Chapter 16 ELECTRIC CIRCUITS

87-86

Observers of twentieth century technological progress have called the 1960's the era of electronic revolution. During this decade, entertainment equipment such as stereo, color television, and cassette tape recorders fell within the budget of the average family; and all segments of society became increasingly affected by the computer. For better or worse, there's simply no way to escape the changes brought about by progress in electronic technology. Whether in favor of or opposed to the directions our society has taken, you definitely should understand something about how these now everyday electronic devices work. You are probably aware that all electronic devices function by virtue of the unique properties of electric current; you are probably not aware of just how much else these various devices have in common. For instance, all electrical devices have a power source (often a battery), a number of interconnected elements (resistors, transistors, diodes, tubes, capacitors, etc.) and some kind of efficient conductor which connects the various devices (usually copper wire).

Electrical current flows only through closed loops or circuits. Thus, the elements which comprise electrical devices are always connected such that they form one or more circuits. The situation becomes complex because each circuit can be subdivided into a number of sub-circuits, each of which can in turn be subdivided, and so forth. Nonetheless, the basis for analysis of any electrical device is the CLOSED CIRCUITS, and it is through an understanding of simple circuits that one can come to grips with more complicated devices.

In this chapter you will learn to analyze basic circuits and the elements which make them up. You will see how and why the performance of an electrical circuit is determined by the manner in which the various elements of the circuit are connected together. This knowledge will not, of course, transform you into a design engineer or television repairer but will provide the basis from which you can begin a detailed study of practical electronics. Even if you do not undertake a more detailed study, this chapter will still serve to make the complex world of electronics more understandable.

PERFORMANCE OBJECTIVES

After completing this chapter, you should:

1. be able to define current and potential difference and realize that current is stated in amperes (A) and potential difference in volts (V)

2. be able to state the relationship between the potential difference across the ends of an ohmic conductor and the current through it (Ohm's Law).

3. be able to define the ohm as a unit of resistance.

4. Solve problems involving Ohm's Law, $V = I R$, including examples with resistors in series and in parallel, which illustrate the conservation of energy and charge in simple circuits.

CHAPTER 16 STUDY GUIDE -1-

Read: Introduction page 325
Section 16-1 Electrical Work and Power page 326

a. The direction of the electric current in a circuit is defined as DIR. "+" CHARGES MOVE .

b. Batteries and power sources are identified by their Emf which is measured in volts which is a Joule per Coulomb .

c. Thus we see that a battery supplies ENERGY to charges that leave the battery (through a chemical oxidation-reduction reaction) when a completed CIRCUIT is created.

d. These charges flow through the circuit losing ENERGY until they return to the battery having lost ALL of the energy that they had received.

e. Optional...See Blue Text

1. The simple voltaic cell. page 415
2. The dry cell as a practical voltaic cell. page 418
3. Storage Cells page 420

f. We define the current (I) through a circuit as the # of CHARGES passing a given point in a given TIME. Thus I = Q/t .

g. Electrical energy supplied to a circuit can do WORK . Given the current (I) and the potential drop (V) we can calculate this energy as: W = qV = ItV .

h. The rate at which energy is supplied to a circuit is known as POWER , has unit called WATT which is a JOULE per SEC. Thus P = W/t = IV (in terms of I and V). We can also say that 1 watt = 1 VOLT x 1 AMP .

2. Problems: page 327: #1

3. Experiment: Ohm's Law (Experimental notes enclosed)

a. Read Study Notes: USE OF ELECTRICAL INSTRUMENTS. Anything unclear? If so seek help from instructor.

4. Read: Section 16-2 Resistors: Ohm's Law page 328

a. Under what conditions is the current through the conductor directly proportional to the voltage across it?

b. Ohm's Law is stated as: V = IR where (R) is ELECT. RESISTANCE measured in a unit called OHM which is a VOLT per AMP.

Problems: page 330: #4 #5 #6 #8
page 350: #33 #35

6. Optional...See enclosed sheet titled DESIGN OF AN ELECTRICAL APPLIANCE for the 110-VOLT CIRCUIT.

CHAPTER 16 STUDY GUIDE -2-

7. Read: Section 16-3 Alternating Currents page 331

   a. What is the frequency of the voltage we receive in our homes and here at school?

   b. When measuring A. C. voltage we measure the effective voltage (V_T) using an A. C. voltmeter. How is this voltage (V_E) related to the peak voltage (V_P)?

8. Problems: page 332: #9 #10

9. Optional...Read: Section 16-4 Semi-Conductors page 332

   a. Why is germanium called a semi-conductor?

   b. How does an increase in temperature affect the resistance of:

      1. a metallic conductor?

      2. a semi-conductor

   c. Thus to protect a semi-conductor that is placed in a circuit, a ____________ must be connected in series with it.

   d. When a piece of germanium doped with antimony is joined with a piece of germanium doped with indium a _______ _______ _______ is created.

   e. This diode has the capabilities of passing ____________ in one direction with little to none in the opposite direction.

10. Optional...Problems: page 335: #11 #12
    page 350: #36 #37

11. Optional...Read: Section 16-5 Zener Diode page 335

    a. Contrast the zener diode with the diode discussed in section 16-4.

12. Optional...Experiment 26 A Zener Diode Voltage Regulator page 62

13. Optional...Problems: page 336: #13 #14 #15 #16

14. Read: Section 16-7 Circuit Elements in Parallel & Series page 338

FOR ELEMENTS CONNECTED IN PARALLEL *

a. The potential drop across each component is the same as the EMF V_T. Thus:
V_T = V_1 = V_2 = V_3

b. The total current in the circuit I_T is equal to the sum of the currents in the components. Thus:
I_T = I_1 + I_2 + I_3

c. Knowing that I = V/R (Ohm's Law)
V_T/R_T = V_1/R_1 + V_2/R_2 + V_3/R_3

FOR ELEMENTS CONNECTED IN SERIES

a. The current through each component is the same as the current through the source I_T
I_T = I_1 = I_2 = I_3 .

b. The total potential drop in the circuit is the sum of the potential drop in each. Thus
V_T = V_1 + V_2 + V_3

c. Knowing that V = I R
$I_T R_T$ = $I_1 R_1$ + $I_2 R_2$ + $I_3 R_3$

add

d. Using the information in (a) we can say that the total or equivalent resistance R_T is:
$1/R_T$ = 1/R1 + 1/R2 + 1/R3

d. Using the information in (a) we can say that the total or equivalent resistance R_T is:
R_T = R1 + R2 + R3

e. For a parallel circuit, the total or equivalent resistance is (less than, equal to, or greater than) any resistance in the circuit.

* As you work through these items, you might wish to refer to and even complete work sheet items A and B as you go along. If not complete them when you have finished this section.

15. Problems: page 341: #20 #21 #22 #25
    page 351: #40 #41
    #35 Back

16. View computer program "CIRCUIT LAB". Then complete Work Sheet item C.

17. Optional...Using directions for CIRCUIT BOARD choose or design a circuit and then complete the circuit using the CIRCUIT BOARD.

18. Optional...Read: Section 16-8 Ammeters and Voltmeters page 342.

19. Optional...Examine enclosed study notes titled AMMETERS AND VOLTMETERS FROM A GALVANOMETER.

20. Optional...Obtain a lecture table meter.

    a. Visually examine the inner parts of the meter.

    b. Visually examine the various hookups available and the way the wires connect to the meter.

    c. Examine the devices labeled 25 volts, 5 volts, 1 volt and 25 millivolts. How are they connected to the meter?

    d. Examine the devices labeled 25 amps, 5 amps, 1 amp, 1 milliamps. How are they connected to the meter?

    e. Ask instructor for assistance as needed.

21. Optional...Read: Section 16-9 Internal Resistance of Batteries and Power Supplies page 343

22. Optional...Problems: page 344: #28 #29

23. Optional...Read: Section 16-10 A Neon Lamp page 345

24. Optional...Problems: page 347: #30 #31

25. Optional...Read: Section 16-11 A Simple Sweep Circuit page 348

26. Optional...Experiment 27 A Simple Sweep Circuit page 64

27. Complete enclosed written exercise. Then have it evaluated.

ANSWERS CHAPTER 16

(a) the direction '+' charges move or would move if able
(b) EMF, volts, joule, coulomb, (c) energy, circuit
(d) energy, all (f) number, charges, time, q/t (g) work, ItV
(h) power, watt, joule, sec, IV, amp, volt

2. (1) (a)(1) 1.7×10^{-2} A (2) 0.83 A (3) 6.3 A (b)(1) 1.4 kwh
(2) 9.0 kwh (3) 3.8 kwh

4. (a) As long as the temperature remains constant
(b) IR, electrical resistance, ohm, volt, amp

5. (4) (a) $P = I^2 R$ (b) $P = V^2/R$ (5) 240 ohm
(6) (a) $R = k\, l/A$ (b) ohm meter, (8) (a) (b) S.A.B.
(33) (a) 0.28 amp (max) (b) 0.64 of way
(35) (a) 0.48 amp (b) (c) (d) S.A.B.

7. (a) 60 Hz (b) $V_P = 1.41\ V_E$

8. (9) 730 watts (10) S.A.B.

9. (a) it has only average ability to conduct electrons (b)(1) increases
(b) (2) decreases (c) resistor (d) solid state diode (e) current

10. (11) (a) Iron = 0.6 A, Germanium = 0.15 A (b) 0.33 (dec), 3 (inc)
(12) (a) ammeter in circuit (b) 'a'=100 ohms, 'b' 5.0×10^6 ohms
(36) (37) S.A.B

13. (13) 0.032 watts (14) (a) decrease (b) stay nearly the same
(15) (a) $I_L = 0.01$ A $I_r = 0.044$ A $I_Z = 0.034$ A (16) increase

14. (a) $V_1 = V_2 = V_3$ $I_1 = I_2 = I_3$
(b) $I_1 + I_2 + I_3$ $V_1 + V_2 + V_3$
(c) $V_1/R_1 + V_2/R_2 + V_3/R_3$
$I_1R_1 + I_2R_2 + I_3R_3$
(d) $1/R_1 + 1/R_2 + 1/R_3$ $R_1 + R_2 + R_3$

Work Sheet Answers

A. $R_T = 18.1$ ohms, $A_1 = 4.42$ amps, $V_1 = V_2 = V_3 = 80$ volts, $A_2 = 2.29$ amp, $A_3 = 0.8$ amps, $A_4 = 1.3$ amps, counterclockwise

B. $R_T = 205$ ohms, $A = 0.88$ amps, $V_1 = 79.0$ volts, $V_2 = 35.1$ volts, $V_3 = 65.9$ volts, clockwise

15. (21) (a) 140 V, 200 V (b) 3.0×10^{-3} A (c) 5.0×10^{-3} A (d) 2.9×10^4 ohm
(22) (a) 7.0×10^{-3} A (b) 160 V (25) 17
(40) (a) 9.2 ohms (b) 2.06 ohms (41) S.A.B.

