circuit is energized?



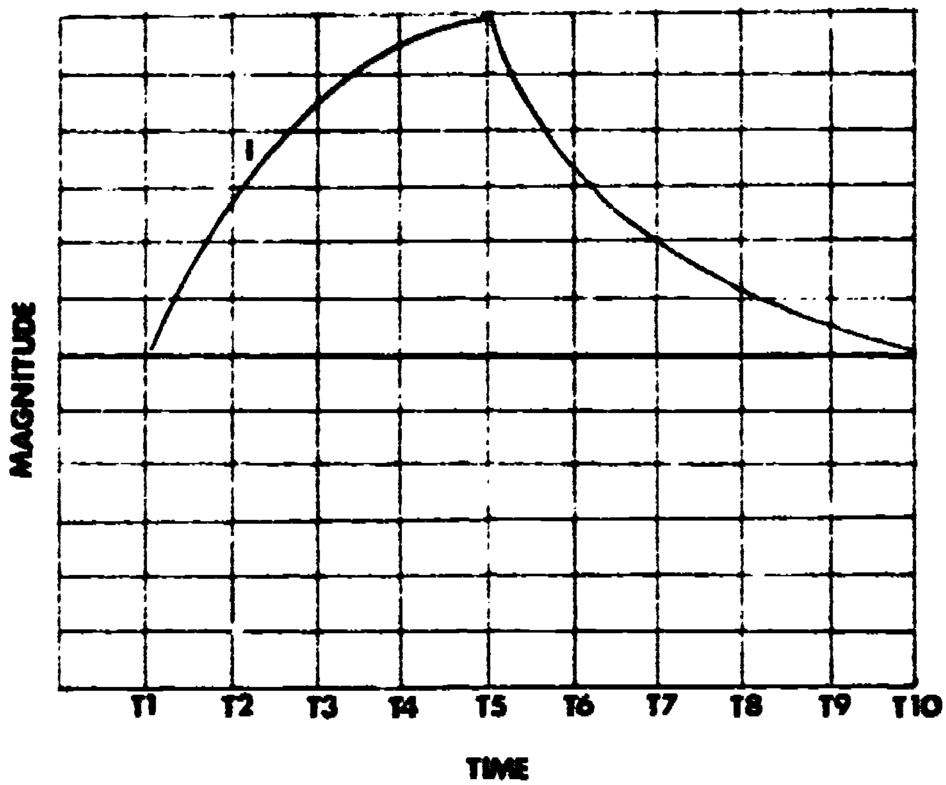
____ a. E_L curve A; E_R curve B

____ b. E_R curve B; I curve B

____ c. E_R curve A; E_L curve B

____ d. C.E.M.F. curve A; I curve A

17. On the graph below, the greatest rate of change is at times:



_____ a. T1-T2 and T6-T7.
_____ b. T2-T3 and T5-T6.
_____ c. T1-T2 and T5-T6.
_____ d. T2-T3 and T6-T7.

PROGRESS CHECK
LESSON II

LR Time Constant

1. A time constant is the length of time required for current to increase or decrease to ___________ of its maximum or minimum value.

2. The greatest increase or decrease in current takes place during the:

____ a. first TC.
____ b. second TC.
____ c. third TC.
____ d. fourth TC.

3. A circuit time constant is determined by the formula:

____ a. $TC = \frac{L}{R}$

____ b. $TC = \frac{R}{L}$

____ c. $TC = R + L$
____ d. $TC = RL$

4. For practical purposes five time constants are required to reach $\underline{I}$ maximum. Each time constant of the five is:

____ a. of equal time.
____ b. inversely proportional to CEMF.
____ c. varied as current varies.
____ d. proportional to applied voltage.

5. The time constant of an LR circuit containing an inductor of 50 millihenrys and a resistor of 5 Kohms is:

____ a. 0.01 seconds
____ b. 10 seconds
____ c. 10 μseconds
____ d. 10 mseconds

6. From the previous question, we find that it will take __________ for circuit current to reach maximum.

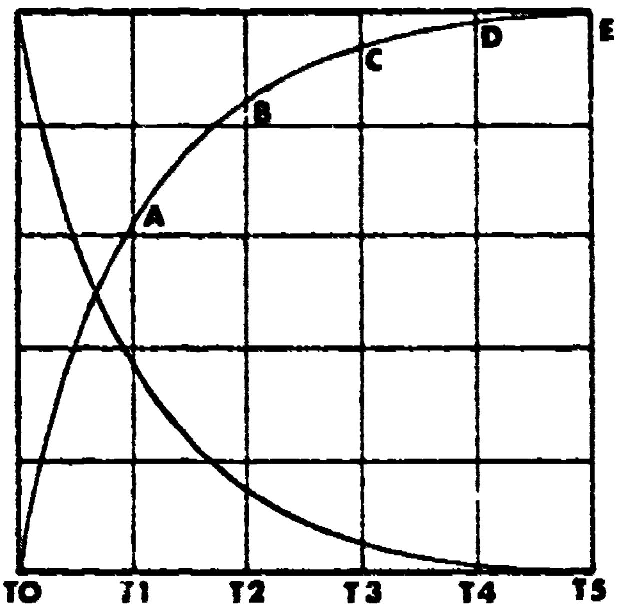
____ a. 50.. seconds
____ b. 63; seconds
____ c. 78.. seconds
____ d. 86.. seconds

7. Which of the following combinations will have the greatest time constant?

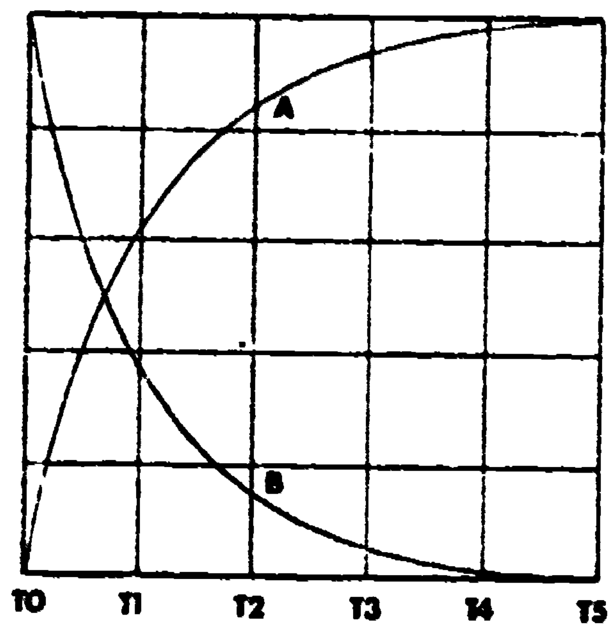
____ a. R = 100 L = 10..h
____ b. L = 100 mh R = 100..
____ c. R = 50.. L = 500 mh
____ d. L = 10 h R = 1..

8. With a maximum value of 7 amps possible, current will be __________ amps after two time constants of current rise.

9. On the graph below, indicate correct values of percentage at each point indicated.



10. The graph below shows current increasing. Curve A represents ____________ or ________________.



11. In an LR circuit, doubling the TC will have what effect on the growth curve?

____ a. Curve will be steeper, current reaching its maximum value quicker.
____ b. Curve will be flatter, indicating a longer time to reach I maximum.

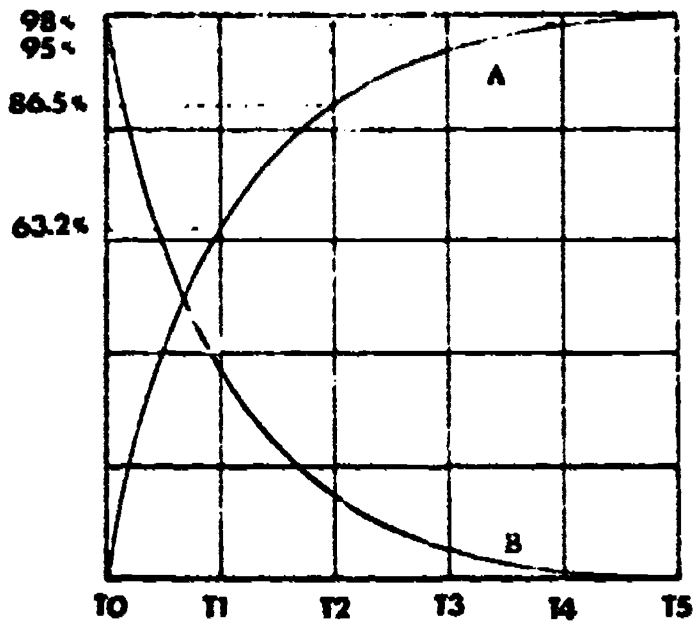
12. One time constant is the length of time required for circuit current to increase to:

____ a. 85.5% of maximum.
____ b. 95% of maximum.
____ c. 63.2% of maximum.
____ d. 62.3% of maximum.

PROGRESS CHECK
LESSON III

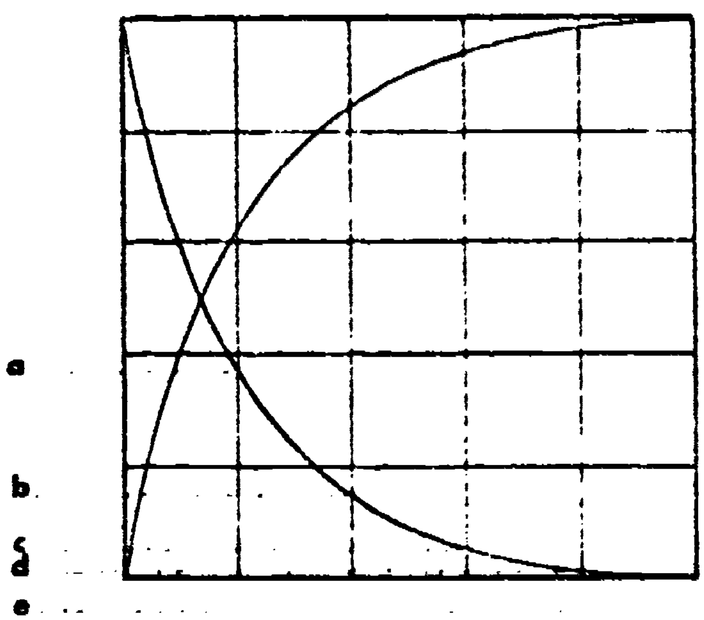
Universal Time Constant Chart

1. Curve A depicts current __________ from ________________ to maximum value in percentages.



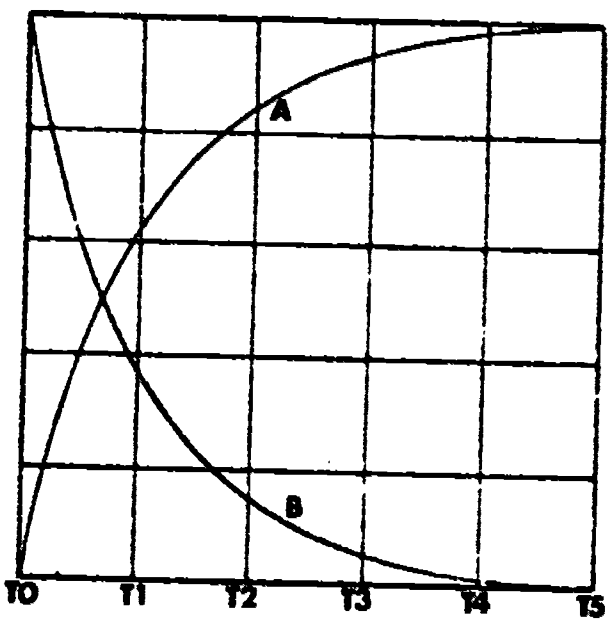
2. In the preceding graph, current has increased to ____________ percent in two time constants and CEMF, if plotted on the graph, would have decreased to ____________ percent.

3. As current is increasing, CEMF is ____________ and may be indicated in percentages. Indicate percentage of CEMF on graph.

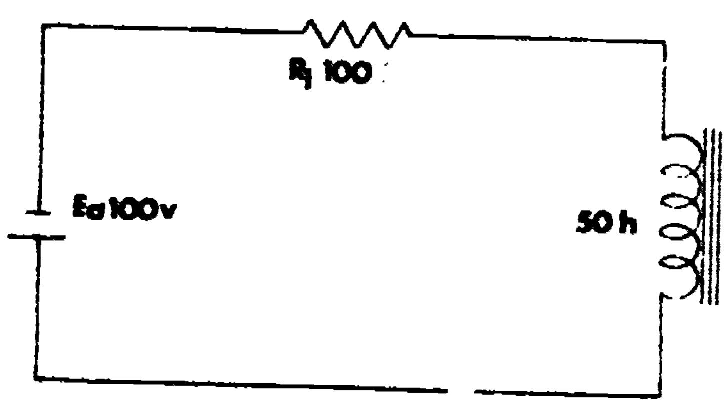


4. As current increases through the circuit, __________ voltage is dropped across L, and ______________ voltage is dropped across R.

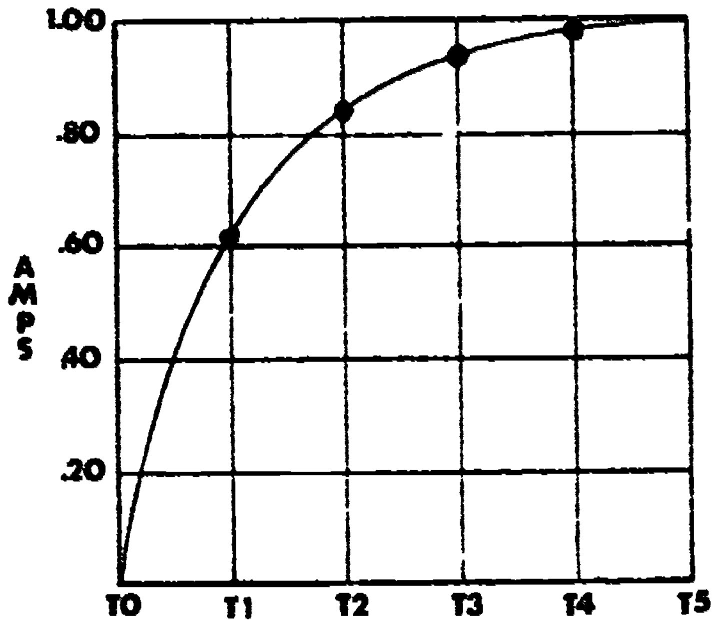
5. As E_L and CEMF are plotted as one, curve A represents __________ voltage drop and curve B represents __________ voltage drop.



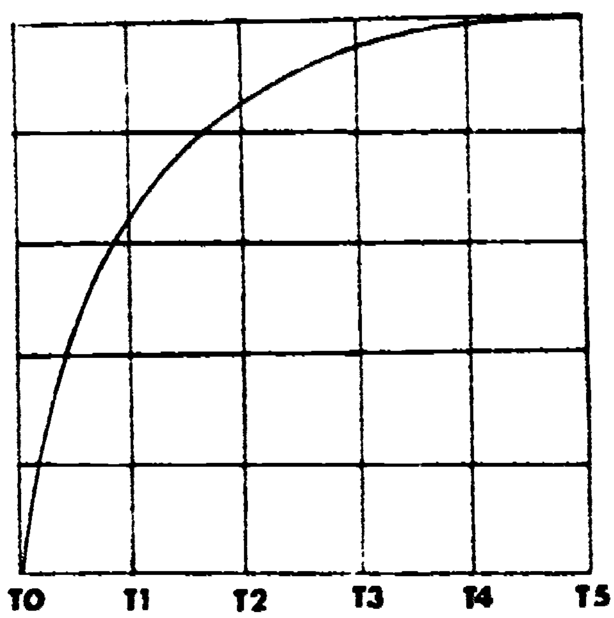
6. The TC of the circuit below is ____________. The current flowing through the resistor at T3 is ______________ amps.



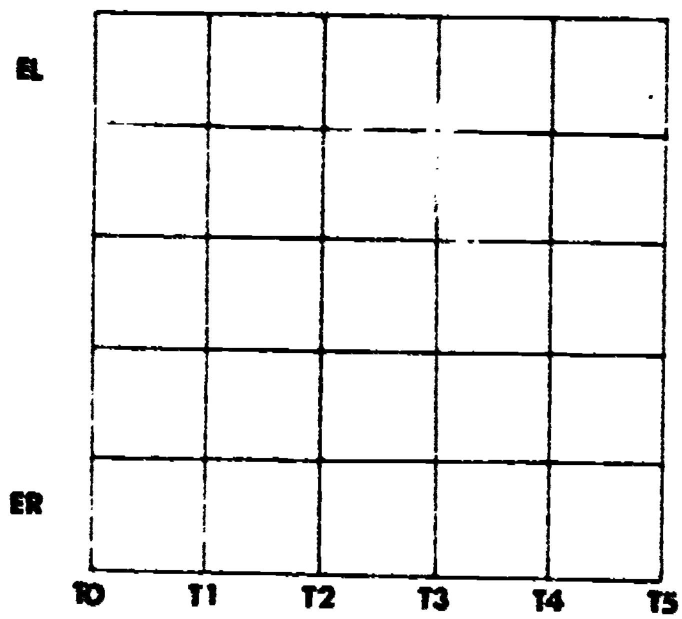
7. Using circuit values in question 6, indicate on the graph the values of I_R at TC points indicated. Draw in the other curve and indicate the value of CEMF/E_L at TC points.



8. Again using the circuit in question 6, plot on the graph the values of E_R at all five time constant points.



9. On the graph draw the E_R and E_L curves and indicate the point at which $E_R = E_L$.



10. In a circuit containing an L of 500 mh, a resistance of 1,000.. (1 k..), and a source of 250 v,

    a. the value of the maximum voltage drop across L is ________ volts at Time ________.
    b. the maximum resistive voltage drop is ________ volts at TC ________.
    c. the TC is ________.
    d. the maximum current possible is ________.

11. Doubling the value of L in question 10 will cause TC to ________.

12. Decreasing the value of R in question 10 by one-half will cause L to ________.

13. With an R of 1 k.., and L of 5,000 mh, TC will be ________.

14. If a source of 500 volts is added to the circuit in question 13, a current of ________ amps will be flowing at T3.

15. Decreasing the source voltage of question 14 by one-half and R by one-half will cause I_T to ________.

PROGRESS CHECK
LESSON IV

Inductive Reactance

1. The property of a coil is such that it ________________ any change in ____________.

2. Frequency is a factor in determining the opposition an inductor offers to circuit current; hence, an inductor is a __________ component.

3. By combining inductance and its property of reactance, we get __________ ____________ which is symbolized by ___________.

4. Inductive reactance is an opposition to current and is measured in _____________.

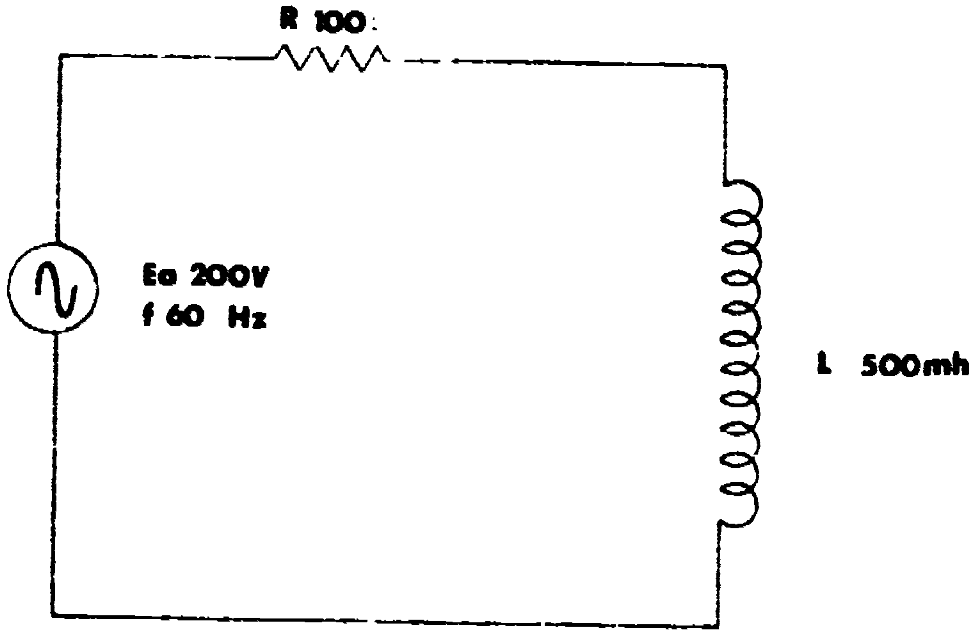
5. Unlike resistance, however, X_L is affected by changes in _______________.

6. As X_L is determined in part by frequency of the source, a circuit containing a source of 250 volts DC would exhibit ______________________ X_L.
(maximum, minimum, zero)

7. The formula for determining the reactance of a coil is X_L = _________________.

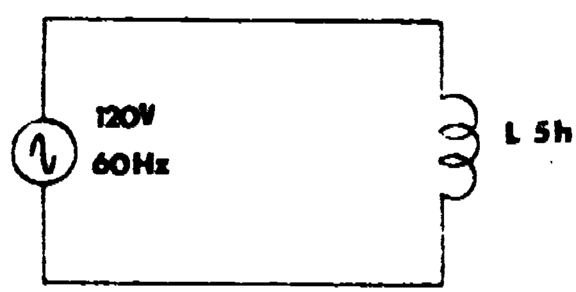
8. From the formula for inductive reactance, it is easy to see that ____________ and _____________ are variables and _________ is a fixed value.

9. The circuit below has an X_L of __________ ohms.



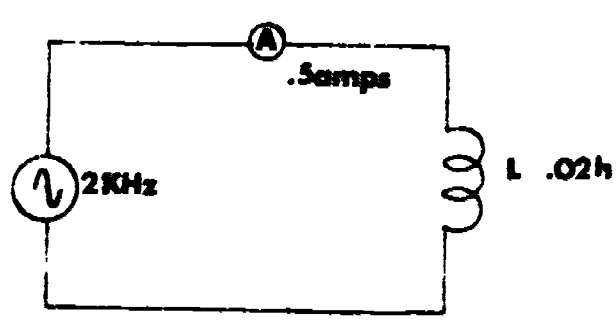
10. The opposition offered to current flow in the circuit below is:

____ a. 18.84Ω.
____ b. 188.4Ω.
____ c. 1,884Ω.
____ d. 18,840Ω.



11. Determine X_L in the circuit below.

____ a. 40 ohms.
____ b. 100 ohms.
____ c. 125 ohms.
____ d. 250 ohms.



12. As the frequency in a purely inductive circuit increases, inductive reactance:

____ a. increases.
____ b. decreases.
____ c. does not change.
____ d. decreases to zero.

13. Which of the following determines the inductance of a coil?

____ a. frequency
____ b. voltage
____ c. current
____ d. physical construction

14. The henry is the unit of:

____ a. inductance
____ b. resistance
____ c. capacitance
____ d. impedance

15. A coil is said to possess an inductance of 1 henry if an EMF of 1 volt is induced in the coil when a current through the coil is changing at the rate of __________ per second.

____ a. 1 ampere
____ b. 2 amperes
____ c. 3 amperes
____ d. 4 amperes

16. If you increase the input frequency of a circuit from 60 Hz to 120 Hz, the inductance will:

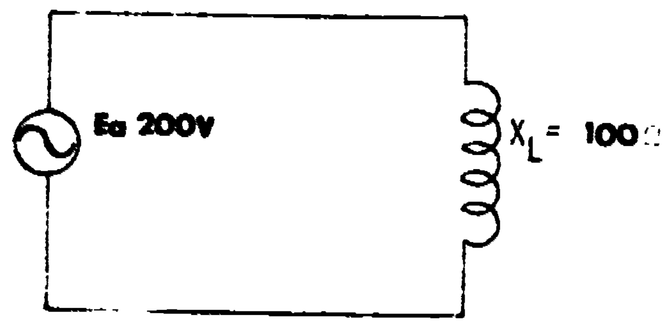
____ a. double.
____ b. halve.
____ c. increase.
____ d. not change.

PROGRESS CHECK
LESSON V

Relationships in Inductive Circuits

1. The value of reactive power (P_x) is determined by using the formula ________________.

2. X_L is an opposition to current as is $\underline{R}$. The circuit current below is ______________ amps.



3. Since an inductor reacts to frequency changes, what effect would the following values experience if frequency were doubled? Answer increase, decrease, or remain the same to each part.

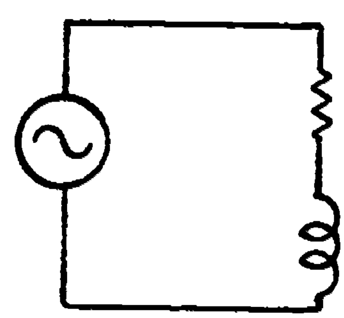
   a. X_L ________________

   b. I_T ________________

   c. E_R ________________

   d. E_L ________________

   e. R ________________



4. In an LR circuit, what would happen to P_t if frequency were increased? ________________

5. What effect would increasing the frequency have on an inductor's magnetic field? ________________

6. True power is dissipated only in a circuit which contains ____________________.

7. In an inductive circuit containing <u>no</u> resistance, power in the circuit is classed as ____________ power.

8. All power in a purely reactive circuit is not in reality consumed; it is stored in a ______________ field.

9. Since it is returned to the circuit on the next half cycle, it is called ______________ power.

10. Power stored in a reactive circuit is measured in ____________.

PROGRESS CHECK
LESSON VI

Phase Relationships in Inductive Circuits

1. In an inductive AC circuit the current lags the applied voltage by:

____ a. 360°.
____ b. 270°.
____ c. 180°.
____ d. 90°.

2. The CEMF of a coil will be greatest when the current sine wave is at:

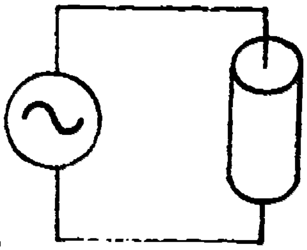
____ a. maximum negative value.
____ b. passing through 0 value.
____ c. .707 of maximum value.
____ d. maximum positive value.

3. In an AC inductive circuit, the voltage is such that it:

____ a. lags current by 90°.
____ b. is in phase with current.
____ c. is out of phase with the current by 180°.
____ d. leads current by 90°.

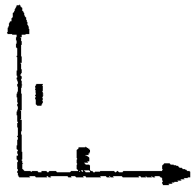
4. In the circuit below, what phase relationship exists between the voltage applied to the conductor and the self-induced voltage in the conductor.

____ a. E_{ind} leads E_a by 90°
____ b. E_a leads E_{ind} by 90°
____ c. E_a and E_{ind} are in phase.
____ d. E_{ind} and E_a are 180° out of phase.

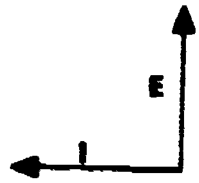


5. Which vector diagram correctly represents the phase relationship between voltage and current in a purely inductive circuit. (Current is the reference value.)

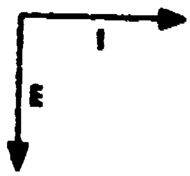
____ a.



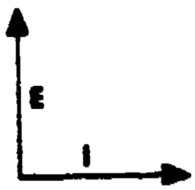
____ b.



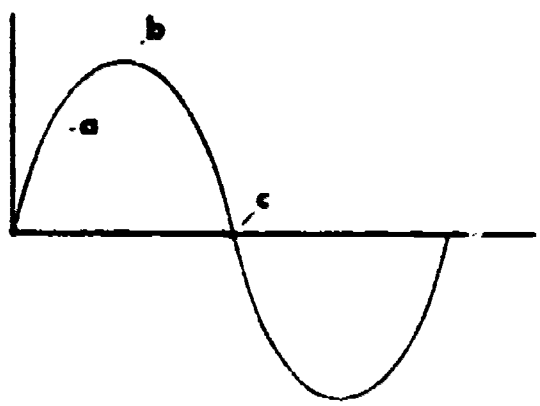
____ c.



____ d.



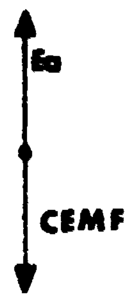
6. At what point on this current sine wave is the current going through its greatest rate of change.



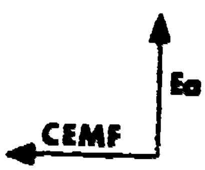
7. Which vector diagram correctly represents the phase relationship between applied voltage and CEMF.

____ a.

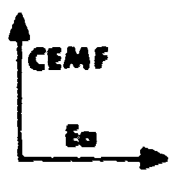
____ b.



____ c.



____ d.



PROGRESS CHECK ANSWERS
MODULE NINE

LESSON I

1. maximum
2. minimum and minimum
3. maximum and maximum
4. zero
5. magnetic
6. collapse, same
7. a
8. time
9. time
10. positive, negative
11. a
12. CEMF
13. CEMF
14. opposes
15. CEMF, E_L
16. c
17. c

LESSON II

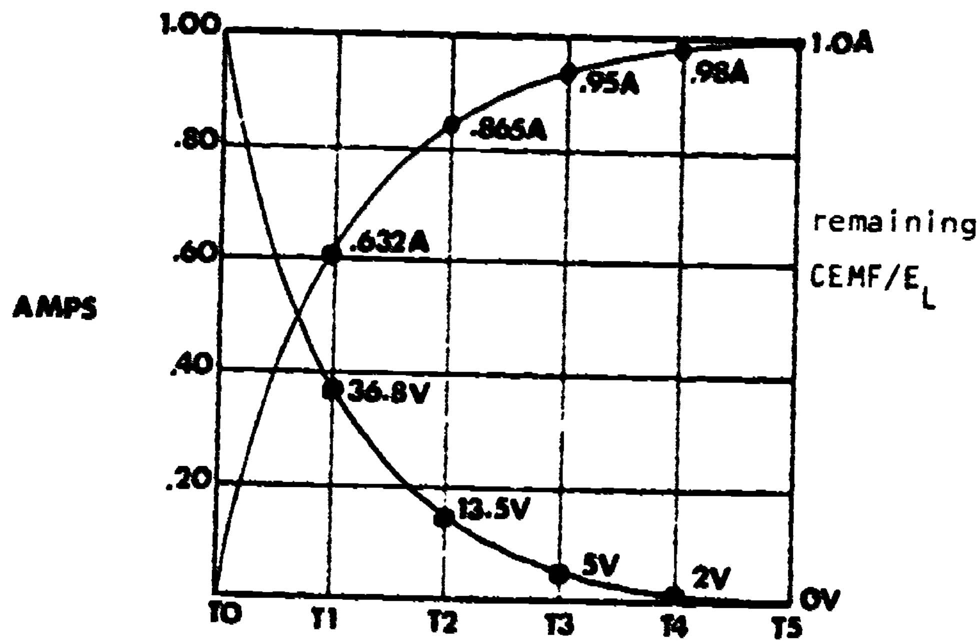
1. 63.2%
2. a
3. a
4. a
5. c
6. a
7. d
8. 6.05 amps
9. A. 63.2%
   B. 86.5%

LESSON II (Cont'd)

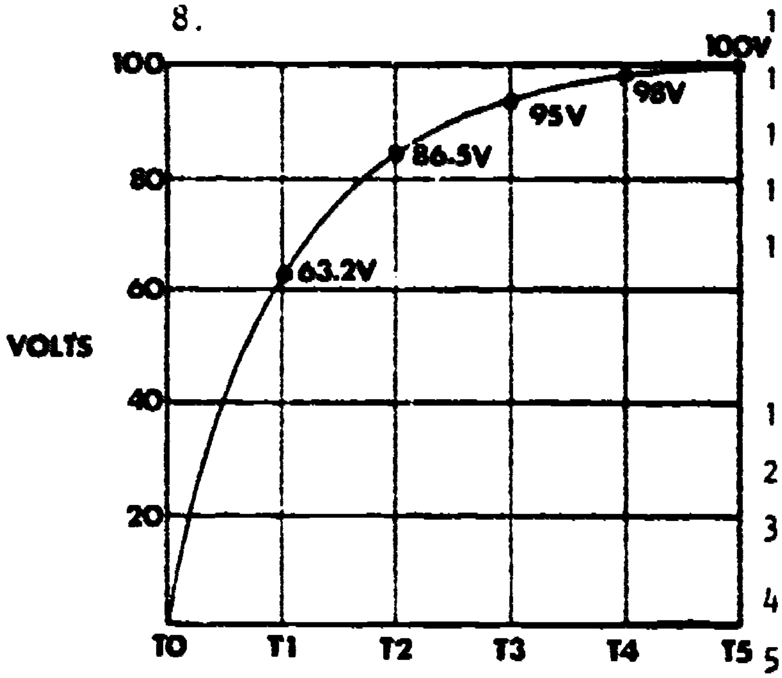
9. C. 95%
   D. 98%
   E. 100%
10. I, ER
11. b
12. c

LESSON III

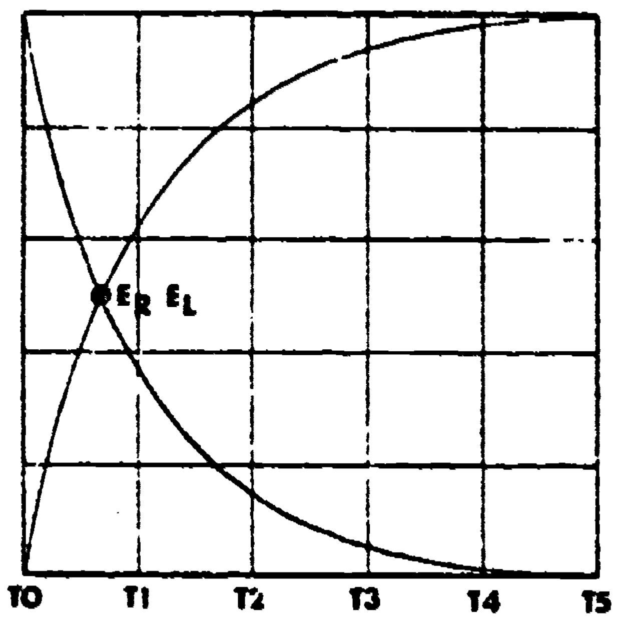
1. growth or rise, minimum
2. 86.5%, 13.5%
3. decreasing
   a. 36.8%
   b. 13.5%
   c. 5%
   d. 2%
   e. 0%
4. less, more
5. resistive, inductive
6. 0.5 seconds, 0.95 a or 950 ma
7.



8.



9.



10. a. 250 v, zero
    b. 250 v, 5
    c. 500 . second
    d. 250 ma

11. double
12. remain constant
13. 5 milliseconds
14. 475 ma
15. remain the same

LESSON IV

1. opposes, current
2. reactive
3. inductive reactance, X_L
4. ohms
5. frequency
6. zero
7. 2 fL
8. frequency and L, 2
9. 188 .
10. c
11. d
12. a
13. d
14. a
15. a
16. d

LESSON V

1. I^2X_L
2. 2
3. a. increase
   b. decrease
   c. decrease
   d. increase
   e. remain the same

LESSON V (Cont'd)

4. P_t would decrease
5. changes will be faster
6. resistance
7. reactive
8. magnetic
9. reactive power
10. volt amps reactive (var)

LESSON VI

1. d
2. b
3. d
4. d
5. d
6. c
7. b

IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON 1

Transformer Construction

1. Due to the methods of construction and materials used, maintenance of ordinary transformers is required:

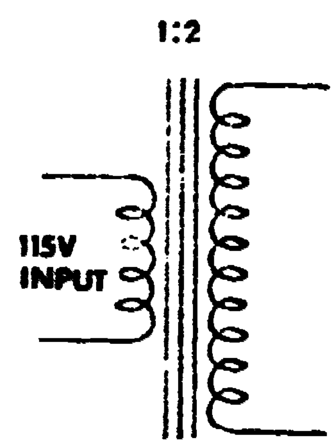
____ a. weekly.
____ b. monthly.
____ c. infrequently.
____ d. often.

2. An air-core transformer, is best at:

____ a. high frequencies.
____ b. low frequencies.
____ c. high current.
____ d. high voltage.

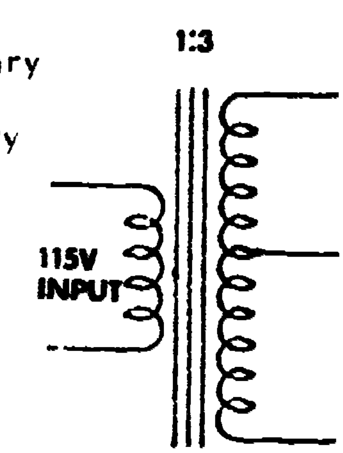
3. The schematic symbol below is for a/an ____________ transformer.

____ a. step-down, iron-core
____ b. step-up, paper-core
____ c. step-down, air-core
____ d. step-up, iron-core



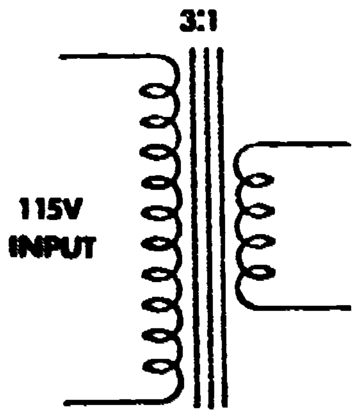
4. The schematic symbol below is for a/an ____________ transformer.

____ a. step-down, iron-core, tapped secondary
____ b. step-up, air-core, tapped primary
____ c. step-down, air-core, tapped secondary
____ d. step-up, iron-core, tapped secondary



5. The schematic symbol below is for a/an ____________ transformer.

____ a. step-down, iron-core
____ b. step-up, air-core
____ c. step-down, air-core
____ d. step-up, iron-core



6. A transformer is a device that transfers electrical energy from one circuit to another electrically-isolated circuit by:

____ a. magnetizing current.
____ b. electromagnetic induction.
____ c. exciting current.
____ d. eddy current.

7. An iron core is used in a power transformer in order to:

____ a. concentrate the field about the windings.
____ b. release the high-frequency currents.
____ c. disperse the field about the windings.
____ d. increase the eddy currents.

8. The part of a transformer connected to the source is called the:

____ a. primary winding.
____ b. secondary winding.
____ c. iron core.
____ d. laminations.

9. The material used to separate the core laminations of a power transformer is usually:

____ a. paper.
____ b. carbon.
____ c. lead.
____ d. varnish.

10. A transformer designed for low-frequency operation requires a core of:

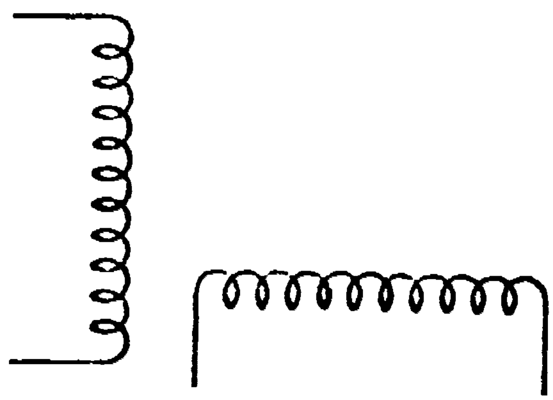
_____ a. low permeability.
_____ b. low reluctance.
_____ c. high retentivity.
_____ d. high copper loss.

11. Iron-core transformers are normally used at:

_____ a. low frequencies.
_____ b. low voltages.
_____ c. high currents.
_____ d. high frequencies.

12. The coefficient of coupling for the two coils would be:

_____ a. maximum.
_____ b. minimum.
_____ c. average.
_____ d. effective.

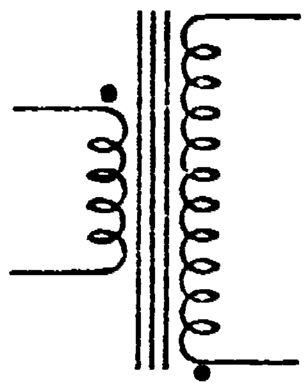


PROGRESS CHECK
LESSON 11

Transformer Theory and Operation

1. On the schematic, the dots indicate the:

____ a. areas where the insulation has broken down.
____ b. top lead of the primary and secondary have the same polarity.
____ c. primary and secondary have the same number of windings.
____ d. polarity of the secondary is opposite to the primary.



2. A step-down transformer receives energy at one voltage and delivers it at a/an:

____ a. equal voltage.
____ b. lower frequency.
____ c. lower voltage.
____ d. higher voltage.

3. The small current that flows in the primary winding of a transformer with no load connected to the secondary is called the ____________ current.

____ a. secondary.
____ b. exciting.
____ c. eddy.
____ d. leakage.

4. The extent of coupling between two inductors is expressed by:

____ a. varying current.
____ b. counter EMF.
____ c. self-inductance.
____ d. coefficient of coupling.

5. The phase of the secondary winding of a simple transformer depends on the polarity of the primary winding and the:

____ a. wire gauge.
____ b. number of windings.
____ c. transformer losses.
____ d. direction of the windings.

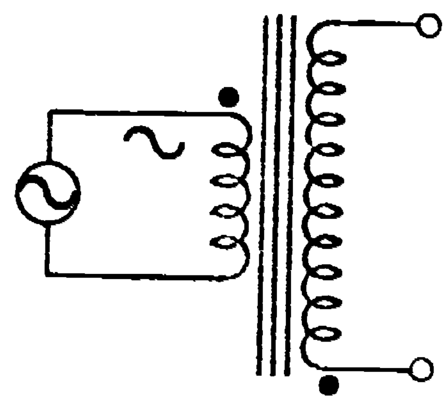
6. Which waveform would be correct for the output of the secondary in the illustration below?

____ a. 

____ b. 

____ c. 

____ d. 



PROGRESS CHECK
LESSON III

Turns and Voltage Ratios

1. If the primary of a power transformer has 2,000 turns with 120 volts AC applied, how many turns are needed in the secondary to have an output of 6 volts AC?

____ a. 60 turns
____ b. 100 turns
____ c. 166 turns
____ d. 600 turns

2. A step-up transformer has low:

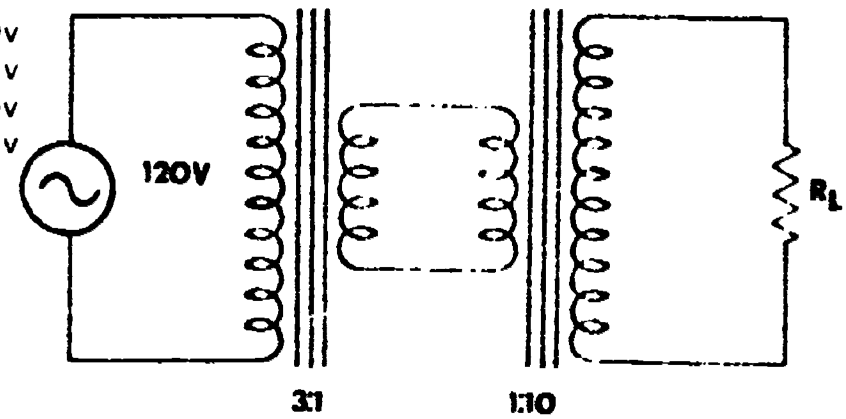
____ a. voltage input, high-voltage output.
____ b. current input, high-current output.
____ c. power input, high-power output.
____ d. frequency input, high-frequency output.

3. If a 5:1 ratio step-down transformer has 250v on the primary, what is the secondary voltage?

____ a. 25v
____ b. 50v
____ c. 250v
____ d. 1250v

4. Compute the output voltage (E_{RL}) in the illustration below.

____ a. 40v
____ b. 30v
____ c. 400v
____ d. 600v



5. A step-down transformer receives energy at one voltage and delivers it at a/an:

____ a. equal voltage.
____ b. lower frequency.
____ c. lower voltage.
____ d. higher voltage.

6. A transformer which has a lower secondary voltage than primary voltage is a/an:

____ a. step-up transformer.
____ b. air-core transformer.
____ c. step-down transformer.
____ d. iron-core transformer.

7. If the primary of a power transformer has 400 turns with 120v AC applied, what is the voltage output from a 50 turn secondary?

____ a. 12 v
____ b. 15 v
____ c. 20 v
____ d. 25 v

PROGRESS CHECK
LESSON IV

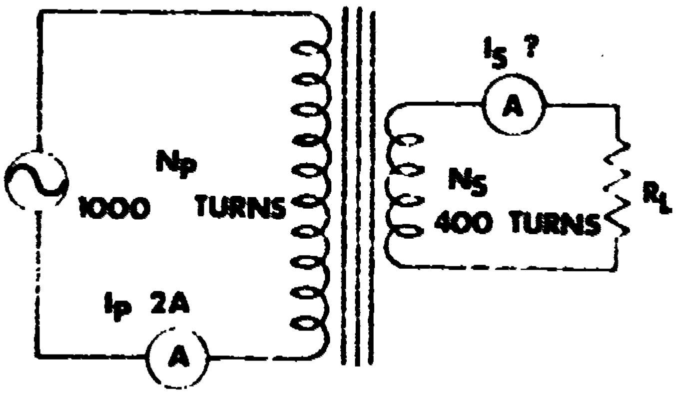
Power and Current

1. If a 3:1 ratio step-down transformer has 3 amps of current in the primary, what is the current in the secondary?

____ a. 1a
____ b. 3a
____ c. 9a
____ d. 6a

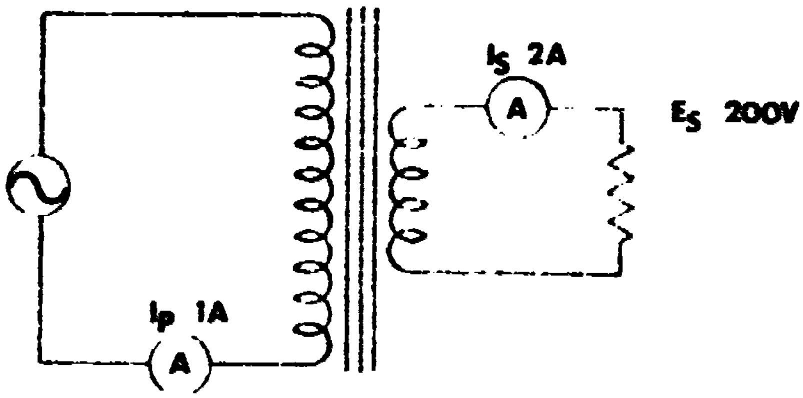
2. How much current is flowing through the resistive load in the circuit below?

____ a. 3 amps
____ b. 4 amps
____ c. 5 amps
____ d. 6 amps



3. In the illustration below the applied voltage is:

____ a. 400 v
____ b. 20 v
____ c. 40 v
____ d. 200 v

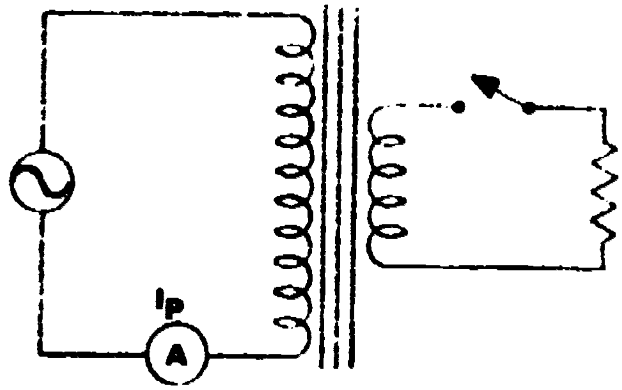


4. In a step-down transformer the current through the secondary will be:

____ a. less than the current in the primary.
____ b. greater than the current in the primary.
____ c. the same as the primary.
____ d. directly proportional to frequency.

5. In the circuit below, if the switch is closed, the current flow in the primary will:

____ a. increase.
____ b. decrease.
____ c. not change
____ d. stop.

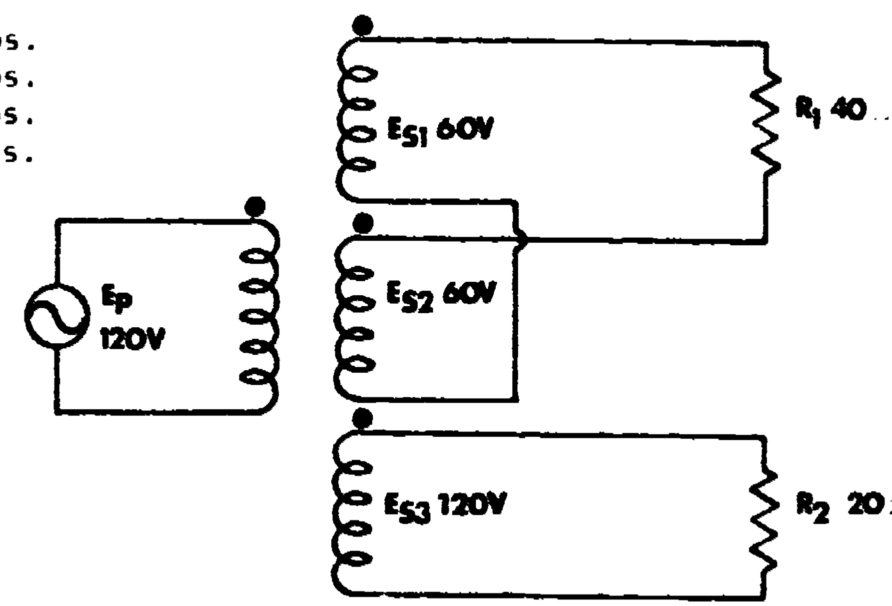


6. In a step-up transformer the primary current is:

____ a. more than the secondary current.
____ b. less than the secondary current.
____ c. equal to the secondary current.
____ d. equal to the coefficient of coupling.

7. Compute the primary current flow for the transformer shown below.

____ a. 2 amps.
____ b. 3 amps.
____ c. 6 amps.
____ d. 9 amps.



PROGRESS CHECK
LESSON V

Transformer Efficiency

1. What is the efficiency of a transformer with an input of 120 volt amperes and an output of 108 watts?

____ a. 100%
____ b. 90%
____ c. 50%
____ d. 0%

2. If the input power of a transformer is 600 va and the output power is 594 w, what is the efficiency?

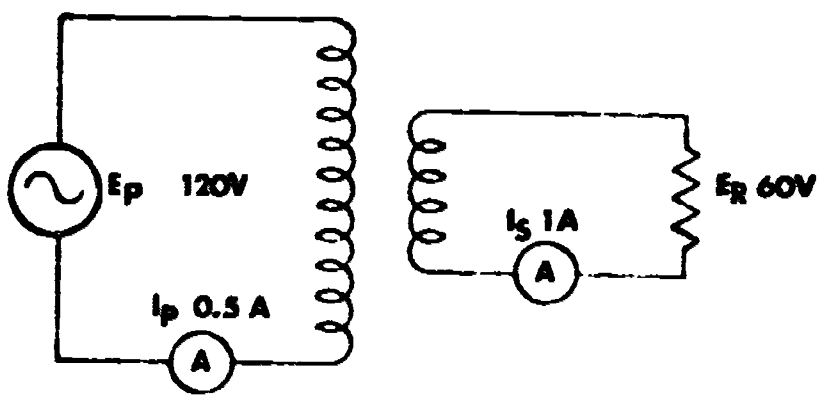
____ a. 90%
____ b. 95%
____ c. 99%
____ d. 100%

3. The energy used to realign the magnetic structure of a transformer core twice each cycle is dissipated as heat. This loss is called:

____ a. copper loss.
____ b. flux leakage.
____ c. hysteresis loss.
____ d. eddy current loss.

4. What is the efficiency of the illustrated transformer?

____ a. 98%
____ b. 60%
____ c. 100%
____ d. 10%



5. Which type of transformer loss is reduced by using silicon steel as the core material?

____ a. copper loss
____ b. flux leakage
____ c. eddy currents
____ d. hysteresis loss

6. The undesirable currents in a transformer core are ____________ currents.

____ a. ratio
____ b. eddy
____ c. primary
____ d. secondary

7. Transformer cores are laminated in order to:

____ a. increase displacement currents.
____ b. reduce mutual inductance.
____ c. provide an easy path for current.
____ d. reduce eddy currents.

8. The current handling capacity of a transformer is determined by the:

____ a. applied voltage.
____ b. thickness of insulation.
____ c. shape of the core.
____ d. physical size of the wire used.

9. Copper losses may be minimized by using:

____ a. larger diameter wire.
____ b. high-resistance wire.
____ c. laminated cores.
____ d. coaxial cable.

10. The power dissipated by winding resistance in a transformer is called I^2R loss, or ________________ loss.

____ a. eddy current
____ b. copper
____ c. hysteresis
____ d. core

PROGRESS CHECK
LESSON VI

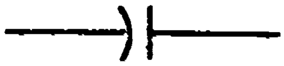
Semiconductor Rectifiers

1. A semiconductor rectifier:

____ a. rectifies AC to pulsating DC.
____ b. rectifies DC to AC.
____ c. pulsates.

2. Select the schematic symbol for a rectifier.

____ a. 

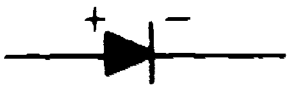
____ b. 

____ c. 

____ d. 

3. Select the drawing which will allow current to flow.

____ a. 

____ b. 

PROGRESS CHECK ANSWERS

MODULE TEN

LESSON I

1. c
2. a
3. d
4. d
5. a
6. b
7. a
8. a
9. d
10. b
11. a
12. b

LESSON II

1. d
2. c
3. b
4. d
5. d
6. b

LESSON III

1. b
2. a
3. b

LESSON III (Cont'd)

4. c
5. c
6. c
7. b

LESSON IV

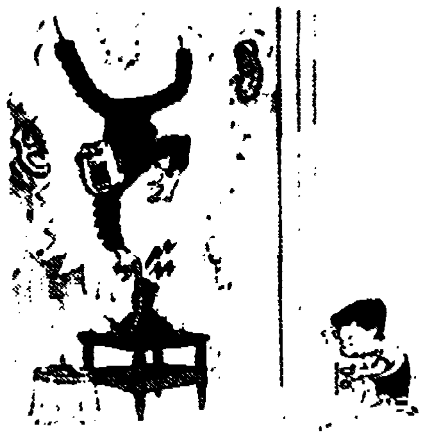
1. c
2. c
3. a
4. b
5. a
6. a
7. c

LESSON V

1. b
2. c
3. c
4. c
5. d
6. b
7. d
8. d
9. a
10. b

LESSON VI

1. a
2. c
3. b



IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

The Capacitor

1. Two metal plates separated by a non-conductor is an example of a/an:

 ____ a. resistor.
 ____ b. inductor.
 ____ c. capacitor.
 ____ d. generator.

2. The material between the plates of a capacitor is called the:

 ____ a. farad.
 ____ b. dielectric.
 ____ c. reactor.
 ____ d. inductor.

3. Charging of a capacitor occurs when electrons are

 ____ a. forced onto both plates.
 ____ b. drawn from both plates.
 ____ c. forced onto one plate and drawn from the other plate.
 ____ d. drawn from the dielectric.

4. Energy is stored in a capacitor in the electrostatic field through the:

 ____ a. plates.
 ____ b. dielectric.
 ____ c. conductors.
 ____ d. leads.

5. The energy used to create an electrostatic field through the dielectric in a capacitor is recovered when:

 ____ a. the electrons are permitted to return to their normal positions on the plates.
 ____ b. the capacitor charges.
 ____ c. current flows between the plates.
 ____ d. a voltage source is connected across the plates.

6. When a capacitor is charged, the bound electrons in the dielectric:

____ a. move from - to + charged plates.
____ b. move from + to - charged plates.
____ c. are not affected by the charged plates.
____ d. have their orbits distorted.

7. A capacitor is able to store energy in an electrostatic field:

____ a. between the plates.
____ b. on the plates.
____ c. in the conductors.
____ d. in the leads.

PROGRESS CHECK
LESSON II

Theory of Capacitance

1. The property of a circuit which opposes a change in voltage is called:

____ a. resistance.
____ b. inductance.
____ c. capacitance.
____ d. current.

2. In a given capacitor, changing the dielectric to one which has a greater dielectric constant will have what effect on its capacitance?

____ a. decrease
____ b. increase
____ c. not change
____ d. decrease by one-half

3. The capacitance of a capacitor is ______________ the plate area.

____ a. directly proportional to
____ b. inversely proportional to
____ c. equal to the square of
____ d. equal to the square root of

4. Which is the correct relationship between plate spacing and capacitance?

____ a. Capacitance is directly proportional to the square of the distance between plates.
____ b. Capacitance is inversely proportional to the square of the distance between plates.
____ c. Capacitance is directly proportional to plate spacing.
____ d. Capacitance is inversely proportional to plate spacing.

5. Since a capacitor reacts to a voltage change by producing a CEMF, a capacitor is said to be:

____ a. inductive.
____ b. resistive.
____ c. electromagnetic.
____ d. reactive.

6. The capacitance of a capacitor is ____________ the distance between the plates.

____ a. directly proportional to
____ b. inversely proportional to
____ c. equal to the square of
____ d. equal to the square root of

PROGRESS CHECK
LESSON III

Total Capacitance

1. Capacitance is the property of a circuit that opposes a change in:

____ a. current.
____ b. voltage.
____ c. resistance.
____ d. capacitive reactance.

2. The plates of a capacitor are separated by a:

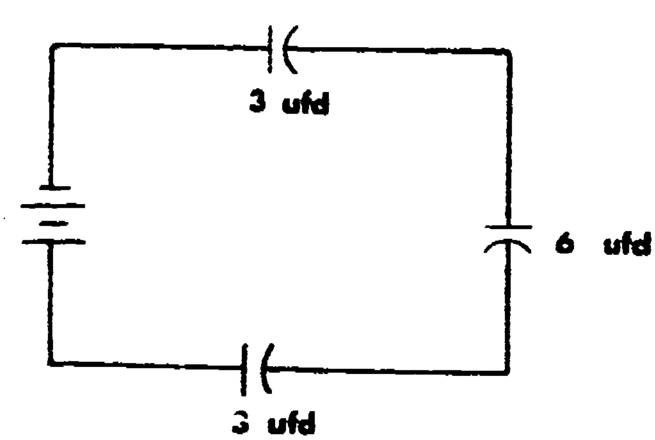
____ a. wire.
____ b. coil.
____ c. semiconductor.
____ d. dielectric.

3. The plates of a capacitor, in relation to the conductors, have:

____ a. a small cross-sectional area.
____ b. a large cross-sectional area.
____ c. high resistance.
____ d. low reactance.

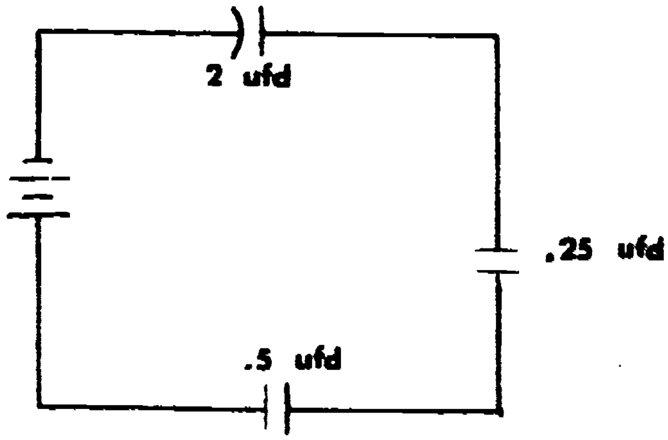
4. The total capacitance in the below circuit is:

____ a. 12 μf.
____ b. 3 μf.
____ c. 1.2 μf.
____ d. 0.3 μf.



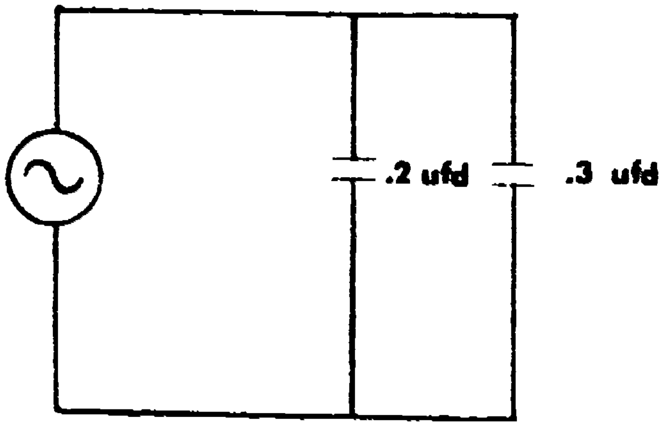
5. Determine total capacitance in the below circuit.

____ a. 2.75 μf.
____ b. 1.62 μf.
____ c. 6.5 μf.
____ d. 0.154 μf.



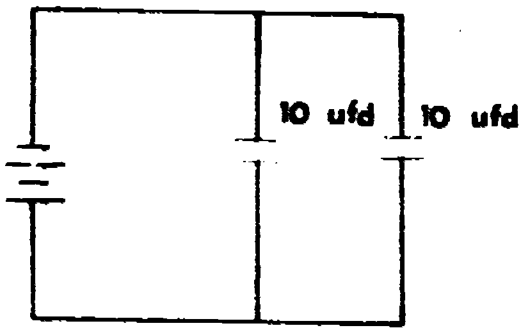
6. Determine the total capacitance in the below circuit.

____ a. 1.2 μf
____ b. 6.0 μf
____ c. 1.0 μf
____ d. 0.5 μf



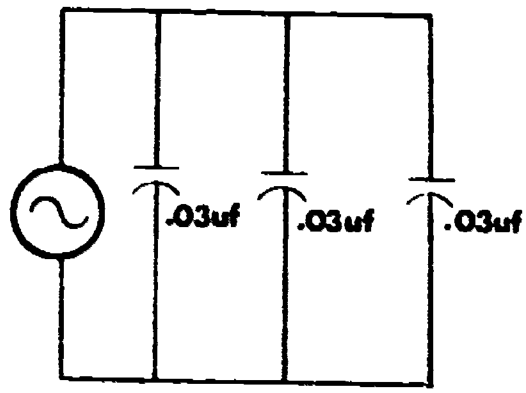
7. The total capacitance of the below circuit is:

____ a. 10 μf.
____ b. 20 μf.
____ c. 5 μf.
____ d. 0.5 μf.



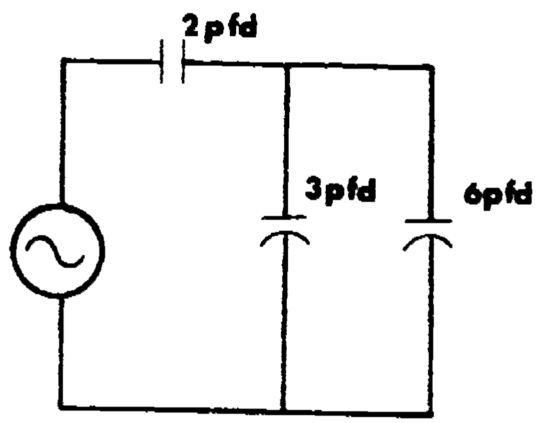
8. What is the total capacitance in the below circuit?

____ a. 0.010 . f.
____ b. 0.090 . f.
____ c. 0.030 . f.
____ d. 0.015 . f.



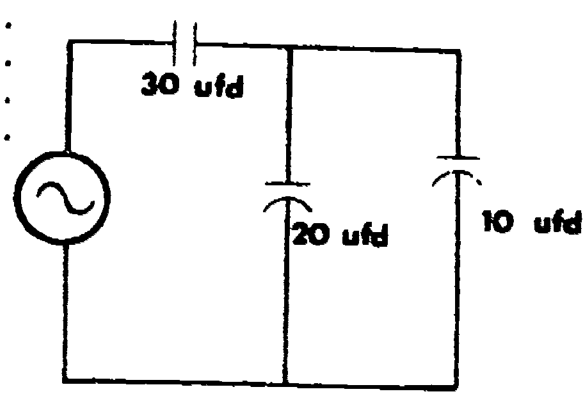
9. What is the total capacitance of the below circuit?

____ a. 1.63 pf
____ b. 4.67 pf
____ c. 11 pf
____ d. 5 pf



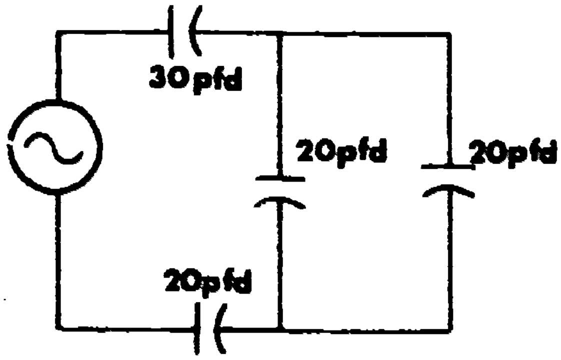
10. Determine the total capacitance in the below circuit.

____ a. 15.00 ..f.
____ b. 60.00 ..f.
____ c 6.66 ..f.
____ d. 36.66 ..f.



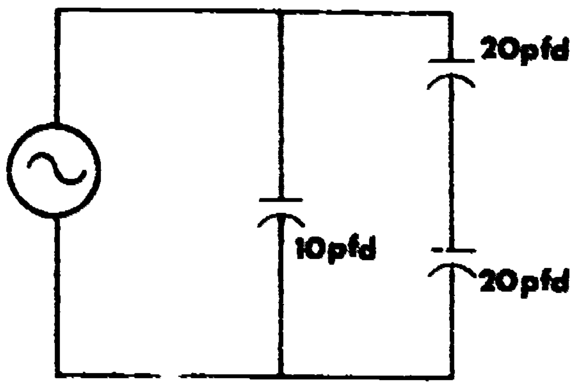
11. What is the total capacitance of the below circuit?

____ a. 5.45 pf
____ b. 9.23 pf
____ c. 90 pf
____ d. 60 pf



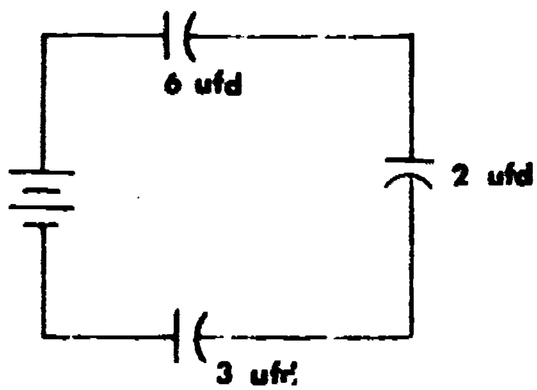
12. The total capacitance of the below circuit is:

____ a. 40 pf.
____ b. 20 pf.
____ c. 10 pf.
____ d. 5 pf.



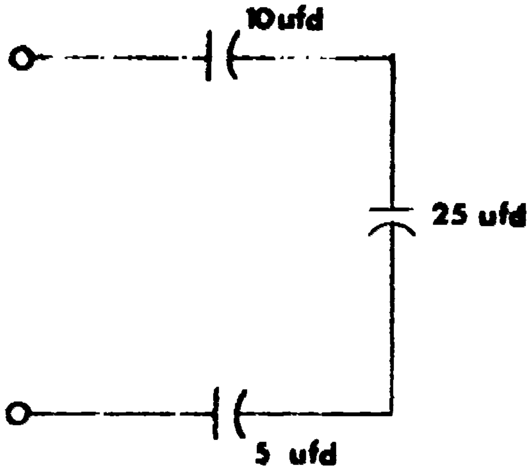
13. Determine the total capacitance of the below circuit.

____ a. 11 μf.
____ b. 1 μf.
____ c. 0.66 μf.
____ d. 0.33 μf.



14. What is the total capacitance of the below capacitors?

____ a. 2.94 μf
____ b. 40 μf
____ c. 0.34 μf
____ d. 294 μf



PROGRESS CHECK
LESSON IV

RC Time Constants

1. As the capacitor assumes a charge, the EMF developed across the capacitor:

____ a. aids the applied voltage.
____ b. opposes the applied voltage.
____ c. causes the current to increase.
____ d. decreases the applied voltage by 1/2.

2. Displacement current is the current which flows in a capacitive circuit when the capacitor is:

____ a. charging only.
____ b. discharging only.
____ c. both charging and discharging.
____ d. shorted.

3. In an RC circuit, the capacitor requires an amount of time to become fully charged due to __________ limiting the charging current.

____ a. EMF
____ b capacitance
____ c. resistance
____ d. inductance

4. If the resistance is doubled in a series RC circuit, the time constant will:

____ a. decrease by half.
____ b. double.
____ c. decrease slowly.
____ d. be 63.2% of its original value.

5. Resistance added to a capacitive circuit causes a decrease of:

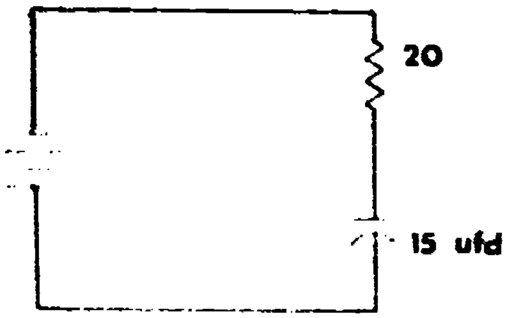
____ a. charging time.
____ b. displacement current.
____ c. applied voltage.
____ d. capacitance.

6. The effect of adding resistance in a capacitive circuit is to:

____ a. increase the charging time.
____ b. decrease the charging time.
____ c. increase the current drawn.
____ d. decrease the total voltage drop.

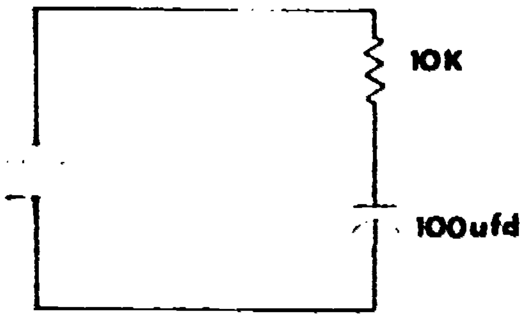
7. What is the time constant of the below circuit?

____ a. 0.3 msec.
____ b. 300 msec.
____ c. 0.3 sec.
____ d. 0.75 sec.



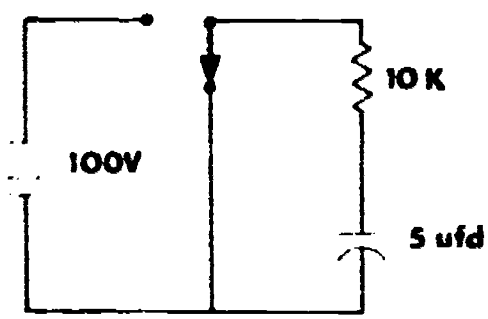
8. What is the time constant of the below circuit?

____ a. 1000 msec
____ b. 100 msec
____ c. 10 msec
____ d. 1 msec



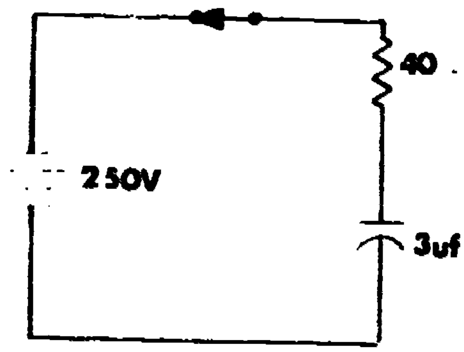
9. Determine the value of voltage across the capacitor at the end of two time constants of discharge. The capacitor had 100 volts across its plates when discharge started.

____ a. 86.5 v
____ b. 5.0 v
____ c. 95.0 v
____ d. 13.5 v



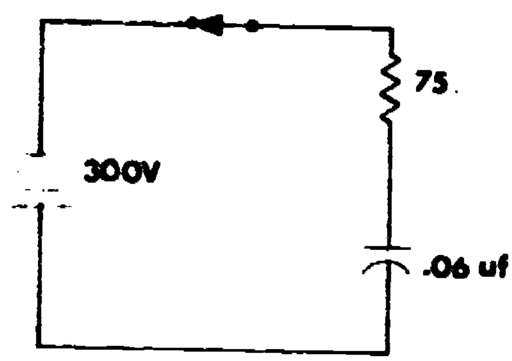
10. During charge time, the voltage across the capacitor after four time constants will be:

____ a. 237.5 v.
____ b. 245 v.
____ c. 12.5 v.
____ d. 5 v.



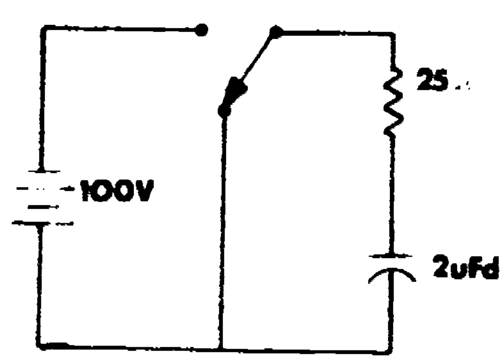
11. After two time constants, the voltage on the resistor in the below circuit will be:

____ a. 294.0 v.
____ b. 259.5 v.
____ c. 40.5 v.
____ d. 15.0 v.



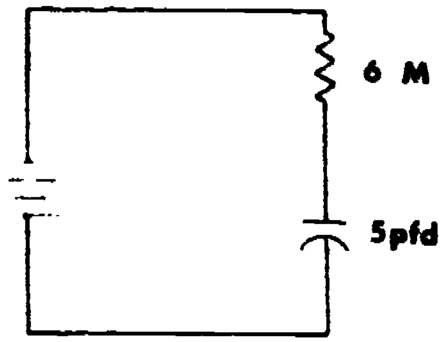
12. During discharge, after 3 time constants, what is the value of current in the below circuit? The capacitor was fully charged before discharge started.

____ a. 0.1 amp.
____ b. 1.0 amp.
____ c. 1.9 amp.
____ d. 0.2 amp.



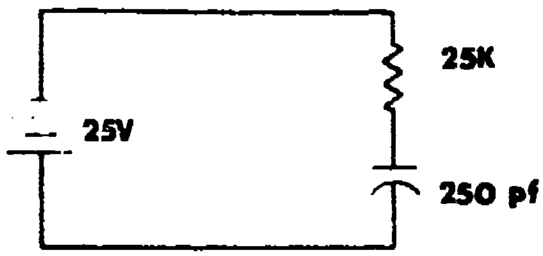
13. Determine the time constant of the below circuit.

____ a. 3 sec.
____ b. 8.3 sec.
____ c. 1.4 sec.
____ d. 30 sec.



14. What is the time constant of the circuit below?

____ a. 1000 picoseconds
____ b. 62.5 microseconds
____ c. 10 picoseconds
____ d. 6.25 microseconds



15. When a conducting path is provided, a charged capacitor acts as a:

____ a. source.
____ b. load.
____ c. conductor.
____ d. resistor.

PROGRESS CHECK
LESSON V

Capacitive Reactance

1. The capacitance of a capacitor can be determined by:

____ a. dividing the voltage by the stored charge.
____ b. multiplying the voltage by the stored charge.
____ c. dividing the stored charge by the voltage.
____ d. dividing the rate of change of current by the voltage.

2. A capacitor has a charge of 0.05 coulombs with 1000 volts difference in potential between its plates. What is its capacitance?

____ a. 0.0005 farads.
____ b. 0.00005 farads.
____ c. 0.000002 farads.
____ d. 20000 farads.

3. Determine the capacitance of a capacitor with 0.001 coulomb of charge stored when 200 volts is applied.

____ a. 0.000005 farads.
____ b. 0.00005 farads.
____ c. 0.000002 farads.
____ d. 0.00002 farads.

4. The opposition a capacitor offers to an alternating current is

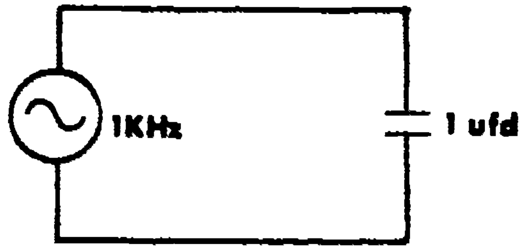
____ a. capacitance.
____ b. farads.
____ c. inductive reactance.
____ d. capacitive reactance.

5. Capacitive reactance is dependent upon both capacitance and:

____ a. circuit current.
____ b. resistance of the circuit.
____ c. magnitude of the applied voltage.
____ d. frequency of the applied voltage.

6. What is the capacitive reactance of the capacitor in the circuit below?

____ a. 1000..
____ b. 100
____ c. 159..
____ d. 1.59 .

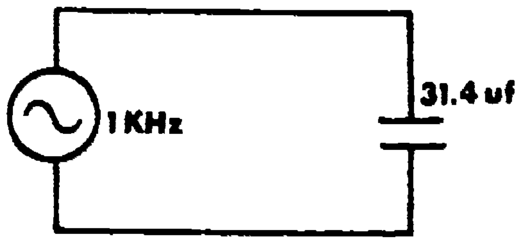


7. Capacitive reactance (X_C) is an inverse function of capacitance and:

____ a. frequency.
____ b. CEMF.
____ c. applied voltage.
____ d. current.

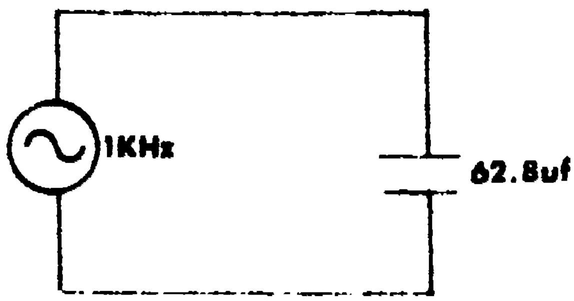
8. What is the capacitive reactance of the capacitor in the circuit below?

____ a. 5
____ b. 500
____ c. 31.4 k..
____ d. 31.4



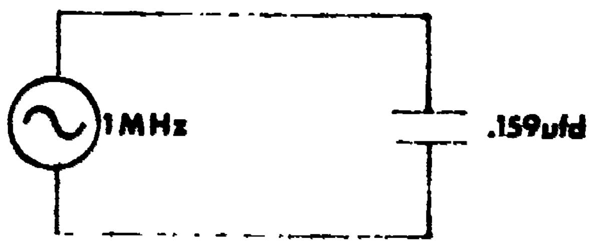
9. What is the capacitive reactance of the capacitor in the circuit below?

____ a. 5.0
____ b. 2.5..
____ c. 62.8 k..
____ d. 62.8..



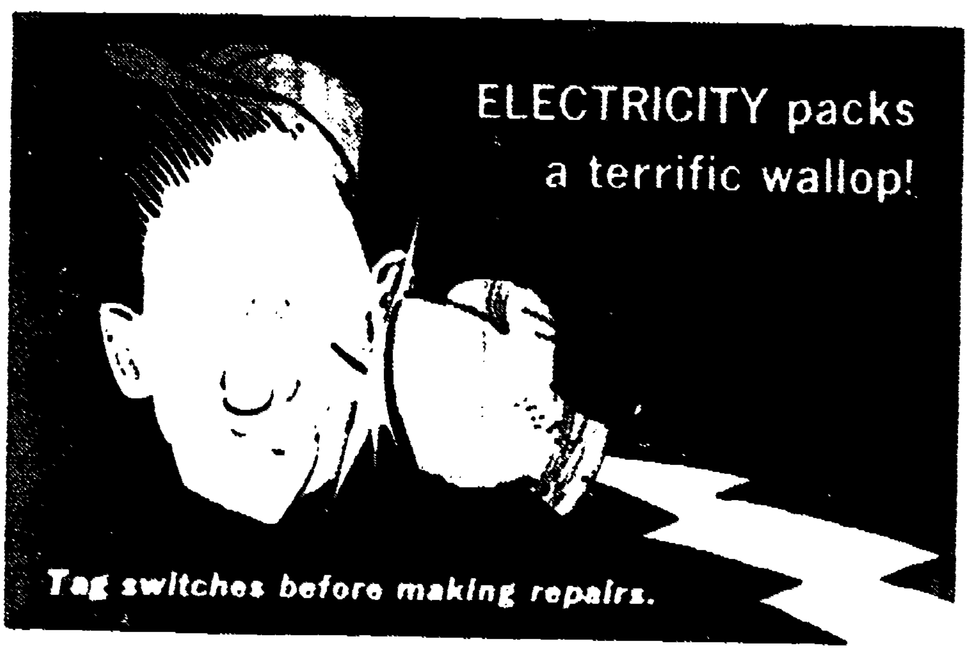
10. What is the capacitive reactance of the capacitor in the below circuit?

____ a. 628..
____ b. 628 k..
____ c. 10 M..
____ d. 1..



11. Capacitive reactance is the opposition a capacitor offers to:

____ a. a change in current.
____ b. a change in voltage.
____ c. alternating current.
____ d. direct current.



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PROGRESS CHECK
LESSON VI

Phase and Power Relationships

1. Capacitance is the property of a circuit that opposes a change in:

   ____ a. current.
   ____ b. voltage.
   ____ c. resistance.
   ____ d. capacitive reactance.

2. The plates of a capacitor are separated by a:

   ____ a. wire.
   ____ b. coil.
   ____ c. semiconductor.
   ____ d. dielectric.

3. When a voltage changing at the rate of 1 volt per second causes a charging current of 1 amp to flow, the capacitance is equal to 1:

   ____ a. henry.
   ____ b. ohm.
   ____ c. coulomb.
   ____ d. farad.

4. In a purely capacitive circuit, with current as a reference, where does the voltage vector lie?

   ____ a. $+90^{\circ}$
   ____ b. -90°
   ____ c. -270°
   ____ d. $+180^{\circ}$

5. In a purely capacitive circuit, the power dissipated is:

   ____ a. 0.707 of instantaneous power.
   ____ b. the product of current and voltage.
   ____ c. zero.
   ____ d. all negative.

6. In an AC capacitive circuit, the current:

    ____ a. is in phase with the voltage.
    ____ b. lags the voltage by 90°.
    ____ c. leads the voltage by 90°.
    ____ d. lags the voltage by 180°.

PROGRESS CHECK
LESSON VII

Capacitor Design Considerations

1. An advantage of the rotor-stator type capacitor is that its capacitance:

____ a. is of very large value.
____ b. may be varied over a prescribed range.
____ c. is of very small value.

2. Polarity must be observed in the wiring connection of ________ capacitors.

____ a. ceramic.
____ b. trimmer.
____ c. variable.
____ d. electrolytic.

3. What type of capacitor is considered to be self-healing?

____ a. Oil.
____ b. Electrolytic.
____ c. Paper.
____ d. Mica.

4. The two primary disadvantages of electrolytic capacitors are that they have a low-leakage resistance and they are:

____ a. polarized.
____ b. self-healing.
____ c. very expensive.
____ d. highly inflammable.

PROGRESS CHECK ANSWERS

MODULE ELEVEN

LESSON I

1. c
2. b
3. c
4. b
5. a
6. d
7. a

LESSON II

1. c
2. b
3. a
4. d
5. d
6. b

LESSON III

1. b
2. d
3. b
4. c
5. d
6. d
7. b
8. b
9. a
10. a
11. b

LESSON III (Cont'd)

12. b
13. b
14. a

LESSON IV

1. b
2. c
3. c
4. b
5. b
6. a
7. a
8. a
9. d
10. b
11. c
12. d
13. d
14. d
15. a

LESSON V

1. c
2. b
3. a
4. d
5. d
6. c
7. a

LESSON V (Cont'd)

8. a
9. b
10. d
11. c

LESSON VI

1. b
2. d
3. d
4. b
5. c
6. c

LESSON VII

1. b
2. d
3. a
4. a

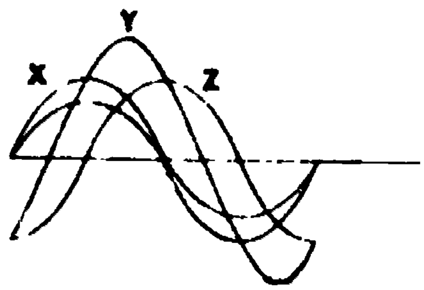
IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON 1

Voltage and Impedance in AC Series Circuits

1. The effective values of the voltage drops in a series LR circuit do not add up to the total voltage because

____ a. effective voltage is not real voltage.
____ b. current through the inductor is not the same as current through the resistor.
____ c. the voltage across the inductor is not in phase with the voltage across the resistor.
____ d. the instantaneous values of the voltage drops do not equal the effective values.

2. 

The graph at the left shows the current sine wave and three voltage curves for a series RC circuit.

Which of the following correctly identifies the three voltage sine waves?

____ a. $x = E_C$; $y = E_R$; $z = E_T$
____ b. $x = E_R$; $y = E_T$; $z = E_C$
____ c. $x = E_T$; $y = E_C$; $z = E_R$
____ d. $x = E_R$; $y = E_C$; $z = E_T$

3. The total opposition to current in a circuit that contains resistance and reactance is called:

____ a. impedance.
____ b. polar notation.
____ c. resistance.
____ d. complex notation.

4. In a reactive circuit, the total opposition to current flow is:

____ a. R_t.

____ b. X_{Lt}.

____ c. Z_T.

____ d. X_{CT}.

5. Impedance is the opposition that an AC circuit offers to:

____ a. a change in current.
____ b. a change in voltage.
____ c. frequency variations.
____ d. current.

6. The vector sum of resistance and reactance in a series RL circuit is:

____ a. reactance.
____ b. inductance.
____ c. capacitance.
____ d. impedance.

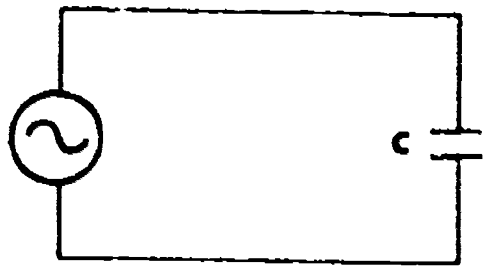
7. In a circuit that contains reactance and resistance, the total opposition to current is called:

____ a. complex notation.
____ b. impedance.
____ c. resistance.
____ d. polar notation.

8. What is the phase relationship between voltage and current in an AC series resistive circuit?

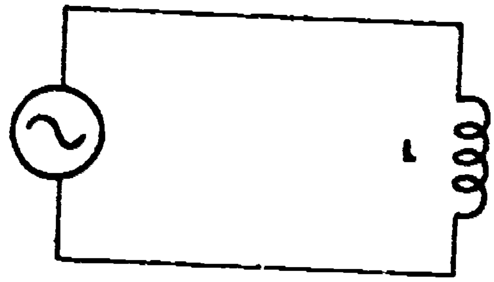
____ a. $\underline{E}$ leads $\underline{I}$ by 90°.
____ b. $\underline{I}$ leads $\underline{E}$ by 90°.
____ c. $\underline{I}$ lags $\underline{E}$ by 90°.
____ d. $\underline{E}$ and $\underline{I}$ are in phase.

9. In the illustration, the current:



____ a. leads the voltage by 90°.
____ b. lags the voltage by 45°.
____ c. leads the voltage by 45°.
____ d. lags the voltage by 90°.

10. In the circuit below, the current:



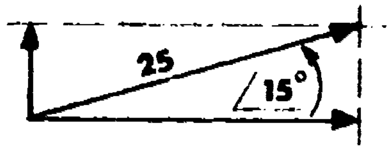
____ a. leads the voltage by 90°.
____ b. lags the voltage by 45°.
____ c. leads the voltage by 45°.
____ d. lags the voltage by 90°.

PROGRESS CHECK
LESSON II

Vector Computations

1. The magnitude of the vector shown below is __________ and its standard direction is ____________.

____ a. 15°, 25
____ b. 25°, 15
____ c. 25, 15°
____ d. 15, 25°



2. The tangent of the angle for a total voltage vector is equal to:

____ a. $\frac{E_L}{E_T}$ ____ b. $\frac{E_L}{E_R}$

____ c. $\frac{R}{X_L}$ ____ d. $\frac{X_L}{Z}$

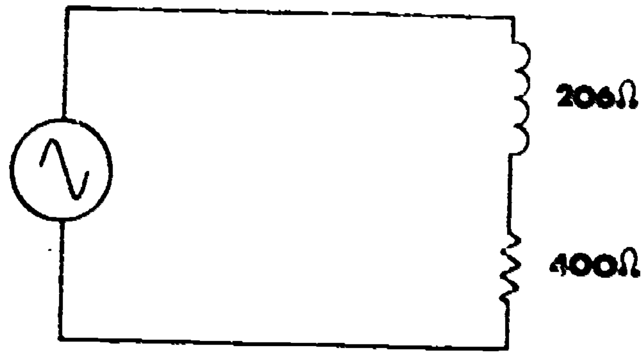
3. The ratio of inductive reactance to impedance is equal to:

____ a. TAN $\angle$
____ b. SIN $\angle$
____ c. COS $\angle$
____ d. $\angle$

4. The cosine of the phase angle in a series circuit can be found using:

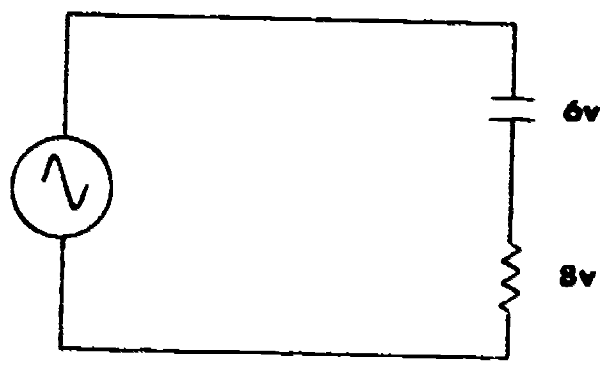
____ a. E_L and R.
____ b. X_L and Z.
____ c. E_R and E_T.
____ d. R and X_L.