16. C. $A_1 = 8$ A, $A_2 = 4/9$ A, $A_3 = 1.33$ A, $A_4 = 8/9$ A
$A_5 = 5.33$ A, $A_6 = 1.78$ A, $A_7 = 16/27$ A, $A_8 = 1.19$ A
$A_9 = 3.56$ A, $A_{10} = 2.67$ A, $A_{11} = 5.33$ A, $V_1 = 80$ V
$V_2 = 40$ V, $V_3 = 37.33$ V, $V_4 = 24.89$ V, $V_5 = 28.44$ V
$V_6 = 14.22$ V, $V_7 = 17.78$ V

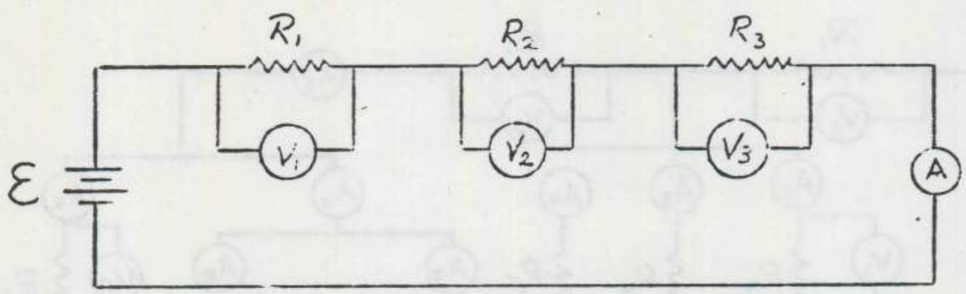
22. (28) (a) 1.36 A (b) 1.36 V
(29) (a) 2.5 A, 5.0 V (b) 1.43 A, 2.86 volts

24. (30) S.A.B. (31) 54 V

Champ

CHAPTER 16 Worksheet Circuit Analysis

Series Circuit



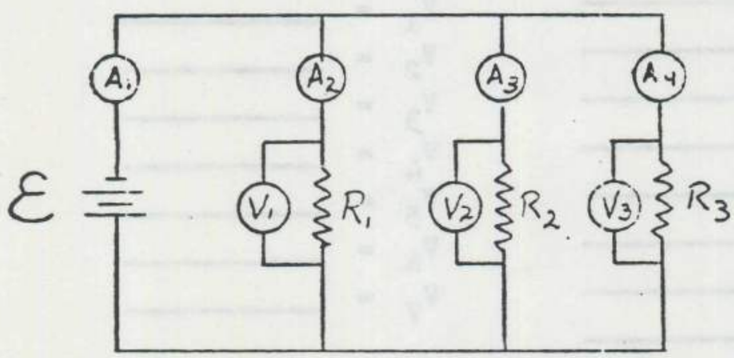
R_1 = 90 ohms R_2 = 40 ohms R_3 = 75 ohms EMF = 180 volts

1. R_T = 205 Ω 2. I_T = 0.88 Amp 3. V_1 = 79.0 v

4. V_2 = 35.1 v 5. V_3 = 65.9 v

6. Which way is the current flowing? clockwise

B. Parallel Circuit Analysis



R_1 = 35 ohms R_2 = 100 ohms R_3 = 60 ohms EMF = 80 volts

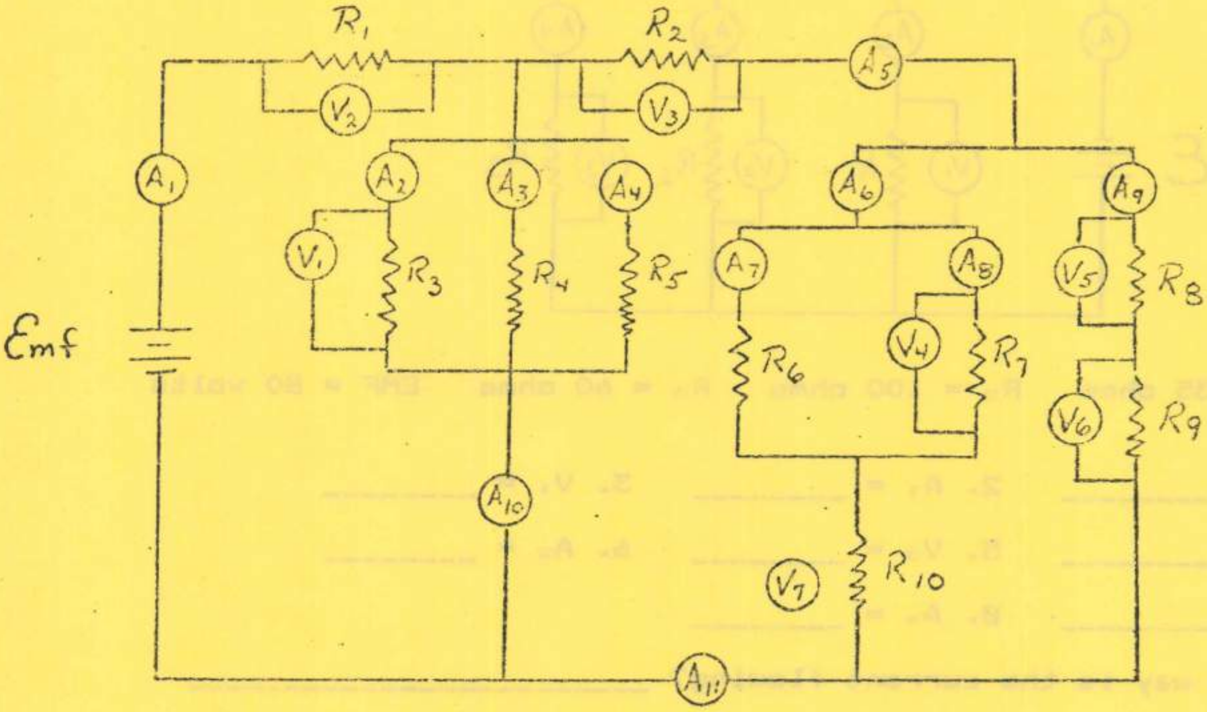
1. R_T = 18.1 Ω 2. I_T = 4.42 amp 3. V_1 = 80 v

4. V_2 = 80 v 5. V_3 = 80 v 6. I_1 = 2.29 Amp

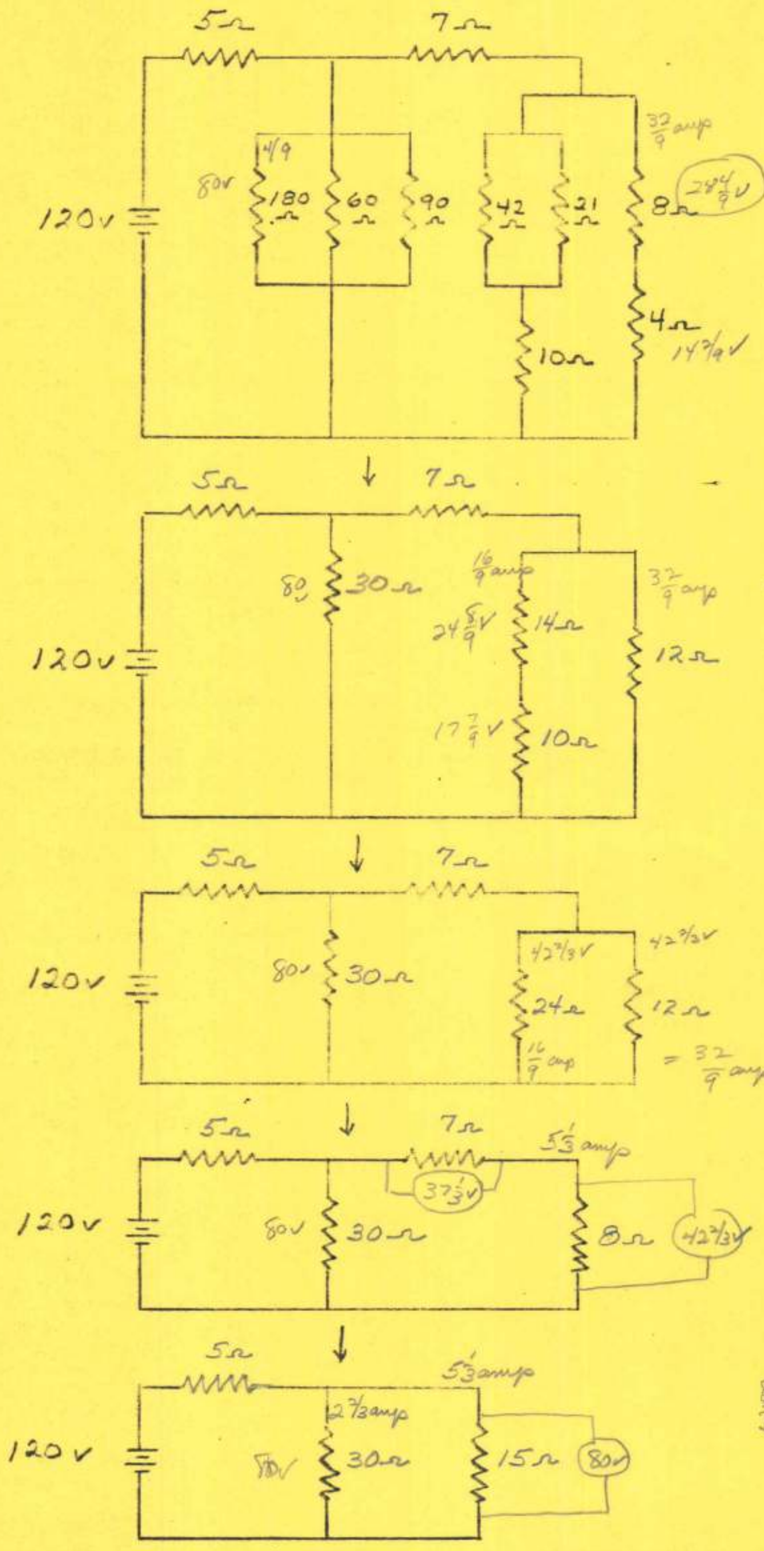
7. I_2 = 0.8 Amp 8. I_3 = 1.3 Amp

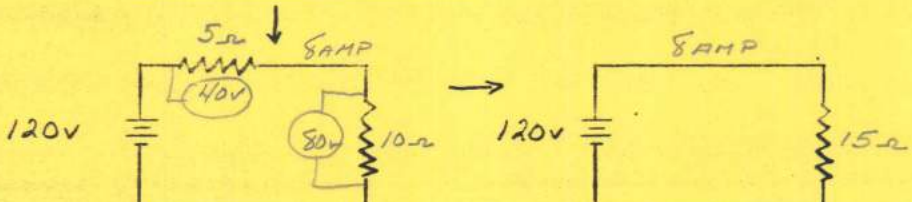
9. Which way is the current flowing? counter clockwise

C.



Emf = 120 volts	A_1 = ________	V_1 = ________
R_1 = 5 ohms	A_2 = ________	V_2 = ________
R_2 = 7 ohms	A_3 = ________	V_3 = ________
R_3 = 180 ohms	A_4 = ________	V_4 = ________
R_4 = 60 ohms	A_5 = ________	V_5 = ________
R_5 = 90 ohms	A_6 = ________	V_6 = ________
R_6 = 42 ohms	A_7 = ________	V_7 = ________
R_7 = 21 ohms	A_8 = ________	
R_8 = 8 ohms	A_9 = ________	
R_9 = 4 ohms	A_{10} = ________	
R_{10} = 10 ohms	A_{11} = ________	





$\frac{1}{R_T} = \frac{1}{42} + \frac{1}{21} = \frac{3}{42}$

$\frac{1}{R_T} = \frac{1}{180} + \frac{3}{180} + \frac{2}{180} = \frac{6}{180}$

$\frac{1}{R_T} = \frac{1}{24} + \frac{2}{24} = \frac{3}{24}$

$\frac{1}{R_T} = \frac{1}{30} + \frac{2}{30}$

$\frac{80}{15} = 5\frac{1}{3}$

Re White

Chapter 16 Design of an Electrical Appliance for the 110-Volt Circuit.

How does the engineer design two very different appliances — an 11-watt night-light and an 1100-watt toaster for the same 110-volt circuit?

Basic definition of the volt: Joules/Coulomb which represents energy per charge.

Every coulomb of electricity that "falls" through the 110-volts difference in potential--whether in the night-light or in the toaster— means the conversion of 110 Joules of energy, electrical into heat or into light. But 11 watts means 11 Joules per second; and 1100watts means 1100 Joules per second.

Obviously, the night-light must have 1/10 coulomb (11watts/110 volts) per second passing through it or a current intensity of 1/10 ampere (coulomb per second); while the toaster must have 10 coulombs (1100 watts/110 volts) per second passing through it or a current of 10 amperes (coulomb per second).

How can this be achieved? Ohm's law enables us to calculate that the operating resistance of the night-light must be 110 volts per 0.1 amp or 1100 ohms; while the operating resistance of the toaster must be 110 volts per 10 amps or 11 ohms. If both appliances are connected across the 110 volts potential difference in parallel, the high resistance appliance will perform less powerfully.

How can the right resistance be achieved? For the night-light, the right <u>length</u> and <u>thickness</u> of tungsten to provide 1100 ohm resistance at the temperature of white heat; for the toaster, the right <u>length</u> and <u>thickness</u> of nichrome to provide the 11 ohm resistance at the temperature of red heat.

volt = Joules/coulomb   watts = Joules/second = volts x amperes

amperes = coulombs/seconds   ohms = volts/amperes

ohms = $(\text{ohms} \times \text{centimeters})_T \; (\text{centimeters}/\text{centimeters}^2)$

Clean up

$V = E/q \qquad P = E/t = V \times I$

$I = q/t \qquad R = V/I$

$$R = R_T \ell / A$$

R_T is resistivity of a given material at a given temperature.

USE OF ELECTRICAL INSTRUMENTS

A. INTRODUCTION: Meters used for electrical measurements are delicate instruments and must be handled with great care. The greater the precision of the instrument, the more fragile it is and therefore, the more easily it may be damaged by abuse or improper use. Ordinary commercial grade meters will provide readings of sufficient accuracy for the majority of experiments. High-grade, laboratory instruments may sometimes be used where a higher order of accuracy is essential.

The greatest care must be used to prevent excessive current from flowing through a meter. You must keep in mind the fact that the heating effect in an electrical circuit increases as the square of the current. It is a good idea to fuse the circuit, in which a meter is to be employed, with a fuse having a capacity less than that of the instrument itself. (Most of our meters here at Midpark are fused so the circuit does not need to be fused. However the cost of a fuse is such that your instructor wishes none to be destroyed.)

Meters are constructed differently for use in A.C. circuits than those for D.C. circuits. One type of instrument MUST NOT be placed in the other type of circuit. Instruments sometimes have more than one range over which readings may be made. In general, more accurate results are obtained by selecting the lowest range on which the reading can be made.

B. THE VOLTMETER: A meter, called a voltmeter, designed to give readings in volts is used to measure the difference in potential between two points of an electrical circuit. A voltmeter is always connected in parallel across a circuit or any part of a circuit of which one wishes to measure the potential difference. We will be using a three-range voltmeter which if used as follows will give excellent results. The three scales are: 0 to 5 volts, 0 to 50 volts, and 0 to 500 volts. You first begin by selecting the highest range (0 to 500 volts). Examine the reading on this scale. If the reading is less than 50 volts, then you can safely change to the 0 to 50 volt scale as the reading will not exceed its maximum value. If the reading on this scale (0 to 50 volts) is less than 5 volts, you can safely switch to the 0 to 5 volt range. Remember to set the meter back to the highest scale before taking the next reading if you are unsure of the range of the voltage to be measured.

Since a voltmeter is connected in parallel across a circuit, it acts to load the circuit (that is it takes some energy from the circuit). In practice, the loading effect should be as low as possible. The range of the meter together with its combined resistance determines the number of ohms-per-volt. If the the meter has a 0 to 5 volt range and 1000 ohms-per-volt, it has a loading effect of 5000 ohms when placed across a circuit. The greater the ohm-per-volt value, the lower the loading effect. Thus a meter with a higher ohm-per-volt value will give a more accurate reading (it disturbs the circuit less). A meter with a higher ohm-per-volt reading will usually be more expensive. The meter resistance should be at least 10 times the resistance of the circuit across which it is connected in order to avoid too much change in the circuit across which is is placed.

C. THE AMMETER: The commercial type of ammeter may consist of a coil pivoted between the poles of a permanent magnet. Since its resistance is very low, a shunt is connected across its terminals to prevent its being "burnt out". The instrument may have different shunts to give varying ranges.

Ammeters are joined in series in a circuit. Great care must be taken before connecting an ammeter in a circuit to see that the current strength through the circuit does not exceed the range of the instrument. If an ammeter has more than one range, always connect it so that you use the highest range first and proceed (as discussed with the voltmeter) to the appropriate scale.

D. GALVANOMETERS: A galvanometer may be used to detect the presence of an electric current, to determine its direction of flow, or to find its strength. However great care must be used as a very minute current will cause the pointer to deflect full scale with possible damage to the meter.

E. RHEOSTATS AND RESISTANCE COILS: A rheostat is used in a circuit to increase the resistance and thus reduces the current strength. It may be graduated so it becomes a measuring instrument. It is made of wire of a high resistance, and of a material which does not change its resistance much with a change in temperature. While a rheostat, or a set of resistance coils, is affected only slightly by a change in temperature, great care must be taken not to heat the coils unduly. Ask your instructor to show you a rheostat, resistance coils, and a variable resistance box.

IN SUMMARY

1. A voltmeter is only connected in parallel. Thus it is never connected as the circuit is being constructed.

2. An ammeter is only connected in series with components in the circuit. Thus when a circuit is constructed, the ammeter is part of the construction.

3. Always use the highest range of any meter if you are unsure of the magnitude of the quantity being measured. Then adjust to appropriate scale.

5. Use only D.C. meters when measuring D.C. current or voltage and A.C. meters when measuring A.C. current or voltage.

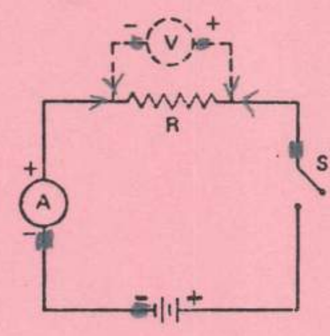
6. And most important, IF IN DOUBT, ASK FOR ASSISTANCE. In so doing, expensive equipment may not be damaged or destroyed.

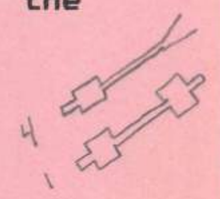
Once upon a time, a person who had no knowledge of Ohm's Law connected one end of a jumper cable to the positive terminal of a 12-volt car battery and the other end of the cable to the negative terminal. He was never heard from again. Yet everyday, we use light bulbs in which 120 volts are applied across the filament wire. Why does one explode, while the other glows? Is it possible to predict in each case how much current would flow? The answer lies in the resistance of a substance and how it controls the amount of current that flows for a given voltage. In this activity you will set up a circuit to demonstrate this relationship.

An electric current will flow through a conductor when there is a complete circuit and a potential difference between both ends. The difference in potential is produced by a generator or battery doing work to develop an accumulation of electrons at one point ('-' terminal) and a deficiency of electrons ('+' terminal) at another point. The unit of potential difference is the volt (V). The potential difference between two points is 1 volt if one joule (J) of work is required to move one coulomb (C) of charge from one point to the other. The difference in potential is the cause of the flow of current (I). The unit of current is the ampere, which is defined as a flow of 1 coulomb of charge per second.

To measure the potential difference, you will us a voltmeter connected across the section of circuit in which you are interested. (Note that the voltmeter is connected in parallel with this section.) You will use an ammeter to measure the current flowing through the circuit. (Note that the ammeter is connected in series with the components of the circuit.)