5. Find the impedance of the circuit.



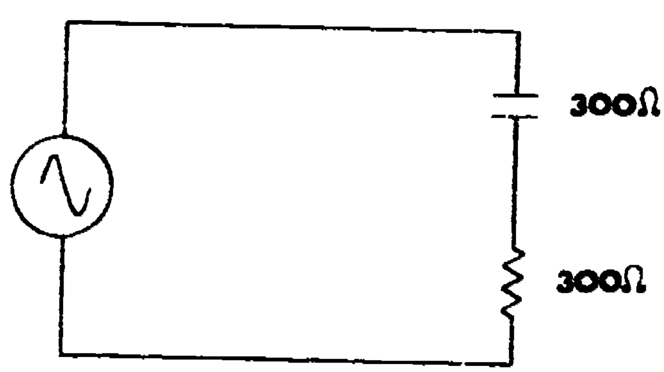
____ a. 200
____ b. 600
____ c. 400
____ d. 450

6. What is the applied voltage in the circuit below?



____ a. 6 v
____ b. 8 v
____ c. 10 v
____ d. 14 v

7. Find the impedance.



____ a. 300
____ b. 424
____ c. 600
____ d. 900

PROGRESS CHECK
LESSON III

Rectangular and Polar Notation

1. Which of the below is proper rectangular notation for the voltage drops in a series RL circuit?

____ a. $R + jX_L$
____ b. $E_R - jE_L$
____ c. $R - jX_L$
____ d. $E_R + jE_L$

2. When a vector is multiplied by $+j$, the vector is rotated:

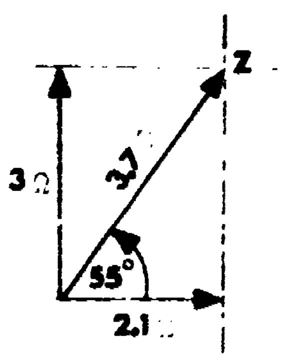
____ a. clockwise 90°.
____ b. clockwise 180°.
____ c. counterclockwise 90°.
____ d. counterclockwise 180°.

3. The j operator used to describe the rotation of the vector illustrated below is:

____ a. $+j$.
____ b. $-j$.
____ c. j^2
____ d. $-j^2$.

4. Describe the vector Z in polar form.

____ a. $3 + j2.1$
____ b. $3.7 \angle 55^\circ$
____ c. $3.0 \angle 55^\circ$
____ d. $2.1 + j3$



5. Divide 60 $\underline{/30^{\circ}}$ by 12 $\underline{/45^{\circ}}$ and express your answer in polar form.

____ a. 5 $\underline{/75^{\circ}}$
____ b. 72 $\underline{/75^{\circ}}$
____ c. 72 $\underline{/-15^{\circ}}$
____ d. 5 $\underline{/-15^{\circ}}$

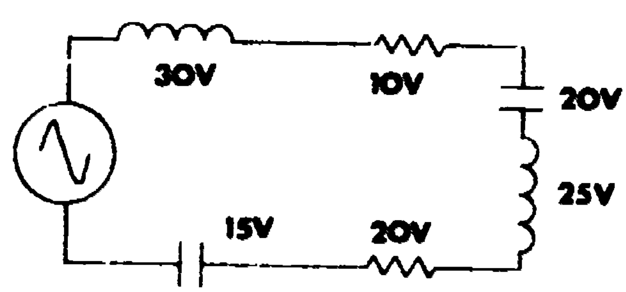
6. Multiply 24 $\underline{/12^{\circ}}$ by 12 $\underline{/28^{\circ}}$ and express your answer in polar form.

____ a. 286 $\underline{/40^{\circ}}$
____ b. 2 $\underline{/16^{\circ}}$
____ c. 36 $\underline{/40^{\circ}}$
____ d. 288 $\underline{/16^{\circ}}$

7. If $Z_1 = 12 + j18$ and $Z_2 = 13 - j2$, what is the Z_T of the two in rectangular form?

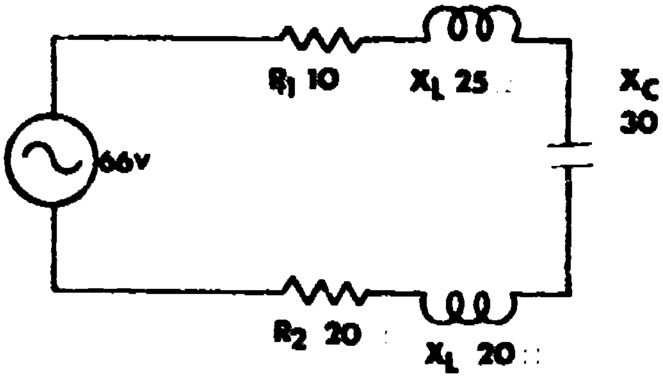
____ a. 30 $\underline{/33^{\circ}}$
____ b. 25 + j16
____ c. 1 + j20
____ d. 30 $\underline{/57^{\circ}}$

8. The total voltage in the below circuit is:



____ a. 20 - j30
____ b. 30 + j20
____ c. 30 - j20
____ d. 30 + j90

9. Find I_T, $\underline{/\theta}$ and PF.



I_T = ____________________

$\underline{/\theta}$ = ____________________

PF = ____________________

PROGRESS CHECK
LESSON IV

Variational Analysis of Series RL Circuits

1. If the frequency applied to an inductor is doubled, the current through the inductor will:

____ a. lead the voltage.
____ b. be in phase with the voltage.
____ c. be reduced by one-half.
____ d. be doubled.

2. If the resistance is increased in a series RL circuit, the circuit phase angle will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $\frac{X_L}{R}$

3. If the applied frequency is not changed but the inductance in a series RL circuit is increased, the current will:

____ a. remain the same.
____ b. increase.
____ c. decrease.
____ d. equal $\frac{E_L}{\cos \angle}$.

4. If the frequency applied to a series RL circuit is increased, the circuit phase angle will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $\frac{E_a}{\cos \angle}$.

5. If the frequency applied to a series RL circuit is reduced, the voltage across the resistor will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $I_T \times \cos \underline{/\theta}$

6. For a given applied frequency, if the inductance of a series RL circuit is increased, the circuit phase angle will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $\frac{E_a}{E_L}$

7. If the resistance is increased in a series RL circuit, the voltage across the coil will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $E_a \times \cos \underline{/\theta}$.

8. For a given applied frequency, if the inductance of a series RL circuit is decreased, the circuit current will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $\frac{E_a}{X_L}$.

9. If the resistance is decreased in a series RL circuit, the circuit phase angle will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $\frac{X_L}{R}$.

10. In an inductive circuit, if the frequency is decreased, the current will be:

____ a. increased.
____ b. decreased.
____ c. unaffected.
____ d. squared.

11. If the frequency applied to a series RL circuit is decreased, the circuit phase angle will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $\frac{E_a}{\cos \angle\theta}$.

12. If the frequency applied to a series RL circuit is decreased, the apparent power will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $\frac{P_t}{P_a}$

13. Solve for:

a. I_t ____

b. R ____

c. Z_t ____

d. $\angle\theta$ ____

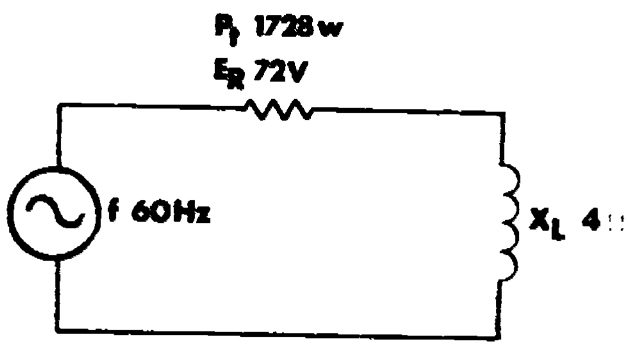
e. E_a ____

f. P_a ____

g. P_x ____

h. PF ____

i. E_L ____



PROGRESS CHECK
LESSON V

Frequency Discrimination in RL Circuits

1. In an RL circuit, cutoff frequency is the point where the true power has decreased to half the maximum power and:

____ a. $X_L = R$.

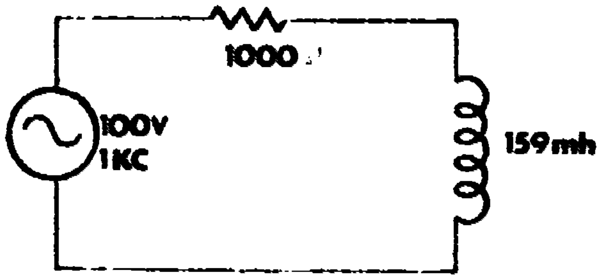
____ b. $X_L = X_C$.

____ c. $P_t = P_a$.

____ d. COS $\angle\theta$ = TAN $\angle\theta$.

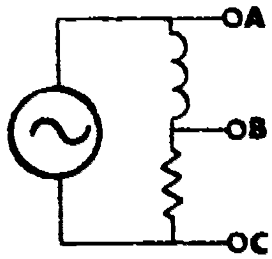
2. In the series RL circuit below, if the frequency applied is the f_{co} of the circuit, what is the value of X_L?

____ a. 100 ohms.
____ b. 159 ohms.
____ c. 1 Kohm.
____ d. 2 Kohms.



3. Match the output connections with the circuit function:

a. High frequency discriminator ____ to ____.
b. High pass filter ____ to ____.
c. Low pass filter ____ to ____.
d. Low frequency discriminator ____ to ____.

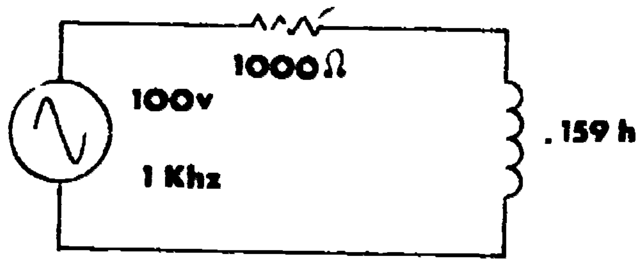


4. When low frequencies are to be attenuated, the output of a series RL filter circuit should be taken from across the:

____ a. resistor.
____ b. resistor and the coil
____ c. coil.
____ d. generator.

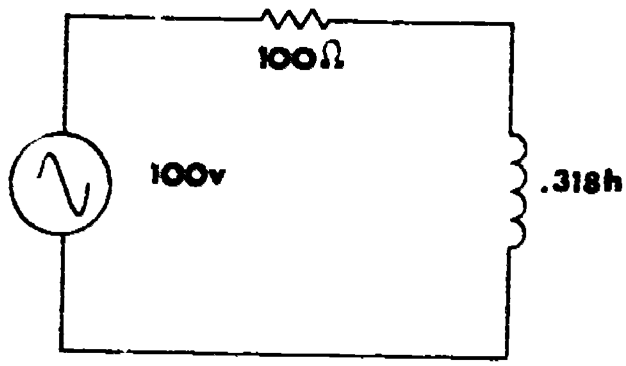
5. In the series RL circuit below, if the frequency applied is the f_{co} of the circuit, what is the circuit phase angle?

____ a. 120°
____ b. 70.7°
____ c. 45°
____ d. 90°



6. What is the cutoff frequency (f_{co}) of the circuit below?

____ a. 31.8 Hz.
____ b. 194 Hz.
____ c. 500 Hz.
____ d. 50 Hz.



PROGRESS CHECK
LESSON VI

Series RC Circuits

1. If the value of capacitance is decreased in a series RC circuit, the voltage across the capacitor will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $E_C \times COS \underline{/\theta}$.

2. When a series RC circuit is used as a high-pass filter, the output is taken from across the:

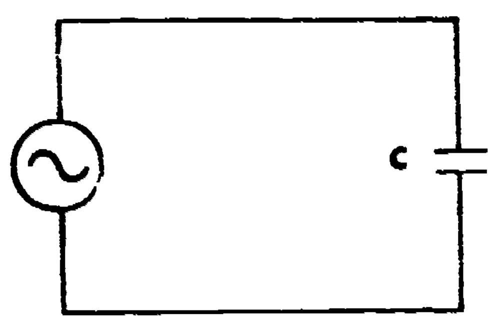
____ a. resistor.
____ b. capacitor.
____ c. resistor and capacitor.
____ d. generator.

3. If the value of resistance is increased in a series RC circuit, the voltage across the resistor will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal $E_a \times SIN \underline{/\theta}$.

4. In the illustration below, the current:

____ a. leads the voltage by 90°.
____ b. lags the voltage by 45°.
____ c. leads the voltage by 45°.
____ d. lags the voltage by 90°.



5. If a series RC circuit is used as a filter and the output is taken from the resistor, the circuit is a ________ filter.

____ a. high frequency discriminating
____ b. band eliminating
____ c. low pass
____ d. high pass

6. In a capacitive circuit, if the frequency is increased, the current will be:

____ a. increased.
____ b. decreased.
____ c. unaffected.
____ d. reduced slightly.

7. If high frequencies are to be attentuated in an RC filter circuit, the output would be taken from across the:

____ a. resistor.
____ b. capacitor.
____ c. resistor and capacitor.
____ d. generator.

8. If the applied frequency is unchanged, but the value of capacitance is increased in a series RC circuit, the current will:

____ a. remain the same.
____ b. increase.
____ c. decrease.
____ d. equal $\frac{E_a}{\cos \underline{/\theta}}$.

9. If low frequencies are to be attenuated in an RC filter circuit, the output would be taken from across the:

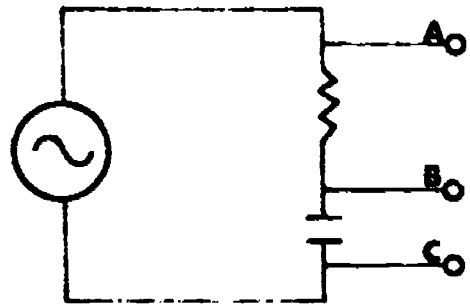
____ a. generator.
____ b. resistor.
____ c. capacitor.
____ d. resistor and capacitor.

10. If the frequency applied to an RC circuit is decreased, the voltage drop across the capacitor will:

____ a. equal E_a multiplied by COS $\underline{/\theta}$.
____ b. remain the same.
____ c. decrease.
____ d. increase.

11. If the filter circuit below is to be used as a low-pass filter, the output will be taken from across points:

____ a. A and B.
____ b. B and C.
____ c. C and A.



12. If the value of resistance is increased in a series RC circuit, the voltage across the capacitor will:

____ a. equal I_C x COS $\angle$.
____ b. increase.
____ c. decrease.
____ d. remain the same.

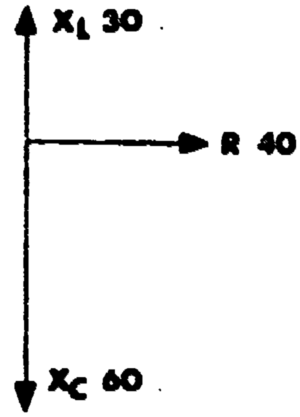
13. When a series RC circuit is used as a low-pass filter the output is taken from across the:

____ a. resistor.
____ b. capacitor.
____ c. resistor and capacitor.
____ d. generator.

14. In a series RC circuit, if the frequency of the applied voltage is decreased, the circuit current will:

____ a. equal $\frac{E_a}{R}$.
____ b. increase.
____ c. decrease.
____ d. equal $\frac{E_a}{X_C}$.

15. Find the impedance in the diagram shown.



____ a. $50 \angle 37^{\circ}$ ohms.

____ b. $50 \angle -37^{\circ}$ ohms.

____ c. $50 \angle 53^{\circ}$ ohms.

____ d. $50 \angle -53^{\circ}$ ohms.

16. In a series RC circuit, the apparent power is 265 va, the phase angle is -67.6° and the frequency of the applied ltage is 60 Hz.

Solve for:

a. P_t = ____

b. P_x = ____

c. PF = ____

PROGRESS CHECK ANSWERS

MODULE TWELVE

LESSON I

1. c, d
2. b
3. a
4. c
5. d
6. d
7. b
8. d
9. a
10. d

LESSON II

1. c
2. b
3. b
4. c
5. d
6. c
7. b

LESSON III

1. d
2. c
3. a
4. b
5. d
6. a
7. b
8. b

LESSON III (Cont'd)

9. $I_T = 2a$

   $\angle\theta = 26.6^\circ$

   $PF = .89$

LESSON IV

1. c
2. b
3. c
4. a
5. a
6. a
7. b
8. a
9. a
10. a
11. b
12. a
13. a. 24a

    b. 3Ω

    c. 5Ω

    d. 53.1°

    e. 120v

    f. 2880 va

    g. 2304 var

    h. .60

    i. 96v

LESSON V

1. a
2. c
3. a. B, C
   b. A, B
   c. B, C
   d. A, B
4. c
5. c
6. d

LESSON VI

1. a
2. a
3. a
4. a
5. d
6. a
7. b
8. b
9. b
10. d
11. b
12. c

LESSON VI (Cont'd)

13. b
14. c
15. b
16. a. 101 w
    b. 245 var
    c. .38

IF YOUR ANSWERS ARE ALL CORRECT, GO TO THE NEXT LESSON. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

Solving Series RLC Circuits

1. At high frequencies, hollow tubing is used for conductors because of the:

____ a. effective resistance.
____ b. proximity effect.
____ c. skin effect.
____ d. circumference effect.

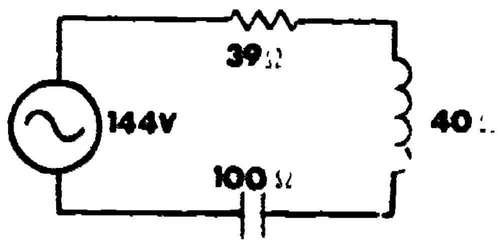
2. What is the impedance in the circuit below?

____ a. 72 $\angle -33^\circ$ ohms.

____ b. 72 $\angle -57^\circ$ ohms.

____ c. 110 $\angle -57^\circ$ ohms.

____ d. 110 $\angle -33^\circ$ ohms.



3. If the frequency applied to a coil decreases, what will be the effect upon the Q of the coil?

____ a. Q will halve.
____ b. Q will increase.
____ c. Q will decrease.
____ d. Q will remain the same.

4. In a series RLC circuit, the current will be:

____ a. greatest through R.
____ b. greatest through L.
____ c. greatest through C.
____ d. equal in R, L, and C.

5. The circuit Q may be maintained at a high level by keeping ___________ to a minimum.

____ a. resistance
____ b. reactance
____ c. capacitance
____ d. inductance

6. When hollow tubing is used as a conductor, it is to take advantage of the ___________ effect.

____ a. proximity
____ b. skin
____ c. Edison
____ d. copper

7. The change in current distribution in a conductor due to the action of an alternating current in a nearby conductor is called the:

____ a. hollow effect.
____ b. tube effect.
____ c. proximity effect.
____ d. skin effect.

8. The tendency of AC conductors to carry the current on the surface rather than throughout the cross-sectional area is known as the:

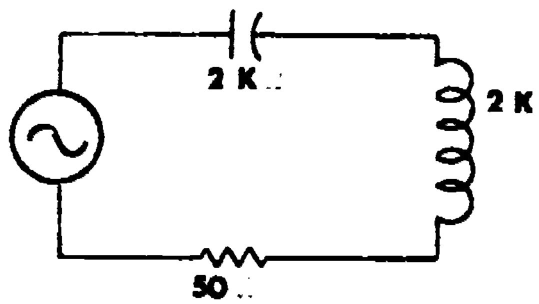
____ a. hollow effect.
____ b. tube effect.
____ c. proximity effect.
____ d. skin effect.

9. The resistance of coils due to proximity effect may be reduced by:

____ a. decreasing the separation between conductors.
____ b. using larger conductors.
____ c. increasing the separation between conductors.
____ d. adding more turns to the coil.

10. What is the $\underline{Q}$ of the circuit below?

____ a. 40
____ b. 400
____ c. 0.05
____ d. 0.005



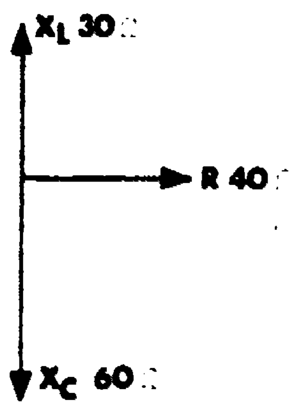
11. Find the impedance represented below.

____ a. 50 $\underline{/37^\circ}$ ohms.

____ b. 50 $\underline{/-37^\circ}$ ohms.

____ c. 50 $\underline{/53^\circ}$ ohms.

____ d. 50 $\underline{/-53^\circ}$ ohms.



12. When a vector is multiplied by +j, the vector will be rotated:

____ a. clockwise 90°.
____ b. clockwise 180°.
____ c. counterclockwise 90°.
____ d. counterclockwise 180°.

13. The figure of merit of a coil may be expressed as:

a. Ten or greater
b. $\frac{P_r}{P_x}$
c. Proximity effect
d. Ratio of power stored to power dissipated in the coil.

14. The effective resistance of any circuit is the combination of:

____ a. DC resistance and the resistance caused by alternating current.

____ b. DC resistance and the circuit resistance.

____ c. all the voltage drops divided by circuit current.

____ d. all the directly measurable resistances.

15. In the circuit shown, solve for:

a. E_a = ____

b. $\angle\theta$ = ____

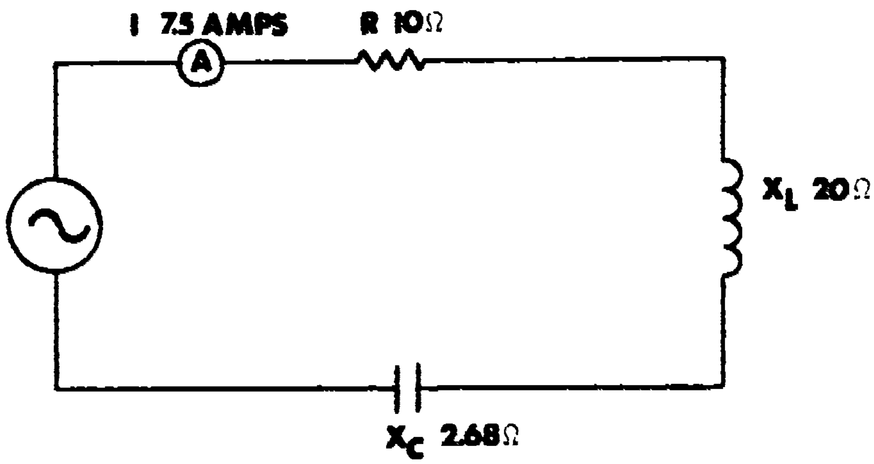
c. Z_t = ____

d. P_a = ____

e. P_t = ____

f. P_x = ____

g. PF = ____



PROGRESS CHECK
LESSON II

Series AC Circuits at Resonance

1. At resonance in a series RLC circuit:

____ a. inductance equals capacitance.
____ b. impedance is minimum.
____ c. current is minimum.
____ d. power factor is 0.707.

2. In a series RLC circuit at resonance the:

____ a. X_L and X_c are equal.

____ b. Z_t of the circuit is equal to circuit R.

____ c. circuit current is maximum.

____ d. phase angle between E and I is zero.

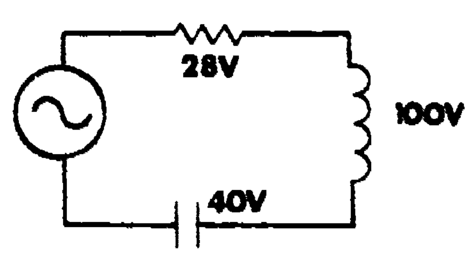
3. The total voltage in the circuit below is ____________ volts.

____ a. 31 $\underline{/65^{\circ}}$

____ b. 32 $\underline{/25^{\circ}}$

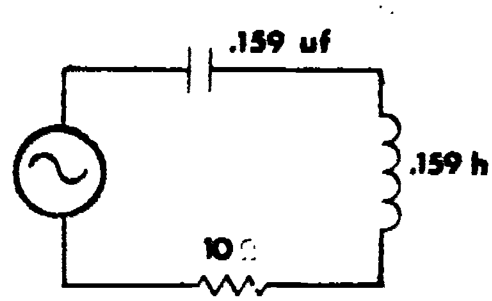
____ c. 66 $\underline{/65^{\circ}}$

____ d. 66 $\underline{/25^{\circ}}$



4. What is the resonant frequency in the circuit below?

____ a. 1 Hz.
____ b. 10 Hz.
____ c. 100 Hz.
____ d. 1000 Hz.



5. Determine the resonant frequency of a series RLC circuit consisting of a 4 μh coil a 1μf capacitor and a 10 ohm resistor.

____ a. 79.5 kHz.
____ b. 89.8 Hz.
____ c. 628.0 Hz.
____ d. 12.56 Hz.

6. If the frequency applied to a series RLC circuit is decreased to a frequency below resonance, the current will:

____ a. increase.
____ b. decrease.
____ c. lag the voltage.
____ d. be unchanged.

7. If the various voltage drops in a series RLC circuit are added vectorially, the resultant will be equal to the:

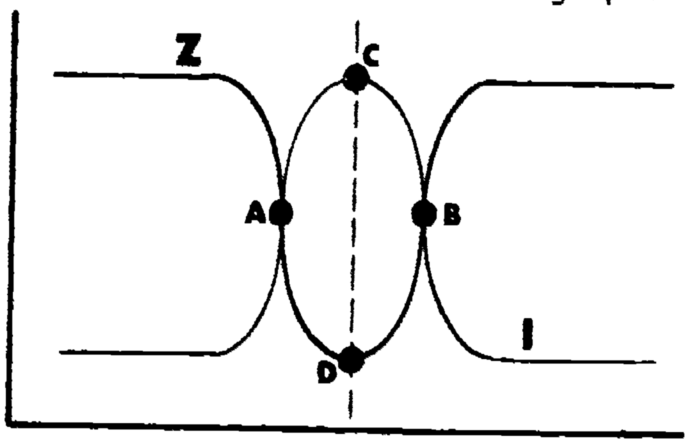
____ a. impedance.
____ b. reactive voltage.
____ c. applied voltage.
____ d. true power.

PROGRESS CHECK
LESSON III

Resonance in Series RC Circuits

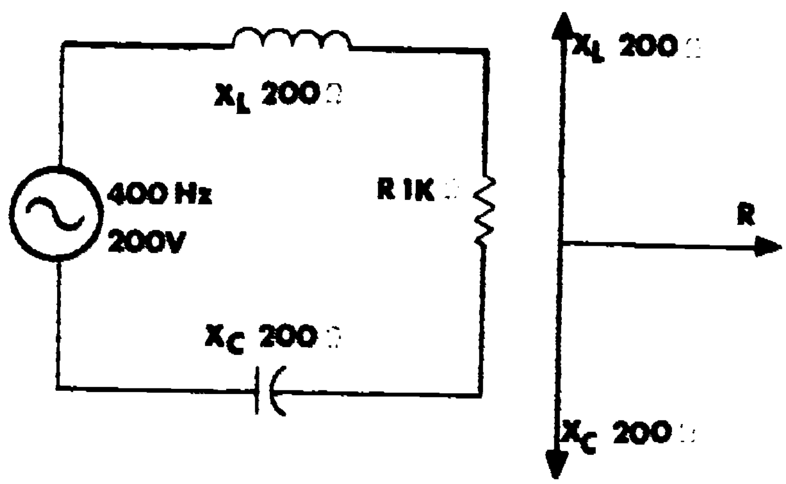
1. What two points indicate a resonant circuit on the graph?

____ a. A and B
____ b. C and D
____ c. A and C
____ d. B and D



2. Comparing the vector diagram to the circuit drawing, you can assume the circuit is operating:

____ a. at the upper f_{co}.
____ b. at resonance.
____ c. at the lower f_{co}.



3. When the frequency of voltage applied to a coil decreases, the Q of the coil will:

____ a. halve.
____ b. not change.
____ c. increase.
____ d. decrease.

4. At resonance in a series RLC circuit, current is:

____ a. maximum.
____ b. limited by reactance.
____ c. minimum.
____ d. out of phase with applied voltage.

5. If a series RLC circuit is operating below resonance, the impedance will appear to be:

____ a. capacitive.
____ b. resistive.
____ c. decreased.
____ d. inductive.

6. If a series RLC circuit is operating above resonance, the impedance will appear to be:

____ a. capacitive.
____ b. resistive.
____ c. decreased.
____ d. inductive.

7. When a series RLC circuit is operating at its resonant frequency, the impedance is equal to:

____ a. $R - jX_C$

____ b. $\dfrac{X_L}{\text{SIN } \underline{/\theta}}$

____ c. $E_a \times \text{COS } \underline{/\theta}$.

____ d. R.

8. When a series RLC circuit is operating at resonance, the line current is:

____ a. lagging E_a.
____ b. leading E_a.
____ c. in phase with E_a.
____ d. minimum.

9. When the frequency of voltage applied to a coil increases, the Q of the coil will:

____ a. not change.
____ b. increase.
____ c. decrease.
____ d. double.

10. If the frequency applied to a series RLC circuit were decreased to a frequency below resonance, the current would:

____ a. increase.
____ b. decrease.
____ c. lag the voltage.
____ d. be unchanged.

11. An impedance vector diagram uses what two quantities to solve for Z?

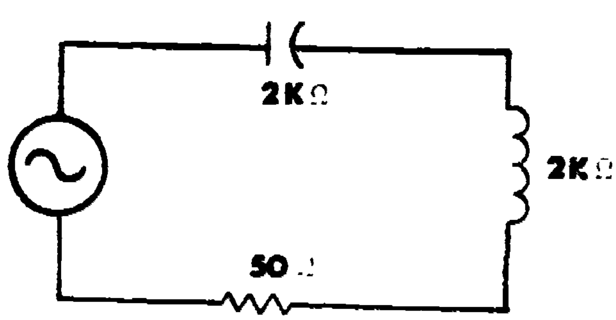
____ a. Reactance and inductance.
____ b. Capacitance and reactance.
____ c. Inductance and capacitance.
____ d. Resistance and reactance.

12. What is the bandwidth of a series circuit if the resonant frequency is 50 Hz and the circuit Q is 50?

____ a. 0.10 Hz.
____ b. 100 Hz.
____ c. 1 Hz.
____ d. 10 Hz.

13. What is the Q of the circuit below?

____ a. 40
____ b. 400
____ c. 0.05
____ d. 0.005



14. If the Q of the coil in a series resonant circuit is lowered, the bandwidth will:

____ a. increase.
____ b. not be affected.
____ c. decrease.
____ d. equal $\frac{R}{X_L}$

15. When a series RLC circuit is operated at resonance, the inductive reactance will equal the __________ of the circuit.

____ a. cut-off frequency
____ b. resistance
____ c. impedance
____ d. capacitive reactance

16. In a series RLC circuit, the current will be:

____ a. greatest through R.
____ b. greatest through L.
____ c. greatest through C.
____ d. equal in R, L, and C.

17. If the half-power points of a series resonant circuit are 550 Hz and 570 Hz, what is the resonant frequency?

____ a. 555 Hz
____ b. 560 Hz
____ c. 565 Hz
____ d. 20 Hz

PROGRESS CHECK ANSWERS

MODULE THIRTEEN

LESSON I

1. c
2. b
3. d
4. d
5. a
6. b
7. c
8. d
9. c
10. a
11. b
12. c
13. d
14. a
15. a. 150 v
    b. 60°
    c. 20 Ω
    d. 1125 va
    e. 562.5 w
    f. 974.25 var
    g. .50

LESSON II

1. b
2. a, b, c, d
3. c
4. d

LESSON II (Cont'd)

5. a
6. b
7. c

LESSON III

1. b
2. b
3. b
4. a
5. a
6. d
7. d
8. c
9. a
10. b
11. d
12. c
13. a
14. a
15. d
16. d
17. b

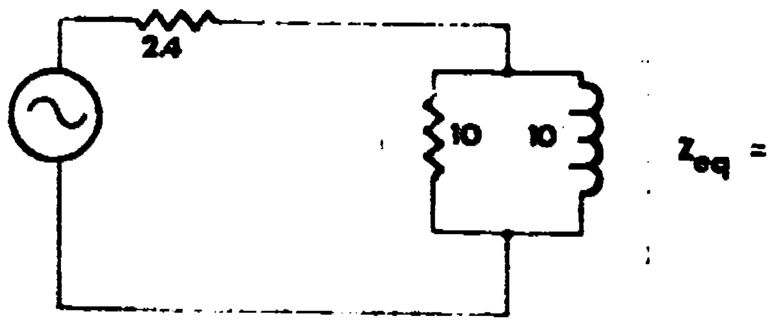
IF YOUR ANSWERS ARE ALL CORRECT, YOU MAY TAKE THE MODULE TEST FOR THIS MODULE. IF NOT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON BEFORE TAKING THE PROGRESS CHECK AGAIN.

PROGRESS CHECK
LESSON I

Solving for Quantities in Parallel RL Circuits

1. What is the equivalent impedance of the parallel network?

____ a. 15.9 ohms.
____ b. 7.1 ohms.
____ c. 5.5 ohms.
____ d. 8.9 ohms.



2. If the resistance is increased in an RL parallel circuit, the total current will:

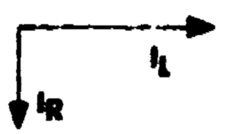
____ a. be reduced to zero.
____ b. increase.
____ c. decrease.
____ d. remain the same.

3. If the inductance in a parallel RL circuit is increased, the ______________ will decrease.

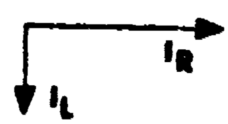
____ a. power factor.
____ b. inductive reactance.
____ c. resistive voltage drop.
____ d. circuit phase angle.

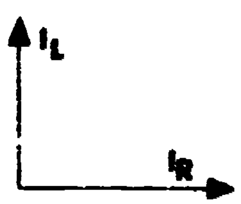
4. Which current vector diagram is correct for the below circuit?

____ a.



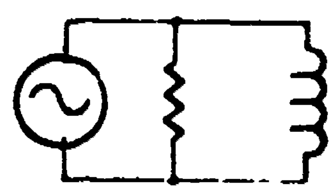
____ b.





____ c.

____ d.



5. What is the phase relationship between voltage and current in a parallel RL circuit?

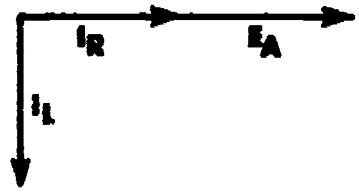
____ a. I_L lags E_a by 90°.

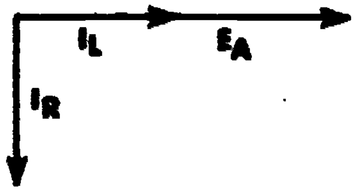
____ b. I_R leads E_a by 90°.

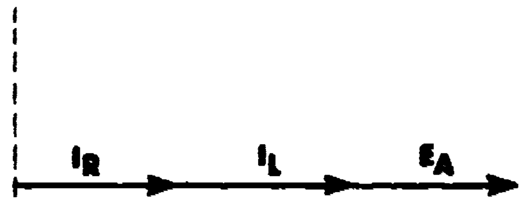
____ c. I_L leads E_a by 90°.

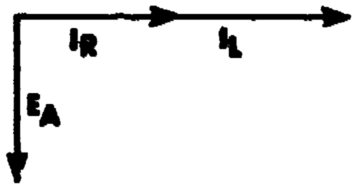
____ d. I_R, I_L, and E_a are in phase.

6. Which of the following diagrams illustrates the phase relationship in a two-branch parallel RL circuit?

____ a. 

____ b. 

____ c. 

____ d. 

7. In a parallel RL circuit, the applied voltage has what phase relationship with the branch currents?

____ a. E_a is in phase with I_L but not I_R.

____ b. E_a is out of phase with I_R and I_L.

____ c. E_a is in phase with I_L and I_R.

____ d. E_a is in phase with I_R but not I_L.

8. An equivalent impedance for a parallel RL circuit is valid only at a given operating frequency because the:

____ a. reactive component varies with the frequency.

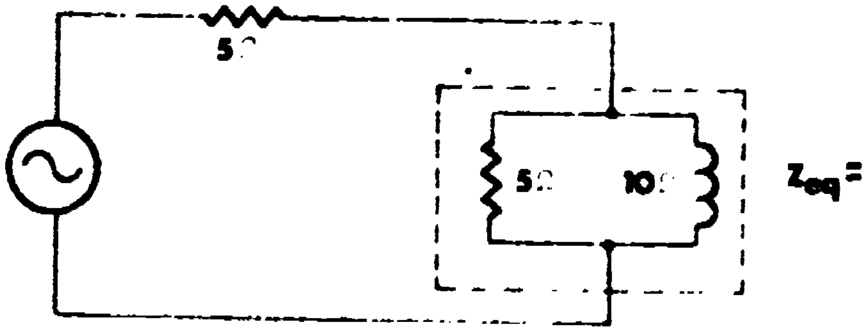
____ b. true power of the circuit is inversely proportional to the frequency of the circuit.

____ c. resistive voltage drop varies directly with the frequency.

____ d. applied voltage increases as the frequency is decreased.

9. What is the equivalent impedance of the parallel section of the below circuit?

____ a. 4.5 ohms
____ b. 9.5 ohms
____ c. 2.5 ohms
____ d. 7.5 ohms



10. If the resistance is decreased in an RL parallel circuit, the total current will:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. drop to zero.

11. When total impedance is computed, coil resistance is usually taken into consideration only if the Q of the coil is:

____ a. more than 50.
____ b. 20.
____ c. 15.
____ d. less than 10.

12. The addition of a resistor in series with the inductive branch in a parallel RL circuit will cause:

____ a. phase angle to increase.
____ b. phase angle to decrease.
____ c. true power to remain the same.
____ d. true power to decrease.

PROGRESS CHECK
LESSON 11

Variational Analysis in RL Parallel Circuits

1. What circuit quantity will be doubled if the frequency of the voltage applied to a parallel RL circuit is doubled?

____ a. inductance.
____ b. inductive reactance.
____ c. inductive branch voltage drop.
____ d. inductive branch current.

2. Decreasing the frequency applied to a parallel RL circuit causes ____________ to decrease.

____ a. I_L
____ b. P_t
____ c. Z_T
____ d. I_R

3. Increasing frequency in a parallel RL circuit will cause I_R to:

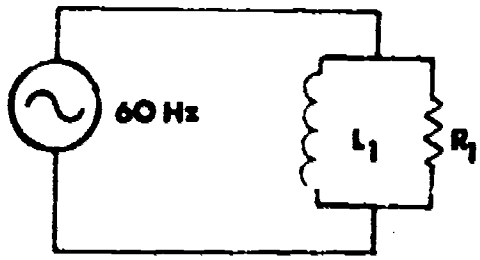
____ a. remain the same.
____ b. decrease.
____ c. increase.
____ d. vary with sine of angle theta.

4. Decreasing the frequency applied to a parallel RL circuit causes ____________ to increase.

____ a. I_T
____ b. Z_T
____ c P_t
____ d. I_R

5. Increasing the frequency of applied voltage will cause the current through L1 to:

____ a. increase.
____ b. decrease.
____ c. remain the same.
____ d. equal E_a x COS $\angle$.



6. The addition of a resistor in series with the inductive branch in a parallel RL circuit will cause __________ to decrease.

____ a. phase angle
____ b. power factor
____ c. true power
____ d. resistive branch current

7. Increasing the frequency applied to a parallel RL circuit causes __________ to increase.

____ a. phase angle
____ b. impedance
____ c. I_T
____ d. I_L

8. Increasing the frequency applied to a parallel RL circuit causes ______________ to decrease.

____ a. I_T
____ b. Z_T
____ c. P_t
____ d. I_R

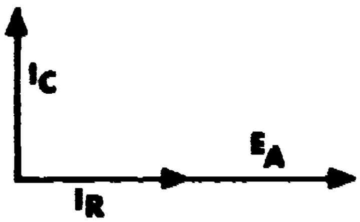
PROGRESS CHECK
LESSON III

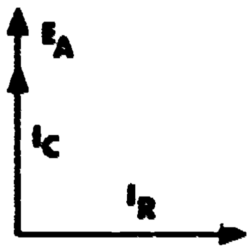
Parallel RC and RLC Circuits

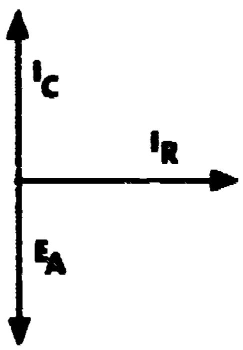
1. What circuit quantity will be halved if the frequency applied to a parallel RC circuit is doubled?

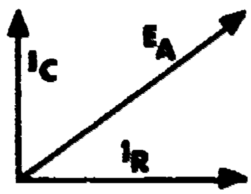
____ a. capacitance
____ b. capacitive branch voltage drop
____ c. capacitive reactance
____ d. capacitive branch current

2. In a parallel RC circuit, the phase relationship of the branch currents and applied voltage is correctly represented by which vector diagram?

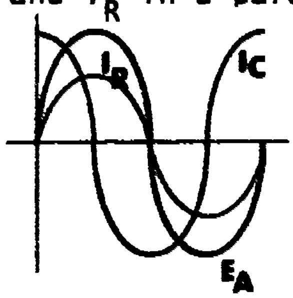
a.____


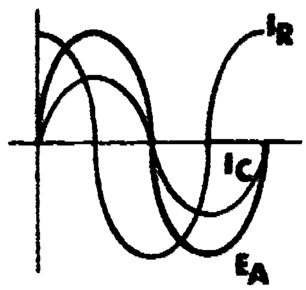
b.____


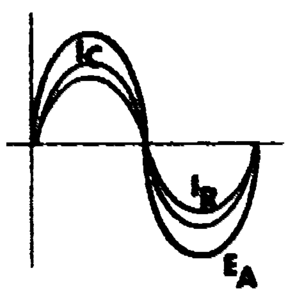
c.____


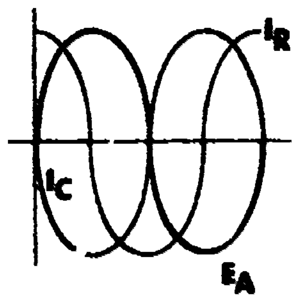
d.____


3. Select the diagram which illustrates the relationship between E_a, I_C, and I_R in a parallel RC circuit.

____ a.


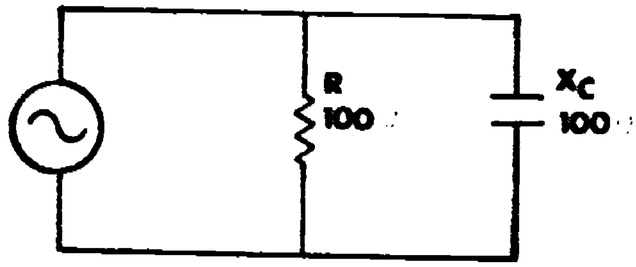
____ b.


____ c.


____ d.


4. The total impedance of this circuit is ____________ ohms.

____ a. 50
____ b. 142
____ c. 112
____ d. 71



5. Decreasing the resistance in a parallel RC circuit causes ________ ________ to decrease.

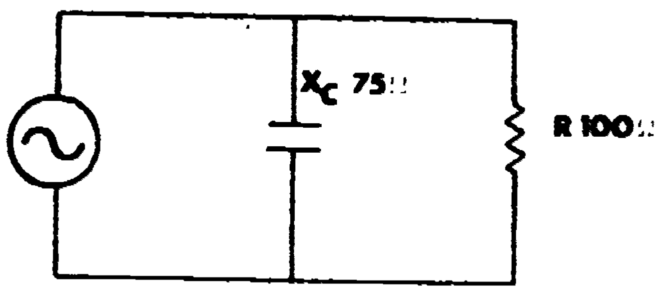
____ a. true power
____ b. capacitive current
____ c. phase angle
____ d. total current

6. If the frequency applied to a parallel RC circuit is increased, the total current will:

____ a. remain the same.
____ b. increase.
____ c. decrease.
____ d. equal E_a x COS $\angle\theta$.

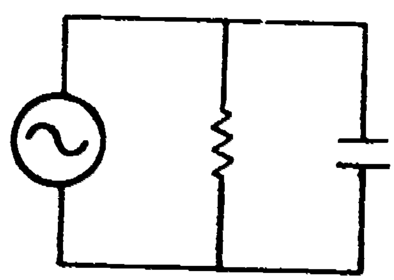
7. Determine total impedance of the circuit below.

____ a. 175 ohms
____ b. 60 ohms
____ c. 100 ohms
____ d. 125 ohms



8. Decreasing the frequency applied to the circuit below will cause ____________ to decrease.

____ a. total current
____ b. impedance
____ c. power factor
____ d. capacitive reactance

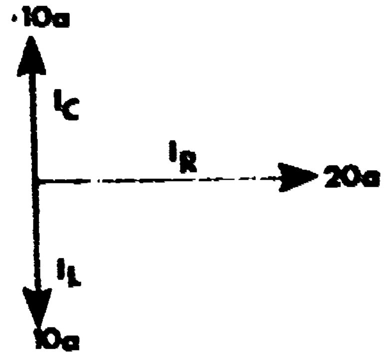


9. If a three-branch parallel RLC circuit is operated at a very low frequency, it will appear ______________ to the source.

____ a. capacitive
____ b. shorted
____ c. inductive
____ d. resistive

10. In a three-branch parallel RLC circuit, if the inductive currents and capacitive currents are equal, the circuit will appear to be purely:

____ a. inductive.
____ b. capacitive.
____ c. resistive.
____ d. reactive.



11. In a parallel RLC circuit, if the circuit phase angle is negative, the circuit appears ____________ to the source.

____ a. capacitive
____ b. inductive
____ c. resistive

PROGRESS CHECK
LESSON IV

Parallel Resonance

1. At resonance, the impedance of an ideal parallel LC circuit is:

_____ a. maximum.
_____ b. capacitive.
_____ c. inductive.
_____ d. minimum.

2. Increasing from resonance the frequency applied to a parallel LC circuit causes the current drawn from the source to:

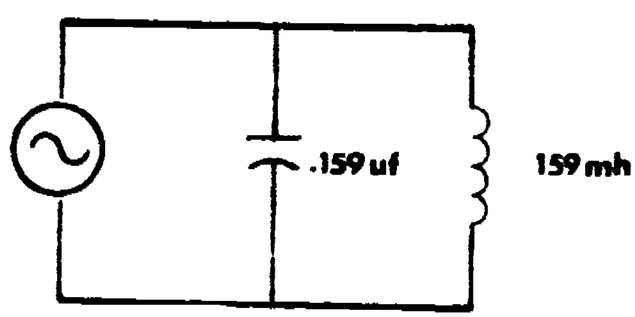
_____ a. appear inductive.
_____ b. decrease.
_____ c. increase.
_____ d. lag the voltage.

3. If an ideal parallel LC circuit is at resonance and X_L is 2000 ohms, what is the value of X_C?

_____ a. 1000 ohms
_____ b. 4000 ohms
_____ c. 2000 ohms
_____ d. 20 Kohms

4. Determine the resonant frequency of the circuit below.

_____ a. 1 KHz
_____ b. 10 KHz
_____ c. 100 KHz
_____ d. 1000 KHz



5. One indication that a two-branch LC circuit is at its resonant frequency is maximum:

_____ a. line current.
_____ b. resistor current.
_____ c. phase angle.
_____ d. impedance.

6. Decreasing the frequency applied to a parallel LC circuit from resonance causes current drawn from the source to:

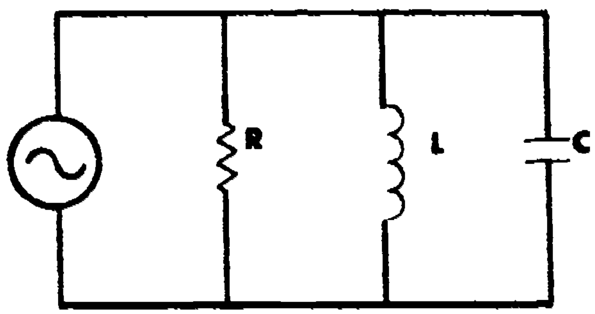
____ a. lead the voltage.
____ b. decrease.
____ c. increase.
____ d. appear capacitive.

7. If a three-branch parallel RLC circuit is operated above its resonant frequency, it will appear __________ to the source.

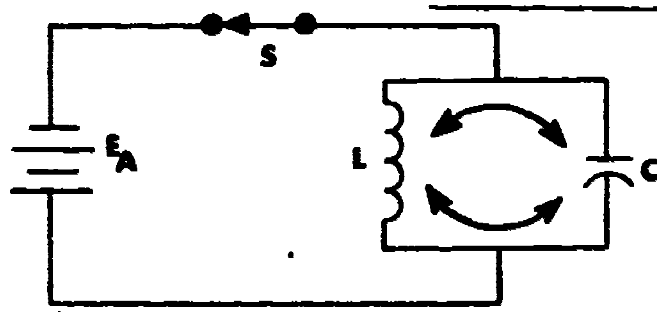
____ a. inductive
____ b. resistive
____ c. open
____ d. capacitive

8. To determine the resonant frequency of the circuit below, the values of ____________ must be known.

____ a. R and L
____ b. L and C
____ c. C and R
____ d. applied frequency and Z



9. After the source of power is removed, the current will continue to circulate back and forth between the inductor and capacitor at a diminishing rate. This action is known as ______________ action.



____ a. LC
____ b. flywheel
____ c. circulating
____ d. damped wave

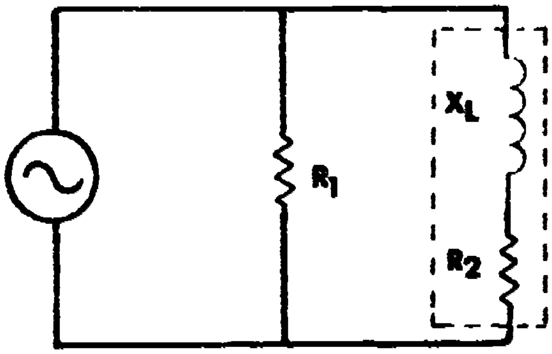
10. A damped wave is caused by the ______________ present in any practical circuit.

____ a. resistance
____ b. capacitance
____ c. inductance
____ d. current

PROGRESS CHECK
LESSON V

Effective Resistance in RL Circuits

1. If the Q of the coil is greater than 10, the effect of R2 on the impedance of the circuit is:



____ a. negligible.
____ b. to increase impedance.
____ c. to decrease impedance.
____ d. to double impedance.

2. One of the effects of a low-Q coil, compared with a high-Q coil, in a parallel RL circuit is:

____ a. higher circuit current.
____ b. lower circuit current.
____ c. higher inductive current.
____ d. lower resistive current.

3. Replacing a high-Q coil with a low-Q coil in a parallel RL circuit will cause:

____ a. an increase in phase angle.
____ b. a decrease in phase angle.
____ c. no change in circuit current.
____ d. an increase in the voltage drop across the coil.

4. A decrease in effective resistance in a parallel RL circuit will have what effect on the voltage drop across the inductor?

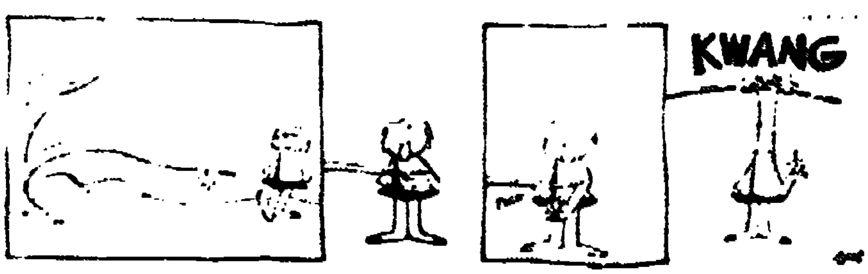
____ a. no change in E_L
____ b. decrease in E_L
____ c. increase in E_L
____ d. E_L will decrease by 1/2

5. Increasing R_{eff} of the coil in a parallel RL circuit will have what effect on true power?

____ a. no effect
____ b. an increase in P_t
____ c. a decrease in P_t

6. If the R_{eff} of the coil in a parallel RL circuit is increased, the power factor of the circuit will:

____ a. remain the same.
____ b. increase.
____ c. decrease.



If you don't know what it does don't fool with it!

PROGRESS CHECK ANSWERS

MODULE FOURTEEN

LESSON I

1. b
2. c
3. d
4. b
5. a
6. a
7. d
8. a
9. a
10. a
11. d
12. b

LESSON II

1. b
2. c
3. a
4. a
5. b
6. a
7. b
8. a

LESSON III

1. c
2. a
3.
4. d

LESSON III (Cont'd)

5. c
6. b
7. b
8. a
9. c
10. c
11. b

LESSON IV

1. a
2. c
3. c
4. a
5. d
6. c
7. d
8. b
9. b
10. a

LESSON V

1. a
2. a
3. b
4. a
5. b
6. b

IF YOUR ANSWERS ARE NOT ALL CORRECT, STUDY ANY OF THE OTHER RESOURCES AVAILABLE FOR THIS LESSON UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

deg	func.	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
0	sin	0.0000	0.0017	0.0035	0.0052	0.0070	0.0087	0.0105	0.0122	0.0140	0.0157
	cos	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9999	0.9999	0.9999
	tan	0.0000	0.0017	0.0035	0.0052	0.0070	0.0087	0.0105	0.0122	0.0140	0.0157
1	sin	0.0175	0.0192	0.0209	0.0227	0.0244	0.0262	0.0279	0.0297	0.0314	0.0332
	cos	0.9998	0.9998	0.9998	0.9997	0.9997	0.9997	0.9996	0.9996	0.9995	0.9995
	tan	0.0175	0.0192	0.0209	0.0227	0.0244	0.0262	0.0279	0.0297	0.0314	0.0332
2	sin	0.0349	0.0366	0.0384	0.0401	0.0419	0.0436	0.0454	0.0471	0.0488	0.0506
	cos	0.9994	0.9993	0.9993	0.9992	0.9991	0.9990	0.9990	0.9989	0.9988	0.9987
	tan	0.0349	0.0367	0.0384	0.0402	0.0419	0.0437	0.0454	0.0472	0.0489	0.0507
3	sin	0.0523	0.0541	0.0558	0.0576	0.0593	0.0610	0.0628	0.0645	0.0663	0.0680
	cos	0.9986	0.9985	0.9984	0.9983	0.9982	0.9981	0.9980	0.9979	0.9978	0.9977
	tan	0.0524	0.0542	0.0559	0.0577	0.0594	0.0612	0.0629	0.0647	0.0664	0.0682
4	sin	0.0698	0.0715	0.0732	0.0750	0.0767	0.0785	0.0802	0.0819	0.0837	0.0854
	cos	0.9976	0.9974	0.9973	0.9972	0.9971	0.9969	0.9968	0.9966	0.9965	0.9963
	tan	0.0699	0.0717	0.0734	0.0752	0.0769	0.0787	0.0805	0.0822	0.0840	0.0857
5	sin	0.0872	0.0889	0.0906	0.0924	0.0941	0.0958	0.0976	0.0993	0.1011	0.1028
	cos	0.9962	0.9960	0.9959	0.9957	0.9956	0.9954	0.9952	0.9951	0.9949	0.9947
	tan	0.0875	0.0892	0.0910	0.0928	0.0945	0.0963	0.0981	0.0998	0.1016	0.1033
6	sin	0.1045	0.1063	0.1080	0.1097	0.1115	0.1132	0.1149	0.1167	0.1184	0.1201
	cos	0.9945	0.9943	0.9942	0.9940	0.9938	0.9936	0.9934	0.9932	0.9930	0.9928
	tan	0.1051	0.1069	0.1086	0.1104	0.1122	0.1139	0.1157	0.1175	0.1192	0.1210
7	sin	0.1219	0.1236	0.1253	0.1271	0.1288	0.1305	0.1323	0.1340	0.1357	0.1374
	cos	0.9925	0.9923	0.9921	0.9919	0.9917	0.9914	0.9912	0.9910	0.9907	0.9905
	tan	0.1228	0.1246	0.1263	0.1281	0.1299	0.1317	0.1334	0.1352	0.1370	0.1388
8	sin	0.1392	0.1409	0.1426	0.1444	0.1461	0.1478	0.1495	0.1513	0.1530	0.1547
	cos	0.9903	0.9900	0.9898	0.9895	0.9893	0.9890	0.9888	0.9885	0.9882	0.9880
	tan	0.1405	0.1423	0.1441	0.1459	0.1477	0.1495	0.1512	0.1530	0.1548	0.1566
9	sin	0.1564	0.1582	0.1599	0.1616	0.1633	0.1650	0.1668	0.1685	0.1702	0.1719
	cos	0.9877	0.9874	0.9871	0.9869	0.9866	0.9863	0.9860	0.9857	0.9854	0.9851
	tan	0.1584	0.1602	0.1620	0.1638	0.1655	0.1673	0.1691	0.1709	0.1727	0.1745
10	sin	0.1736	0.1754	0.1771	0.1788	0.1805	0.1822	0.1840	0.1857	0.1874	0.1891
	cos	0.9848	0.9845	0.9842	0.9839	0.9836	0.9833	0.9829	0.9826	0.9823	0.9820
	tan	0.1763	0.1781	0.1799	0.1817	0.1835	0.1853	0.1871	0.1890	0.1908	0.1926
11	sin	0.1908	0.1925	0.1942	0.1959	0.1977	0.1994	0.2011	0.2028	0.2045	0.2062
	cos	0.9816	0.9813	0.9810	0.9806	0.9803	0.9799	0.9796	0.9792	0.9789	0.9785
	tan	0.1944	0.1962	0.1980	0.1998	0.2016	0.2035	0.2053	0.2071	0.2089	0.2107
12	sin	0.2079	0.2096	0.2113	0.2130	0.2147	0.2164	0.2181	0.2198	0.2215	0.2232
	cos	0.9781	0.9778	0.9774	0.9770	0.9767	0.9763	0.9759	0.9755	0.9751	0.9748
	tan	0.2126	0.2144	0.2162	0.2180	0.2199	0.2217	0.2235	0.2254	0.2272	0.2290
13	sin	0.2250	0.2267	0.2284	0.2300	0.2318	0.2334	0.2351	0.2368	0.2385	0.2402
	cos	0.9744	0.9740	0.9736	0.9732	0.9728	0.9724	0.9720	0.9715	0.9711	0.9707
	tan	0.2309	0.2327	0.2345	0.2364	0.2382	0.2401	0.2419	0.2438	0.2456	0.2475
deg	func.	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°

		0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
14	sin	[illegible]	[illegible]	0.2453	0.2470	0.2487	0.2504	0.2521	0.2538	0.2554	0.2571
	cos	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.9681	0.9677	0.9673	0.9668	0.9664
	tan	[illegible]	[illegible]	0.2530	[illegible]	[illegible]	[illegible]	0.2605	0.2623	0.2642	0.2661
15	sin	[illegible]	0.2605	0.2622	0.2639	[illegible]	0.2672	0.2689	0.2706	0.2723	0.2740
	cos	[illegible]	[illegible]	0.9650	0.9646	0.9641	0.9636	0.9632	0.9627	0.9622	0.9617
	tan	[illegible]	0.2698	0.2717	0.2736	0.2754	0.2773	0.2792	0.2811	0.2830	0.2849
16	sin	[illegible]	0.2773	0.2790	0.2807	0.2823	0.2840	0.2857	0.2874	0.2890	0.2907
	cos	0.9613	0.9608	0.9603	0.9598	0.9593	0.9588	0.9583	0.9578	0.9573	0.9568
	tan	0.2867	0.2886	0.2905	0.2924	0.2943	0.2962	0.2981	0.3000	0.3019	0.3038
17	sin	0.2924	0.2940	0.2957	0.2974	0.2990	0.3007	0.3024	0.3040	0.3057	0.3074
	cos	0.9563	0.9558	0.9553	0.9548	0.9542	0.9537	0.9532	0.9527	0.9521	0.9516
	tan	0.3057	0.3076	0.3096	0.3115	0.3134	0.3153	0.3172	0.3191	0.3211	0.3230
18	sin	0.3090	0.3107	0.3123	0.3140	0.3156	0.3173	0.3190	0.3206	0.3223	0.3239
	cos	0.9511	0.9505	0.9500	0.9494	0.9489	0.9483	0.9478	0.9472	0.9466	0.9461
	tan	0.3249	0.3269	0.3288	0.3307	0.3327	0.3346	0.3365	0.3385	0.3404	0.3424
19	sin	0.3256	0.3272	0.3289	0.3305	0.3322	0.3338	0.3355	0.3371	0.3387	0.3404
	cos	0.9455	0.9449	0.9444	0.9438	0.9432	0.9426	0.9421	0.9415	0.9409	0.9403
	tan	0.3443	0.3463	0.3482	0.3502	0.3522	0.3541	0.3561	0.3581	0.3600	0.3620
20	sin	0.3420	0.3437	0.3453	0.3469	0.3486	0.3502	0.3518	0.3535	0.3551	0.3567
	cos	[illegible]	0.9391	0.9385	0.9379	0.9373	0.9367	0.9361	0.9354	0.9348	0.9342
	tan	[illegible]	[illegible]	0.3679	0.3699	0.3719	0.3739	0.3759	0.3779	0.3799	0.3819
21	sin	0.3584	0.3600	0.3616	0.3633	0.3649	0.3665	0.3681	0.3697	0.3714	0.3730
	cos	0.9336	0.9330	0.9323	0.9317	0.9311	0.9304	0.9298	0.9291	0.9285	0.9278
	tan	[illegible]	[illegible]	0.3879	0.3899	0.3919	0.3939	0.3959	0.3979	0.4000	0.4020
22	sin	0.3746	0.3762	0.3778	0.3795	0.3811	0.3827	0.3843	0.3859	0.3875	0.3891
	cos	0.9272	0.9265	0.9259	0.9252	0.9245	0.9239	0.9232	0.9225	0.9219	0.9212
	tan	0.4040	0.4061	0.4081	0.4101	0.4122	0.4142	0.4163	0.4183	0.4204	0.4224
23	sin	0.3907	0.3923	0.3939	0.3955	0.3971	0.3987	0.4003	0.4019	0.4035	0.4051
	cos	0.9205	0.9198	0.9191	0.9184	0.9178	0.9171	0.9164	0.9157	0.9150	0.9143
	tan	0.4245	0.4265	0.4286	0.4307	0.4327	0.4348	0.4369	0.4390	0.4411	0.4431
24	sin	0.4067	0.4083	0.4099	0.4115	0.4131	0.4147	0.4163	0.4179	0.4195	0.4210
	cos	0.9135	0.9128	0.9121	0.9114	0.9107	0.9100	0.9092	0.9085	0.9078	0.9070
	tan	0.4452	0.4473	0.4494	0.4515	0.4536	0.4557	0.4578	0.4599	0.4621	0.4642
25	sin	0.4226	0.4242	0.4258	0.4274	0.4289	0.4305	0.4321	0.4337	0.4352	0.4368
	cos	0.9063	0.9056	0.9048	0.9041	0.9033	0.9026	0.9018	0.9011	0.9003	0.8996
	tan	0.4663	0.4684	0.4706	0.4727	0.4748	0.4770	0.4791	0.4813	0.4834	0.4856
26	sin	0.4384	0.4399	0.4415	0.4431	0.4446	0.4462	0.4478	0.4493	0.4509	0.4524
	cos	0.8988	0.8980	0.8973	0.8965	0.8957	0.8949	0.8942	0.8934	0.8926	0.8918
	tan	0.4877	0.4899	0.4921	0.4942	0.4964	0.4986	0.5008	0.5029	0.5051	0.5073
27	sin	0.4540	0.4555	0.4571	0.4586	0.4602	0.4617	0.4633	0.4648	0.4664	0.4679
	cos	0.8910	0.8902	0.8894	0.8886	0.8878	0.8870	0.8862	0.8854	0.8846	0.8838
	tan	0.5095	0.5117	0.5139	0.5161	0.5184	0.5206	0.5228	0.5250	0.5272	0.5295
		0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°

deg	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
28	sin	0.4695	0.4710	0.4726	0.4741	0.4756	0.4772	0.4787	0.4802	0.4818	0.4833
	cos	0.8829	0.8821	0.8813	0.8805	0.8796	0.8788	0.8780	0.8771	0.8763	0.8755
	tan	0.5317	0.5340	0.5362	0.5384	0.5407	0.5430	0.5452	0.5475	0.5498	0.5520
29	sin	0.4848	0.4863	0.4879	0.4894	0.4909	0.4924	0.4939	0.4955	0.4970	0.4985
	cos	0.8746	0.8738	0.8729	0.8721	0.8712	0.8704	0.8695	0.8686	0.8678	0.8669
	tan	0.5543	0.5566	0.5589	0.5612	0.5635	0.5658	0.5681	0.5704	0.5727	0.5750
30	sin	0.5000	0.5015	0.5030	0.5045	0.5060	0.5075	0.5090	0.5105	0.5120	0.5135
	cos	0.8660	0.8652	0.8643	0.8634	0.8625	0.8616	0.8607	0.8599	0.8590	0.8581
	tan	0.5774	0.5797	0.5820	0.5844	0.5867	0.5890	0.5914	0.5938	0.5961	0.5985
31	sin	0.5150	0.5165	0.5180	0.5195	0.5210	0.5225	0.5240	0.5255	0.5270	0.5284
	cos	0.8572	0.8563	0.8554	0.8545	0.8536	0.8526	0.8517	0.8508	0.8499	0.8490
	tan	0.6009	0.6032	0.6056	0.6080	0.6104	0.6128	0.6152	0.6176	0.6200	0.6224
32	sin	0.5299	0.5314	0.5329	0.5344	0.5358	0.5373	0.5388	0.5402	0.5417	0.5432
	cos	0.8480	0.8471	0.8462	0.8453	0.8443	0.8434	0.8425	0.8415	0.8406	0.8396
	tan	0.6249	0.6273	0.6297	0.6322	0.6346	0.6371	0.6395	0.6420	0.6445	0.6469
33	sin	0.5446	0.5461	0.5476	0.5490	0.5505	0.5519	0.5534	0.5548	0.5563	0.5577
	cos	0.8387	0.8377	0.8368	0.8358	0.8348	0.8339	0.8329	0.8320	0.8310	0.8300
	tan	0.6494	0.6519	0.6544	0.6569	0.6594	0.6619	0.6644	0.6669	0.6694	0.6720
34	sin	0.5592	0.5606	0.5621	0.5635	0.5650	0.5664	0.5678	0.5693	0.5707	0.5721
	cos	0.8290	0.8281	0.8271	0.8261	0.8261	0.8241	0.8231	0.8221	0.8211	0.8202
	tan	0.6745	0.6771	0.6796	0.6822	0.6847	0.6873	0.6899	0.6924	0.6950	0.6976
35	sin	0.5736	0.5750	0.5764	0.5779	0.5793	0.5807	0.5821	0.5835	0.5850	0.5864
	cos	0.8192	0.8181	0.8171	0.8161	0.8151	0.8141	0.8131	0.8121	0.8111	0.8100
	tan	0.7002	0.7028	0.7054	0.7080	0.7107	0.7133	0.7159	0.7186	0.7212	0.7239
36	sin	0.5878	0.5892	0.5906	0.5920	0.5934	0.5948	0.5962	0.5976	0.5990	0.6004
	cos	0.8090	0.8080	0.8070	0.8059	0.8049	0.8039	0.8028	0.8018	0.8007	0.7997
	tan	0.7265	0.7292	0.7319	0.7346	0.7373	0.7400	0.7427	0.7454	0.7481	0.7508
37	sin	0.6018	0.6032	0.6046	0.6060	0.6074	0.6088	0.6101	0.6115	0.6129	0.6143
	cos	0.7986	0.7976	0.7965	0.7955	0.7944	0.7934	0.7923	0.7912	0.7902	0.7891
	tan	0.7536	0.7563	0.7590	0.7618	0.7646	0.7673	0.7701	0.7729	0.7757	0.7785
38	sin	0.6157	0.6170	0.6184	0.6198	0.6211	0.6225	0.6239	0.6252	0.6266	0.6280
	cos	0.7880	0.7869	0.7859	0.7848	0.7837	0.7826	0.7815	0.7804	0.7793	0.7782
	tan	0.7813	0.7841	0.7869	0.7898	0.7926	0.7954	0.7983	0.8012	0.8040	0.8069
39	sin	0.6293	0.6307	0.6320	0.6334	0.6347	0.6361	0.6374	0.6388	0.6401	0.6414
	cos	0.7771	0.7760	0.7749	0.7738	0.7727	0.7716	0.7705	0.7694	0.7683	0.7672
	tan	0.8098	0.8127	0.8156	0.8185	0.8214	0.8243	0.8273	0.8302	0.8332	0.8361
40	sin	0.6428	0.6441	0.6455	0.6468	0.6481	0.6494	0.6508	0.6521	0.6534	0.6547
	cos	0.7660	0.7649	0.7638	0.7627	0.7615	0.7604	0.7593	0.7581	0.7570	0.7559
	tan	0.8391	0.8421	0.8451	0.8481	0.8511	0.8541	0.8571	0.8601	0.8632	0.8662
41	sin	0.6561	0.6574	0.6587	0.6600	0.6613	0.6626	0.6639	0.6652	0.6665	0.6678
	cos	0.7547	0.7536	0.7524	0.7513	0.7501	0.7490	0.7478	0.7466	0.7455	0.7443
	tan	0.8693	0.8724	0.8754	0.8785	0.8816	0.8847	0.8878	0.8910	0.8941	0.8972
deg	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°

deg	function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
	sin	0.6691	0.6704	0.6717	0.6730	0.6743	0.6756	0.6769	0.6782	0.6794	0.6807
42	cos	0.7431	0.7420	0.7408	0.7396	0.7385	0.7373	0.7361	0.7349	0.7337	0.7325
	tan	0.9004	0.9036	0.9067	0.9099	0.9131	0.9163	0.9195	0.9228	0.9260	0.9293
	sin	0.6820	0.6833	0.6845	0.6858	0.6871	0.6884	0.6896	0.6909	0.6921	0.6934
43	cos	0.7314	0.7302	0.7290	0.7278	0.7266	0.7254	0.7242	0.7230	0.7218	0.7206
	tan	0.9325	0.9358	0.9391	0.9424	0.9457	0.9490	0.9523	0.9556	0.9590	0.9623
	sin	0.6947	0.6959	0.6972	0.6984	0.6997	0.7009	0.7022	0.7034	0.7046	0.7059
44	cos	0.7193	0.7181	0.7169	0.7157	0.7145	0.7133	0.7120	0.7108	0.70[illegible]	0.7083
	tan	0.9657	0.9691	0.9725	0.9759	0.9793	0.9827	0.9861	0.9896	0.9930	0.9965
	sin	0.7071	0.7083	0.7096	0.7108	0.7120	0.7133	0.7145	0.7157	0.7169	0.7181
45	cos	0.7071	0.7059	0.7046	0.7034	0.7022	0.7009	0.6997	0.6984	0.6972	0.6959
	tan	1.0000	1.0035	1.0070	1.0105	1.0141	1.0176	1.0212	1.0247	1.0283	1.0319
	sin	0.7193	0.7206	0.7218	0.7230	0.7242	0.7254	0.7266	0.7278	0.7290	0.7302
46	cos	0.6947	0.6934	0.6921	0.6909	0.6896	0.6884	0.6871	0.6858	0.6845	0.6833
	tan	1.0355	1.0392	1.0428	1.0464	1.0501	1.0538	1.0575	1.0612	1.0649	1.0686
	sin	0.7314	0.7325	0.7337	0.7349	0.7361	0.7373	0.7385	0.7396	0.7408	0.7420
47	cos	0.6820	0.6807	0.6794	0.6782	0.6769	0.6756	0.6743	0.6730	0.6717	0.6704
	tan	1.0724	1.0761	1.0799	1.0837	1.0875	1.0913	1.0951	1.0990	1.1028	1.1067
	sin	0.7431	0.7443	0.7455	0.7466	0.7478	0.7490	0.7501	0.7513	0.7524	0.7536
48	cos	0.6691	0.6678	0.6665	0.6652	0.6639	0.6626	0.6613	0.6600	0.6587	0.6574
	tan	1.1106	1.1145	1.1184	1.1224	1.1263	1.1303	1.1343	1.1383	1.1423	1.1463
	sin	0.7547	0.7559	0.7570	0.7581	0.7593	0.7604	0.7615	0.7627	0.7638	0.7649
49	cos	0.6561	0.6547	0.6534	0.6521	0.6508	0.6494	0.6481	0.6468	0.6455	0.6441
	tan	1.1504	1.1544	1.1585	1.1626	1.1667	1.1708	1.1750	1.1792	1.1833	1.1875
	sin	0.7660	0.7672	0.7683	0.7694	0.7705	0.7716	0.7727	0.7738	0.7749	0.7760
50	cos	0.6428	0.6414	0.6401	0.6388	0.6374	0.6361	0.6347	0.6334	0.6320	0.6307
	tan	1.1918	1.1960	1.2002	1.2045	1.2088	1.2131	1.2174	1.2218	1.2261	1.2305
	sin	0.7771	0.7782	0.7793	0.7804	0.7815	0.7826	0.7837	0.7848	0.7859	0.7869
51	cos	0.6293	0.6280	0.6266	0.6252	0.6239	0.6225	0.6211	0.6198	0.6184	0.6170
	tan	1.2349	1.2393	1.2437	1.2482	1.2527	1.2572	1.2617	1.2662	1.2708	1.2753
	sin	0.7880	0.7891	0.7902	0.7912	0.7923	0.7934	0.7944	0.7955	0.7965	0.7976
52	cos	0.6157	0.6143	0.6129	0.6115	0.6101	0.6088	0.6074	0.6060	0.6046	0.6032
	tan	1.2799	1.2846	1.2892	1.2938	1.2985	1.3032	1.3079	1.3127	1.3175	1.3222
	sin	0.7986	0.7997	0.8007	0.8018	0.8028	0.8039	0.8049	0.8059	0.8070	0.8080
53	cos	0.6018	0.6004	0.5990	0.5976	0.5962	0.5948	0.5934	0.5920	0.5906	0.5892
	tan	1.3270	1.3319	1.3367	1.3416	1.3465	1.3514	1.3564	1.3613	1.3663	1.3713
	sin	0.8090	0.8100	0.8111	0.8121	0.8131	0.8141	0.8151	0.8161	0.8171	0.8181
54	cos	0.5878	0.5864	0.5850	0.5835	0.5821	0.5807	0.5793	0.5779	0.5764	0.5750
	tan	1.3764	1.3814	1.3865	1.3916	1.3968	1.4019	1.4071	1.4124	1.4176	1.4229
	sin	0.8192	0.8202	0.8211	0.8221	0.8231	0.8241	0.8251	0.8261	0.8271	0.8281
55	cos	0.5736	0.5721	0.5707	0.5693	0.5678	0.5664	0.5650	0.5635	0.5621	0.5606
	tan	1.4281	1.4335	1.4388	1.4442	1.4496	1.4550	1.4605	1.4659	1.4715	1.4770

| deg | function | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° |

deg	function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
56	sin	0.8290	0.8300	0.8310	0.8320	0.8329	0.8339	0.8348	0.8358	0.8368	0.8377
	cos	0.5592	0.5577	0.5563	0.5548	0.5534	0.5519	0.5505	0.5490	0.5476	0.5461
	tan	1.4826	1.4882	1.4938	1.4994	1.5051	1.5108	1.5166	1.5224	1.5282	1.5340
57	sin	0.8387	0.8396	0.8406	0.8415	0.8425	0.8434	0.8443	0.8453	0.8[illegible]2	0.8471
	cos	0.5446	0.5432	0.5417	0.5402	0.5388	0.5373	0.5358	0.5344	0.5329	0.5314
	tan	1.5399	1.5458	1.5517	1.5577	1.5637	1.5697	1.5757	1.5818	1.5880	1.5941
58	sin	0.8480	0.8490	0.8499	0.8508	0.8517	0.8526	0.8536	0.8545	0.8554	0.8563
	cos	0.5299	0.5284	0.5270	0.5255	0.5240	0.5225	0.5210	0.5195	0.5180	0.5165
	tan	1.6003	1.6066	1.6128	1.6191	1.6255	1.6319	1.6383	1.6447	1.6512	1.6577
59	sin	0.8572	0.8581	0.8590	0.8599	0.8607	0.8616	0.8625	0.8634	0.8643	0.8652
	cos	0.5150	0.5135	0.5120	0.5105	0.5090	0.5075	0.5060	0.5045	0.5030	0.5015
	tan	1.6643	1.6709	1.6775	1.6842	1.6909	1.6977	1.7045	1.7113	1.7182	1.7251
60	sin	0.8660	0.8669	0.8678	0.8686	0.8695	0.8704	0.8712	0.8721	0.8729	0.8738
	cos	0.5000	0.4985	0.4970	0.4955	0.4939	0.4924	0.4909	0.4894	0.4879	0.4863
	tan	1.7321	1.7391	1.7461	1.7532	1.7603	1.7675	1.7747	1.7820	1.7893	1.7966
61	sin	0.8746	0.8755	0.8763	0.8771	0.8780	0.8788	0.8796	0.8805	0.8813	0.8821
	cos	0.4848	0.4833	0.4818	0.4802	0.4787	0.4772	0.4756	0.4741	0.4726	0.4710
	tan	1.8040	1.8115	1.8190	1.8265	1.8341	1.8418	1.8495	1.8572	1.8650	1.8728
62	sin	0.8829	0.8838	0.8846	0.8854	0.8862	0.8870	0.8878	0.8886	0.8894	0.8902
	cos	0.4695	0.4679	0.4664	0.4648	0.4633	0.4617	0.4602	0.4586	0.4571	0.4555
	tan	1.8807	1.8887	1.8967	1.9047	1.9128	1.9210	1.9292	1.9375	1.9458	1.9542
63	sin	0.8910	0.8918	0.8926	0.8934	0.8942	0.8949	0.8957	0.8965	0.8973	0.8980
	cos	0.4540	0.4524	0.4509	0.4493	0.4478	0.4462	0.4446	0.4431	0.4415	0.4399
	tan	1.9626	1.9711	1.9797	1.9883	1.9970	2.0057	2.0145	2.0233	2.0323	2.0413
64	sin	0.8988	0.8996	0.9003	0.9011	0.9018	0.9026	0.9033	0.9041	0.9048	0.9056
	cos	0.4384	0.4368	0.4352	0.4337	0.4321	0.4305	0.4289	0.4274	0.4258	0.4242
	tan	2.0503	2.0594	2.0686	2.0778	2.0872	2.0965	2.1060	2.1155	2.1251	2.1348
65	sin	0.9063	0.9070	0.9078	0.9085	0.9092	0.9100	0.9107	0.9114	0.9121	0.9128
	cos	0.4226	0.4210	0.4195	0.4179	0.4163	0.4147	0.4131	0.4115	0.4099	0.4083
	tan	2.1445	2.1543	2.1642	2.1742	2.1842	2.1943	2.2045	2.2148	2.2251	2.2355
66	sin	0.9135	0.9143	0.9150	0.9157	0.9164	0.9171	0.9178	0.9184	0.9191	0.9198
	cos	0.4067	0.4051	0.4035	0.4019	0.4003	0.3987	0.3971	0.3955	0.3939	0.3923
	tan	2.2460	2.2566	2.2673	2.2781	2.2889	2.2998	2.3109	2.3220	2.3332	2.3445
67	sin	0.9205	0.9212	0.9219	0.9225	0.9232	0.9239	0.9245	0.9252	0.9259	0.9265
	cos	0.3907	0.3891	0.3875	0.3859	0.3843	0.3827	0.3811	0.3795	0.3778	0.3762
	tan	2.3559	2.3673	2.3789	2.3906	2.4023	2.4142	2.4262	2.4383	2.4504	2.4627
68	sin	0.9272	0.9278	0.9285	0.9291	0.9298	0.9304	0.9311	0.9317	0.9323	0.9330
	cos	0.3746	0.3730	0.3714	0.3697	0.3681	0.3665	0.3649	0.3633	0.3616	0.3600
	tan	2.4751	2.4876	2.5002	2.5129	2.5257	2.5386	2.5517	2.5649	2.5782	2.5916
69	sin	0.9336	0.9342	0.9348	0.9354	0.9361	0.9367	0.9373	0.9379	0.9385	0.9391
	cos	0.3584	0.3567	0.3551	0.3535	0.3518	0.3502	0.3486	0.3469	0.3453	0.3437
	tan	2.6051	2.6187	2.6325	2.6464	2.6605	2.6746	2.6889	2.7034	2.7179	2.7326
deg	function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°

deg	fn	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
70	sin	[illegible]	[illegible]	[illegible]	0.9415	0.9421	[illegible]	0.9432	[illegible]	0.9444	0.9449
	cos	0.3420	0.3404	0.3387	0.3371	[illegible]	0.3338	0.3322	0.3305	[illegible]	0.3272
	tan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.8716	[illegible]
71	sin	[illegible]	[illegible]	[illegible]	[illegible]	0.9478	0.9483	[illegible]	0.9494	0.9500	0.9505
	cos	[illegible]	[illegible]	[illegible]	0.3206	0.3190	[illegible]	0.3156	0.3140	0.3123	[illegible]
	tan	[illegible]	[illegible]	[illegible]	[illegible]	2.9714	[illegible]	3.0061	3.0237	3.0415	[illegible]
72	sin	0.9511	[illegible]	0.9521	0.9527	0.9532	0.9537	0.9542	0.9548	[illegible]	[illegible]
	cos	[illegible]	0.3074	0.3057	0.3040	0.3024	0.3007	0.2990	0.2974	0.2957	0.2940
	tan	[illegible]	[illegible]	3.1146	3.1334	3.1524	[illegible]	3.1910	3.2106	3.2305	3.2506
73	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	cos	[illegible]	[illegible]	0.2890	0.2874	[illegible]	0.2840	0.2823	0.2807	0.2790	0.2773
	tan	[illegible]	[illegible]	3.3122	3.3332	[illegible]	[illegible]	3.3977	3.4197	3.4420	3.4646
74	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.9641	0.9646	0.9650	0.9655
	cos	[illegible]	0.2740	0.2723	0.2706	[illegible]	0.2672	0.2656	0.2639	0.2622	0.2605
	tan	3.4874	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.7062
75	sin	[illegible]	[illegible]	[illegible]	[illegible]	0.9677	0.9681	[illegible]	[illegible]	[illegible]	[illegible]
	cos	0.2588	0.2571	[illegible]	[illegible]	0.2521	0.2504	0.2487	0.2470	0.2453	0.2436
	tan	3.7321	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.9232	3.9520	3.9812
76	sin	0.9703	0.9707	0.9711	0.9715	0.9720	0.9724	0.9728	0.9732	0.9736	0.9740
	cos	0.2419	0.2402	0.2385	0.2368	0.2351	0.2334	0.2317	0.2300	0.2284	0.2267
	tan	4.0108	4.0408	4.0713	4.1022	4.1335	4.1653	4.1976	4.2303	4.2635	4.2972
77	sin	0.9744	0.9748	0.9751	0.9755	0.9759	0.9763	0.9767	0.9770	0.9774	0.9778
	cos	0.2250	0.2232	0.2215	0.2198	0.2181	0.2164	0.2147	0.2130	0.2113	0.2096
	tan	4.3315	4.3662	4.4015	4.4374	4.4737	4.5107	4.5483	4.5864	4.6252	4.6646
78	sin	0.9781	0.9785	0.9789	0.9792	0.9796	0.9799	0.9803	0.9806	0.9810	0.9813
	cos	0.2079	0.2062	0.2045	0.2028	0.2011	0.1994	0.1977	0.1959	0.1942	0.1925
	tan	4.7046	4.7453	4.7867	4.8288	4.8716	4.9152	4.9594	5.0045	5.0504	5.0970
79	sin	0.9816	0.9820	0.9823	0.9826	0.9829	0.9833	0.9836	0.9839	0.9842	0.9845
	cos	0.1908	0.1891	0.1874	0.1857	0.1840	0.1822	0.1805	0.1788	0.1771	0.1754
	tan	5.1446	5.1929	5.2422	5.2924	5.3435	5.3955	5.4486	5.5026	5.5578	5.6140
80	sin	0.9848	0.9851	0.9854	0.9857	0.9860	0.9863	0.9866	0.9869	0.9871	0.9874
	cos	0.1736	0.1719	0.1702	0.1685	0.1668	0.1650	0.1633	0.1616	0.1599	0.1582
	tan	5.6713	5.7297	5.7894	5.8502	5.9124	5.9758	6.0405	6.1066	6.1742	6.2432
81	sin	0.9877	0.9880	0.9882	0.9885	0.9888	0.9890	0.9893	0.9895	0.9898	0.9900
	cos	0.1564	0.1547	0.1530	0.1513	0.1495	0.1478	0.1461	0.1444	0.1426	0.1409
	tan	6.3138	6.3859	6.4596	6.5350	6.6122	6.6912	6.7720	6.8548	6.9395	7.0264
82	sin	0.9903	0.9905	0.9907	0.9910	0.9912	0.9914	0.9917	0.9919	0.9921	0.9923
	cos	0.1392	0.1374	0.1357	0.1340	0.1323	0.1305	0.1288	0.1271	0.1253	0.1236
	tan	7.1154	7.2066	7.3002	[illegible]	[illegible]	[illegible]	[illegible]	7.8062	7.9158	8.0285
83	sin	0.9925	0.9928	[illegible]	[illegible]	[illegible]	0.9936	0.9938	0.9940	0.9942	0.9943
	cos	0.1219	0.1201	[illegible]	[illegible]	[illegible]	0.1132	0.1115	0.1097	0.1080	0.1063
	tan	8.1443	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.9152	9.0579	9.2052	9.3572
deg	fn	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°

deg	func.	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
84	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	cos	0.1045	[illegible]	0.1011	[illegible]	[illegible]	[illegible]	0.0941	0.0924	[illegible]	[illegible]
	tan	[illegible]	[illegible]	[illegible]	10.02	10.20	[illegible]	[illegible]	[illegible]	[illegible]	11.20
85	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.9972	0.9973	0.9974
	cos	0.0872	0.0854	0.0837	[illegible]	[illegible]	[illegible]	[illegible]	0.0750	0.0732	0.0715
	tan	11.43	[illegible]	[illegible]	[illegible]	12.43	12.71	13.00	13.30	[illegible]	[illegible]
86	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.9981	0.9982	0.9983	0.9984	[illegible]
	cos	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0541
	tan	14.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
87	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	cos	0.0523	[illegible]	[illegible]	0.0471	[illegible]	[illegible]	[illegible]	0.0401	0.0384	[illegible]
	tan	[illegible]	[illegible]	20.45	21.20	22.02	[illegible]	[illegible]	[illegible]	[illegible]	27.27
88	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	cos	[illegible]	0.0332	0.0314	[illegible]	[illegible]	[illegible]	0.0244	0.0227	[illegible]	[illegible]
	tan	[illegible]	30.14	31.82	[illegible]	[illegible]	[illegible]	40.92	44.07	[illegible]	[illegible]
89	sin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.000	1.000	1.000	1.000	1.000
	cos	0.0175	0.0157	0.0140	0.0122	0.0105	0.0087	0.0070	[illegible]	0.0035	0.0017
	tan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	143.2	191.0	[illegible]	573.0
deg	func.	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°

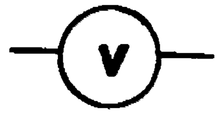
SUMMARY OF MODULES

Voltage

Voltage is a force which does work upon electrical charges to maintain a difference of potential between the terminals of a voltage source. Voltage sources convert other forms of energy (chemical, mechanical, etc.) to electrical potential energy.

Symbol: "E" (for Electromotive Force, or Energy)

Basic unit of measure: Volt (abbreviated "V.")

Measuring device: Voltmeter Schematic symbol: 

Connected in parallel, voltmeters "work" only in energized circuits.

Voltage "rise": The difference of potential measured between the terminals of a voltage source.

Voltage "fall" or "drop": A difference of potential measured at the terminals of an electrical "load", (or across parts of the "load"). Voltage "drops" can be measured only when there is current flow through the load.

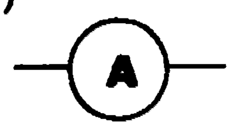
Purpose: Voltage (E) causes current flow in electrical/electronic circuits when a complete "path" (for the current) is connected to the terminals of a voltage source.

Current

Current is the directed "drift" or "flow" of free electrons which is caused when a complete "path" is connected to the terminals of a voltage source.

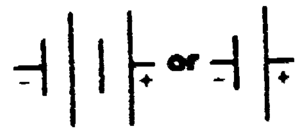
Symbol: "I"

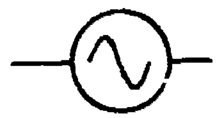
Basic unit of measure: ampere (abbreviated "a")

Measuring device: Ammeter Schematic symbol: 

Connected in series, ammeters "work" only in energized circuits.

Two types of current: "DC" and "AC". DC, direct-current is "one-way" current flow: the direction of electron current flow within the current "path" or circuit, is away from the (-) terminal of the voltage source, through the complete "path" (circuit) and on towards the (+) terminal of the source. DC voltage sources are batteries, generators with a commutator and electronic "power" supplies. AC, alternating current is "two-way" current flow: The direction of electron flow within the current "path" is the same as for DC, but the direction of flow alternates, or reverses, with periodic reversals of polarity of the voltage source. AC voltage sources are generators with slip-rings, electronic "power" supplies and electronic "signal" generators.

Schematic symbol:  Battery

Schematic symbol:  (AC source)

Purpose:

Current (I) is the directed drift or flow of free electrons on their way to do useful work within an electrical "load". Current flow is the "mechanism through which electrical energy is converted to other forms of energy: heat and/or light, mechanical, etc."

Resistance

Resistance is opposition to current flow. The amount of resistance, or opposition, is determined primarily by the atomic structure of materials used as the "path" for current flow. Materials with few free electrons have great opposition ... high resistance. These materials are called insulators. Materials with many free electrons have little opposition ... low resistance. These materials are called conductors. Resistors (and "semi-conductors") have values of opposition to current which fall between insulators and conductors.