Obtain the necessary apparatus and construct the circuit (Figure 1). Use one of the three power resistors. The power is taken from the D.C. terminals (red and black) outlets. Be sure the voltage knob is set to zero and the power source is not plugged in until your instructor has checked connections. Make sure the polarities of the meters are connected as shown.





Adjust the power supply until the readings on the voltage is 5 volts. Read the ammeter and record the reading. Then turn the power supply down in 5 or 6 steps, each time reading the ammeter and voltage readings until the voltage reads zero. Repeat using the other two resistors.

Then replace the last resistor with a 1.5 meter length of #____ nichrome wire and repeat the above measurements. To prevent short circuits, secure the wire to the table with several pieces of masking tape. Before removing the wire, measure its length to the nearest millimeter. Measure only that portion that extends between the two clips.

From your data, plot the voltage as a function of the current for each resistor and the wire on one axis.

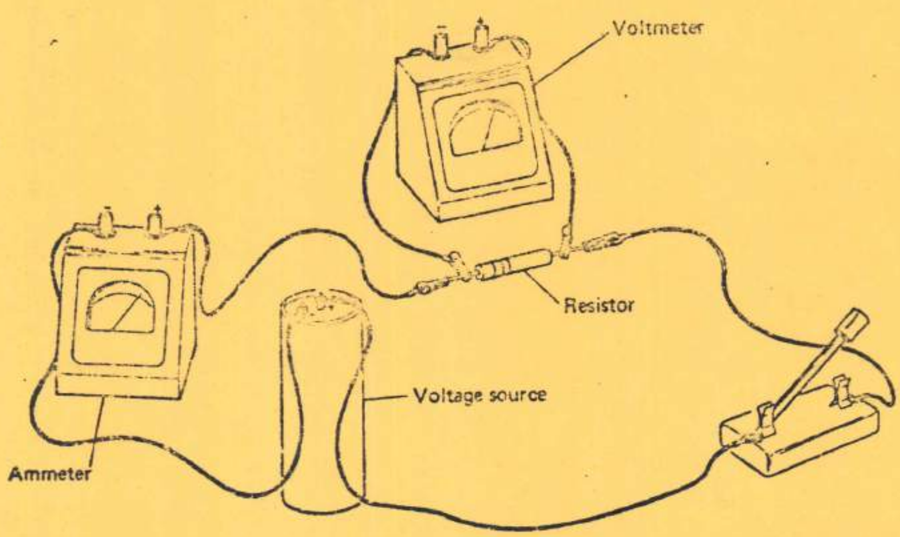
1. By inspection of the lines on the graph, which resistance would allow the most current to flow if a constant voltage were applied to each?

2. Determine the slope for each of the lines. (Don't forget units.) Next write the equation for each line. The coefficient of the current (the slope) is defined as the resistance of the material expressed with the unit 'ohm'. Thus an 'ohm' is equivalent to the ________________ (units of the slope of V vs I).

3. The relationship that you have just found between V, I and R is know as Ohm's Law. This law is most useful in designing and working with electrical circuits. However, one must use this relationship with caution as for many materials, the resistance of an object will change if its temperature changes.

4. The manufacturer of the resistors states that the actual value of the resistor will be within a certain percent which is indicated by the color of the 4th stripe. If the color is gold, the value should be within 1%; if the color is silver, the value should be within 10%. Compare your calculated resistance with the stated resistance and compute the percent of error. Is the resistance within stated tolerance?

5. Calculate the resistance per centimeter of the #____ nichrome wire. Compare your answer to the value found in a handbook of physics and chemistry



	d (cm)	B&S Gauge	Calld	d (cm)	B&S	Ω/cm
Small	0.31 MM	30	28	0.03150	30	0.2214
				0.03454	28	0.1394
	0.50 MM	25		0.04166	27	
				0.04572	26	0.0876
				0.05080	25	
				0.05588	24	0.0548

small 0.17 Ω/cm

Galvanometers

Galvanometers are meters used to indicate and/or measure small currents in sensitive circuits. Figure 1 shows the interior of the galvanometer. A moveable coil of fine wire with an attached pointer is suspended between two pole pieces of a permanent magnet. The coil and attached pointer are suspended between the pole pieces by copper wire springs at the ends of the coil. The suspension provides control over the coil movement and electrical connections between the movable coil and the external circuit.

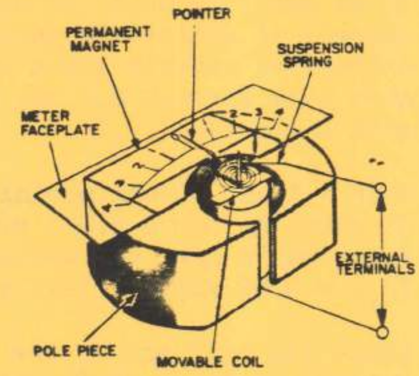


Figure 1

Current through the movable coil sets up a magnetic field. This field opposes the fixed magnetic field of the pole pieces, causing the coil and attached pointer to deflect from their normal position.

The meter has a linear scale because the pointer deflection is directly proportional to the current through its moving coil.

The construction of a given meter determines the range of values it can measure. The number of turns and size of wire of the coil, the physical size of the coil, the strength of the magnet and the strength of the control springs are factors which affect the meter range.

Meter sensitivity is determined by the amount of current required for full-scale deflection of the meter pointer. A sensitivity of 1-mA means that 1 milliampere is required for full scale deflection.

A galvanometer can be used as several different types of meters, depending upon the way the meter is connected in the circuit as well as how resistors are connected to the meter.

The Ammeter

The basic galvanometer can be used as a milli-ammeter without any alterations. If full-scale deflection is 1-mA (0.001 amperes), then the maximum current the galvanometer can measure is 1-mA. This entire current passes through the moving coil which is between the negative and posituve meter terminals as shown in Figure 2.

To measure a larger current, an alternate path for the current in excess of a maximum of 1-mA must be provided as the meter movement can safely carry a maximum current of 1-mA.

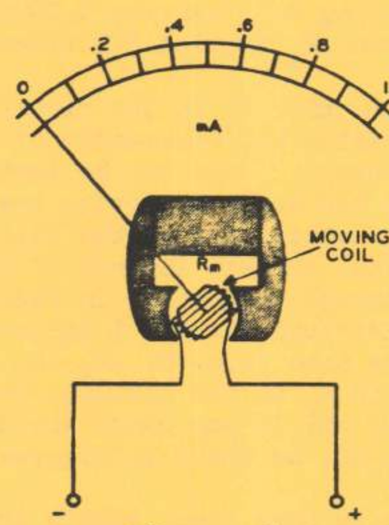


Figure 2

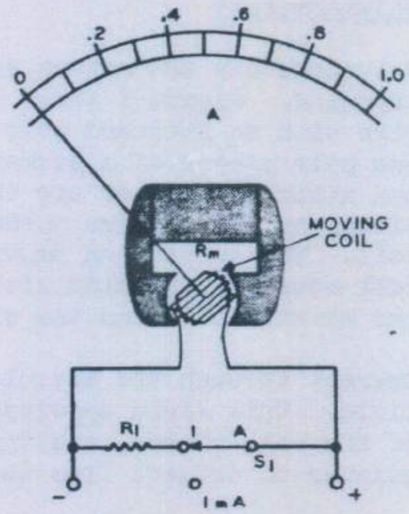


Figure 3

Thus a shunt R_1 is connected across the moving coil as shown in Figure 3. Thus two parallel current paths between the meter terminals are provided.

If we want the meter to measure 1.0 amperes current at full-scale deflection, then the difference between 1.0-A and 1-mA or 0.999-A must pass through R_1, the shunt in parallel with the meter.

With a 1-mA, 50-ohm moving coil, the resistance of shunt R_1 for a 1.0-A range can be found. Using Ohm's Law, the voltage across the coil $(V_m) = 0.05$ volts (1-mA x 50 ohms).

Since the coil and R_1 are in parallel, the voltage across each is the same. Again using Ohm's Law and knowing that $V_{R_1} = 0.05$ volts

and $I_{R_1} = 0.999\text{-A}$ (1.0-A - 1-mA): $R_1 = \frac{0.05 \text{ volts}}{0.999 \text{ amps}} = .05$ ohms

In Figure 4 a second shunt R_2 is connected in parallel with the meter and R_1. If the meter is to be used to measure a maximum of 10 amps, then the switch is connected across R_2 which has a resistance of :

$$R_2 = \frac{0.05 \text{ volts}}{9.999 \text{ amps}} = 0.005 \text{ ohms}$$

Thus the current always divides between the moving coil and shunt in exactly the same ratio. R_1 will carry 999 times as much current as the moving coil. Thus with a current of 1-A, shunt R_1 carries 0.999-A and the moving coil 0.001-A. When the total current is reduced to 0.8-A, the moving coil carries 0.0008-A and the shunt R_1 carries 999 times or 0.7992-A.

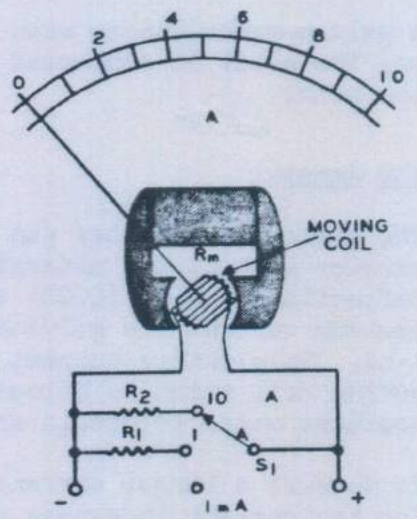


Figure 4

Thus with R_1 in the circuit, the coil always carries one thousandth of the total current. This can be indicated directly on the scale by moving the decimal point (if necessary) so the scale reads the total current instead of the current through the coil. In Figure 2, the scale divisions for the 1 ampere range would be the same (i.e. 0, .2, .4, .6, .8, 1.0). With R_2 in the circuit, the scale divisions for the 10 amp range would be 0, 2, 4, 6, 8, 10, as shown in Figures 3 and 4.

As we have seen, shunts are used to extend the range of the meter only. They cannot be used to make the meter indicate by full-scale deflection a current lower than that for which the meter movement was designed.

The D. C. Voltmeter

The movement used in Figure 1 can also be used as a voltmeter as shown in Figure 5. The voltmeter is actually operated by the current through its coil. The meter is calibrated to read the voltage required across its terminals to cause a given amount of meter pointer deflection. This is done when the moving coil leads are connected in parallel with a circuit. Note that a current-limiting resistor R_1 is connected in series with the moving coil.

As indicated previously, the current sensitivity of the meter makes it necessary to limit the current flowing through the moving coil to a safe level when connecting the meter to measure voltages. The current divides at the point of measurement when the voltmeter is placed in parallel with the circuit under test. The amount of current through the moving coil will be small if the series-limiting resistor is large.

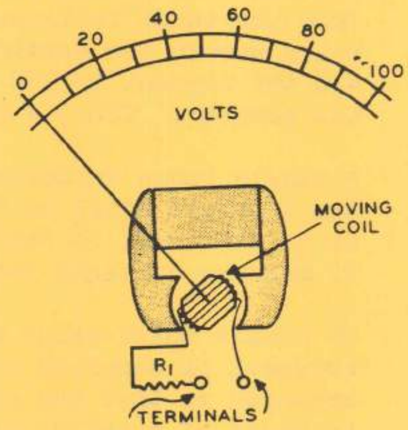


Figure 5

Instead of referring to the sensitivity of voltmeters in terms of the current required for full-scale deflection, it is common to state the voltmeter sensitivity in terms of ohms-per-volt (ohms/volt). This means that the meter circuit resistance is a certain number of ohms for each volt (at full-scale deflection). In Figure 5, assume that the total resistance of the meter circuit is 100,000 ohms for a full-scale reading of 100 volts. Thus, its sensitivity is 1000 ohms/volt. A meter movement that operates with less current for full-scale deflection requires more resistance in the meter circuit, and its ohms/volt rating is higher. Thus, the greater the sensitivity, the higher the ohms/volt rating of the meter.

The ohms/volt rating of any meter can be calculated by dividing 1 by the full-scale current of the meter. Thus:

$$\text{ohms-per-volt} = \frac{1}{\text{full scale current}}$$

For example, a meter requiring 1-mA for full-scale deflection has an ohms-per-volt rating of 1000. If the meter movement of Figure 5 required 100 microamperes (0.0001 ampere) for full-scale deflection, the sensitivity rating would be 10,000 ohms/volt.

Thus a voltmeter is an ammeter with a series resistance to limit the current through the meter movement. Thus we can adapt the ammeter (discussed previously) to operate as a voltmeter. The meter (same one used for the ammeter) has a resistance of 50 ohms and requires a current of 1-mA for full-scale deflection.

When connected directly across any two points of different potentials, the resistance of the voltmeter circuit must be high enough to limit the current to that required for full-scale deflection. Therefore, resistor R_1 is connected in series with the moving coil; R_1 is called a multiplier resistor, or simply, a multiplier.

Let's determine what is required to permit the voltmeter in Figure 5 to indicate a maximum potential of 100 volts. Since one milliampere of current in the moving coil produces full-scale deflection, the total resistance of R_1 plus the resistance of the moving coil, which is 50 ohms, must be such that the current is limited to 1-milliampere when 100 volts is applied. Using Ohm's Law:

$$R_T = \frac{E}{I} = \frac{100 \text{ volts}}{.001 \text{ amps}} = 100{,}000 \text{ ohms}$$

The value of R_1 can be determined by subtracting the resistance of the moving coil from the total resistance: 100,000 ohms - 50 ohms = 99,950 ohms. Then, with 100 volts across the terminals, the voltage is across a total resistance of 100,000 ohms, and the current is 100 volts/100,000 ohms, or 1-mA, for full-scale deflection of the pointer. Thus, a number 100 is marked on the high end of the scale.

A single range voltmeter is limited in application. If 2 or 3 volts is applied to the 100-volt meter in Figure 5, the resulting pointer deflection is so small that it is difficult to read on the scale. Thus a multi-range voltmeter is constructed to measure voltages ranging from a fraction of a volt to several hundred volts.

To obtain multi-range operation, a single meter movement is supplied with several multipliers, arranged so that the proper one can be selected by means of a switch or by using separate terminals For example, in Figure 6, multipliers R_1, R_2, R_3, and R_4 are connected in series between the moving coil and the 1000-volt terminal. The junctions between the resistors are connected to provide ranges of 10, 100, 500, and 1000 volts. With one test lead connected directly to one end of the moving coil (the negative terminal of the meter), the desired voltage range is selected by connecting a second test lead into one of the four other terminals. D.C. voltages of either polarity can be measured by simply reversing the leads to the circuit.

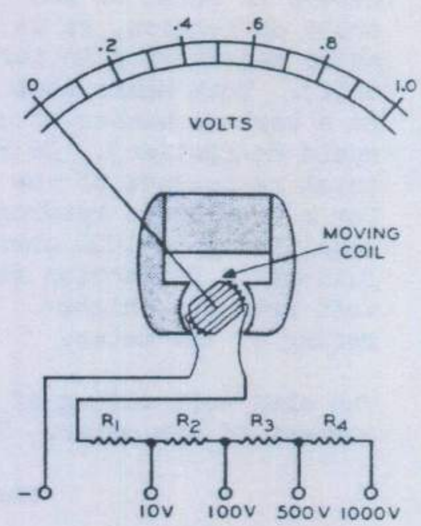


Figure 6

To calculate the value of R_1 one first determines the voltage for full scale deflection (10 volts). Using Ohm's Law:

$$R_T = \frac{E}{I} = \frac{10 \text{ volts}}{.001 \text{ amps}} = 10{,}000 \text{ ohms}$$

Thus $R_1 = R_T - R_{meter} = 10{,}000 \text{ ohms} - 50 \text{ ohms} = 9{,}950 \text{ ohms}$

To determine R_2 (so that full scale deflection of meter indicates 100 volts):

$$R_T = \frac{100 \text{ volts}}{.001 \text{ amps}} = 100{,}000 \text{ ohms}$$

$$R_2 = R_T - (R_1 + R_{meter}) = 100{,}000 \text{ ohms} - 10{,}000 \text{ ohms} = 90{,}000 \text{ ohms}$$

It is left to you to determine that R_3 = 400,000 ohms and R_4 = 600,000 ohms.

GUIDE FOR LAB S-20.1 RETURN TO TRAY

EXAMPLES OF:

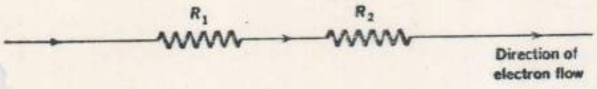


Fig. 37–1 Two resistors in series

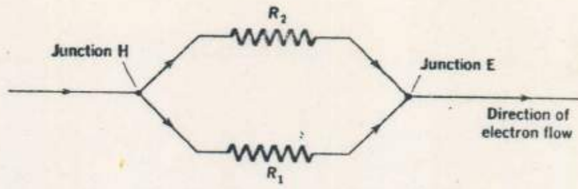


Fig. 37–2 Two resistors in parallel

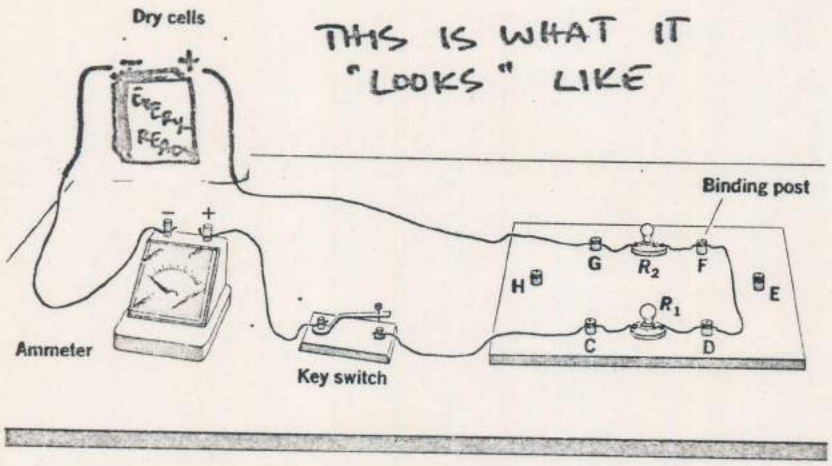


Fig. 37–3 A wired circuit with two resistors in series

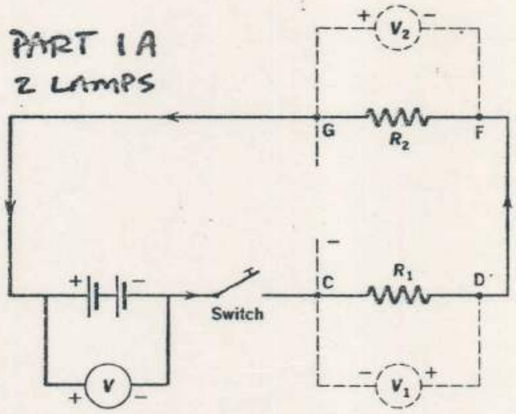


Fig. 38–2 Schematic wiring diagram for measuring terminal voltage and division of voltage in a series circuit

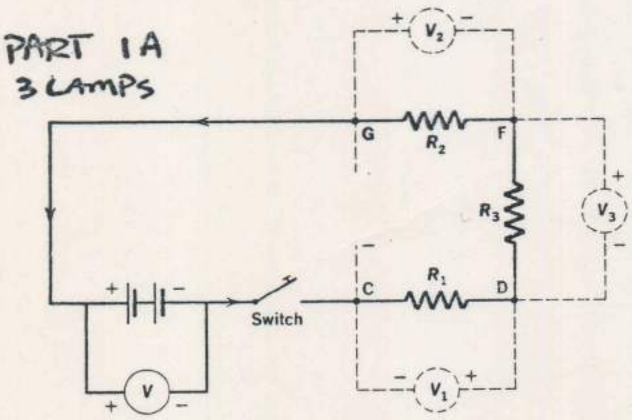


Fig. 38–3 Schematic wiring diagram for measuring terminal voltage and division of voltage across three resistors in series