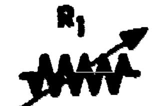
Symbol: "R"

Basic unit of measure: Ohm

Symbol: Ω

Schematic symbols for resistors: Fixed 

Tapped 



Variable

Measuring device: Ohmmeter (Ohmmeters "work" only in deenergized circuits.)

"Open": an incomplete path ... permits no (0) current flow. The value of (R), in ohms, is infinite (∞) or maximum.

"Short": permits maximum current flow ... the current "path" has no (0) opposition ... no resistance. The value of (R), in ohms, is essentially zero (0).

Purpose: Resistance (R) is used to "control" the amount of current flow by affecting the number of free electrons available within the current "path" or circuit, which could become directed. "R" represents an electrical "load", or "loads"; devices in which electrical energy is converted to other forms of energy (heat and/or light, mechanical, etc.) when current flows through them.

RELATIONSHIP BETWEEN (E), (I), AND (R).

Ohm's Law:

"The (value of) total circuit current is directly proportional to the (value of) applied voltage and indirectly proportional to the (ohmic value of) total circuit resistance."

Expression:

$$I \text{ (amperes)} = \frac{E \text{ (Volts)}}{R \text{ (Ohms)}} \text{ or, } a. = \frac{V.}{\Omega}$$

Relationship:

The value of circuit current depends upon the value of applied voltage and the value of resistance. When (E) does not change, and the ohmic value of (R) INCREASES, the value of (I) must DECREASE. The end result is a smaller fraction, and vice-versa. When the value of (E) is INCREASED, and the ohmic value of (R) is NOT CHANGED, the value of (I) must INCREASE. The end result is a larger fraction, and vice-versa.

When rearranged, the expression can be used as a tool to determine the direction of change (in value) of voltage drops.

Expression:

$$E_{(\text{voltage "drop"})} = I_{(\text{amperes})} \times R_{(\text{ohms})}$$

Relationship:

When (I) INCREASES, and the ohmic value of (R) does NOT CHANGE, the voltage "drop" (E) must INCREASE, and vice-versa. When the ohmic value of (R) CHANGES [such a change will always affect the value of (I)] the direction of change of the voltage drop (E), will always follow the same direction as the change in (R).

CHARACTERISTICS OF ANY SERIES CIRCUIT.

Current:

The value of current in any series circuit is the same in every part and component ("loads") of the circuit because THERE IS ONLY ONE PATH FOR CURRENT FLOW. Total circuit current (I_T) is equal to the current flow through each load in the circuit (I_{R1}, I_{R2}, etc).

Expression:

$I_T = I_{R1} = I_{R2} \ldots = I_{Rn}$. (See M5, M6 and M7 in Figure 1)

Voltage:

The value of the voltage drop across each load resistance in a series circuit is equal to the value of current through the load (I_{R1}, I_{R2}, etc.) times the ohmic value of the load (R_1, R_2, etc.).

Expression:

$E_{R(drop)} = I_T \times R_1$ (or R_2, etc.)

The total voltage drop (E_T) is equal to the sum of the individual voltage across (E_{R1}, E_{R2}, etc.).

Expression:

$E_T = E_{R1} + E_{R2} \ldots + E_{Rn}$. (See M1, M2, M3 and M4 in Figure 1.)

The total voltage drop (E_T) must always be equal to the value of the applied voltage (E_a).

Expression:

$E_T = E_a$

Resistance:

The ohmic value of total circuit resistance (R_T) is equal to the sum of the individual ohmic values of resistance (or resistors) in the circuit.

Expression:

$R_T = R_1 + R_2 \ldots + R_n$

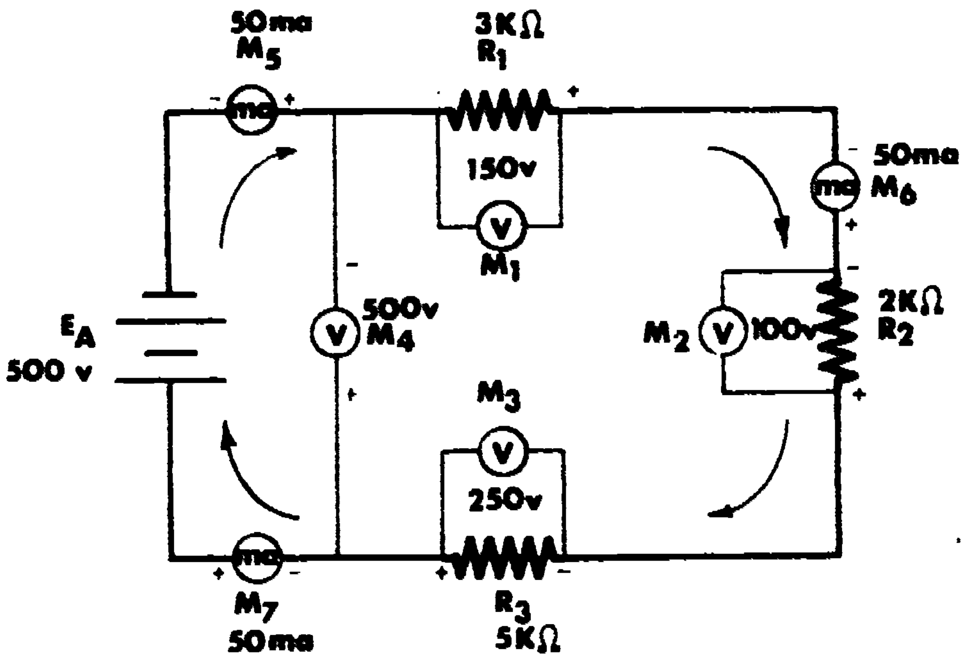


FIGURE 1 (Sample Series Circuit)

Voltage drops:

E_{R1} (M1) = I_T (M5, 6 or 7) x R_1

= .05a X 3000Ω

= 150V, (M1)

E_{R2} (M2) = I_T X R_2

= .05a X 2000Ω

= 100V (M2)

E_{R3} (M3) = I_T X R_3

= .05a X 5000Ω

= 250V (M3)

E_{RT} (M4) = I_T X R_T

= .05a X 10,000Ω

= 500V (M4)

Current:

$I_T = I_{R1} = I_{R2} = I_{R3} = 0.05a$ (50ma) M5 = M6 = M7

Voltage:

E_{R1} (150V) + E_{R2} (100V) + E_{R3} (250V) = E_T (500V) = E_a (500V)

also $(I_T \times R_1) + (I_T \times R_2) + (I_T \times R_3) = (I_T \times R_T)$

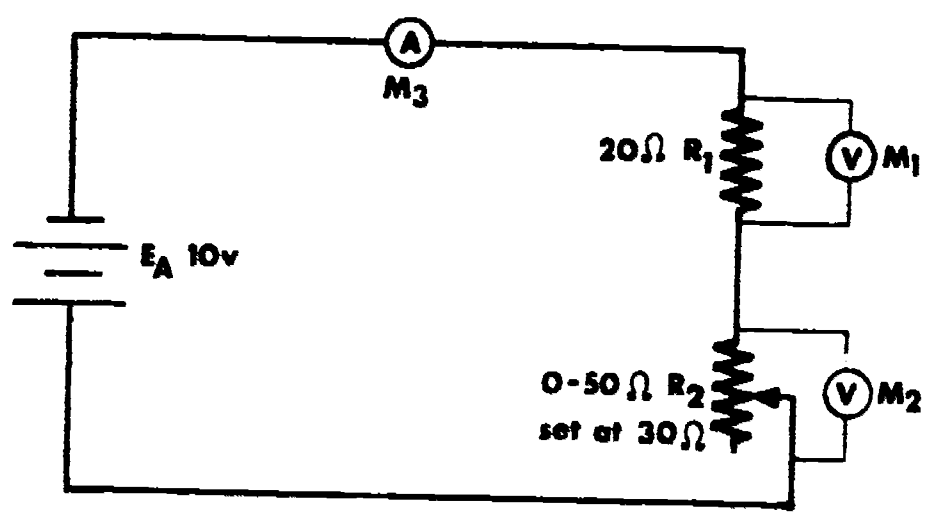
$(.05a \times 3K\Omega) + (.05a \times 2K\Omega) + (.05a \times 5K\Omega) = (.05a \times 10K\Omega)$

Resistance:

R_1 (3KΩ) + R_2 (2KΩ) + R_3(5KΩ) = R_T (10KΩ)

HOW TO USE THE EXPRESSIONS FOR SERIES CIRCUIT CHARACTERISTICS, WITH OHM'S LAW, TO ANALYZE ANY SERIES CIRCUIT WHEN THE OHMIC VALUE OF A RESISTOR CHANGES, OR IS CHANGED.

Circuit to be analyzed:



Resistance Characteristic:

$R_T = R_1 + R_2 = 20\Omega + 30\Omega = 50\Omega$

Ohm's Law:

$$I_T = \frac{E_a}{R_T} = \frac{10V}{50\Omega} = 0.2a$$

Current Characteristic:

$I_T = I_{R1} = I_{R2} = 0.2$ amperes (200 ma.) The indication on M3 should be 0.2 amperes.

Voltage drops:

$E_{R1} = I_{R1} \times R_1 = 0.2a \times 20\Omega = 4V$. The indication on M1 should be 4V.

$E_{R2} = I_{R2} \times R_2 = 0.2a \times 30\Omega = 6V$. The indication on M2 should be 6V.

Voltage Characteristic:

$E_{R1} + E_{R2} = E_T = E_a$

$4V + 6V = 10V = 10V$

Test Situation:

The ohmic value of R_2 is DECREASED to 5 ohms.

Resistance Characteristic:

$R_1 + R_2\downarrow = R_T\downarrow \; (20\Omega + 5\Omega = 25\Omega)$

The direction of change of total circuit resistance: DECREASED.

Ohm's Law:

$$I_T = \frac{E_{a\rightarrow}}{R_T\downarrow} = \frac{10V}{25\Omega} = 0.4a\uparrow$$

The value of I_T has increased; therefore, the indication on M3 should increase. (Note that the value of E_a has NOT CHANGED; neither has the ohmic value of R_1.)

Current Characteristic:

$\uparrow I_T = \uparrow I_{R1} = \uparrow I_{R2} = 0.4a.$

Voltage drops:

$\uparrow E_{R1} = \uparrow I_T \times R_1\rightarrow = 0.4a \times 20\Omega = 8V$. The value of E_{R1} has INCREASED; therefore, the indication on M1 should INCREASE.

$\downarrow E_{R2} = \uparrow I_T \times R_2\downarrow = 0.4a \times 5\Omega = 2V$. The value of E_{R2} has DECREASED; therefore, the indication on M2 should DECREASE. (Note that the direction of change of the voltage drop followed the direction of change in ohmic value of the resistor.)

Voltage Characteristic:

$E_{R1}\uparrow + E_{R2}\downarrow = E_T\rightarrow = E_a\rightarrow$

$8V + 2V = 10V = 10V$

CHARACTERISTICS OF ANY PARALLEL CIRCUIT

Voltage:

The value of the applied voltage (E_a), total voltage drop (E_T) and each branch voltage drop is the same! Every branch (current path for a load) is (electrically) connected directly to the terminals of the voltage source.

Expression:

$E_{R1} = E_{R2} = E_{Rn} = E_T = E_a$ (See M6, M7 and M8 next page.)

Current:

The value of total circuit current (I_T) is equal to the sum of the individual branch currents. There is more than one path for current flow.

Expression:

$I_T = I_{R1} + I_{R2} + I_{Rn}$ (See M1, M2, M3, M4, and M5 next page.)

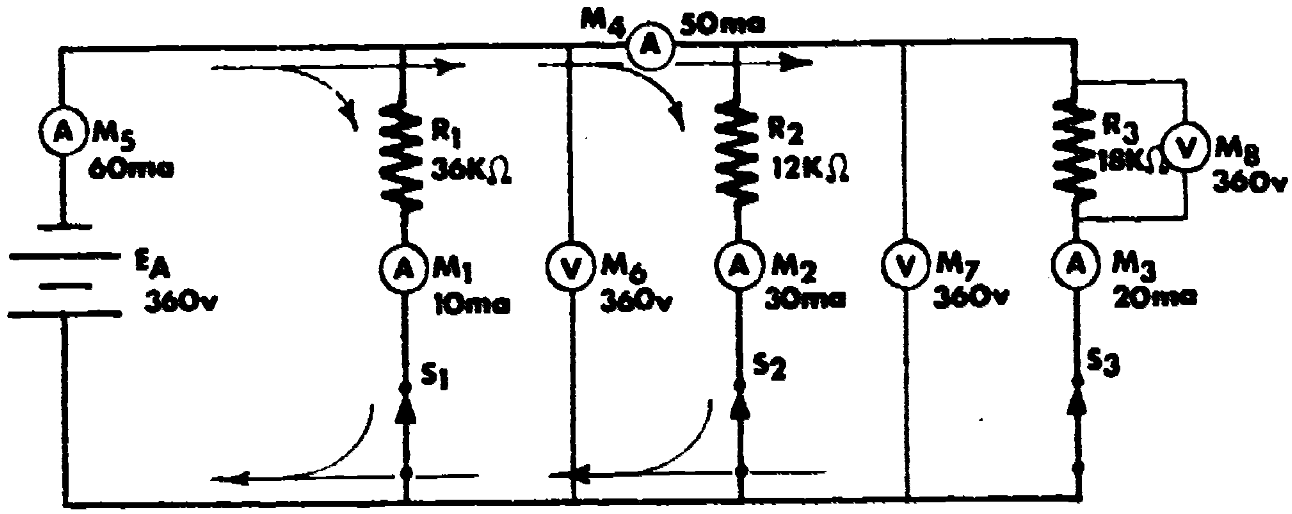
Resistance:

When more current paths are added, the total circuit current increases therefore, the ohmic value of total circuit resistance (R_T or R_{EQ}) will always be less than the ohmic value of the branch with the smallest ohmic value.

Expression:

$$\frac{1}{R_T \text{ (or } R_{EQ})} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R_n} \text{ also, } R_T \text{ (or } R_{EQ}) = \frac{R1 \times R2}{R1 + R2}$$

SAMPLE PARALLEL CIRCUIT



Voltage:

$E_a = E_T = E_{R1} = E_{R2} \ldots = E_{Rn}$ M6 = M7 = M8

also, $I_T\ R_T = I_{R1} \times R1 = I_{R2} \times R2 \ldots I_{Rn} \times R_n$

Ohm's Law:

$$I_{R1} = \frac{E_{R1}}{R1} = \frac{360V}{36K\Omega} = .01a. \quad (10ma.)$$

$$I_{R2} = \frac{E_{R2}}{R2} = \frac{360V}{12K\Omega} = .03a. \quad (30ma.)$$

$$I_{R3} = \frac{E_{R3}}{R3} = \frac{360V}{18K\Omega} = .02a. \quad (20ma.)$$

Current:

$I_T = I_{R1} + I_{R2} \ldots + I_{Rn} = 10ma + 30ma + 20ma = 60ma$

also, $\frac{E_T}{R_T} = \frac{E_{R1}}{R1} + \frac{E_{R2}}{R2} \ldots + \frac{E_{Rn}}{Rn}$ M2 + M3 = M4
M4 + M1 = M5

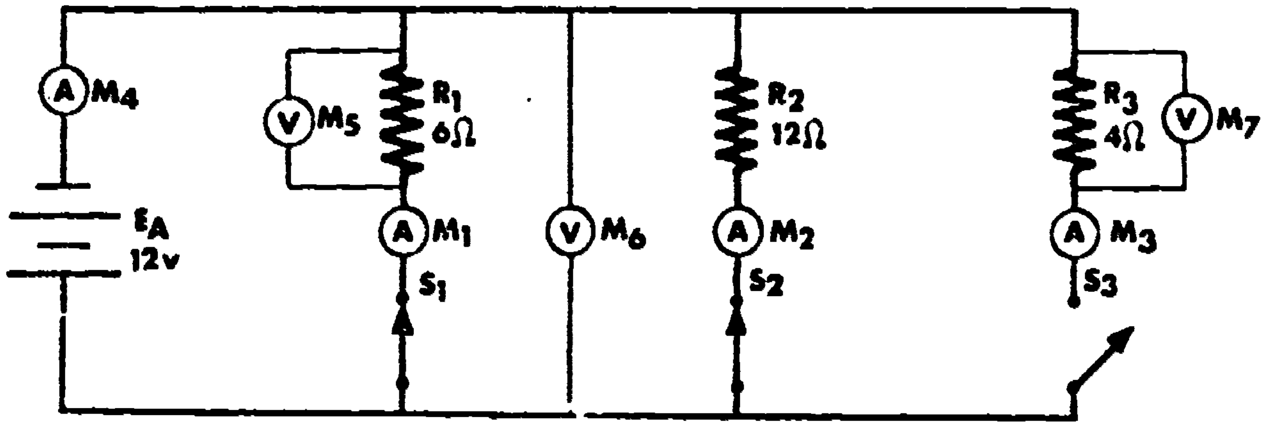
Resistance:

$$\frac{1}{R_T} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \left(\frac{1}{36K} + \frac{1}{12K} + \frac{1}{18K}\right) = \left(\frac{1}{36K} + \frac{3}{36K} + \frac{2}{36K} = \frac{6}{36K}\right)$$

$\frac{1}{R_T} = \frac{6}{36K}$ $\frac{36K}{6} = \frac{R_T}{1}$ $R_T = 6$ Kohms

also, $R_T = \frac{E_T}{I_T} = \frac{360V}{60ma} = 6$Kohms (6000 ohms)

HOW TO USE THE EXPRESSIONS FOR PARALLEL CIRCUIT CHARACTERISTICS, WITH OHM'S LAW, TO ANALYZE ANY PARALLEL CIRCUIT WHEN A BRANCH IS CONNECTED (ADDED) OR DISCONNECTED (REMOVED).



VOLTAGE CHARACTERISTIC:

$Ea = E_T = E_{R1} = E_{R2} = 12V$ ($E_{R3} = 0$ because S3 is OPEN).

Meters M5 and M6 should indicate 12V; M7 should indicate 0 Volts.

Ohm's Law:

$I_{R1} = \frac{E_{R1}}{R1} = \frac{12V}{6} = 2.0$amps. Indication on M1: NO CHANGE

$I_{R2} = \frac{E_{R2}}{R2} = \frac{12V}{12} = 1.0$amps. Indication on M2: NO CHANGE

Current Characteristic:

$I_T = I_{R1} + I_{R2} = 2.0a + 1.0a = 3.0a$. The indication on M4 should be 3.0 amperes.

Resistance Characteristic:

$R_T = \frac{R1 \times R2}{R1 + R2} = \frac{6\Omega \times 12\Omega}{6\Omega + 12\Omega} = \frac{72}{18} = 4$ ohms

Test Situation Switch S3 is now closed. (This adds another path to the circuit.)

Voltage Characteristic:

$E_a = E_T = E_{R1} = E_{R2} = E_{R3} = 12V$. The indication on M5 and M6 should NOT CHANGE; M7 indication INCREASES; should indicate 12V.

Ohm's Law:

$I_{R1} = \frac{E_{R1}}{R1} = \frac{12V}{6\Omega} = 2.0a$. Indication on M1: NO CHANGE

$I_{R2} = \frac{E_{R2}}{R2} = \frac{12V}{12\Omega} = 1.0a$. Indication on M2: NO CHANGE

$I_{R3} = \frac{E_{R3}}{R3} = \frac{12V}{4\Omega} = 3.0a$. Indication on M3: INCREASE

Current Characteristic:

$I_T = I_{R1} + I_{R2} + I_{R3} = 2.0a + 1.0a + 3.0a = 6.0a.$

The indication on M3 should INCREASE to 3.0a: the indication on M4 should INCREASE.

Resistance Characteristic:

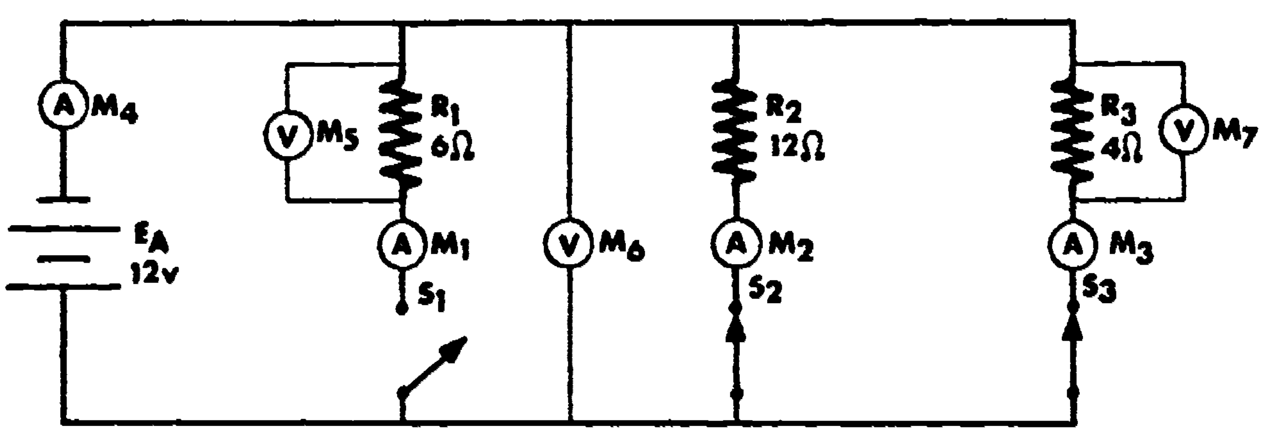
$$\frac{1}{R_T} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \left(\frac{1}{6\Omega} + \frac{1}{12\Omega} + \frac{1}{4\Omega}\right) = \left(\frac{2}{12} + \frac{1}{12} + \frac{3}{12}\right) = \frac{6}{12}$$

$$\frac{1}{R_T} = \frac{6}{12} \quad = \quad \frac{12}{6} \quad = \quad \frac{R_T}{1} \quad = \quad 2 \text{ ohms}$$

also, $R_T = \frac{E_a}{I_T} = \frac{12V}{6a} = 2$ ohms

Test Situation:

S3 remains CLOSED; S1 is OPENED.



Voltage Characteristics:

$E_a = E_T = E_{R2} = E_{R3}$ (E_{R1} indicated by M5, is 0 because S1 is open.) The indication on M5 should DECREASE (to 0); the indication on M6 and M7 should NOT CHANGE.

Ohm's Law:

$I_{R1} = \frac{E_{R1}}{R1} = \frac{0V}{6\Omega} = 0a.$ Indication on M1: DECREASE

$I_{R2} = \frac{E_{R2}}{R2} = \frac{12V}{12\Omega} = 1.0a.$ Indication on M2: NO CHANGE

$I_{R3} = \frac{E_{R3}}{R3} = \frac{12V}{4\Omega} = 3.0a.$ Indication on M3: NO CHANGE

Current Characteristic:

$I_T = I_{R1} + I_{R2} + I_{R3} = 0a. + 1.0a + 3.0a. = 4.0a.$ The indication on M4 should DECREASE (it was 6.0a before S1 was opened).

Resistance Characteristic:

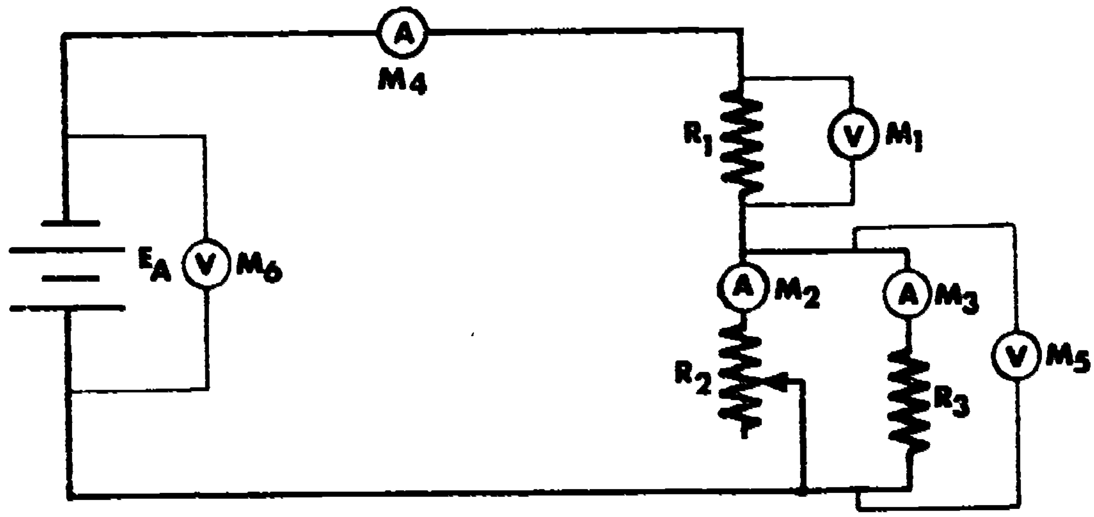
$R_T = \frac{R2 \times R3}{R2 + R3} = \frac{12\Omega \times 4\Omega}{12\Omega + 4\Omega} = \frac{48\Omega}{16\Omega} = 3$ ohms

The value of total circuit resistance (R_T) has INCREASED because one of the current paths of the circuit was removed (disconnected) when S1 was opened.

Note that the ohmic value of R_T (3 ohms) is still <u>less</u> than the ohmic value of R3 (4 ohms), the branch with the <u>smallest</u> ohmic value.

HOW TO USE THE EXPRESSIONS FOR THE CHARACTERISTICS OF SERIES AND PARALLEL CIRCUITS, WITH OHM'S LAW, TO ANALYZE COMBINATION CIRCUITS:

Series-Parallel Combination:



R_2 and R_3 form a parallel circuit.

Voltage: $E_{R2} = E_{R3} = M5$

Current: $I_{R2} + I_{R3} = I_{R1}$

$I_{R1} = I_T$

$M2 + M3 = M4$

Resistance: R_{Eq} of R_2 and $R_3 = \frac{R2 \times R3}{R2 + R3}$

R_1 and R_{Eq} (of R_2 and R_3) form a series circuit.

Voltage: $Ea = E_T = E_{R1} + E_{R_{Eq}}$ of R2 and R3 $\quad M1 + M5 = M6$

Current: $I_T = I_{R1} = (I_{R2} + I_{R3})$

Resistance: $R_T = R_1 + R_{Eq}$ of R2 and R3

Test Situation:

The ohmic value of R_2 is INCREASED.

Resistance Characteristic (Series):

$R_T\uparrow = R_1\rightarrow + \uparrow R_{Eq}$ of R_2 and R_3

Ohm's Law:

$$\frac{E_{a\rightarrow}}{R_T\uparrow} = I_{T\downarrow}$$

When the ohmic value of R2 INCREASES, the ohmic value of R_T must also INCREASE. This will then cause I_T to DECREASE (the value of E_a has NOT CHANGED) and the indication on M4 should DECREASE.

Voltage drops:

$E_{R1} = I_{R1\downarrow} \times R_{1\rightarrow}$ Since I_T has DECREASED (same as I_{R1}) then the voltage drop across R_1 should DECREASE. The indication on M1 should DECREASE, when the voltage drop across R_1 DECREASES then the voltage drop across R_2 must INCREASE, BECAUSE the value of Ea and the total voltage drop (E_T) has NOT CHANGED.

Voltage Characteristic (Series):

$Ea = E_T = E_{R1}\downarrow + \uparrow E_{REq}$ of R_2 and R_3

Ohm's Law:

$$\frac{E_{R2\uparrow}}{R_2\uparrow} = I_{R2}\downarrow \qquad \frac{E_{R3\uparrow}}{R_3\rightarrow} = I_{R3}\uparrow$$

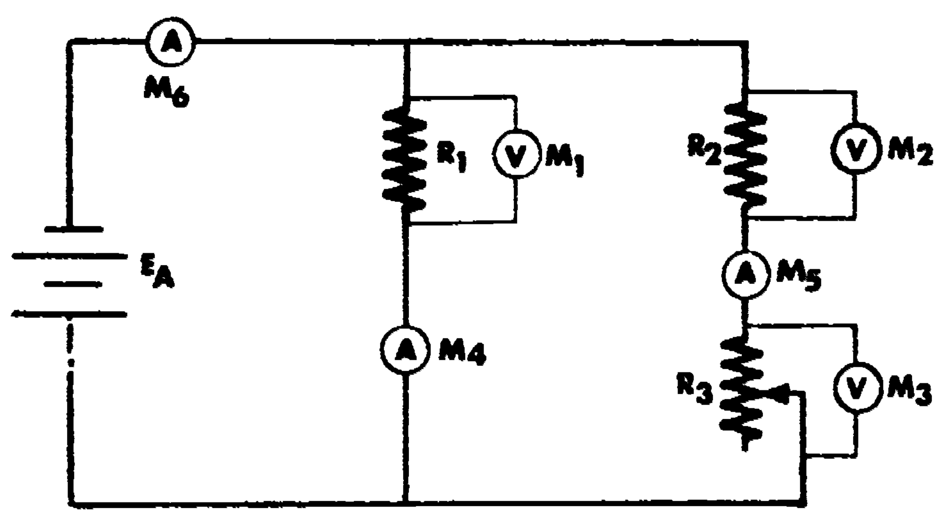
Current Characteristic:

When the ohmic value of R_2 INCREASES, the indication on M2 should DECREASE. However, the voltage drop across R_3 has INCREASED which must cause the current through R_3 to INCREASE and the indication on M3 should INCREASE.

$$\downarrow I_T = I_{R1}\downarrow = (I_{R2}\downarrow + \uparrow I_{R3})$$

Note: The change (increase) in ohmic value is always greater than the change (increase) in voltage drop, which results in a smaller fraction.

Parallel - Series Combination:



R_2 and R_3 form a <u>series</u> circuit.

Current: $I_{R2} = I_{R3} = M5$

Voltage: $E_{R2} + E_{R3} = M1$

Resistance: $R_2 + R_3 = REq$

R_1 and R_{Eq} (of R_2 and R_3) form a <u>parallel</u> circuit.

Voltage Characteristic:

$Ea = E_T = E_{R1} = (E_{R1} + E_{R3})$ $M1 = M2 + M3$

Current Characteristic:

$I_T = I_{R1} + I_{R2}$ (or I_{R3}) $M4 + M5 = M6$

Resistance Characteristic:

$$R_T = \frac{R_1 \times (R_2 + R_3)}{R_1 + (R_2 + R_3)} = \frac{R_1 \times R_{Eq}\ (\text{Series})}{R_1 + R_{Eq}\ (\text{Series})}$$

<u>Test Situation</u>:

The ohmic value of R_3 is DECREASED.

Resistance:

Since the ohmic value of R_3 DECREASES, the ohmic value of R_{Eq} $(R_2 + R_3)$ must also DECREASE. This will cause the ohmic value of R_T to DECREASE.

When R_T DECREASES, and the value of Ea does NOT CHANGE, the value of I_T should INCREASE. This indication on M6 should INCREASE.

Ohm's Law:

$$\frac{E_a \rightarrow}{R_T \downarrow} = I_T \uparrow$$

Note: In parallel circuits, when the ohmic value in one branch changes, it will not affect the value of (I), (E) or (R) in any other branch (unless a "short" occurs which "blows" a fuse. Therefore, the indication on M4 should NOT CHANGE. The indication on M1 should NOT CHANGE unless the value of Ea changes.

If the indication on M6 has INCREASED, and the indication on M4 has NOT CHANGED, then the indication on M5 must have INCREASED to account for the direction of change in M6.

Current Characteristic:

$\uparrow I_T = I_{R1} + I_{R2}\uparrow$ (or I_{R3})

Voltage drops:

$E_{R2}\uparrow = I_{R2}\uparrow \times R_2\rightarrow$ The indication on M2 should INCREASE.

$E_{R3}\downarrow = I_{R3}\uparrow \times R_3\downarrow$ The indication on M3 should DECREASE.

Note: Even though the value of I_{R3} INCREASED, the ohmic value of R_3 has DECREASED (the original change); therefore, the indication on M3 DECREASES.

Voltage Characteristic:

$Ea\rightarrow = E_{R2}\uparrow + E_{R3}\downarrow$

The sum of the voltage drops across R_2 and R_3 ($E_{R2} + E_{R3}$) must still be equal to the value of Ea.

<u>INDUCTANCE</u>:

The property of electrical circuits that opposes any <u>change</u> in the value of circuit current is called "inductance". Inductors convert electrical energy in the form of current flow, to electrical <u>potential</u> energy in the form of a magnetic field.

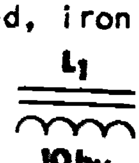
<u>Symbol</u>: "L"

<u>Basic unit of measure</u>: henry (abbreviated "h." or "hy.")

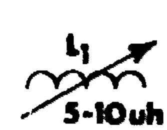
<u>Schematic symbols</u>:

Fixed, air core

Fixed, iron core



Variable



Phase relationship between current and voltage:

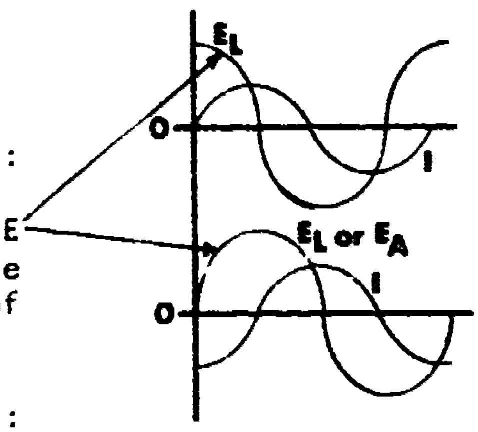
Whenever the value of current in a coil increases or decreases (changes) a counter-electromotive force (CEMF) is created by the moving (expanding or collapsing) magnetic field. The polarity of the CEMF will always be such as to oppose the direction of change in current. This action causes the current flowing through the coil to LAG the voltage applied to the coil (E_L). As a consequence, inductive circuits cause circuit current to lag the applied voltage as shown by the expression "ELI". In AC circuits, the voltage (E) comes before (ahead of) current (I) in inductive (L) circuits. In other words, (I) lags (E)

Waveform diagram:

Current reference:

I lags E because E always crosses the Time-Base ahead of I

Voltage reference:

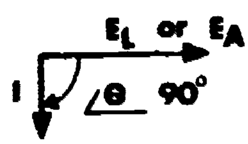


Vector diagram:

Current reference:

Vectors and reference both rotate. (I) is always displaced from E_L by a LAG of 90°.

Voltage reference:



Inductive reactance:

In AC circuits, the value of current is always changing (increasing and decreasing) at the same rate as the frequency (f) of the applied voltage (Ea). This produces an average value of opposition to circuit current (really an average value of CEMF) which has the SAME EFFECT upon alternating current AS RESISTANCE has. In other words, inductive reactance is opposition offered by inductors (or coils) to alternating current.

Symbol:

"X_L" ("X" represents reactance and "sub-L" represents self inductance.)

Basic unit of measure:

ohm Symbol: ..

Factors which affect the ohmic value of X_L:

Frequency (f) of the applied voltage and inductance (L).

Expression:

$X_L = 2\text{-}fL$ (The ohmic value of X_L follows in the same direction of change as (f) or (L).)

Purpose of inductors:

Because inductors are "frequency sensitive" they are used in filtering circuits, phase-shifting circuits and special wave-form shaping circuits.

POWER:

A term used to describe electrical energy in the process of being converted and "supplied" by voltage sources, and being converted and "used" by electrical loads... a complete system of energy conversion. Voltage sources convert other forms of energy to electrical energy and electrical loads convert electrical energy to other forms of energy, or store electrical energy in magnetic or electrical fields.

In keeping with the Law of Conservation of Energy, P_{out}, the power "used" by elelctrical loads must always be equal to P_{in}, the power "supplied" by voltage sources. Electrical loads "tell" the source how much they need by the value of circuit current, in accordance with the relationships $I_T = \frac{Ea}{Z}$.

As a consequence, circuit current (I) is the common factor between P_{in} and P_{out}.

True Power:

(Abbreviated T.P.) is considered to be P_{out}. "True" power describes electrical energy being converted to other forms of energy: heat and/or light. Resistance is the only circuit component which "uses" "true" power.

Basic unit of measure:

Watt (abbreviated W. or w)

Expression:

T.P. = I^2R (Watts = $a.^2 \times \Omega$)

In "purely" resistive DC and AC circuits, with any load connection arrangement, total (true) power (P_T) is always equal to the sum of the individual powers.

Expression:

$$P_{Total} = P_1 + P_2 \ldots + P_n$$

Reactive Power:

(Abbreviated R.P.) is also considered to be P_{out}. However, reactive power is electrical energy that is converted to another form of electrical energy. (Magnetic or electrical fields) when current flows in circuits which contain inductance and capacitance. In AC circuits (only) reactive power is stored in magnetic or electric fields and, at some later time, this electrical energy is returned to the source!

Basic unit of measure: (Volt-amperes Reactive) (VAR)

Expression: R.P. - $I^2 X_L$ (or I^2X_C) (VAR = $a.^2 \times \Omega$ (reactive))

Apparent Power:

(Abbreviated A.P.) Apparent Power is always considered to be P_{in}. Apparent Power describes the power DC and AC voltage sources must supply to the total electrical load.

Basic unit of measure: VA (Volt-amperes)

Expression: A.P. - EaI_T (VA = Volts x amperes)

In summary, $P_{in} = EaI_T$ and $P_{out} = I^2R_T$ (for resistive circuits only) or $P_{out} = I^2Z$ (for resistive-reactive AC circuits only). Since $P_{in} = P_{out}$, then $EaI_T = I^2R_T$ (or I^2Z). Notice that circuit current (I) is common ... it appears on both sides of the equal sign.

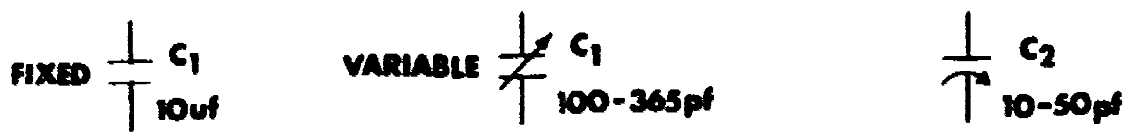
CAPACITANCE:

The property of electrical circuits which opposes any change in the value of circuit voltage is called "capacitance". Capacitors convert electrical energy in the form of voltage, to electrical potential energy in the form of an electrostatic (electrical) field that is created in the "dielectric" material between two metal "plates" when the capacitor "charges".

Symbol: "C" (for Capacitance)

Basic unit of measure: farad (abbreviated uf. (microfarad) or pf. (pico farad)

Schematic symbols:



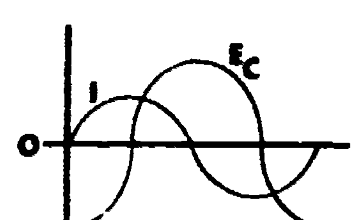
Phase relationship between current and voltage:

Whenever the value of voltage applied to a capacitor changes (increases or decreases), the capacitor charges or discharges so as to oppose the direction of change of the applied voltage. This action causes the displacement (charging or discharging) current into or out of the capacitor to LEAD the voltage applied to the capacitor (E_C). As a consequence, capacitive circuits cause the current to lead the applied voltage as shown by the expression "ICE". In AC circuits, the current (I) comes before (ahead of) voltage (E) in capacitive (C) circuits. (I) leads (E).

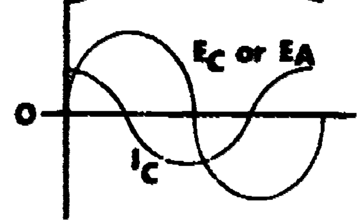
Waveform diagram:

Current reference:

I leads E because I always crosses the time-base ahead of E.



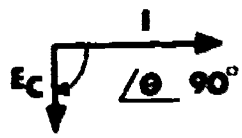
Voltage reference:



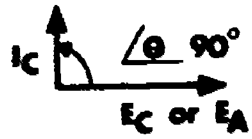
Vector diagram:

Current reference:

Vectors and reference both rotate. (I) is always displaced from E_C by a LEAD of 90°.



Voltage reference:



Capacitive reactance:

In AC circuits, the value of applied voltage is changing at the same rate as the frequency of the applied voltage. This produces an average value of opposition to circuit current (sometimes referred to as "counter-voltage" because the polarity is always opposing the polarity of the applied voltage). This opposition has the same effect upon alternating current as resistance has! In other words, capacitive reactance is opposition offered by capacitors to alternating current.

Symbol: "X_C" ("X" represents reactance and "sub-C" represents capacitance.)

Basic unit of measure: ohm Symbol: Ω

Factors which affect the ohmic value of X_C: Frequency (f) of the applied voltage and Capacitance (C).

Expression:

$X_C = \frac{1}{2\pi fC}$ (The ohmic value of X_C is always in the opposite direction of change of (f) or (C).)

Purpose of capacitors:

Because capacitors are "frequency sensitive". They are used in filtering circuits, phase-shifting circuits and special wave-form shaping circuits.

IMPEDANCE:

The total opposition to alternating current in any AC circuit is called impedance.

Symbol: "Z"

Basic unit of measure: ohm Symbol: Ω

The impedance (Z) of alternating current circuits is composed of resistance (R) and/or reactance (X).

Expression:

RL Circuits: $Z = \sqrt{R^2 = X_L^2}$ RC Circuits: $Z = \sqrt{R^2 + (-X_C^2)}$

Indicates Ea lags I_T

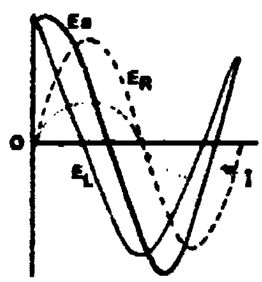
Waveform and Vector Relationships:

AC circuit voltages (E_R), (E_L), (E_C) and (Ea) are vector quantities.

AC circuit oppositions (R), (X_L), (X_C) and (Z) are also vector quantities.

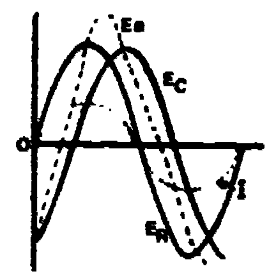
RL Circuit: ($R = X_L$)

Waveform diagram:

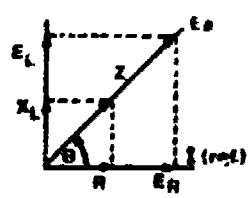


RC Circuit: ($R = X_C$)

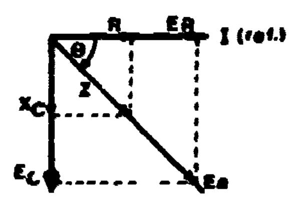
Waveform diagram:



Vector diagram:



Vector diagram:



RELATIONSHIP BETWEEN I_T, Ea and Z.

Ohm's Law:

The (value of) total circuit current (I_T) is directly proportional to the (value of) applied voltage (Ea) and inversely proportional to the (ohmic value of) total circuit opposition (Z).

Expression: $I_T = \frac{E_a}{Z}$

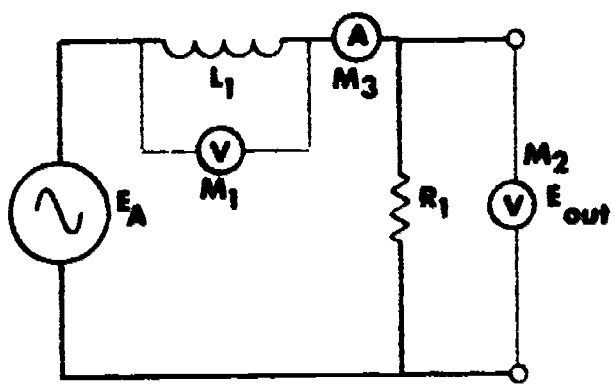
Relationship:

Whenever the value of I_T changes, the direction of the change will always be such as to follow the direction of change in the value of applied voltage (Ea) or, in the opposite direction of change in the value of impedance (Z). However, you must understand that the direction of change in the ohmic value of (Z) is ALWAYS determined by the direction of change in the value of resistance (R), in ohms, the value of inductance (L), in henries, the value of capacitance (C), in farads, or the frequency (f), in Hertz, of the applied voltage.

HOW TO USE THE EXPRESSIONS FOR (X_L), (X_C), AND (Z), WITH OHM'S LAW, TO ANALYZE AC SERIES RL OR RC CIRCUITS WHEN (f), (L), (C) OR (R) IS INCREASED OR DECREASED:

RL CIRCUITS:

Circuit diagram:



RL Series Circuit Relationships:

Current: $I_T = I_{L1} = I_{R1} = M3$

Voltage drops: $E_T = \sqrt{E_{R1}^2 + E_{L1}^2}$

Note: $Ea = E_T = E_{in}$ $E_{L1} = M1$

$E_{R1} = E_{out} = M2$

Impedance: $Z = \sqrt{R_1^2 + X_{L1}^2}$

Test Situation:

The frequency (f) of Ea (or E_{in}) is DECREASED. ($f \overset{1}{\downarrow}$)

Effect of change in (f) on reactance: $2\pi f \overset{1}{\downarrow} L_1 = X_{L1} \overset{2}{\downarrow}$

Effect of change in (f) on impedance: $\sqrt{R_1{}^2 \rightarrow + X_{L1}{}^2 \overset{2}{\downarrow}} = Z \overset{3}{\downarrow}$

Effect of change in (f) on circuit current: (Ohm's Law) $\dfrac{Ea \rightarrow}{Z \underset{3}{\downarrow}} = I_T \underset{4}{\uparrow}$

The indication on M3 should INCREASE.