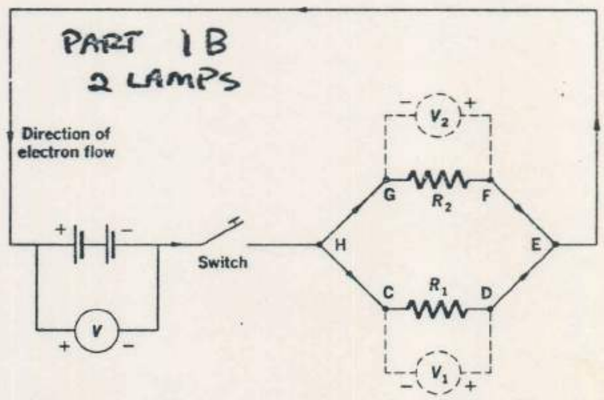


Fig. 38–4 Schematic wiring diagram for measuring terminal voltage and voltage across two resistors in parallel

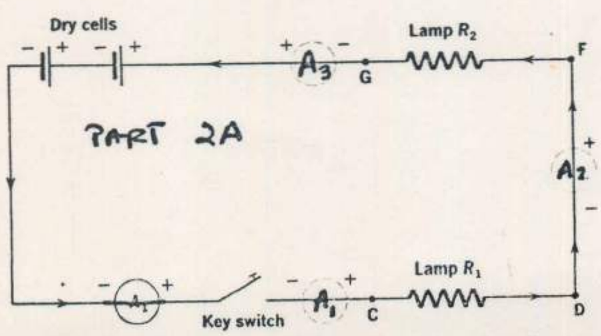


Fig. 37–4 Wiring diagram, series circuit

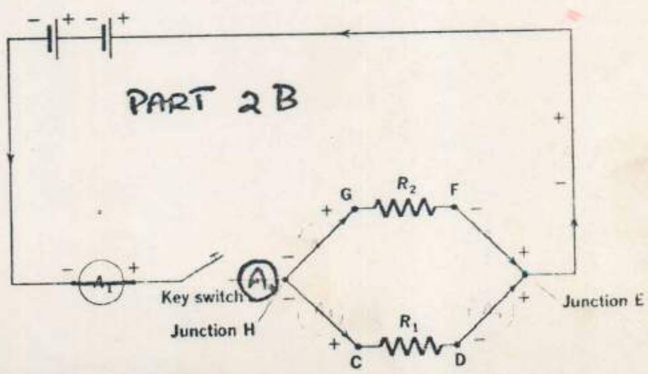


Fig. 37–5 Wiring diagram, parallel circuit

Charges and Currents

When an excess charge is placed on an insulator, the charge "stays put." The charge produces an electric field, but there are no charges that are free to move in an insulator. In a conductor, however, an electric field causes free charges to move. If a charge is placed at a point on a conductor, the resulting field acts on the free charges so that they quickly redistribute themselves until there is no field in the conductor. The charges within the conductor then experience no electrostatic force, and the entire conductor is at the same potential.

If an external source, such as a battery or a generator, continues to supply charges to one end of the conductor and to remove them from the other end, a field is maintained in the conductor. Charges then experience a force and move continuously in the conductor—there is a current. Work is done on the charges, and so there must be a potential difference between the ends of the conductor. This can be expressed as a potential gradient, which is the ratio between the potential difference between two points in the field and the distance between the points. The units are volts per meter.

The Problem

In this experiment we shall produce an electric field in a uniform wire, determine how the

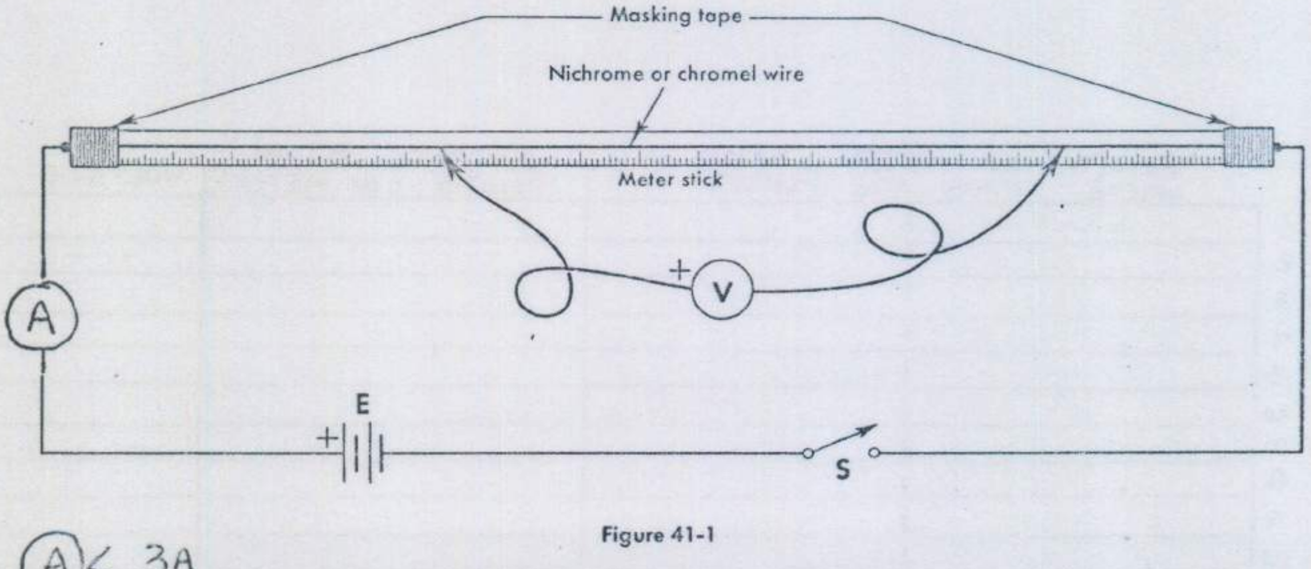


Figure 41-1

(A) < 3A

potential difference between points in the wire depends on their separation, and then compute the potential gradient and the electric field strength in the wire.

Measuring the Potential Gradient in a Wire

Stretch a length of nichrome or chromel wire along a meter stick. Hold the ends of the wire in place with masking tape (*Figure 41-1*). Use copper wire to connect the ends to a low-voltage source (E) through a switch (S). Connect a voltmeter (V) with its polarity as shown to the test wire. Use leads that can be easily moved along the test wire. (1) Measure the potential difference as indicated by the voltmeter for a number of different distances between points on the wire. The switch should be closed only when taking a reading.

(2) Plot a graph of potential difference against distance. What is the significance of the slope of this graph? Compute the potential gradient in the wire in volts per meter.

How much work is done on one coulomb of charge in moving it from one end of the wire to the other, a distance of one meter?

The Electric Field Strength

What force would be experienced by a charge of one coulomb if placed in this potential gradient? What is the electric field strength in the wire?

Changing the Field Strength

By what two methods could you change the electric field strength in the wire? If you have time, try one of these changes and measure the new value of the electric field strength.

	POINTS ON METER STICK WHERE LEADS ARE PLACED		DISTANCE BTWN POINTS (IN METERS)	VOLTAGE READING
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

S-____ USE OF ELECTRIC METERS Name ______________________ - mod ____

I 1. Pick up the handout "Rules for Use of Electric Meters" and read it (return the copy to the tray by the end of the period)

What does rule #1 say? ____

____

3. What does the second sentence of rule 4 say? ______________________

____

4. What does rule 7 say? ____

____

Connect the probes to your meter: red is (+) and black is (-).

To learn to use the meter you will first use it to measure the "voltage" (or potential) of a flashlite battery. Set the meter on an appropriate scale (remember rule 4) and touch the probes of the meter to the ends of the battery --- red to the (+) and black to the (-) ends of the battery.

5. What does the meter read? ________ Can you use a different scale and get a more precise reading? _____ If so, select a new scale and now what does it read? _______ How many scales could you use and get a reading for this battery? __________.

II Turn to the lab table in front or behind you and learn to use the meter sitting there (it's different than yours). Be careful, the scales are different. Measure the voltage of your battery again using the new meter. Check to see if other scales on this meter could be used.

6. On your meter, (the one you started with):

What is the largest volt scale __________ the smallest __________

What is the largest amp scale __________ the smallest __________

What is the largest ohm scale __________ the smallest __________

III. GO THE THE SET-UPS IN THE FRONT OF THE ROOM:

Learn to use the meter sitting there, an AMMETER, used to measure the "current" or flow of charges in a simple circuit. Choose an appropriate scale on the meter and connect the black wire from the meter to the clip. Have your circuit checked. Now connect the red wire from the (+) side of the battery to the (+) terminal of the meter.

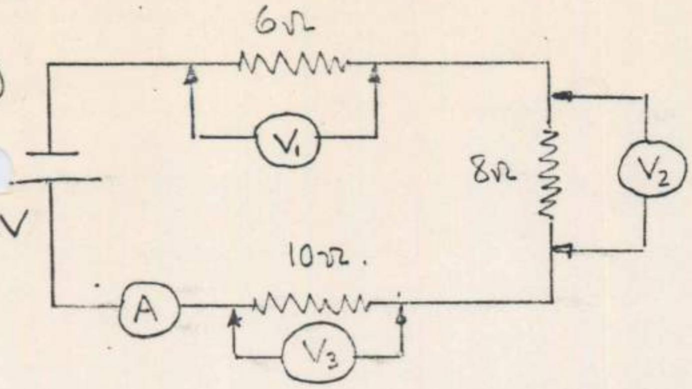
7. What does the meter read? __________ Can you safely use a different scale and if so what does the meter read? __________.

Which scale gives the more precise reading? ______________________

Make a simple diagram ON THE BACK OF THIS PAGE to show the flow of the charge from the batteries to the meter to the lite bulb and back to the batteries.