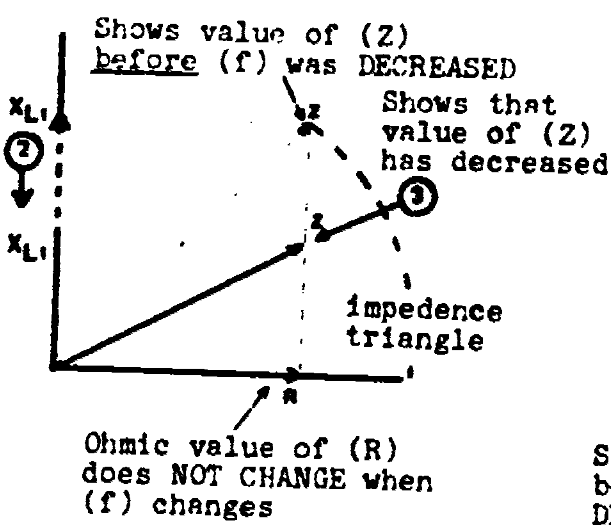
Effect of change in (f) on circuit voltage drops:

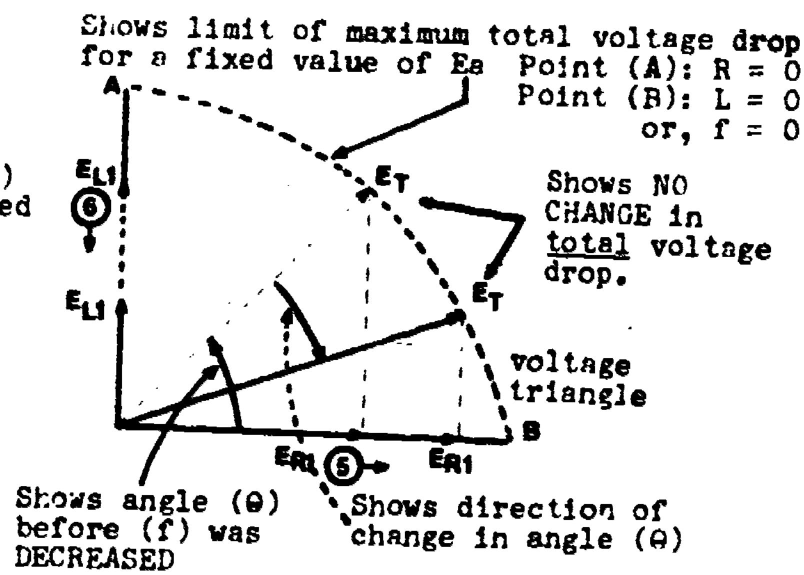
$I_T \underset{4}{\uparrow} \times R_1 \rightarrow = E_{R1} \underset{5}{\uparrow}$ The indication on M2 should INCREASE.

$I_T \underset{4}{\uparrow} \times X_{L1} \overset{2}{\downarrow} = E_{L1} \overset{6}{\downarrow}$ The indication on M1 should DECREASE.

$\sqrt{E_{R1}{}^2 \underset{5}{\uparrow} + E_{L1}{}^2 \overset{6}{\downarrow}} = E_T \rightarrow$ NO CHANGE in the value of total voltage drop.

VECTOR ANALYSIS OF THE CHANGE:





FILTER CHARACTERISTICS STUDY GUIDE

1. Purpose:

The purpose of any filter circuit is to "pass" a desired range or "band" of frequencies and eliminate (reject or discriminate against) all other frequencies.

The term "pass" means that the amplitude of the output voltage for all frequencies "passed" by the filter circuit will have high enough amplitudes to be used, or is useable, by other circuits.

The term "eliminate" or "discriminate" means that the amplitude of the output voltage for all frequencies eliminated or discriminated against by the filter circuit will not have high enough amplitudes to be used by other circuits.

2. Types of filter circuits:

Low-pass - Output voltage amplitude of all "low" frequencies, below the cut-off frequency (f_{co}), is useable.

Discriminates against "high" frequencies (all frequencies above (f_{co}).

High-pass - Opposite of the low-pass filter. Output voltage amplitude of all "high" frequencies, above the cut-off frequency (f_{co}), is useable.

Discriminates against "low" frequencies (all frequencies below (f_{co}).

Band-pass - Output voltage amplitude of all frequencies within a given range or "band" of frequencies is useable. Hence, the term "band-pass".

Discriminates against all frequencies above the upper cut-off frequency, and below the lower cut-off frequency.

Band-Eliminator - Opposite of the band-pass filter. Output voltage amplitude of all frequencies within a given "band" is not useable ... discrimates against these frequencies.

All frequencies above the upper cut-off frequency, and below the lower cut-off frequency have useable output voltage amplitudes.

Also called "band-reject" filter, "band-stop" filter or "wavetrap".

3. Cut-off frequency (f_{co}): The cut-off frequency of a filter circuit is the frequency of the applied voltage at which the amplitude of the output voltage (E_{out}) is equal to the 0.707 (70.7%) of the applied (input) voltage (E_{in}). ($E_{out} = 0.707 \times E_{in}$) (When the output voltage (at any frequency is greater that 70.7% of the input voltage, the amplitude is considered to be "useable".)

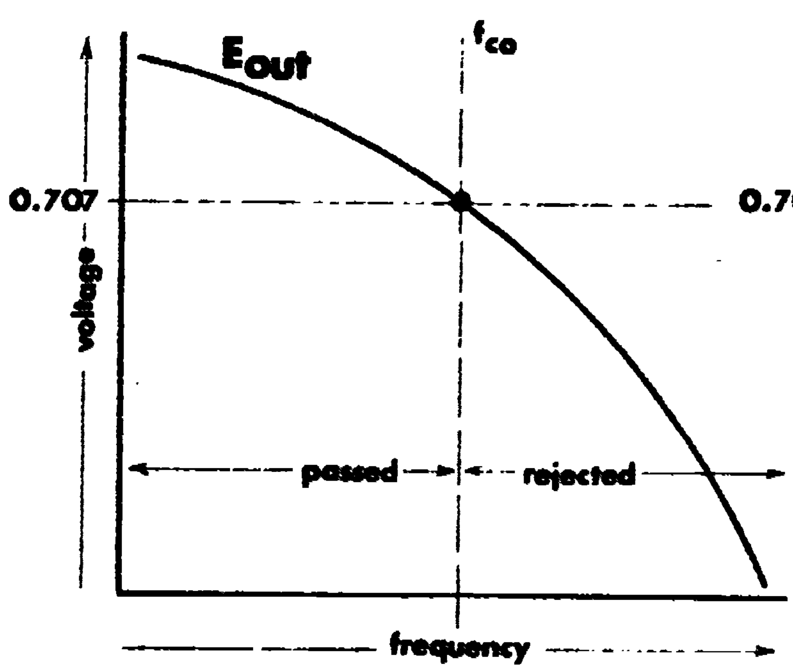
NOTE: The frequency at which the above condition occurs in low pass or high pass filter circuits is determined by the value of R and L for RL circuits, R and C for RC circuits, and the value of L and C for LC filter circuits.

The upper and lower cut-off frequency of any RLC band-pass or band-eliminator filter circuit is determined by the value of (L), (C) and "Q" of the circuit.

4. Filter response curves: Output voltage (E_{out}) vs. frequency (f).

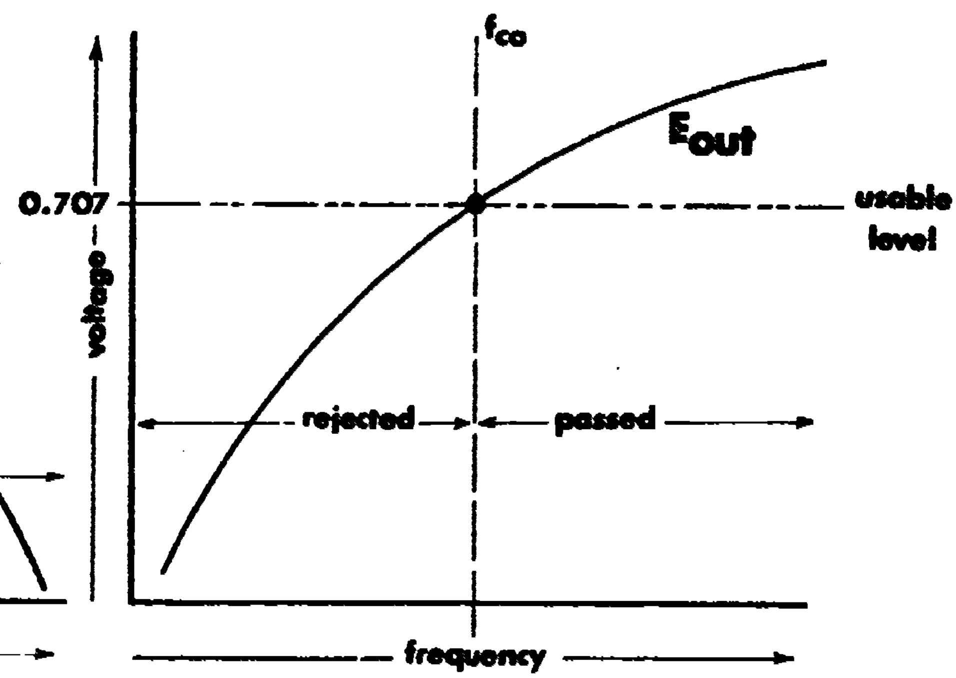
<u>Low-Pass</u>

RL, RC or LC Circuit

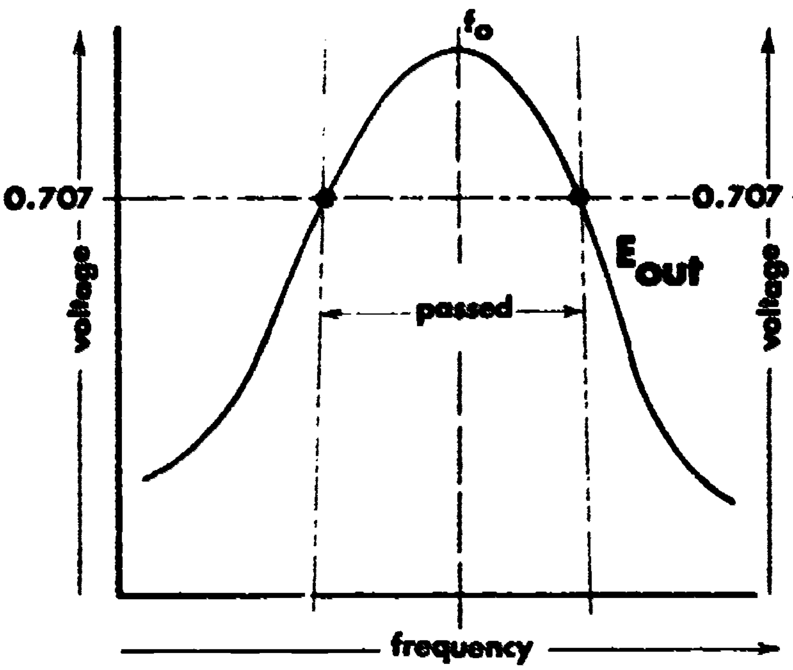


<u>High-Pass</u>

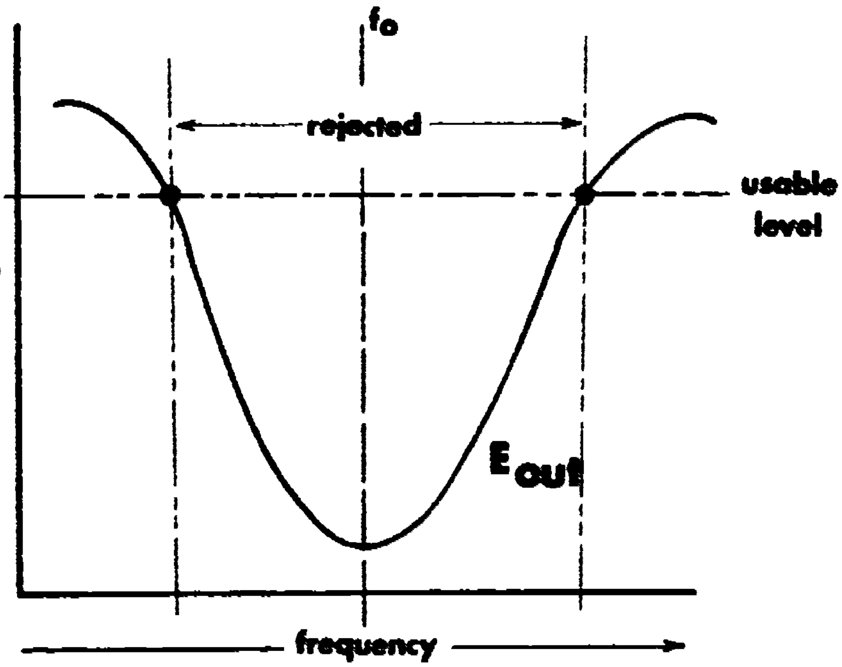
RL, RC or LC Circuit



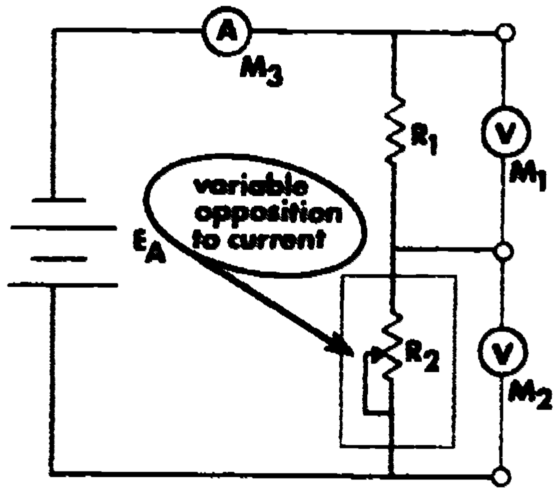
Band-Pass RLC Circuit

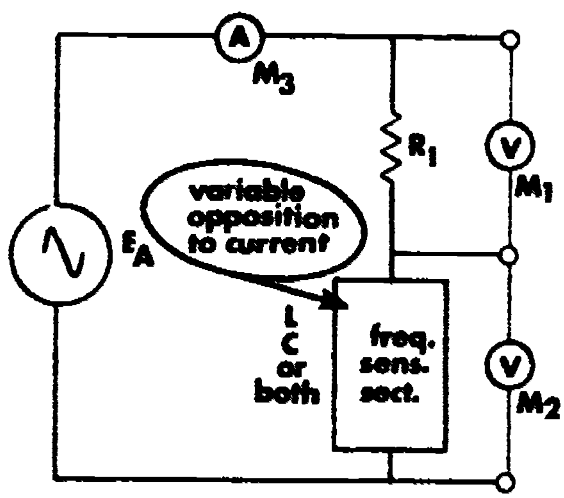


Band-Eliminator RLC Circuit



5. Any filter circuit, low-pass, high-pass, band-pass or band-eliminator can be simplified and analyzed using a basic circuit arrangment that you learned to analyze in Module 5: a series circuit with two resistors, one of which is variable.





The analysis of either circuit follows the same pattern:

DC Circuit. Let's assume the ohmic value of R2 is increased (by turning its control knob). This change should cause the value of total circuit opposition to current (R_T) to increase. The direction of change in R_T causes the total circuit current (I_T) to decrease (indication on M3 should decrease). The direction of change in I_T

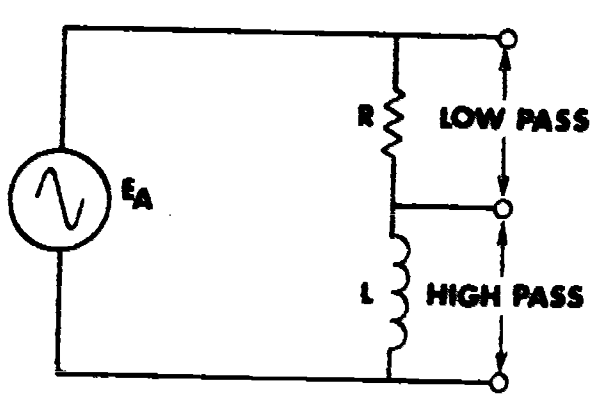
causes the voltage drop across R1 to decrease (indication on M1 should decrease) and the voltage drop across R2 should increase (as should the indication on M2), because the total voltage drop across R1 and R2 (E_T) must be equal to the value of E_a.

Filter Circuit. Let's assume that the frequency (f) of the applied voltage (E_a) is increased, and that the increase in (f) causes the variable opposition to current in the box marked "frequency sensitive" section, to increase. This direction of change causes the value of total circuit opposition (Z) to increase. The direction of change in Z causes total circuit current (I_T) to decrease (indication on M3 should decrease). The direction of change in I_T causes the voltage drop across R1 to decrease (indication on M1 should decrease) and the voltage drop across the "frequency sensitive" section increases (as should the indication on M2) because (E_T), the vector sum of the voltage drop across R1 and the "frequency sensitive" section, must be equal to the value of E_a. (Note: Changing the frequency of the voltage applied to a filter circuit is NOT the same thing as changing the value of the applied voltage. The frequency of E_a is stated in Hertz, whereas the value of E_a is stated in volts. When analyzing AC circuits in which the frequency of E_a is increased (or decreased), you must assume that the value of E_a (in volts) has not changed.)

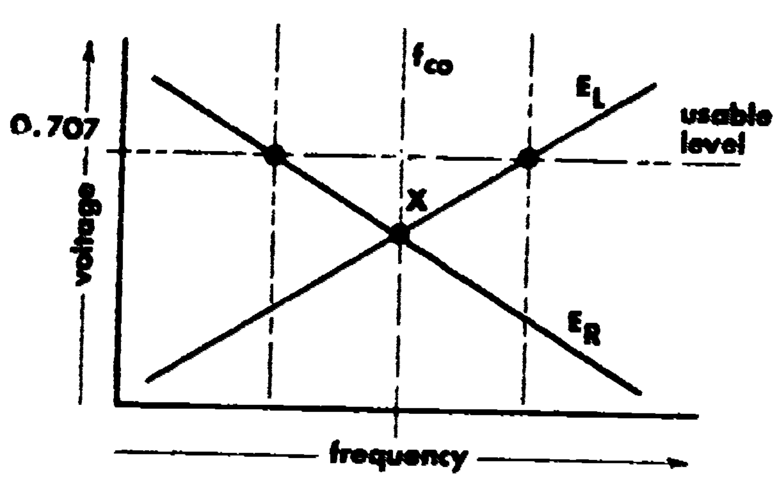
Conclusion. The "frequency sensitive" section of the filter circuit acts just like the variable resistor in the DC series circuit. In either circuit, the value of voltage drop across the variable opposition to current flow "follows" the direction of change in ohmic value. In other words, "As an opposition changes, so goes its voltage drop." (This "rule" has two exceptions, both of which are explained on page 303 of this booklet.)

6. RL Filter Circuits

Circuit Diagram:



Voltage drop vs. frequency curves:



Analysis of RL filter circuits when the frequency (f) of the applied voltage (E_a) is increased from a low value to a higher value.

1. Effect of an increase in (f) on the "frequency sensitive" (reactive) component:

   $2 \cdot f\uparrow \cdot L \cdot = X_L\uparrow$ (increases)

2. Effect of the change in inductive reactance (X_L) on circuit impedance (Z):

   $\sqrt{R^2 \cdot + X_L^2\uparrow} = Z\uparrow$ (increases)

3. Effect of the change in (Z) on total circuit current (I_T):

   $\frac{E_a \cdot}{Z\uparrow} = I_T\downarrow$ (decreases)

4. Effect of the change in (I_T) on the voltage drop across (R) and (L):

   Resistor: $I_T\downarrow \times R\cdot = E_R\downarrow$ (decreases)*

   Inductor: $I_T\downarrow \times X_L\uparrow = E_L\uparrow$ (increases)*

   * The vector sum of E_R and E_L will always be equal to the value E_a.

   Note: All changes are in the opposite direction when the value of (f) is decreased (from a high value to a lower value).

For all frequencies of the applied votlage below (f_{co}), the value of E_R is greater than E_L. (The ohmic value of R is greater than X_L)

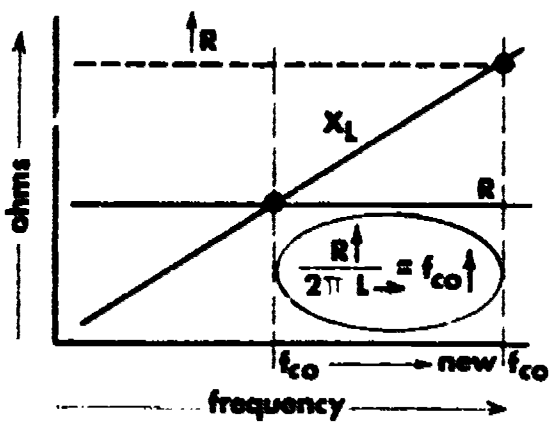
When the frequency of E_a is adjusted to f_{co}, $E_R = E_L$ (point "X"); $X_L = R$, $\angle\theta = 45°$ and $E_{out} = 0.707 \times E_{in}$ (point "X").

For all frequencies of the applied voltage above (f_{co}), the value of E_L is greater than E_R. (The ohmic value of X_L is greater than R)

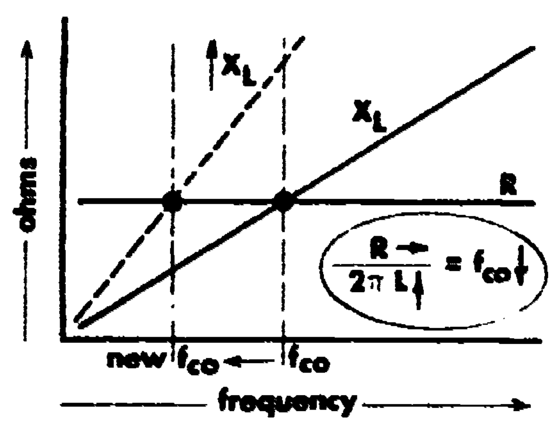
Cut-off frequency: The frequency at which $X_L = R$ can be determined using the expression $f_{co} = \frac{R}{2\pi L}$

5. Effect of a change in the value of (R) or (L) on f_{co}:

Increased (R)



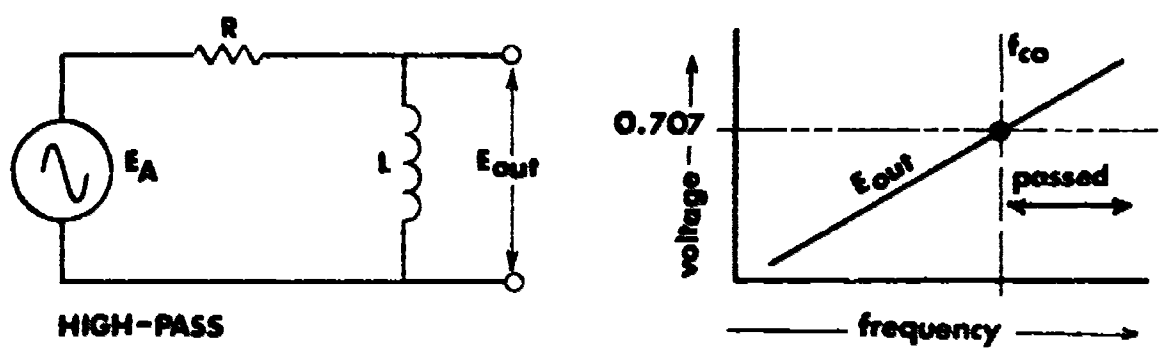
Increased (L)

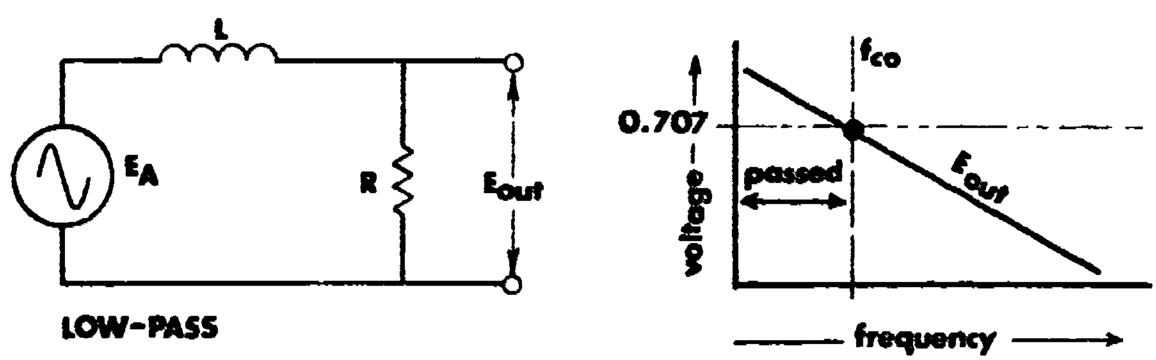


6. Possible arrangements for RL filter circuits:

Circuit Diagrams:

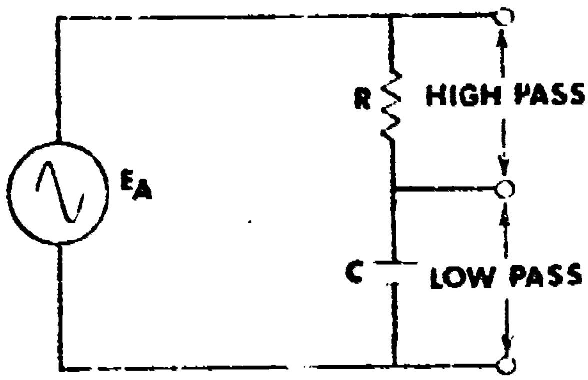
Response Curves: (E_{out} vs. f)

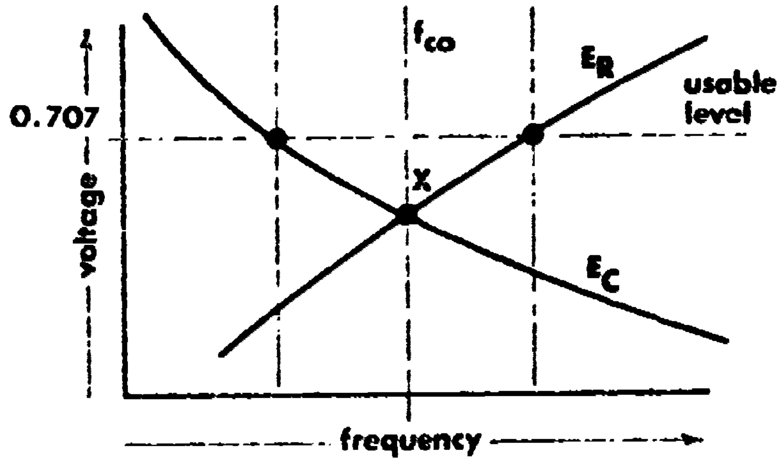




7. RC Filter Circuits

Circuit Diagram: Voltage drop vs. frequency curves:





Analysis of RC filter circuits when the frequency (f) of the applied voltage (E_a) is increased from a low value to a higher value.

1. Effect of an increase in (f) on the "frequency sensitive" (reactive) component:

$$\frac{1}{2\pi\, f\uparrow\, C\rightarrow} = X_C\downarrow \text{ (decreases)}$$

2. Effect of the change in capacitive reactance (X_C) on circuit impedance (Z):

$$\sqrt{R^2\rightarrow + (-X_C\downarrow)^2} = Z\downarrow \text{ (decreases)}$$

3. Effect of the change in (Z) on total circuit current (I_T):

$$\frac{E_a\rightarrow}{Z\downarrow} = I_T\uparrow \text{ (increases)}$$

4. Effect of the change in (I_T) on the voltage drop across (R) and (C):

Resistor: $I_T\uparrow \times R\rightarrow = E_R\uparrow$ (increases)*

Capacitor: $I_T\uparrow \times X_C\downarrow = E_C\downarrow$ (decreases)*

* The vector sum of E_R and E_C will always be equal to the value of E_a.

NOTE: All changes are in the opposite direction when the value of (f) is decreased (from a high value to a lower value).

For all frequencies of the applied voltage below (f_{co}), the value of E_C is greater than E_R. (The ohmic value of X_C is greater than R)

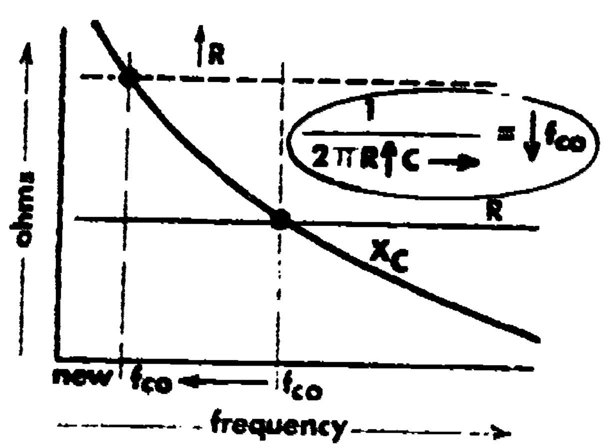
When the frequency of E_a is adjusted to f_{co}, $E_C = E_R$ (point "X"); $X_C = R$, $\angle\theta = 45°$ and $E_{out} = 0.707 \times E_{in}$ (point "X").

For all frequencies of the applied votlage above (f_{co}), the value of E_R is greater than E_C (the ohmic vlaue of R is greater than X_C).

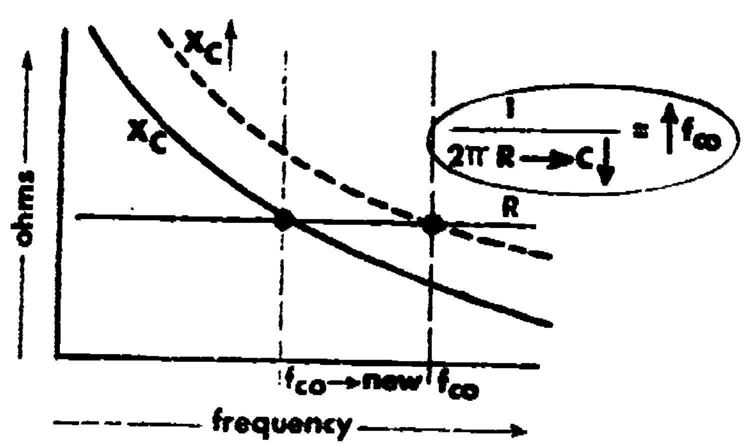
Cut-off frequency: The frequency at which $X_C = R$ can be determined using the expression $f_{co} = \frac{1}{2\pi\ RC}$

Effect of a change in the value of (R) or (C) on f_{co}:

Increased (R)

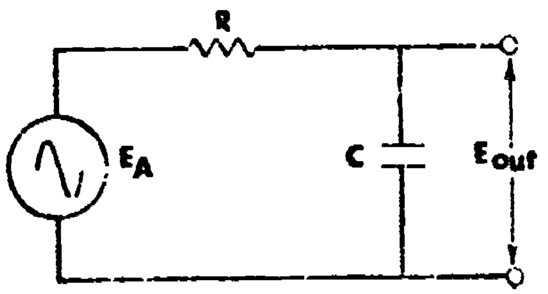


Decreased (C)

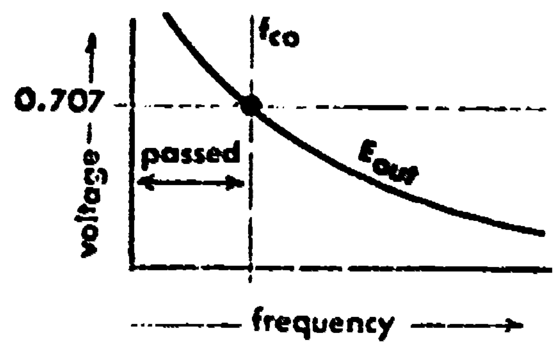


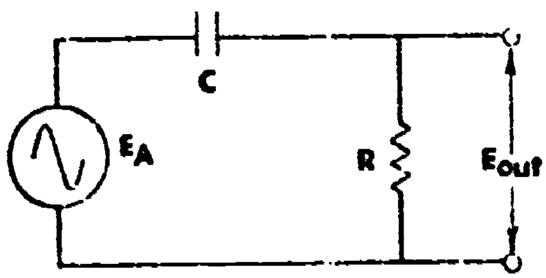
Possible arrangements for RC filter circuits:

Circuit Diagrams: Response Curves: E_{out} vs. f

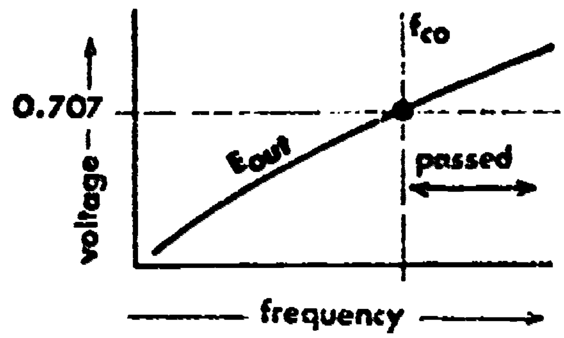


LOW-PASS



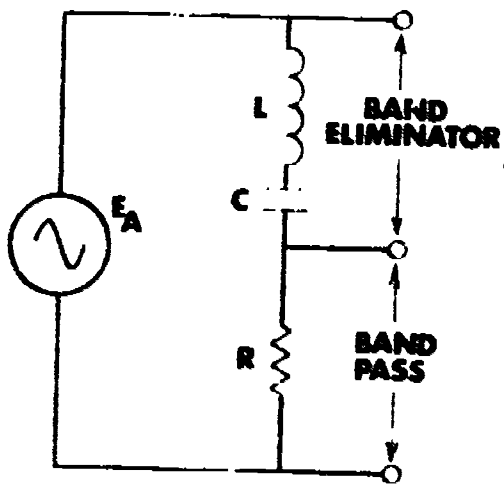


HIGH-PASS

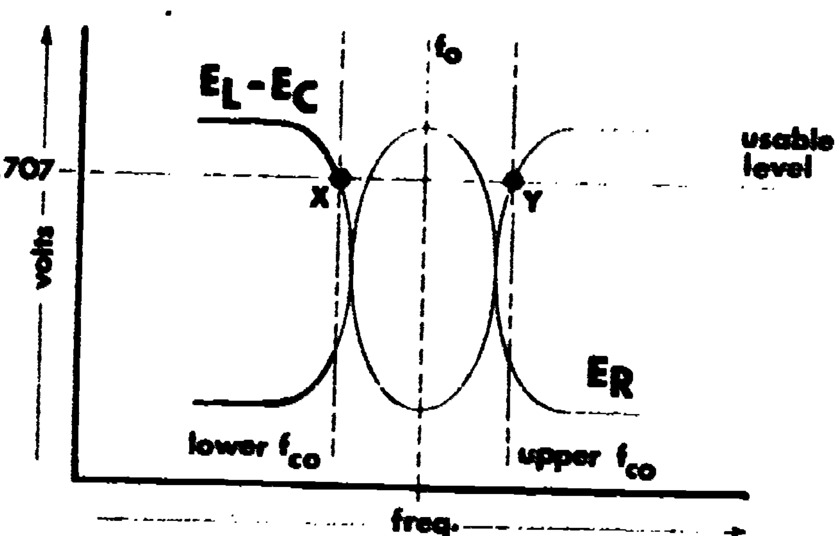


8. Series RLC Band-Pass/Band-Eliminator Filter Circuits

Circuit Diagram:



Voltage drops vs. frequency curves:



Analysis of series RLC filter circuits when the frequency (f) of the applied voltage (E_a) is increased from a low value to a higher value.

1. At low frequencies, the "frequency sensitive" (reactive) components have the following relative values:

$$2\pi f_{Lo} L = X_L \text{ (small value)} \qquad \frac{1}{2\pi f_{Lo} C} = X_C \text{ (large value)}$$

2. Effect of an increase in (f) on the "frequency sensitive" (reactive) components:

$$2\pi f\uparrow L\rightarrow = X_L\uparrow \text{ (increases)} \qquad \frac{1}{2\pi f\uparrow C\rightarrow} = X_C\downarrow \text{ (decreases)}$$

3. Effect of the change in net reactance ($X_L - X_C$)* on circuit impedance (Z):

$$\sqrt{R^2 + (X_L\uparrow - X_C\downarrow)^2} = Z\downarrow \text{ (decreases)}$$

The difference between the value of X_L and X_C is decreasing.

4. Effect of the change in circuit impedance (Z) on the value of total circuit current (I_T):

$$\frac{E_a\cdot}{Z\downarrow} = I_T\uparrow \text{ (increases)}$$

5. Effect of the change in I_T on the voltage drop across (R), (L) and (C):

Resistor: $I_T\uparrow \times R\rightarrow = E_R\uparrow$ (increases)**

Inductor: $I_T\uparrow \times X_L\uparrow = E_L\uparrow$ (increases)

Capacitor: $I_T\uparrow \times X_C\downarrow = E_C\downarrow$ (decreases)**

Inductor <u>and</u> Capacitor: $(E_L\uparrow - E_C\downarrow)$ $\downarrow$(decreases)**

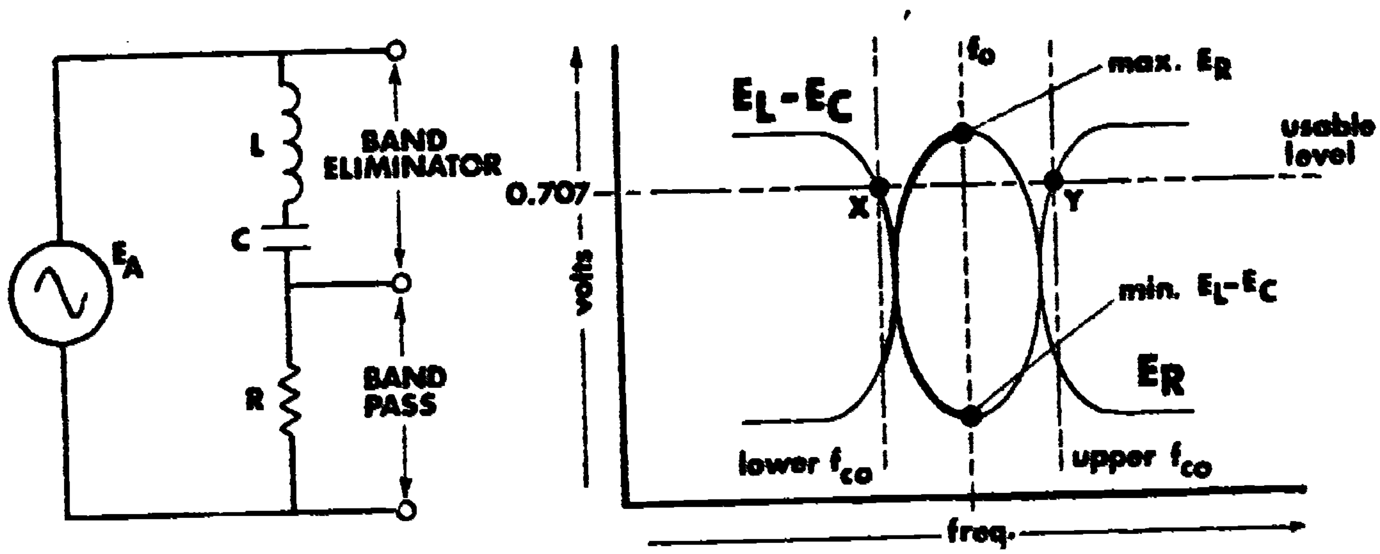
** The vector sum of E_R and the value of $(E_L - E_C)$ will always be equal to the value of E_a.

When the frequency of E_a is increased to the lower cut-off frequency, $E_R = (E_L - E_C)$, point "X" on the voltage curves.

NOTE: For <u>all</u> frequencies of E_a, below (f_o), the ohmic value X_C is greater than X_L; consequently, the value of E_C is greater than E_L so the circuit appears capacitive to the source: I_T <u>leads</u> E_a. To see the <u>equivalent series circuit</u>, cover the inductor (L) of the circuit diagram.

Circuit diagram:

Voltage vs. frequency curves:



Analysis of series RLC filter circuits when the frequency (f) of the applied voltage (E_a) is increased from the lower f_{co} to f_o. (f_o) designates the "resonant" frequency of an RLC circuit. (f_o) is the frequency of the applied voltage which causes the value of X_L to have the same ohmic value as X_C. Note: Any frequency of E_a, can be a "resonant" frequency, it all depends on the value of (L) and (C) in an RLC circuit.

When the frequency (f) of the applied voltage is adjusted to the frequency which causes "resonance" the following circuit conditions exist:

Progress Check

Summary

1. Net circuit reactance: X_C has decreased and X_L has increased until, at f_o, $X_L = X_C$; consequently, the difference between these two values $(X_L - X_C)$ is zero (or minimum).

2. Effect of minimum value of net circuit reactance on circuit impedance (Z):

$$\sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (0)} = Z \qquad (\text{At } f_o,\ Z = R)$$

The value of (Z) is minimum.

3. Effect of minimum circuit impedance (Z) on the value of total circuit current (I_T):

$$\frac{E_a}{Z_{min}} = I_T \text{ (maximum)}$$

4. Effect of maximum value of I_T on voltage drop across (R), (L) and (C):

resistor: $I_T(\max) \times R = E_R$ (maximum)

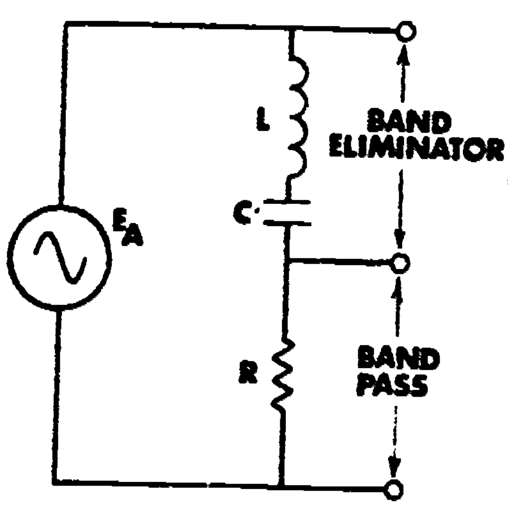
inductor: $I_T(\max) \times X_L = E_L$ (very large value)

capacitor: $I_T(\max) \times X_C = E_C$ (very large value)

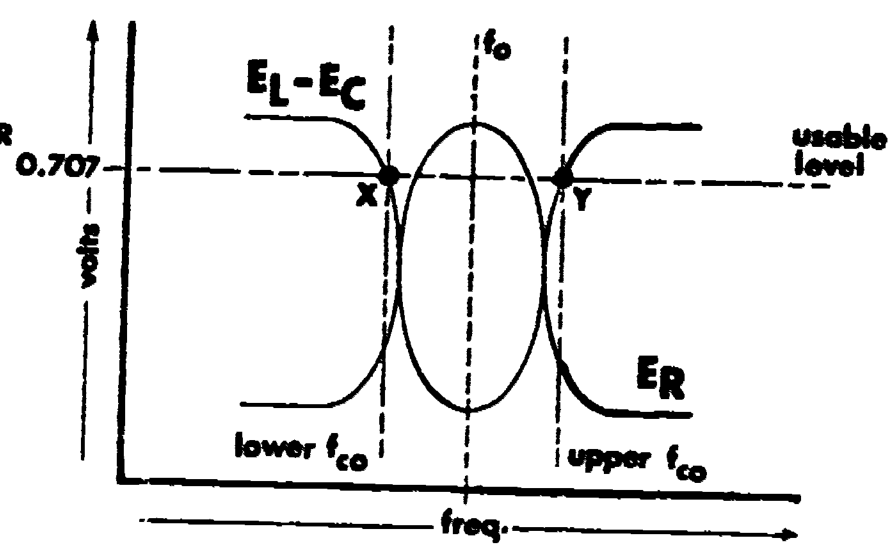
$$E_L = E_C$$

Inductor and Capacitor: $(E_L - E_C) = 0$ (minimum)

Circuit Diagram:



Voltage drop vs. frequency curves:



Analysis of series RLC filter circuits when the frequency (f) of the applied voltage (E_a) is increased from f_o to the upper f_{co}.

1. When the frequency of E_a is the resonant frequency, the following circuit conditions exist:

   $X_L = X_C$; therefore, $(X_L - X_C) = 0$. Z is minimum (equal to R)

   $E_L = E_C$; therefore, $(E_L - E_C) = 0$. E_R is <u>maximum</u> (equal to E_a)

   Since the value of (Z) is minimum, I_T is <u>maximum</u>.