CIRCUIT WORK SHEET (R) NAME ____________________

(1)

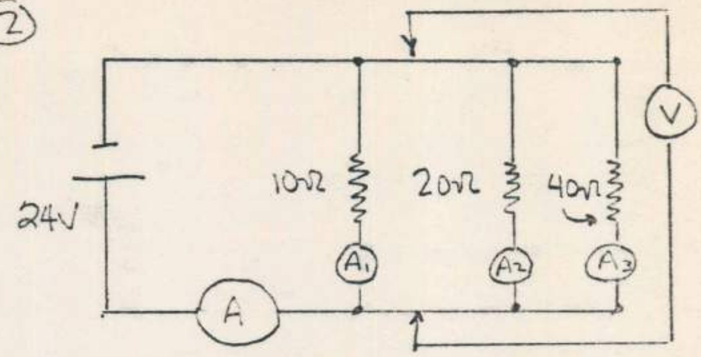


R_T = ________ V_1 = ________

V_T = ________ V_2 = ________

A = ________ V_3 = ________

(2)

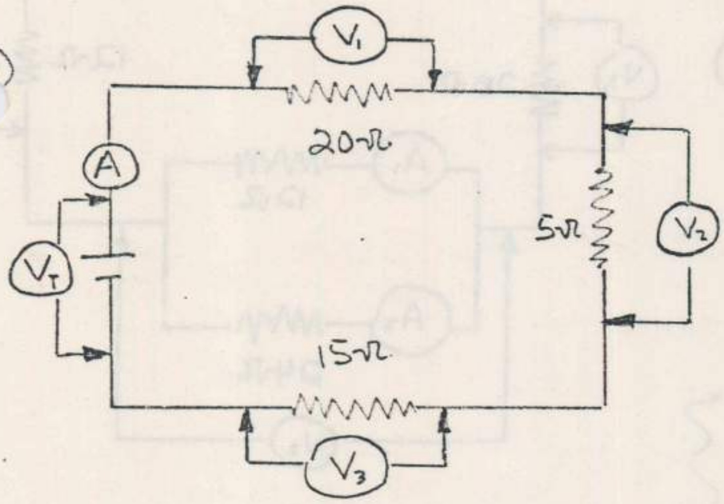


R_T = ________ A_2 = ________

A = ________ A_3 = ________

A_1 = ________ V = ________

(3)



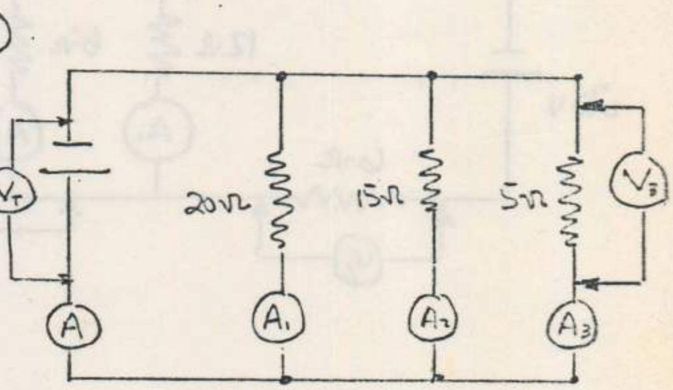
GIVEN V_1 = 40V

R_T = ________ V_3 = ________

A = ________ V_T = ________

V_2 = ________

(4)



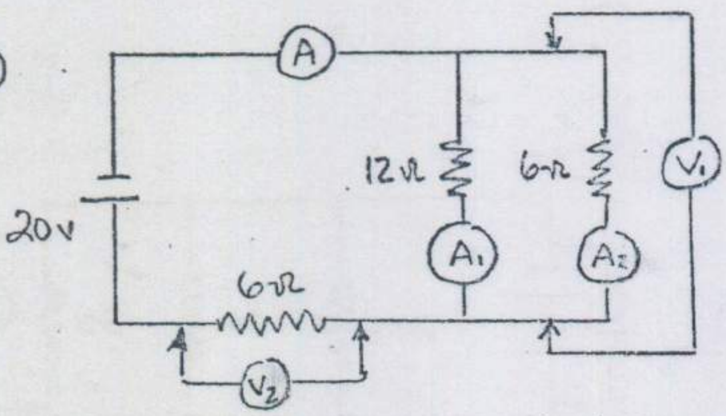
GIVEN A_1 = 3A

V_3 = ________ V_T = ________

A_2 = ________ R_T = ________

A_3 = ________ A = ________

(3)



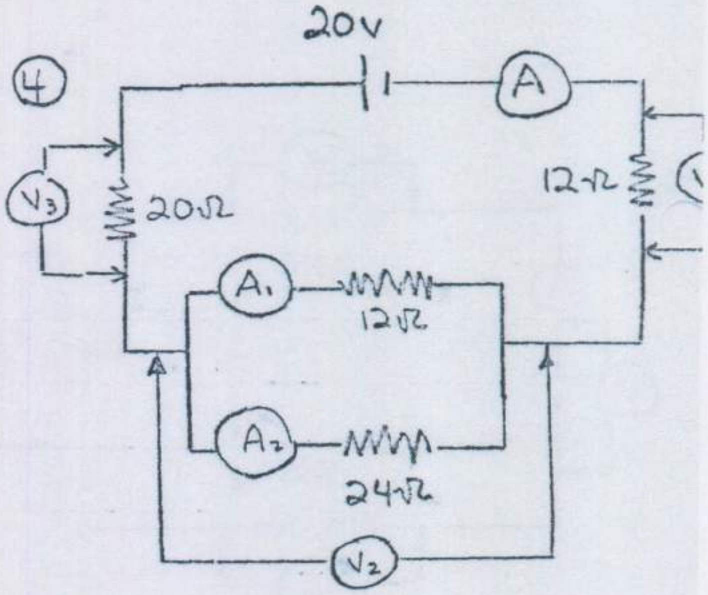
R_T ________ V_1 ________

A ________ V_2 ________

A_1 ________

A_2 ________

(4)

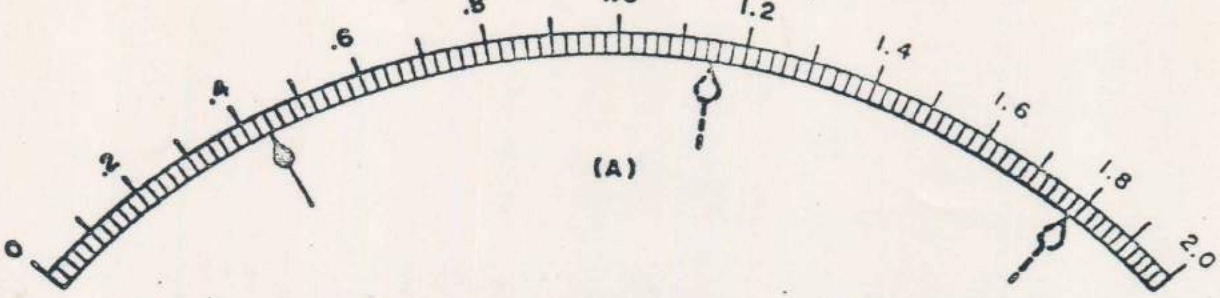


R_T ________ V_1 ________

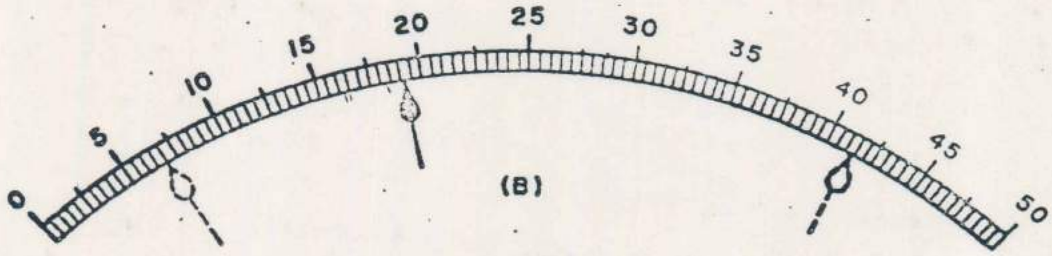
A ________ V_2 ________

A_1 ________ V_3 ________

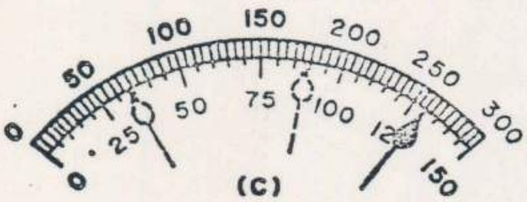
A_2 ________ V_T ________



(A)

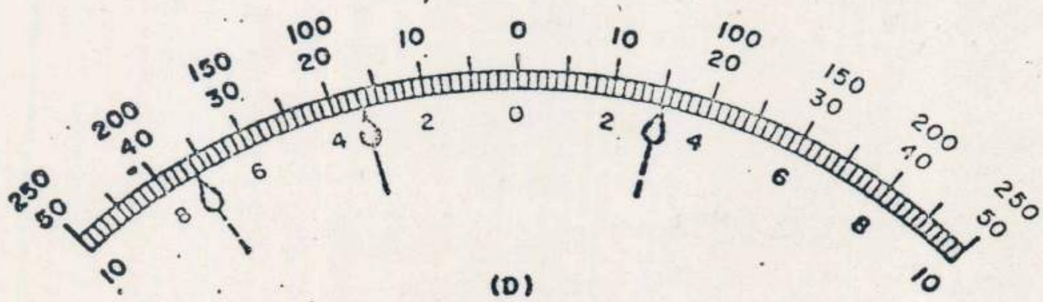


(B)



(C)

SCALE		FIRST POSITION	SECOND POSITION	THIRD POSITION
A				
B				
C	0-300			
	0-150			
D	250-0-250			
	50-0-50			
	10-0-10			



(D)

28

Appendix **D**

Rules for Use of Electric Meters

Electric meters are expensive to buy and maintain. They can be easily damaged. Properly used, they are dependable tools essential for many of your experiments.

Follow These Rules

1. Handle meters as gently as you would a good wristwatch. They are delicate physically as well as electrically.
2. Always connect voltmeters across a circuit or a portion of a circuit – *in parallel*. Always connect ammeters *in series* with a circuit. If an ammeter is connected incorrectly, it may be damaged.
3. The polarity labels on meter terminals tell you how to connect them. The terminal marked + should be wired either directly or through other components to the positive side of the voltage source.
4. Use meters having scale ranges that will accommodate the quantities to be measured. If in doubt, use a range that is obviously too high to get an approximate indication of the voltage or current. Then change to the correct range.
5. Study the scales of the meters before closing the circuit switch so that you can take accurate readings quickly. This is especially important if there is sufficient power in the circuit to cause heating of the circuit elements.
6. Your instructor may want you to use the "tapping rule" when first closing a circuit. Disconnect one of the leads in the main line, close the switch, and tap the lead lightly and momentarily against the terminal from which it was disconnected. Watch the meters to see whether the readings are off scale or whether the polarity is reversed.
7. Until you are very sure in connecting circuits, obtain approval before closing the switch.
8. Report trouble immediately.

ly

S- ____ USE OF ELECTRIC METERS Name ________________ mod ____

I. 1. Pick up the handout "Rules for Use of Electric Meters" and read it (return the copy to the tray by the end of the period)

2. What does rule #1 say? ____

____

3. What does the second sentence of rule 4 say? ____________________

____

4. What does rule 7 say? ____

____

II. 5. You are using a multi-meter. Why is it called this, i.e., what quantities does it measure? (hint: some meters are marked "V", "Ω" and M or mA) ____

____

6. Connect the probes to your meter: red is (+) and black is (-).

7. To learn to use the meter you will first use it to measure the "voltage" (or potential) of a flashlite battery. Set the meter on an appropriate scale (remember rule 4) and touch the probes of the meter to the ends of the battery --- red to the (+) and black to the (-) ends of the battery.