2. Effect of a further increase in (f) on the "frequency sensitive" (reactive) components:

   $2\pi f\uparrow L\cdot = X_L\uparrow$ (increases) $\frac{1}{2\pi f\uparrow C\cdot} = X_C\downarrow$ (decreases)

3. Effect of the change in <u>net</u> reactance $(X_L - X_C)$* on circuit impedance (Z):

   $\sqrt{R^2 + (X_L\uparrow - X_C\downarrow)^2} = Z\uparrow$ (increases)

   *The difference between the value of X_L and X_C is now increasing, because the value of X_L is greater than X_C.

4. Effect of the change in circuit impedance (Z) on the value of total circuit current (I_T):

   $\frac{E_a\cdot}{Z\uparrow} = I_T\downarrow$ (decreases)

5. Effect of the change in I_T on the voltage drop across (R), (L) and (C):

   Resistor: $I_T\downarrow \times R\cdot = E_R\downarrow$ (decreases)

   Inductor: $I_T\downarrow \times X_L\uparrow = E_L\uparrow$ (increases)

   Capacitor: $I_T\downarrow \times X_C\downarrow = E_C\downarrow$ (decreases)

   Inductor and Capacitor: $(E_L\uparrow - E_C\downarrow)\uparrow$(increases)

When the frequency of E_a is increased to the upper cut-off frequency, $E_R = (E_L - E_C)$, point "Y" on the voltage curves. Note: For all frequencies of E_a, above (f_o), the ohmic value of X_L is greater than X_C; consequently, the value of E_L is greater than E_C, so the circuit appears inductive to the source: I_T <u>lags</u> E_a. To see the equivalent series circuit, cover the capacitor (C) of the circuit diagram.

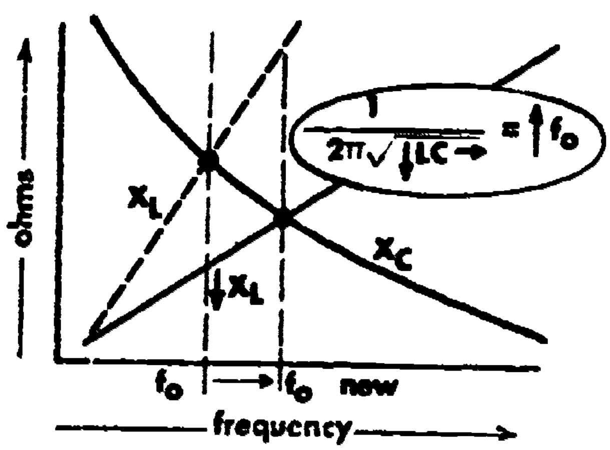
Resonant frequency (f_o):

When the frequency (f) of E_a is such that the ohmic value of X_L is equal to X_C, for any RLC circuit, that frequency is called the "resonant" frequency. The value of (f_o) for any RLC circuit is determined only by the values of (L) and (C) in the circuit.

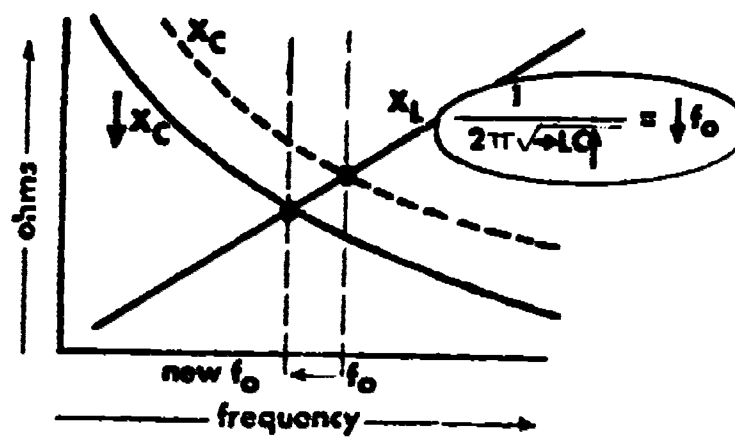
$$f_o = \frac{1}{2\pi\sqrt{LC}} \quad \text{or} \quad f_o = \frac{.159}{\sqrt{LC}}$$

Effect of changing the value of (L) or (C) on the value of (f_o):

Decreased (L)

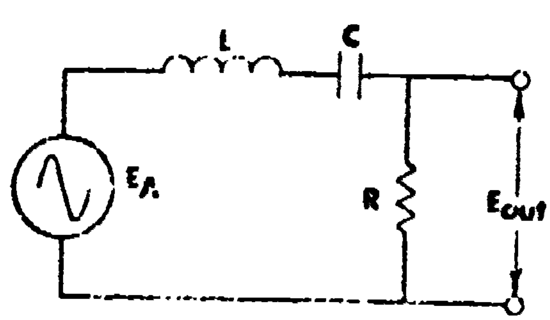


Increased (C)

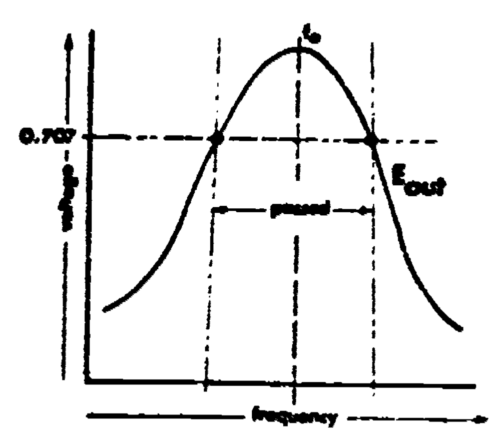


Possible arrangements for series RLC filter circuits:

Circuit Diagrams:

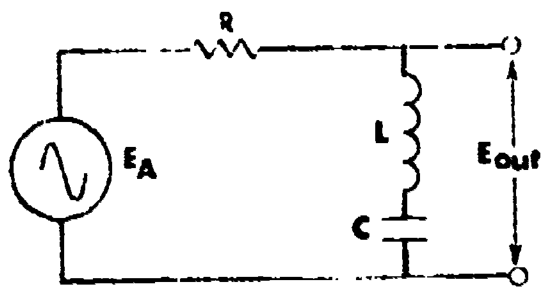


Response Curves: (E_{out} vs. f)

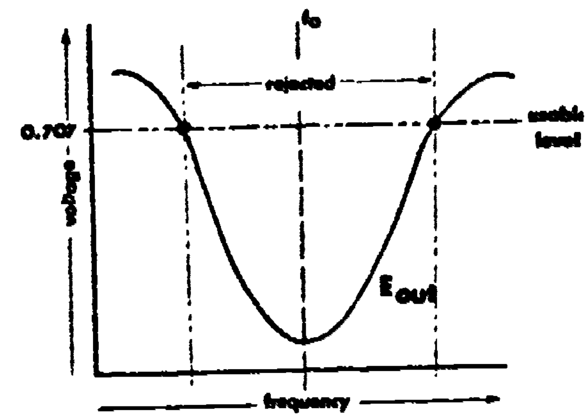


Possible arrangements for series RLC filter circuits (con't):

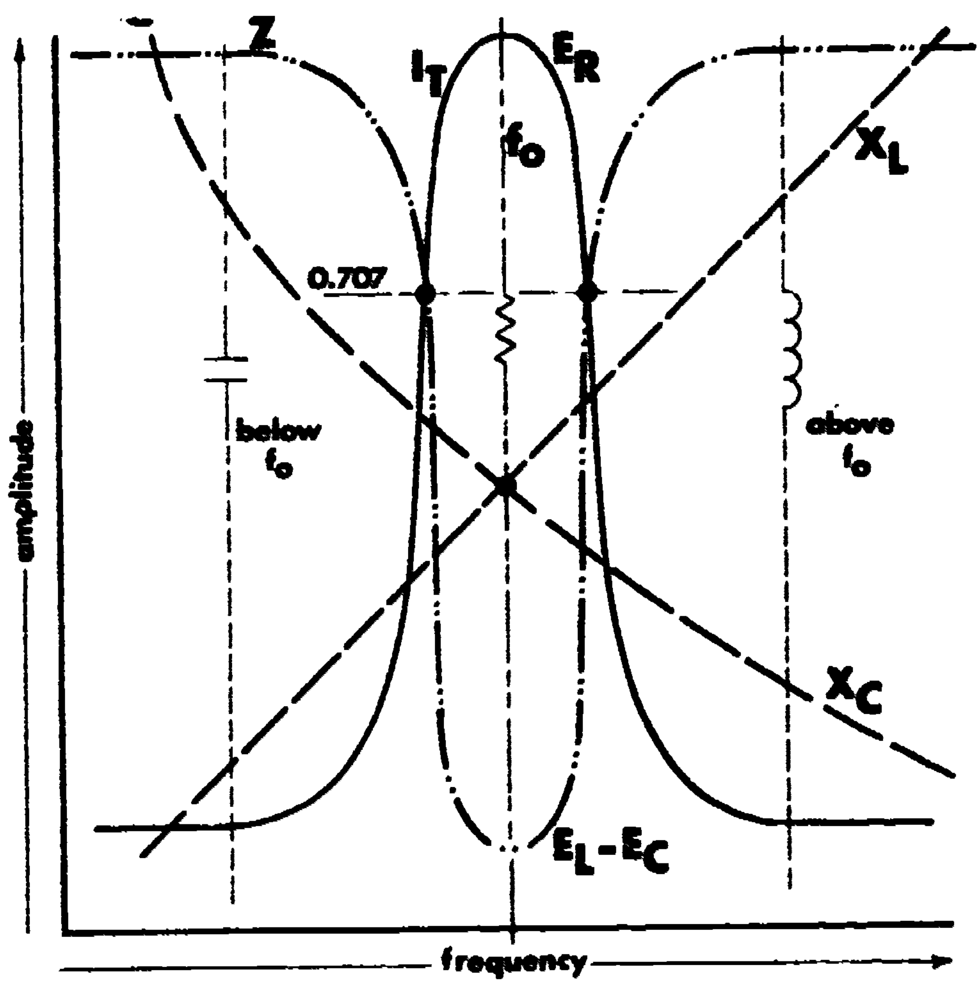
Circuit Diagrams:



Response Curves: (E_{out} vs. f)



Summary of Series RLC Circuit Conditions:



Circuit conditions <u>below</u> resonance:

1. The ohmic value of X_C is larger than X_L.
2. Z is a large value (due to large value of X_C).
3. I_T is a small value (due to large value of Z).
4. E_C is larger than E_L.
5. $(E_L - E_C)$ is large (due to large value of E_C). E_R is small.
6. The circuit appears capacitive to the source: I_T leads E_a.

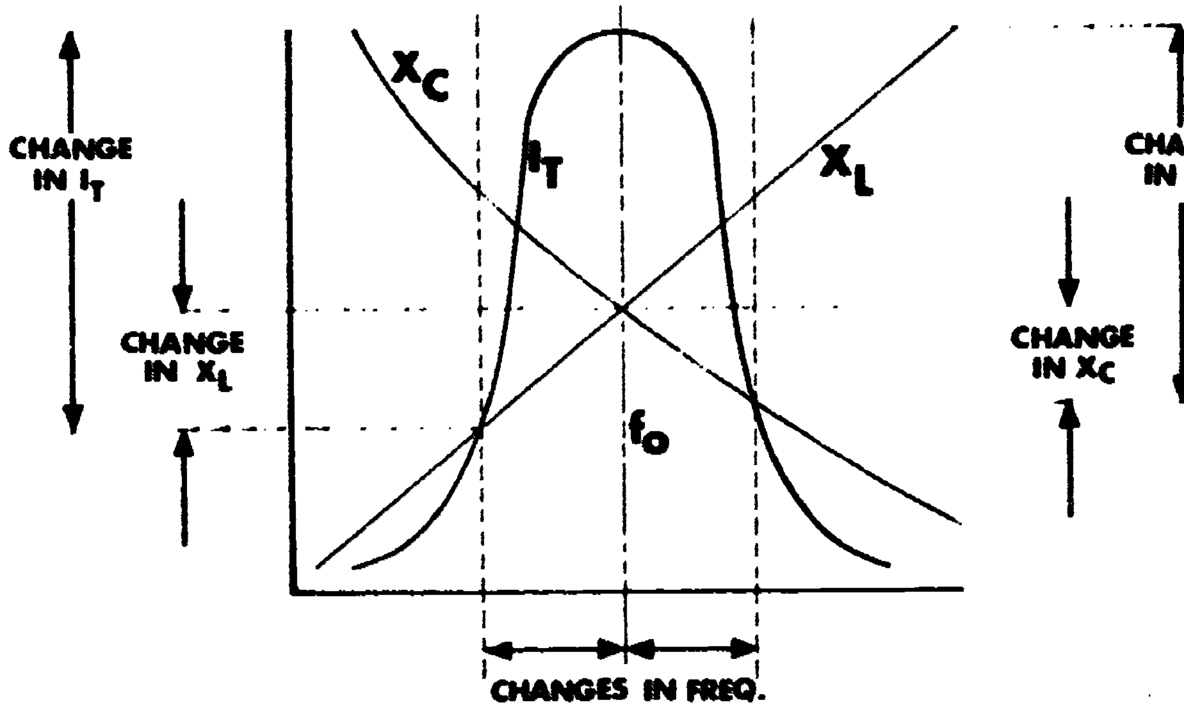
Circuit conditions <u>at</u> resonance:

1. The ohmic value of X_C is equal to X_L.
2. Z is minimum (equal to the ohmic value of R.) $(X_L - X_C) = 0$
3. I_T is maximum (due to the minimum value of Z)
4. E_L is equal to E_C (very large voltages).
5. E_R is maximum. $(E_L - E_C)$ is minimum.
6. The circuit appears <u>resistive</u> to the source: I_T <u>in phase</u> with E_a.

Circuit conditions <u>above</u> resonance:

1. The ohmic value of X_L is larger than X_C.
2. Z is a large value (due to large value of X_L).
3. I_T is a small value (due to large value of Z).
4. E_L is larger than E_C.
5. $(E_L - E_C)$ is large (due to large value of E_L). E_R is small.
6. The circuit appear <u>inductive</u> to the source: I_T <u>lags</u> E_a.

An Exception to the "Rule" about Circuit Voltage Drops:



One of the most useful "rules" you can learn to help you understand the voltage relationships in electrical circuits is the one that states: "as an opposition (R, X or Z) changes, so goes its voltage drop." In other words, the voltage drop across an opposition should "follow" the change in opposition. An exception to this "rule" occurs in high-Q RLC series circuits when the circuit is made resonant by adjusting the frequency of E_a or "tuning" (changing the value of C or L).

In the diagram above, note that as the frequency of E_a is increased from f_1 towards f_o, X_C decreases; Z decreases, so I_T increases. The change in X_C is small, whereas the change in I_T is very large. Even though X_C decreases, the drastic increase in I_T causes the value of E_C to increase ($I_T\uparrow \times X_C\downarrow = E_C\uparrow$): an exception to the aforementioned "rule". In a similar manner, when the frequency of E_a is decreased from f_2 towards f_c, X_L decreases; Z decreases so I_T increases. Even though X_L decreases, the drastic change in I_T causes the value of E_L to increase ($I_T\uparrow \times X_L\downarrow = E_L\uparrow$): the other exception to the "rule".

Voltage "gain": At resonance, high-Q RLC series circuits have voltage "gain" (when the voltage drop across (L) or (C) is considered.) When circuit resonance is approached, from either direction, the impedance

(Z) of the circuit decreases sharply with a corresponding drastic increase in total circuit current (I_T). The large current causes the individual voltage drops across (L) and (C) to increase to very high voltages at resonance. (In some circuits, it is possible for the value of E_L (and E_C) to be many times the value of E_a!) The large increase in value of E_L (and E_C), at resonance, is called voltage "gain".

Note: Voltage "gain" is very useful in series RLC band-pass filter circuits, particularly when the coil (L) is the primary of a transformer. Also, the voltage and current rating of the parts used in high-Q RLC band-pass and band-eliminator filter circuits must be capable of handling the large current and high voltages which can occur when a circuit is caused to be resonant.

"Q": The "Q" (for Quality) of a coil is a number that represents the ratio of energy stored (in the magnetic field of the coil) to energy used (converted to heat) by the "effective resistance" of the coil. There are two kinds of "Q": Q_{coil} and Q_{ckt}.

Q_{coil}: The value of Q_{coil} is determined by the following relationship:

$$\left(\frac{X_L}{R_{eff}} = Q_{coil} \qquad \frac{X_L}{R_{eff}} = \frac{2\pi f\uparrow L\rightarrow}{R_{eff}\uparrow} = Q_{coil}\rightarrow\right)$$

(Refer to the example in the parentheses above.) Within the limits of the frequency range for which it is designed, the value of Q_{coil} should not change with changes in frequency of E_a. This is because the ohmic value of R_{eff} (due to "skin effect" and "proximity effect") changes in the same direction as the value of X_L when the frequency of E_a is changed.

Q_{ckt}: The value of Q_{ckt} is determined by the following relationship:

$$\frac{X_L}{R_T} = Q_{ckt} \qquad \frac{X_L}{R_T} = \frac{2\pi f\uparrow L\rightarrow}{R_T\rightarrow} = Q_{ckt}\uparrow$$

In the case of Q_{ckt}, the total resistance of the circuit includes the ohmic value of R_{eff} of the coil. The value of Q_{ckt} should always be smaller than Q_{coil}. As with Q_{coil}, the value of X_L follows the direction of change in frequency of E_a; however, unlike Q_{coil}, the effect of any change in value of R_{eff} (normally a small ohmic value) is "swamped" (reduced) by other resistances in the circuit. (The value of total circuit current is also less.) The "swamping" effect of other circuit resistances causes the value of Q_{ckt} to change when the frequency of E_a is changed. As a consequence, the lower value of Q_{ckt} is used as the figure to determine the bandwidth of RLC bandpass and band-eliminator filter circuits.

Bandwidth: This term is used to describe the number of frequencies contained within the "band" between the upper and lower cut-off frequency occurs is determined by Q_{ckt} in accordance with the following relationship:

$$\frac{f_o}{Q_{ckt}} = \text{Bandwidth (B.W.)}$$

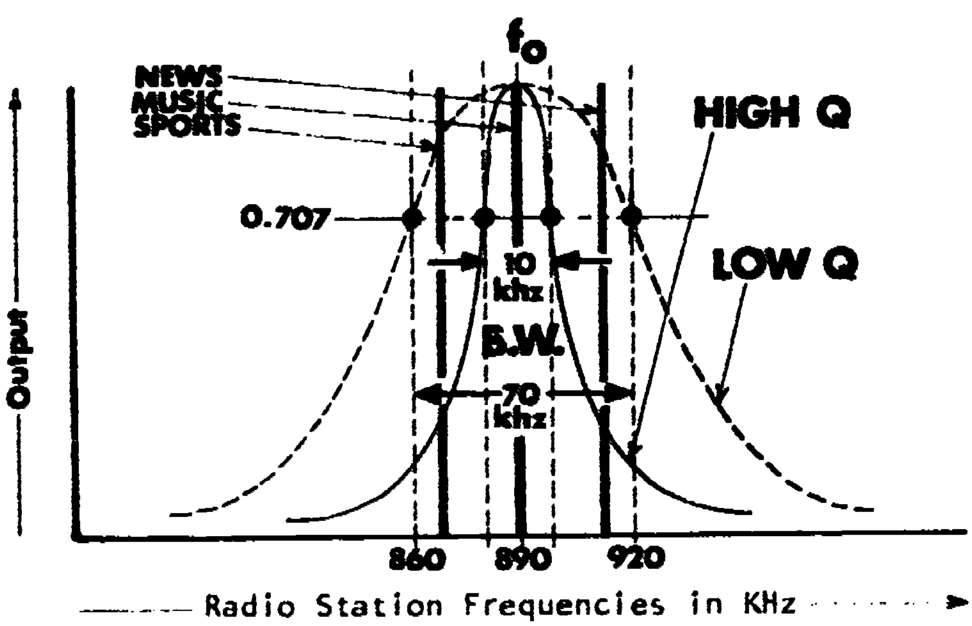
(Note: Use of this relationship assumes that f_o, the frequency of E_a which causes the filter circuit to become resonant, is the center frequency within the bandwidth.)

Bandwidth may also be determined by subtracting the lower cut-off frequency (f_1) from the upper cut-off frequency (f_2) as follows:

$$(\text{upper } f_{co} - \text{lower } f_{co}) = (f_2 - f_1) = \text{Bandwidth (B.W.)}$$

Low-Q circuits (Q's less than 10) have <u>wide</u> bandwidths. (Many frequencies between f_1 and f_2), and high-Q circuits have <u>narrow</u> bandwidths (fewer frequencies between f_1 and f_2). The higher the value of Q_{ckt}, the narrower the bandwidth of the circuit. The illustrations show how the bandwidth of RLC filter circuits is affected by the value of Q_{ckt}.

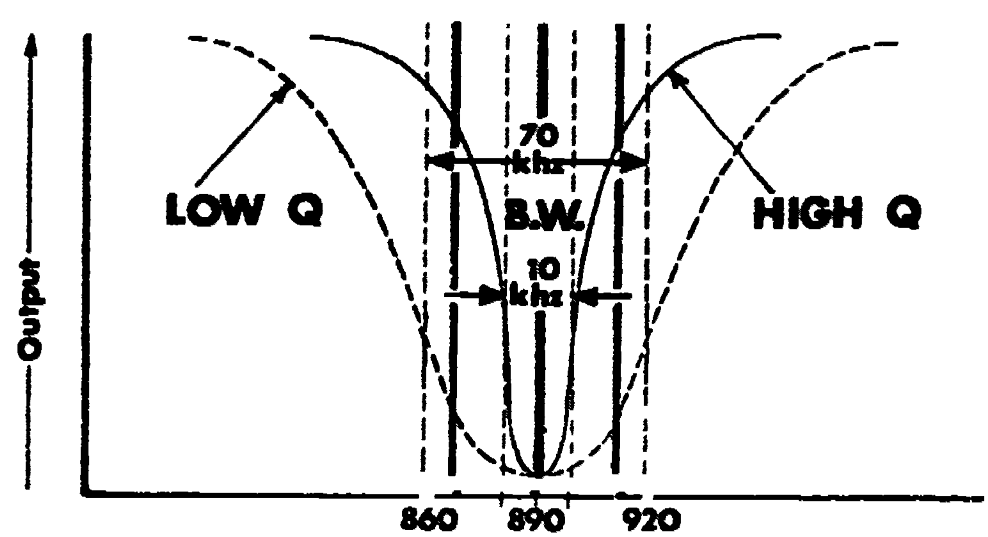
9. Effect of Value of "Q" on Bandwidth of Filter Circuits:



To see how the value of Q_{ckt} affects the output voltage vs. frequency response of band-pass filter circuits, let's assume that you live in a town which has three radio stations that are close together, as far as their broadcasting frequencies are concerned. You want to listen to the station which broadcasts on a frequency of 890 KHz., but the filter circuits in your radio have a low value of "Q". Now, refer to the low-Q band-pass filter response curve on the diagram. It has a wide bandwidth. As a consequence, there is a useable output voltage amplitude at the frequency of each radio station .... they are all being "passed". With this kind of response, when you tuned the radio to 890 KHz., you would hear all three radio stations at the same time! Now look at the curve for the high-Q band-pass filter circuit. It has a narrow bandwidth. When the filter circuits in a radio have this kind of response, only the frequency of 890 KHz (5KHz on either side of 890 KHz) will have a useable output voltage and be "passed". By comparing the two response curves, you should be able to see that the frequencies of the other two radio stations are effectively filtered out by the narrow bandwidth of the high-Q filter circuit.

Note: The ability of filter circuits to discriminate between frequencies that are close together is called "selectivity". (Low-Q circuits are not as frequency selective as high-Q circuits.)

The diagram below shows how the value of Q_{ckt} affects the bandwidth (and the selectivity) of band-eliminator filter circuits.

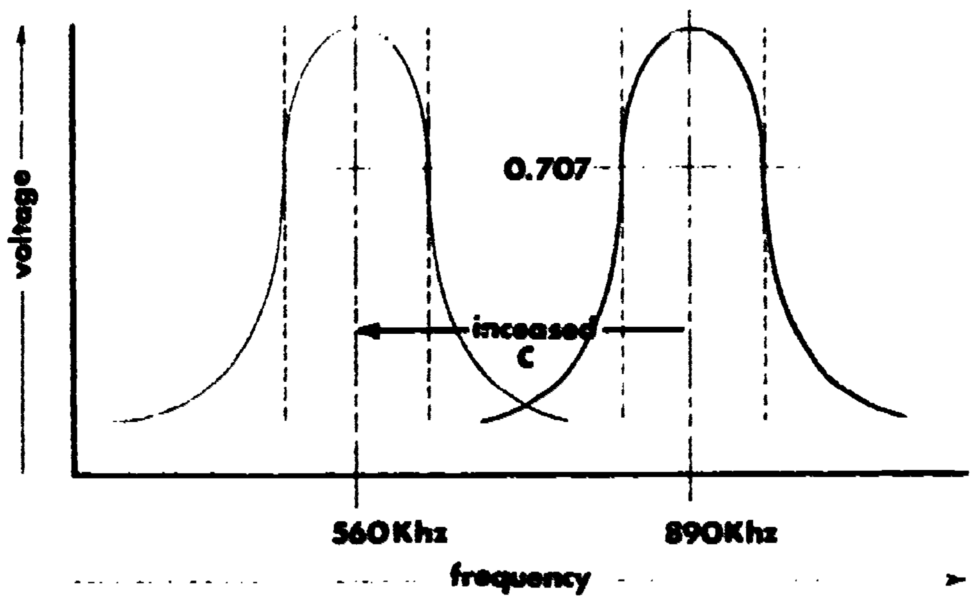


10. "Tuning" of RLC Band-Pass Filter Circuits:

"Tuning" is the process of changing the value of (L) or (C) of an RLC filter circuit so it will be resonant to a different frequency of applied voltage. (The most common method is to change the value of (C), using a variable capacitor.) The following diagrams illustrate what happens to (f_o) and bandwidth of a band-pass filter circuit when the value of (C) is changed.

In Figure 1, the LC product of the circuit makes it resonant to an applied voltage with a frequency of 890KHz. When the circuit is "tuned", by increasing the value of (C), the circuit is caused to be resonant to a lower value of (f_o). Notice that the bandpass curve shifts and centers itself over the new value of (f_o).

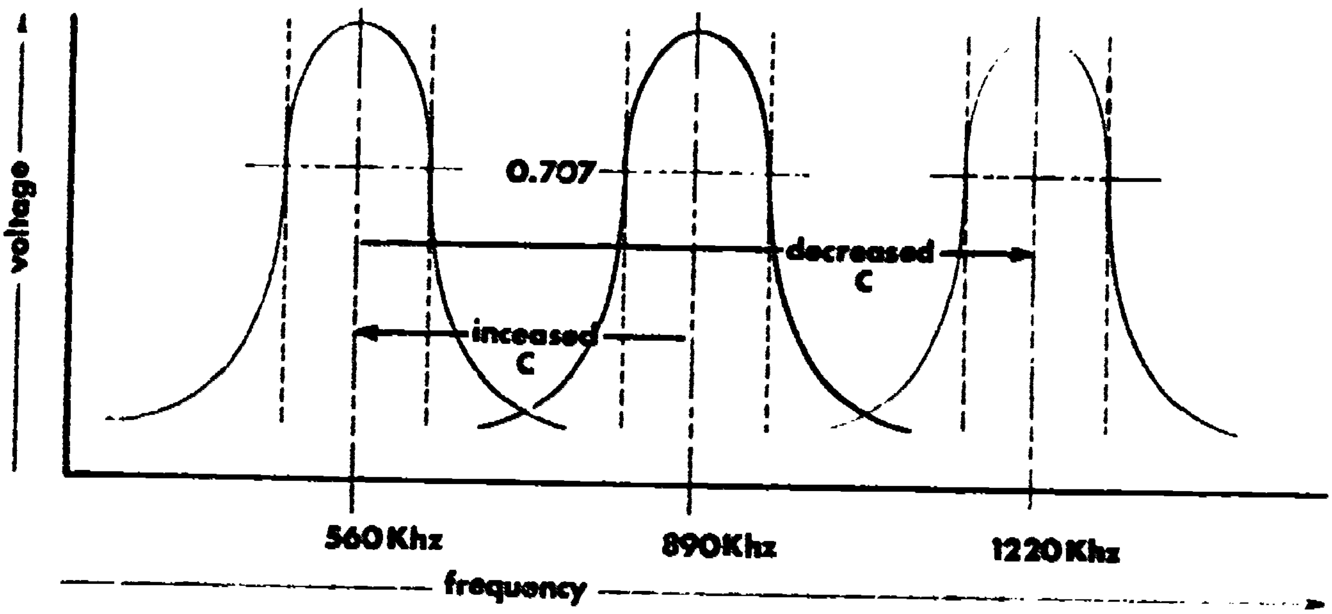
Figure 1.



In Figure 2, the circuit is tuned to a higher value of (f_o) by decreasing the value of (C). In this case the band-pass curve shifts and centers itself over the new, higher value of (f_o).

$$\frac{1}{2\pi\sqrt{L \cdot C\downarrow}} = f_o\uparrow$$

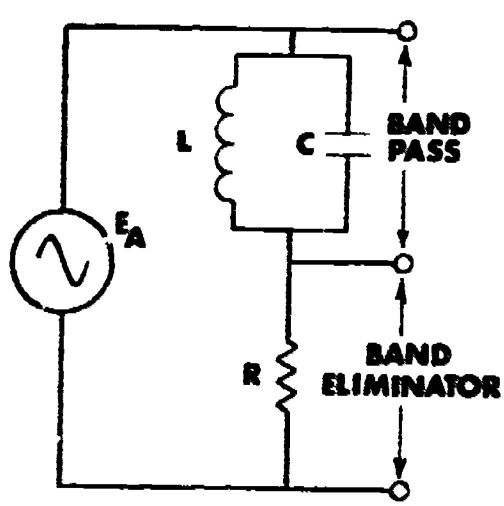
Figure 2.



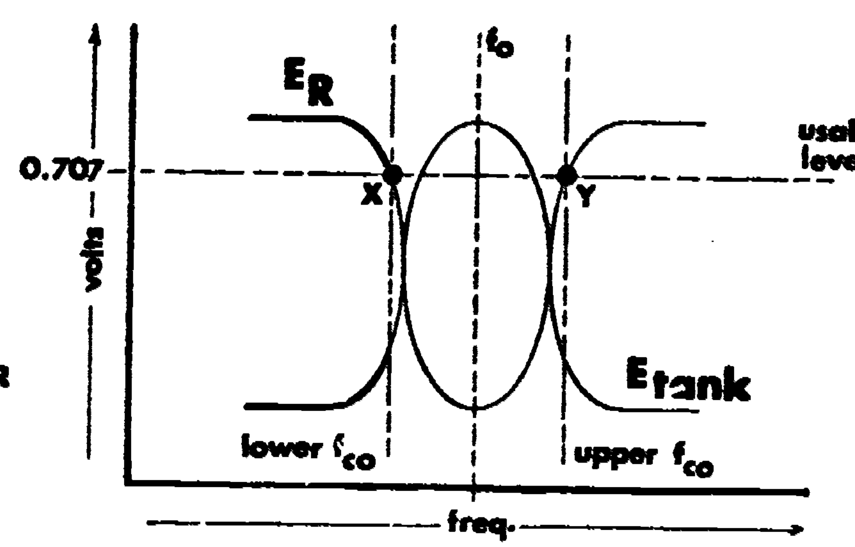
Notice that there is no appreciable change in circuit bandwidth when the circuit is tuned. This is because the value of Q_{ckt} changes in the same direction as f_o; consequently, the bandwidth remains essentially constant.

11. RLC (Parallel L-C Tank) Band-Pass/Band-Eliminator Filter Circuits

Circuit Diagram:



Voltage Drop vs. Frequency Curves:



Analysis of RLC filter circuits (represented by the diagram above) when the frequency (f) of the applied voltage (E_a) is increased from a low value to a higher value.

1. At low frequencies, the "frequency sensitive" (reactive) components have the following relative values: (L) and (C) are connected in parallel; therefore, $E_L = E_C$. The ohmic value of X_L is small, so I_L should be large. The value of X_C is large, so I_C should be small. (The value of I_L is greater than I_C.)

2. Effect of an increase in (f) on the "frequency sensitive" (reactive) components:

Inductor: $2\pi f\uparrow L\rightarrow = X_L\uparrow \quad \frac{E_L}{X_L\uparrow} = I\downarrow$ Capacitor: $\frac{1}{2\pi f\uparrow C\rightarrow} = X_C\downarrow$

$$\frac{E_C}{X_C\downarrow} = I_C\uparrow$$

3. Effect of changes in value of I_L and I_C on total circuit current (I_T), also called I_{line}: For the circuit arrangement shown, the value o[f] is equal to the difference between the values of I_L and I_C $(I_L - I_C) = I_T$ (or I_{line})

$$(I_L\downarrow - I_C\uparrow) = I_T\downarrow$$

As (f) of E_a is increased towards the lower f_{co}, the value of $(I_L - I_C)$ decreases; therefore, I_T must decrease. Since $I_R = I_T$, the value of I_R must also decrease.

4. Since the value of I_T is decreasing, the value of total circuit impedance (Z) must be increasing. The value of (R) has not changed, so the increase in (Z) must be caused by the L-C tank.

5. Effect of change in total circuit current (I_T) on circuit voltage drops:

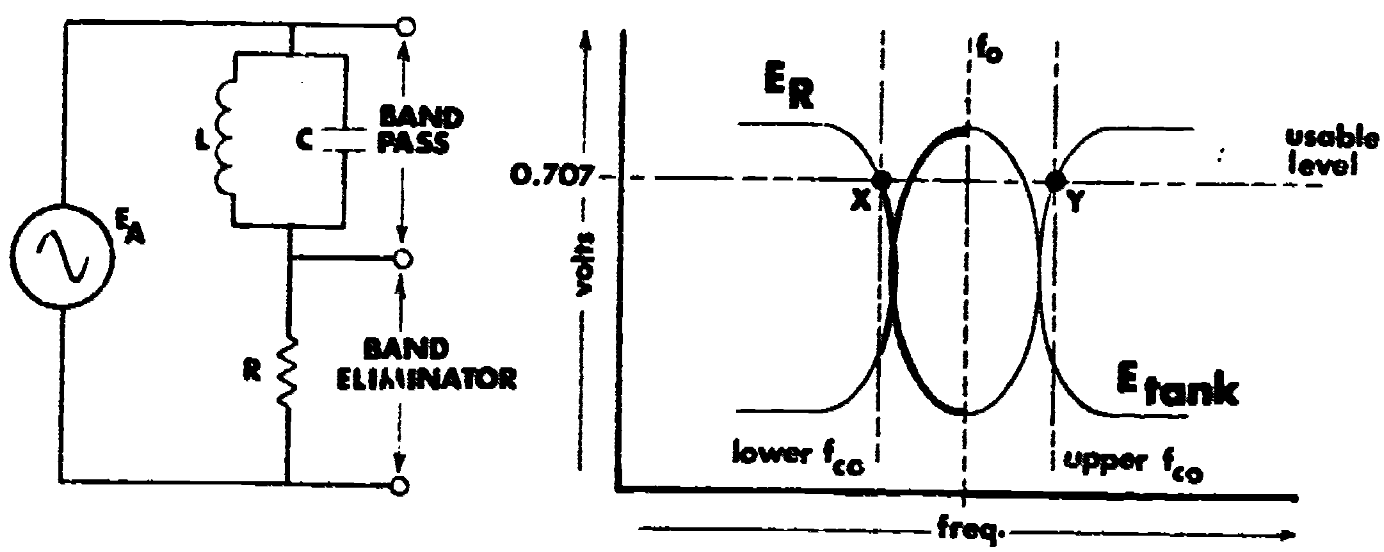
Resistor $I_T\downarrow \times R\rightarrow = E_R\downarrow$ (decreases)*

L-C Tank $I_T\downarrow \times Z_{Tank}\uparrow = E_{Tank}\uparrow$ (increases)*

*The vector sum of E_R and E_{Tank} must be equal to the value of E_a. Note that the direction of change in voltage drop across the L-C tank "follows" the change in value of Z_{Tank}.

When the frequency of E_a is increased to the lower cut-off frequency, $E_R = E_{Tank}$. (Point "X" on the voltage curves.) Note: For all frequencies of E_a, below f_o, the value of X_L is less than X_C; therefore, the value of I_L is greater than I_C. The circuit appears inductive to the source. I_T lags E_a. To see the equivalent series circuit, cover the capacitor (C) of the circuit diagram.

Circuit Diagram: Voltage Drop vs. Frequency Curves:



Analysis of RLC filter circuits (represented by the diagram above) when the frequency (f) of the applied voltage (E_a) is increased from the lower f_{co} to f_o. (f_o) designates the "resonant" frequency of the L-C tank. (f_o) is the frequency of the applied voltage which causes the value of X_L to have the same ohmic value as X_C. Note: Any frequency of E_a can be a resonant frequency depending upon the value of (L) and (C) of the L-C tank.

When the frequency (f) of the applied voltage is adjusted to the frequency which causes "resonance" the following circuit conditions exist:

1. Reactance: $X_L = X_C$ (L) and (C) are connected in parallel; $E_L = E_C$.

2. Current: $\frac{E_L}{X_L} = \frac{E_C}{X_C} = I_L = I_C = I_{circulating}$

Within the L-C tank, the circulating current (I_{circ}) is maximum. (Limited only by the resistance in the tank.)

(I_L - I_C) = I_T at f_o, I_L = I_C; therefore, the value of (I_L - I_C) = 0.

Total circuit current (I_T) is <u>minimum</u>. (Note: The minimum value of I_T depends on the value of Q_{ckt})

3. Impedance: When the tank is made resonant, it offers maximum opposition (Z) to circuit current.

Total circuit impedance (Z) is maximum.

4. Circuit voltage drops:

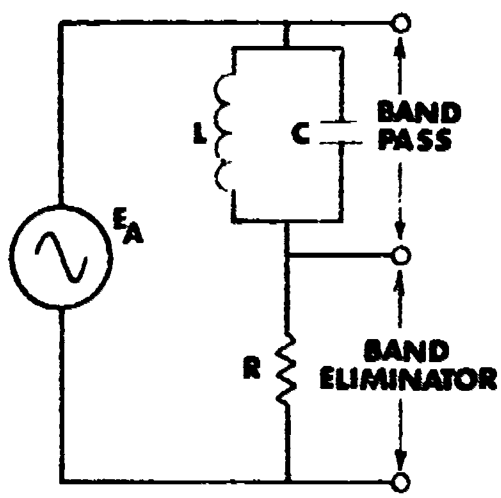
Resistor: $I_T(min) \times R = E_R$ (minimum)

Inductor: $I_{circ}(max) \times X_L = E_L$ (maximum)

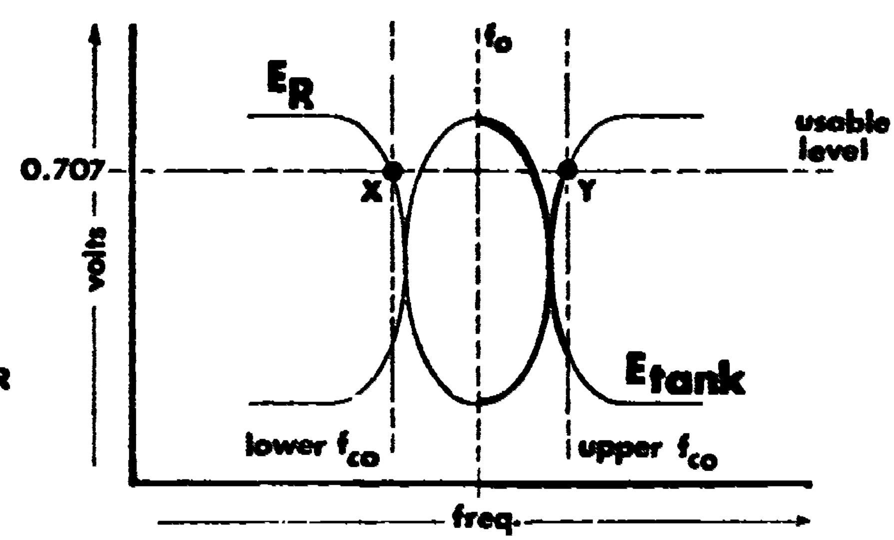
Capacitor: $I_{circ}(max) \times X_C = E_C$ (maximum)

L-C Tank: $I_T(min) \times Z_{Tank}(max) = E_{Tank}$ (maximum)

Circuit Diagram:



Voltage Drop vs. Frequency Curves:



Analysis of RLC filter circuits (represented by the diagram when the frequency (f) of the applied voltage (E_a) is increased from f_o to the upper f_{co}.

1. When the circuit is resonant, the following conditions exist: $X_L = X_C$; (L) and (C) are connected in parallel, so $E_L = E_C$. $I_L = I_C$ which is also the value of I_{circ}. (Z) is <u>maximum</u>; (I_T) is <u>minimum</u>. E_{Tank} is maximum; E_R is <u>minimum</u>.

2. Effect of an increase in (f) on the "frequency sensitive" (reactive) components:

Inductor: $2\pi f\uparrow L\rightarrow = X_L\uparrow$ $\frac{E_L}{X_L\uparrow} = I_L\downarrow$ Capacitor: $\frac{1}{2\pi f\uparrow C\rightarrow} = X_C\downarrow$

$$\frac{E_C}{X_C\downarrow} = I_C\uparrow$$

3. Effect of changes in value of I_L and I_C on total circuit current (I_T), also called I_{line}: For the circuit arrangement shown, the value of I_T is equal to the <u>difference</u> between the values of I_L and I_C. $(I_L - I_C) = I_T$ (or I_{line})

$$(I_L\downarrow - I_C\uparrow) = I_T\uparrow$$

As (f) of E_a is increased, from f_o towards the upper f_{co}, I_C becomes greater than I_L. The value of $(I_L - I_C)$ increases; therefore, I_T must increase. Since $I_R = I_T$, the value of I_R must also increase.

4. Since the value of I_T is increasing, the value of total circuit impedance (Z) must be decreasing. The value of (R) has not changed, so the decrease in (Z) must be caused by the L-C tank.

5. Effect of change in total circuit current (I_T) on circuit voltage drops:

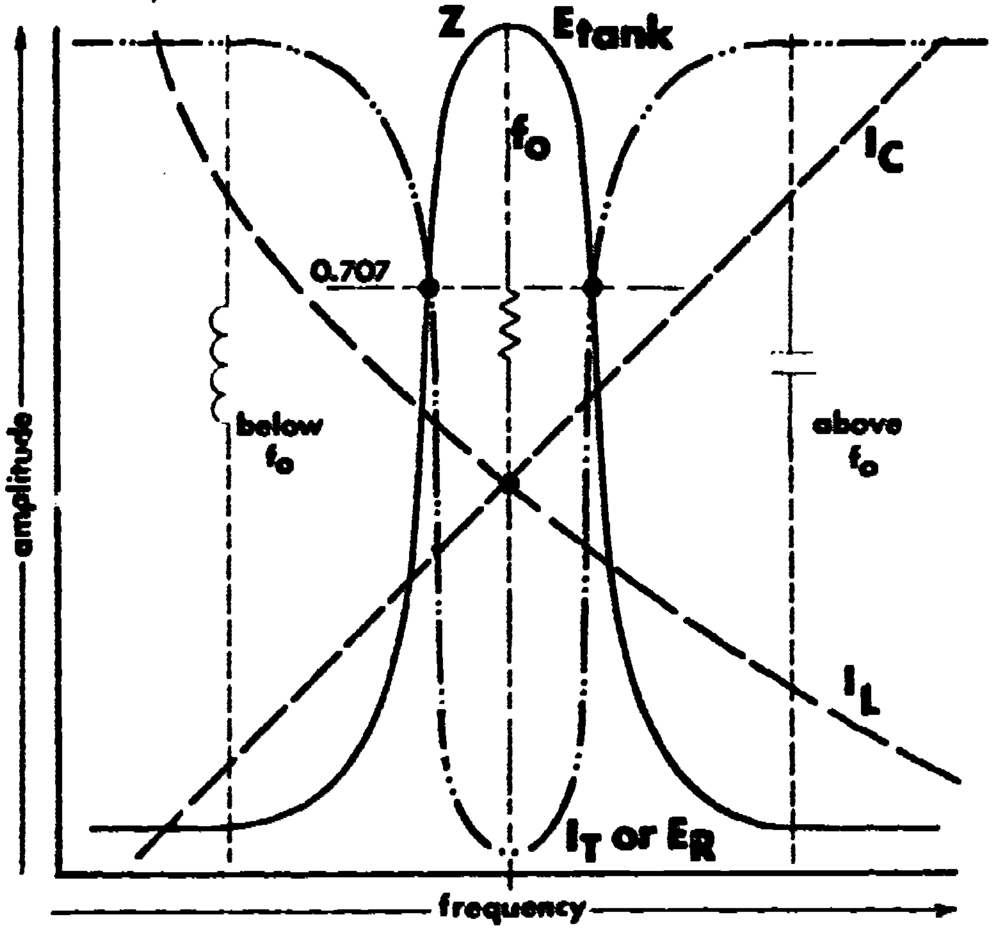
Resistor: $I_T\uparrow \times R\rightarrow = E_R\uparrow$ (increases)*

L-C Tank: $I_T\uparrow \times Z_{Tank}\downarrow = E_{Tank}\downarrow$ (decreases)*

*The vector sum of E_R and E_{Tank} must be equal to the value of E_a. Note that the direction of change in voltage drop across the L-C tank still "follows" the change in value of Z_{Tank}.

When the frequency of E_a is increased to the upper cut-off frequency, $E_R = E_{Tank}$. (Point "Y" on the voltage curves.) Note: For all frequencies, of E_a <u>above</u> f_o, the value of X_C is less than X_L; therefore, the value of I_C is greater than I_L. The circuit appears <u>capacitive</u> to the source: I_T <u>leads</u> E_a. To see the <u>equivalent series circuit</u>, cover the inductor (L) of the circuit diagram.

12. Summary of Circuit Conditions:



Circuit conditions <u>below</u> resonance:

1. The ohmic value of X_C is larger than X_L.
2. The value of I_L is larger than I_C. $(I_L - I_C) = I_T$
3. I_T is a large value (due to large value of I_L).
4. Z is a relatively small value.
5. E_R is large. E_{Tank} is small (due to small value of Z_{Tank}).
6. The circuit appears inductive to the source: I_T lags E_a.

Circuit conditions at resonance:

1. The ohmic value of X_C is equal to X_L.
2. The value of I_L is equal to I_C. $(I_L - I_C) = 0$.
3. I_T is minimum. (Minimum value depends on Q_{ckt}).
4. Z_{Tank} is maximum.
5. E_{Tank} is maximum. E_R is minimum (due to minimum value of I_T).
6. The circuit appears resistive to the source: I_T in phase with E_a. (L-C tank acts like a resistance with a large ohmic value.)

Circuit conditions above resonance:

1. The ohmic value of X_L is larger than X_C.
2. The value of I_C is larger than I_L. $(I_C - I_L) = I_T$.
3. I_T is a large value (due to large value of I_C).
4. Z is a relatively small value.
5. E_R is large. E_{Tank} is small (due to small value of Z_{Tank}).
6. The circuit appears capacitive to the source: I_T leads E_a.

Miscellaneous Circuit Characteristics:

Resonant frequency: $f_o = \dfrac{1}{2\pi\sqrt{LC}}$ or $\dfrac{.159}{\sqrt{LC}}$

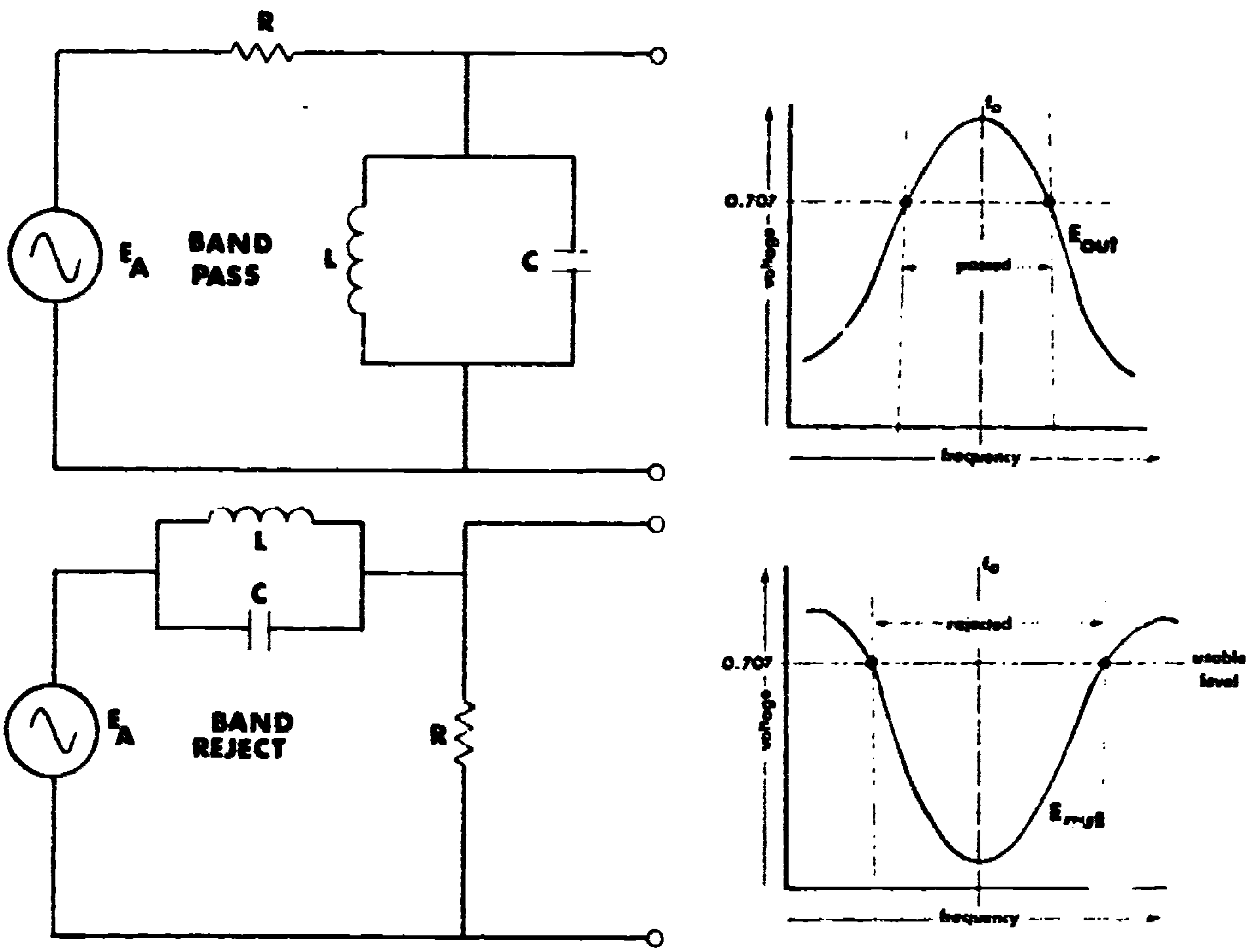
Effect of changing the value of (L) or (C) on f_o: See page 321.
Effect of "tuning": See page 327.

Effect of Q_{ckt} on bandwidth: See page 325.

Possible arrangements for parallel RLC filter circuits:

Circuit Diagrams: Response Curves:

(E_{out} vs. f)



WAVE FORMS, VECTORS AND PHASE RELATIONSHIPS

LEARNING OBJECTIVES:

Recognize the relationship between in-phase and out-of-phase a-c voltage waveforms and their corresponding diagrams in terms of amplitude, phase, magnitude and direction, given statements, written problems, waveform diagrams or vector diagrams.

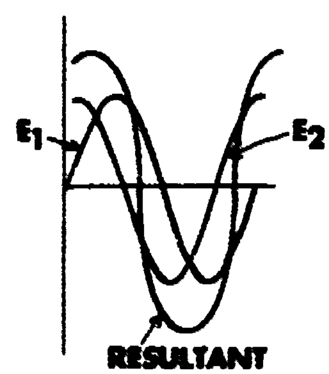
REFERENCES:

NAVPERS 93400A-1A, Fundamentals of Electronics, pages 156-160.

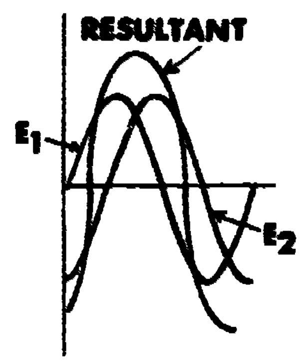
Application Items:

1. Identify the phase relationship of E1 with respect to E2 and the phase relationship of the resultant waveform with respect to E1 or E2 in terms of leading, lagging, or in-phase for the following:

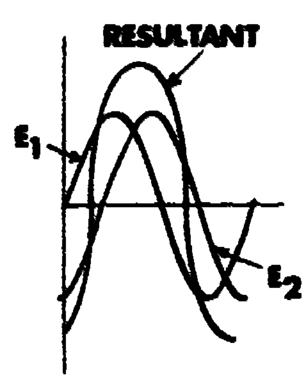
a. E1 is ________ E2, the resultant is ________ E1.



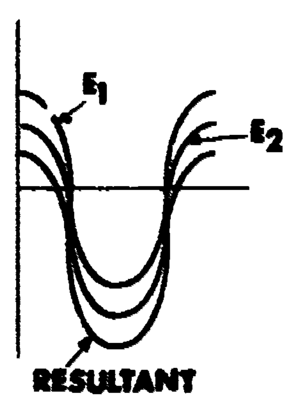
b. E1 is ________ E2, the resultant is ________ E2.



c. E1 is ________ E2, the resultant is ________ E1.

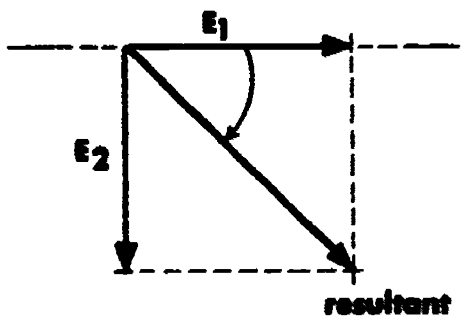


d. E1 is ________ E2, the resultant is ________ E2.

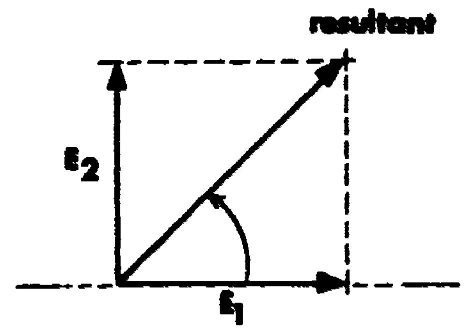


2. Identify the phase relationship of E1 with respect to E2 and the phase relationship of the resultant vector with respect to E1 or E2 in terms of leading, lagging, or in-phase for the following:

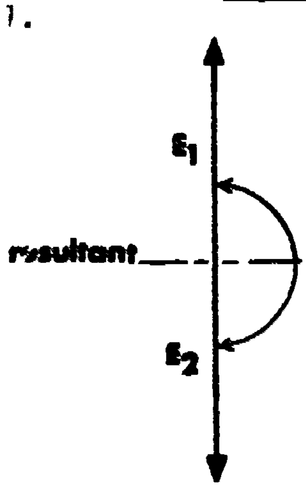
a. E1 is __________ E2, the resultant is __________ E1.



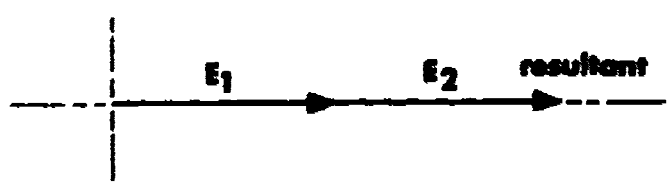
b. E1 is __________ E2, the resultant is __________ E2.



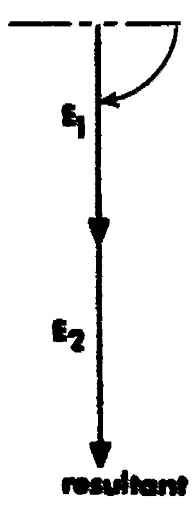
c. E1 is __________ E2, the resultant is __________ E1.



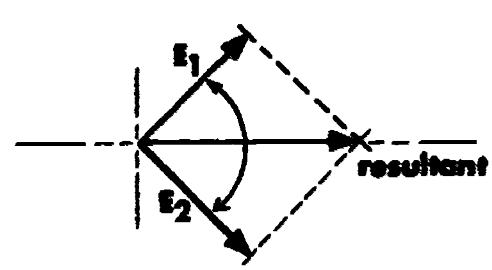
d. E1 is __________ E2, the resultant is __________ E2.



e. E1 is __________ E2, the resultant is __________ E2.

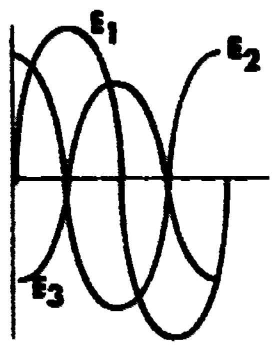


f. E1 is __________ E2, the resultant is __________ E1.

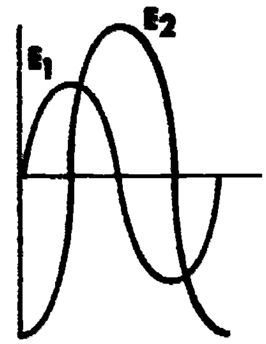


3. Match the waveform diagrams with their corresponding vector diagrams. The resultant waveform has been omitted for clarity. (Hint: Observe the difference in amplitude of the various waveforms.)

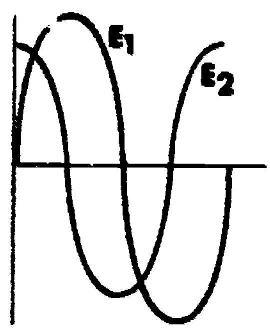
a. ____



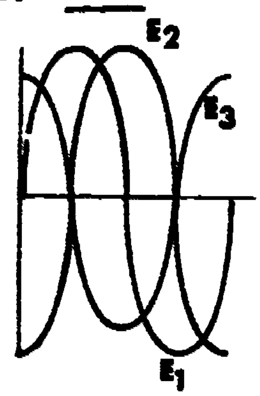
b. ____



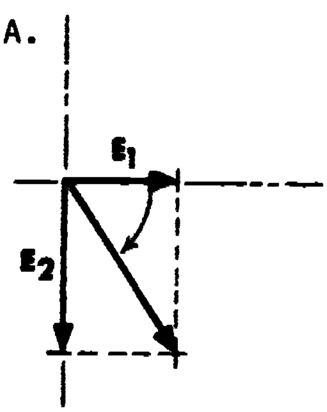
c. ____



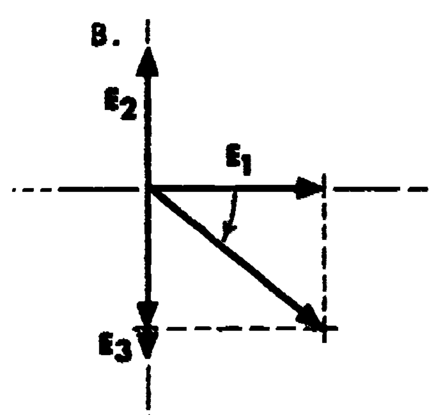
d. ____



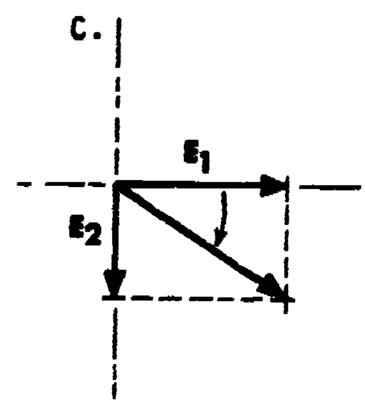
A.



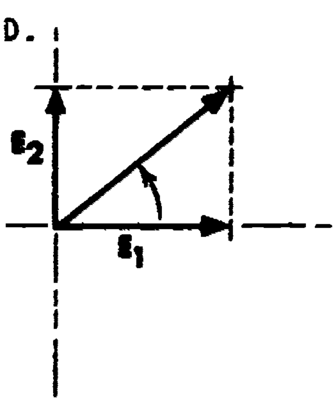
B.



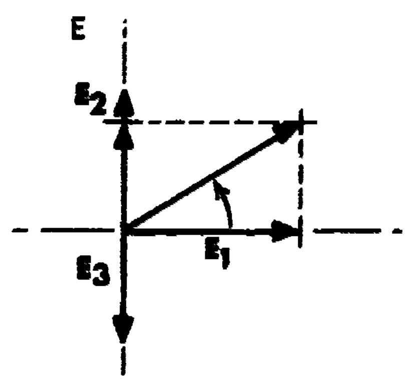
C.



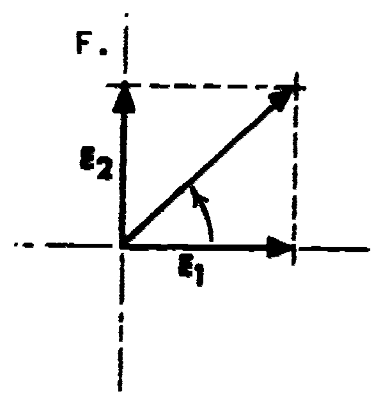
D.



E



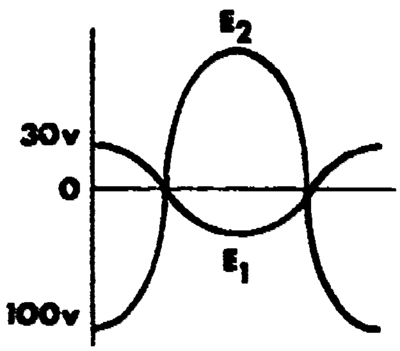
F.

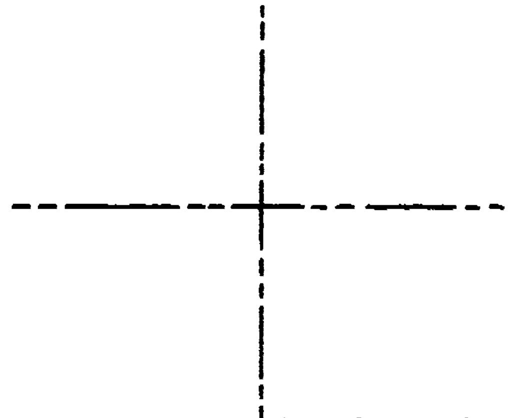


4. Solve the following problems for the quantities indicated:

a. Effective value of the resultant voltage: ____________________

Draw a vector diagram that shows E1, E2 and the resultant vector.

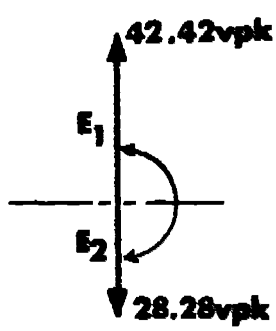


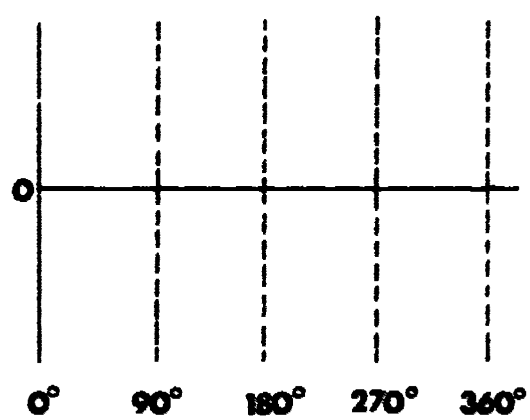


If the peak value of E1 was increased by 70 volts, what would be the magnitude of the resultant ____________________.

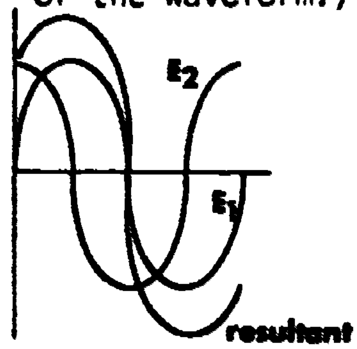
b. Effective value of the resultant voltage? ____________________.

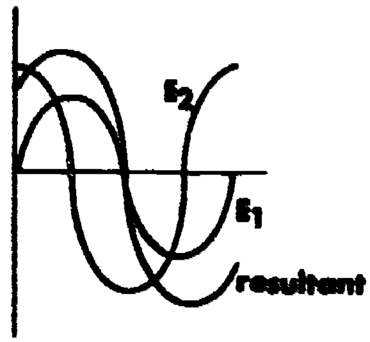
Draw a waveform that shows E1, E2 and the resultant waveform.

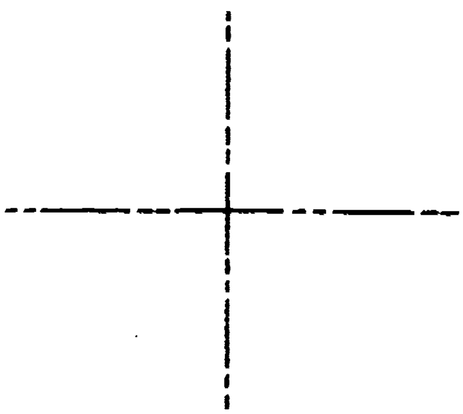


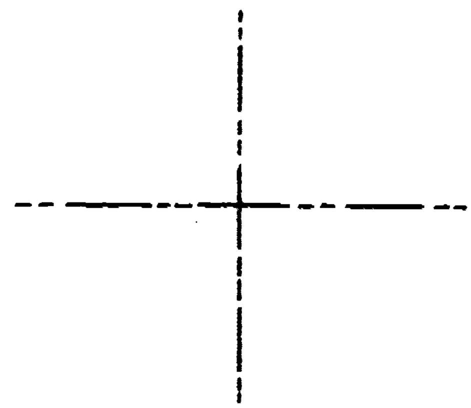


5. Draw the vector diagrams that represent each of the quantities of the waveform illustrated below: (Show relative amplitude of the waveform.)

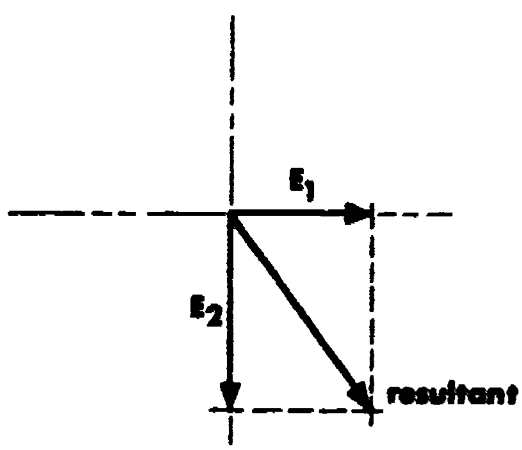


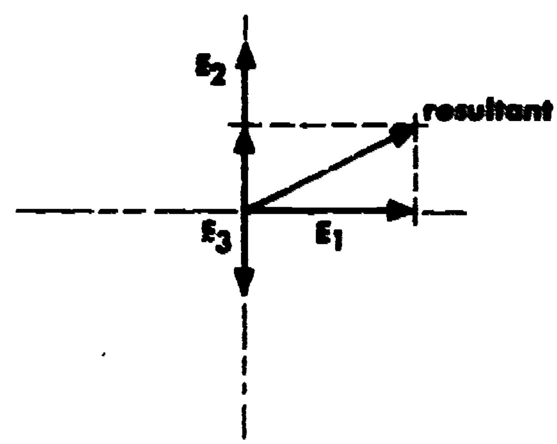


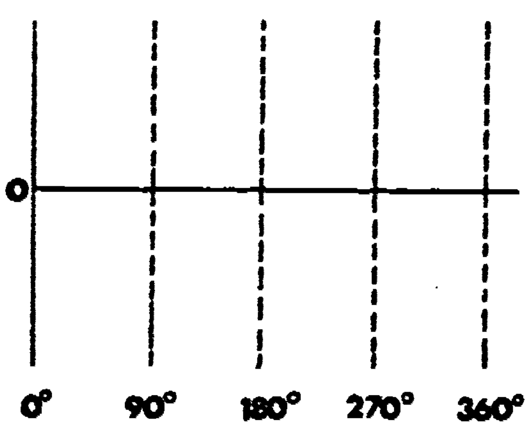


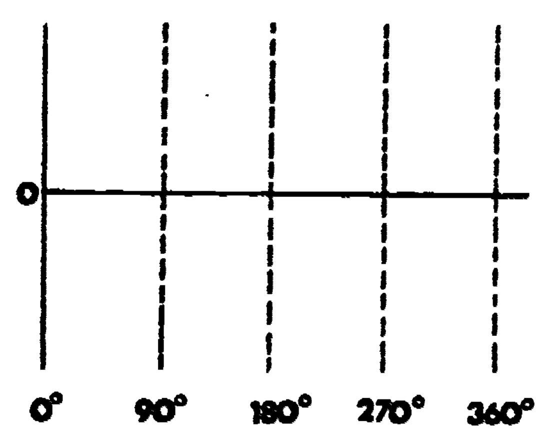


6. Draw the waveform diagrams that are represented by the vector diagrams shown. (Show relative magnitude of vectors.)

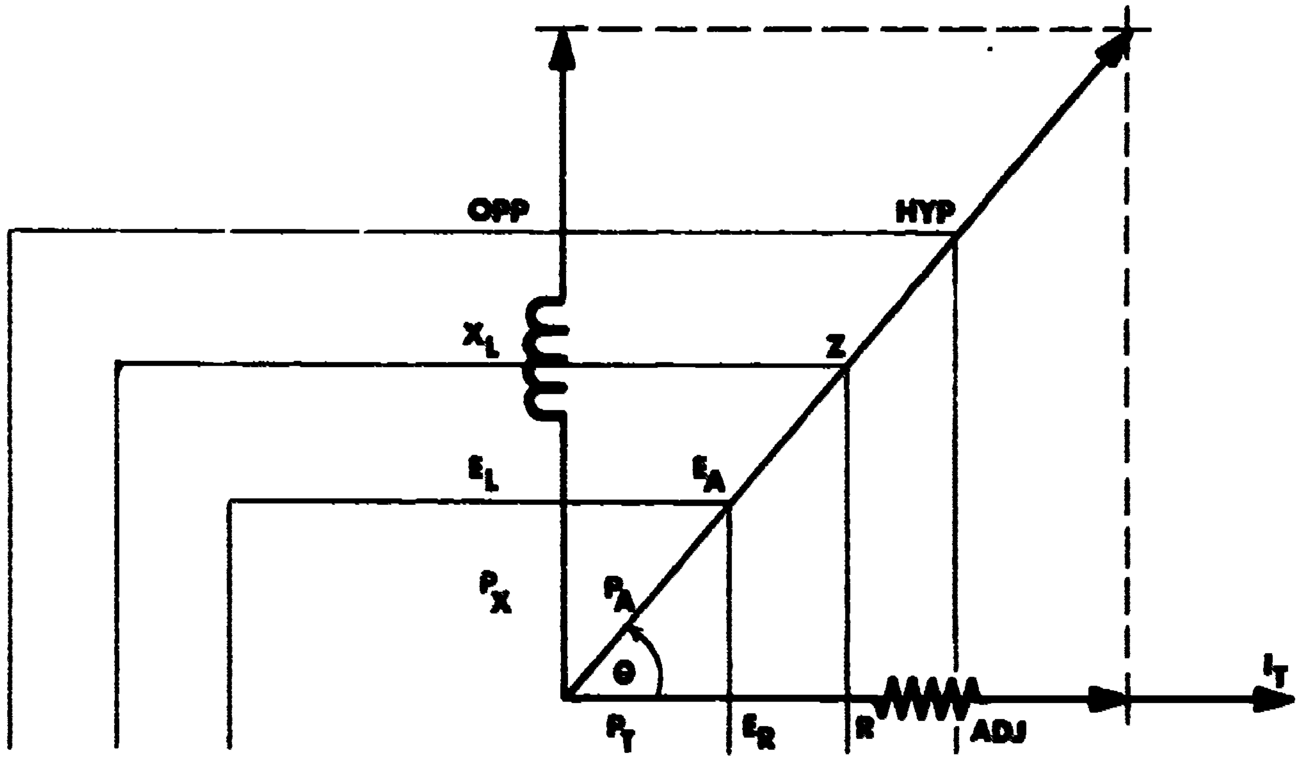








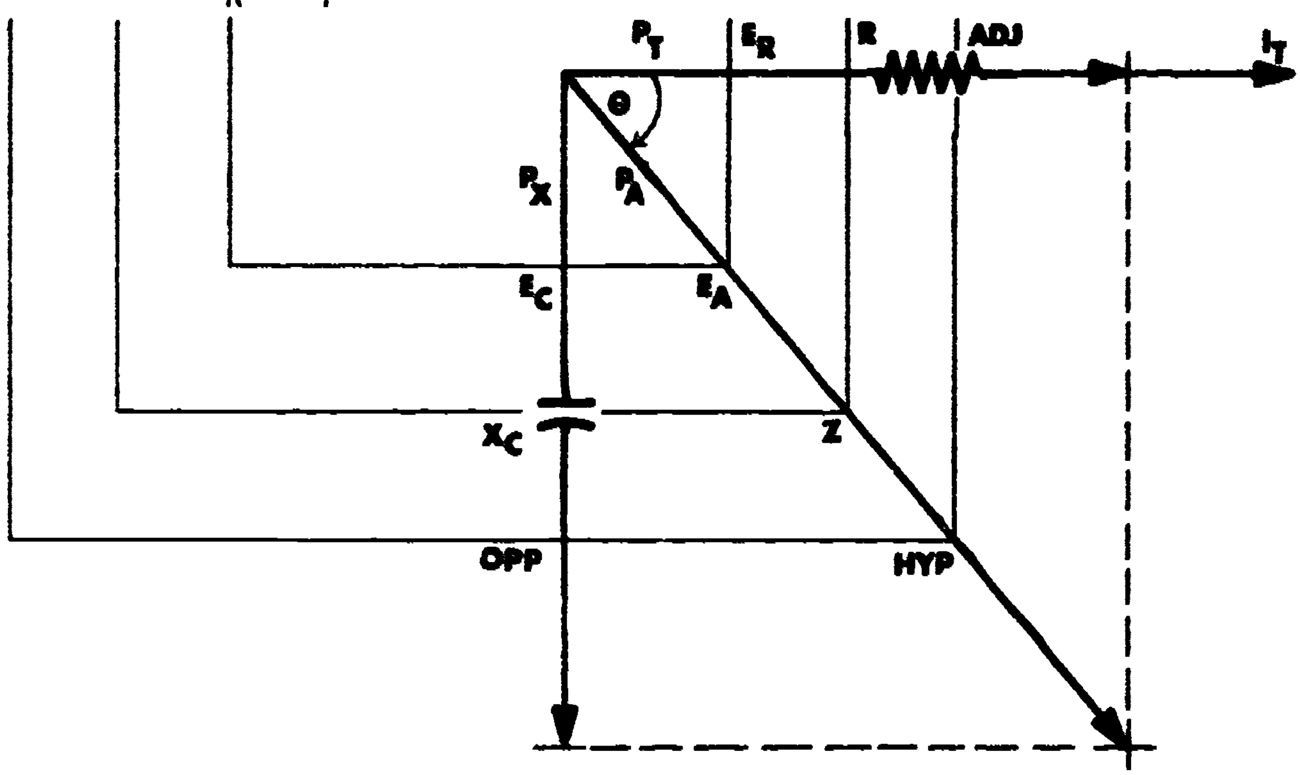
SERIES CIRCUITS



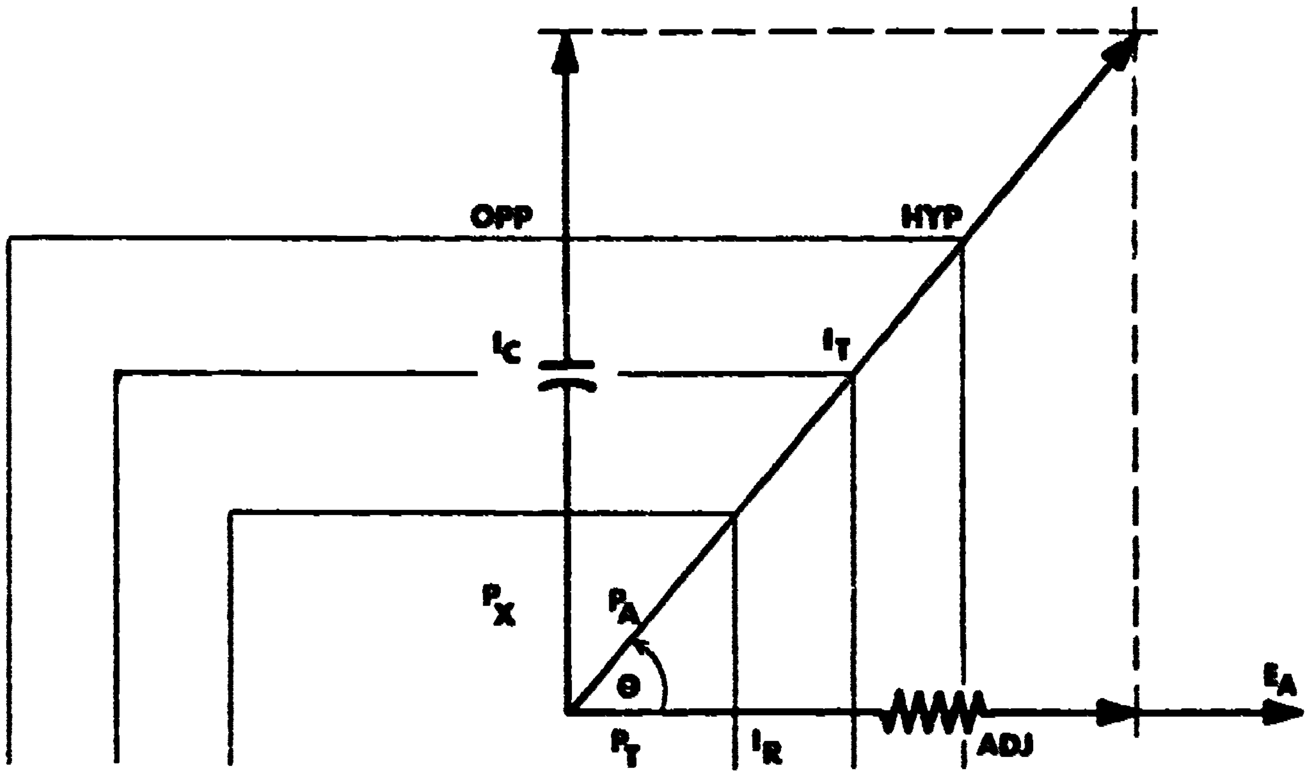
$$\text{SIN} = \frac{X}{Z} = \frac{E_x}{E_A} = \frac{P_x}{P_A} = \frac{\text{OPP}}{\text{HYP}}$$

$$\text{COS} = \frac{R}{Z} = \frac{E_R}{E_A} = \frac{P_T}{P_A} = \frac{\text{ADJ}}{\text{HYP}}$$

$$\text{TAN} = \frac{X}{R} = \frac{E_x}{E_R} = \frac{P_x}{P_T} = \frac{\text{OPP}}{\text{ADJ}}$$



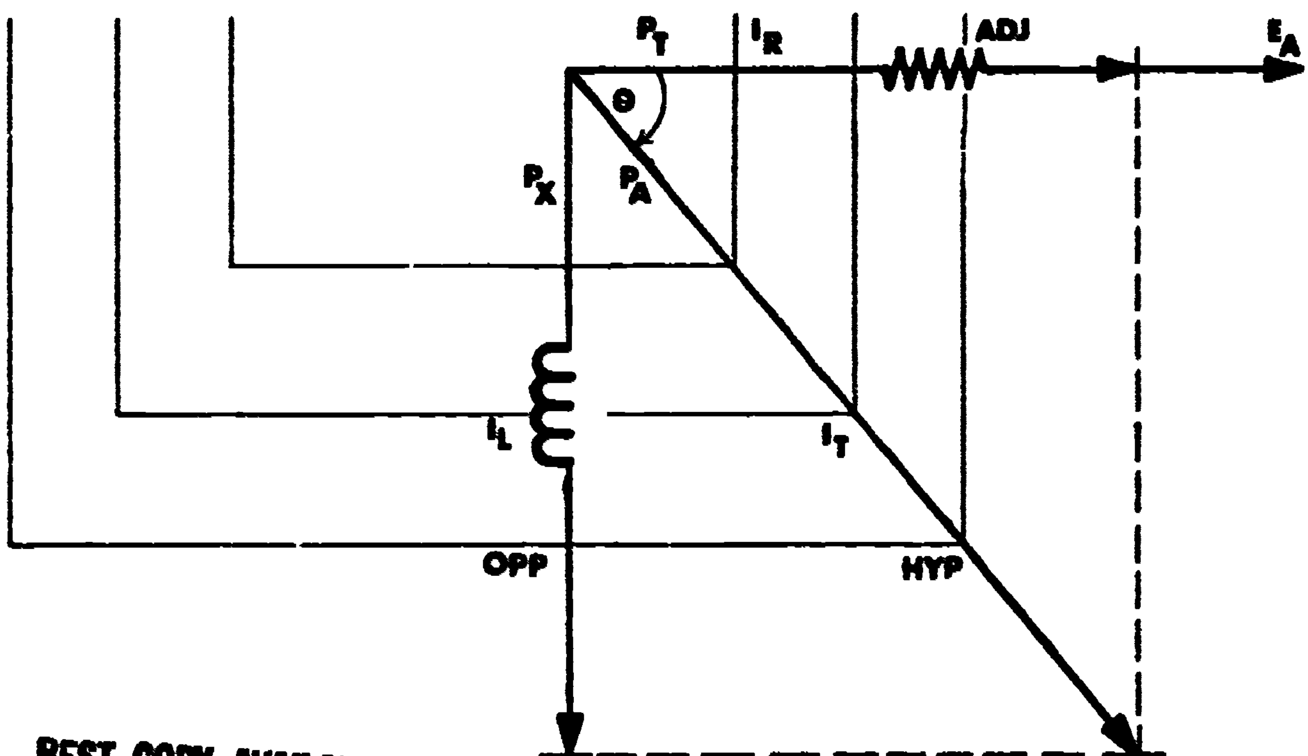
PARALLEL CIRCUITS



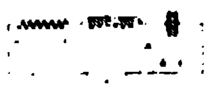
$$\frac{OPP}{HYP} = \frac{I_X}{I_T} = \frac{P_X}{P_A}$$

$$\frac{ADJ}{HYP} = \frac{I_R}{I_T} = \frac{P_T}{P_A}$$

$$\frac{OPP}{ADJ} = \frac{I_X}{I_R} = \frac{P_X}{P_T}$$

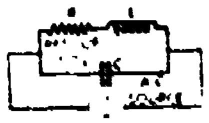


SERIES-RESONANT CIRCUITS



1. The coil, the capacitor and the AC voltage source are all in series.
2. Resonance occurs when the reactance of L is equal to the reactance of C.
3. At resonance, source current is a maximum (very high).
4. At resonance, a series resonant circuit acts like a resistor of low ohmic value.
5. At resonance, the voltages across L and C are equal in magnitude by 180 degrees out of phase with each other.
6. At resonance, the same current flows through the entire circuit.
7. At resonance, the voltage across either L or C may be greater than that of the source, giving resonant voltage step-up.
8. At resonance, increasing the value of coil resistance R lowers the circuit current, thereby lowering the resonant voltage step-up.
9. Off resonance, the circuit acts like that part which has the higher reactance.
   a. Increasing C above its at-resonance value makes the circuit act like a coil.
   b. Reducing C below its at-resonance value makes the circuit act like a capacitor.
   c. Increasing L above its at-resonance value makes the circuit act like a coil.
   d. Reducing L below its at-resonance value makes the circuit act like a capacitor.
   e. Applying a higher frequency than the resonant one makes the circuit act like a coil.
   f. Applying a lower frequency than the resonant one makes the circuit act like a capacitor.
10. The product LC is constant for any given resonant frequency.
11. Increasing L or increasing C lowers the resonant frequency.
12. Decreasing L or decreasing C raises the resonant frequency.
13. The Q factor of the circuit is essentially equal to the coil reactance divided by the AC resistance of the coil.

PARALLEL-RESONANT CIRCUITS



1. The coil, the capacitor and the AC voltage source are all in parallel.
2. Resonance occurs when the reactance of L is equal to the reactance of C.
3. At resonance, source current is a minimum (very low).
4. At resonance, a parallel resonant circuit acts like a resistor of high ohmic value.
5. At resonance, the voltages across L, C, and the source [illegible]e all the same in magnitude and [illegible]e.
6. At resonance, [illegible] currents through L and C are essentially equal in magnitude but are 180 degrees out of phase.
7. At resonance, the current through either L or C is greater than the source current, giving resonant current step-up.
8. At resonance, increasing the value of coil resistance R increases line current, thereby lowering the resonant current step-up.
9. Off resonance, the circuit acts like that part which has the lower reactance.
   a. Increasing C above its at-resonance value makes the circuit act like a capacitor.
   b. Reducing C below its at-resonance value makes the circuit act like a coil.
   c. Increasing L above its at-resonance value makes the circuit act like a capacitor.
   d. Reducing L below its at-resonance value makes the circuit act like a coil.
   e. Applying a higher frequency than the resonant one makes the circuit act like a capacitor.
   f. Applying a lower frequency than the resonant one makes the circuit act like a coil.
10. The product LC is constant in any given resonant frequency.
11. Increasing L or increasing C lowers the resonant frequency.
12. Decreasing L or decreasing C raises the resonant frequency.
13. The Q factor of the circuit is essentially equal to the coil reactance divided by the AC resistance of the coil.

FORMULA SHEET

$E_T = E_1 + E_2 + E_3 \ldots E_n$

$R_T = R_1 + R_2 + R_3 \ldots R_n$

$P_T = P_1 + P_2 + P_3 \ldots P_n$

$E_T = E_1 = E_2 = E_3 \ldots E_n$

$I_T = I_1 + I_2 + I_3 \ldots I_n$

$I_T = I_1 = I_2 = I_3 \ldots I_n$

$R_{EQ} = \frac{R_1 \cdot R_2}{R_1 + R_2}$ $R_{EQ} = \frac{R}{N}$

$R_{EQ} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots \frac{1}{R_n}}$

$I = \frac{Q}{T}$ $I = \frac{E}{R}$ $E = IR$ $R = \frac{E}{I}$

$P = \frac{W}{T}$ $P = IE$ $P = I^2R$ $P = \frac{E^2}{R}$

$L_T = L_1 + L_2 + L_3 \ldots L_n$

$L_T = \frac{L_1 \cdot L_2}{L_1 + L_2}$

$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \ldots \frac{1}{L_n}}$

$TC = \frac{L}{R}$ $X_L = 2\pi fL$

$I = \frac{E}{X_L}$ $E = I \cdot X_L$ $X_L = \frac{E}{I}$

$P_X = IE$ $P_X = I^2X_L$ $P_X = \frac{E^2}{X_L}$

$C = \frac{Q}{E}$ $C_T = \frac{C}{N}$ $C_T = \frac{C_1 \cdot C_2}{C_1 + C_2}$

$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots \frac{1}{C_n}}$

$C_T = C_1 + C_2 + C_3 \ldots C_n$

$T.C. = RC$ $X_C = \frac{1}{2\pi fC}$ $X_C = \frac{.159}{fC}$

$I = \frac{E}{X_C}$ $E = IX_C$ $X_C = \frac{E}{I}$

$P_X = IE$ $P_X = I^2X_C$ $P_X = \frac{E^2}{X_C}$

$V/T = \frac{E_p}{N_p} = \frac{E_s}{N_s}$ $\frac{E_p}{E_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$

$P_p = P_S$ $E_pI_p = E_sI_s$

$\%$ of efficiency $= \frac{\text{OUTPUT}}{\text{INPUT}} \times 100$

$I_T = \frac{E_A}{Z_T}$ $E_A = I_TZ_T$ $Z_T = \frac{E_A}{I_T}$

$PA = E_AI_T$ $PA = I_T^2 . Z_T$

$P_t = E_A . I_T(\cos \underline{/\theta})$ $F = \cos \underline{/\theta} = \frac{P_t}{P_A}$

$Z = R + jX_L$ $Z = R - jX_C$

$Z = \sqrt{R^2 + X^2}$ $R = Z(\cos \underline{/\theta})$

$X = Z(\sin \underline{/\theta})$ $f_{co} = \frac{R}{2\pi L}$

$f_o = \frac{1}{2\pi RC}$ $f_o = \frac{1}{2\pi\sqrt{LC}}$ $f_o = \frac{.159}{\sqrt{LC}}$

$TAN \underline{/\theta} = \frac{E_L}{E_R} = \frac{X_L}{R} = \frac{O}{A}$

$SIN \underline{/\theta} = \frac{E_L}{E_A} = \frac{X_L}{Z} = \frac{O}{H}$

$COS \underline{/\theta} = \frac{E_R}{E_A} = \frac{R}{Z} = \frac{A}{H}$

$Q_{COIL} = \frac{P_x}{P_t} = \frac{X_L}{R_{AC}}$ $BW = \frac{f_o}{Q}$

$I_T = I_R - jI_L$ $I_T = I_R + jI_C$

$I_T = (I_C - I_L)$ $I_{LINE} = I_T$

$TAN \underline{/\theta} = \frac{I_L}{I_R} = \frac{I_C}{I_R}$

$Q_{ckt} = \frac{P_x}{P_T} = \frac{X_L}{R_T}$