What does the meter read? ________ Can you use a different scale and get a more precise reading? ____ If so, select a new scale and now what does it read? ______ How many scales could you use and get a reading for this battery? ________.

8. Turn to the lab table in front or behind you and learn to use the meter sitting there (it's different than yours). Be careful, the scales are different. Measure the voltage of your battery again using the new meter. Check to see if other scales on this meter could be used.

9. On your meter, (the one you started with):

What is the largest volt scale ________ the smallest ________

What is the largest amp scale ________ the smallest ________

What is the largest ohm scale ________ the smallest ________

III. Go the station #1 in the front of the room.

10. Learn to use the meter sitting there. First find the voltage of the battery sitting by the meter; BE CAREFUL, the scales are different.

11. Now use the meter as an OHMmeter to measure "resistance". You must first "zero" your meter (and this must be done every time you change scales and periodically needs to be checked as you are using the meter). Set the switch on the meter to an appropriate scale (remember.....) using the OHM (Ω) scales; touch and hold the probes to the opposite ends of the small "resistor" given you.

What does the meter read? ________ Can you use any other scale and get a more precise reading and if so what does it read? ____________

Now, use the second resistor and get a reading on it. ____________

IV. Go to station 2 in the front of the room.

12. Learn to use the meter sitting there, an AMMETER, used to measure the "current" or flow of charges in a simple circuit. Choose an appropriate scale on the meter and connect the black wire from the meter to the clip. Have your circuit checked. Now connect the red wire from the (+) side of the battery to the (+) terminal of the meter.

What does the meter read? __________ Can you safely use a different scale and if so what does the meter read? _________.

Which scale gives the more precise reading? ________________________

13. Make a simple diagram to show the flow of the charge from the batteries to the meter to the lite bulb and back to the batteries.

SPECIAL # ________ The Effect of Temperature on Resistance Name ____________

Intro: The electrical resistance of nearly all substances changes as the temperature changes. This variation may cause serious problems in very precise laboratory mea-measurements or in some electronic devices in which the resistance of one or more components is critical. For use in these situations special alloys have been developed that show very little variation in resistance as the temperature changes. On the other hand, the phenomenon can be put to use for temperature measurements or for automatic control of some circuits.

The problem: In this experiment we shall study the change of resistance of a wire as its temperature is varied over a wide range. For the test sample we use the tungsten filament of a small electric lamp. By operating the lamp at various voltages, we can vary the filament temperature from about room temperature to nearly 3,000 C°. Although we cannot easily measure the filament temperature, we can observe its brightness and color, and from its appearance make a rough and qualitative judgement as to how hot it is.

Doing the experiment: Set up the equipment as indicated by the instructor. Use the voltmeter-ammeter circuit for measuring the voltage and current. (Before turning the power supply on, have your circuit approved). Take current and voltage reading for five filament temperature conditions ranging from cool to incandescent. Be sure to check the meter scale you are using, and recheck the meter reading before recording your results. For the five readings, use these definitions; bright: power supply on all the way; medium bright: have the bulb "glowing"about half as bright as when it was on full power; dim: have the bulb filament just barely glowing -- the least amount of glow above having the bulb not glowing; no glow: current is flowing, but the bulb is not glowing; minimum: reduce the power supply to the lowest point where current can be detected on the meter. Remove the lamp from the circuit and measure its resistance using the ohmmeter.

Data: . fill in the table

TEMPERATURE	VOLTAGE	CURRENT	VOLTAGE/CURRENT (RESISTANCE)
bright			
medium			
dim			
no glow			
minimum			
Resistance of bulb (not in the circuit) = ________ ohms			

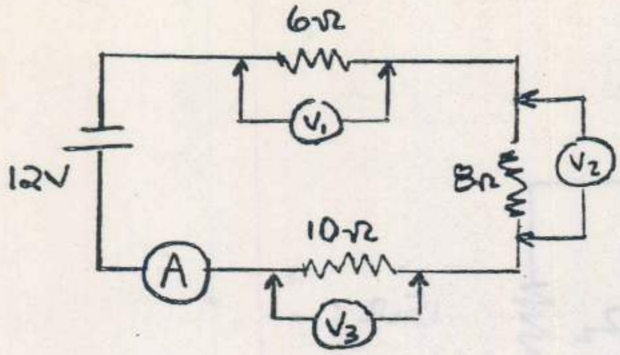
- Draw the graphs of current against voltage and resistance against current.

- Write a general statement about the resistance of a metal conductor as its temperature increases.

CIRCUIT WORK SHEET (H) #1

NAME ______________

(1)

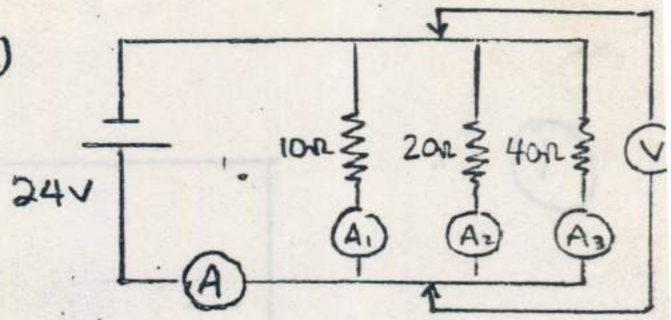


R_T ______ V_2 ______

A ______ V_3 ______

V_1 ______ V_T ______

(2)

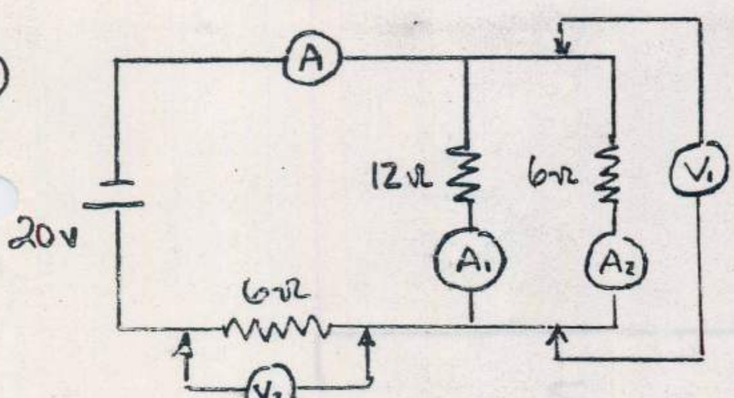


R_T ______ A_3 ______

A_1 ______ A ______

A_2 ______ V ______

(3)



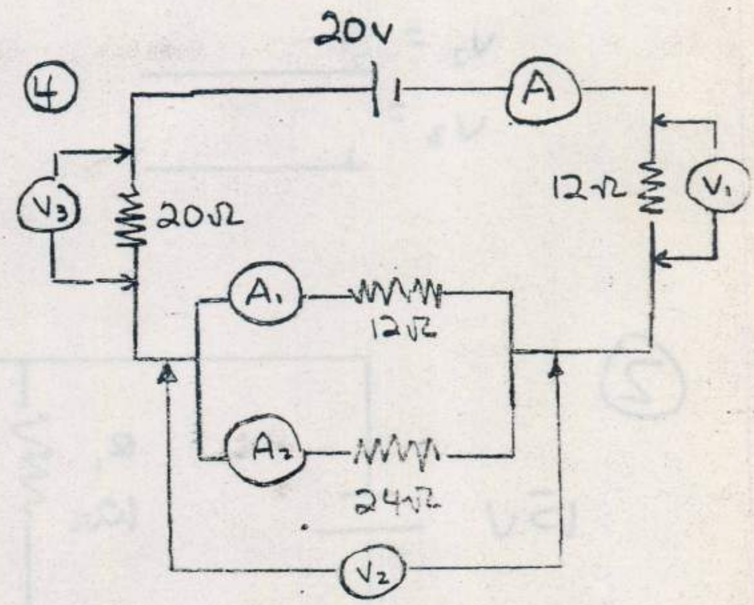
R_T ______ V_1 ______

A ______ V_2 ______

A_1 ______

A_2 ______

(4)



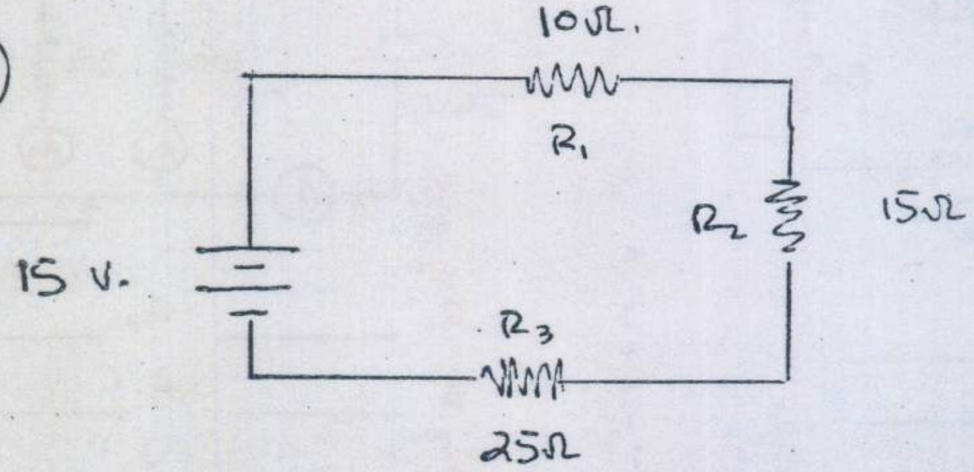
R_T ______ V_1 ______

A ______ V_2 ______

A_1 ______ V_3 ______

A_2 ______ V_T ______

(1)



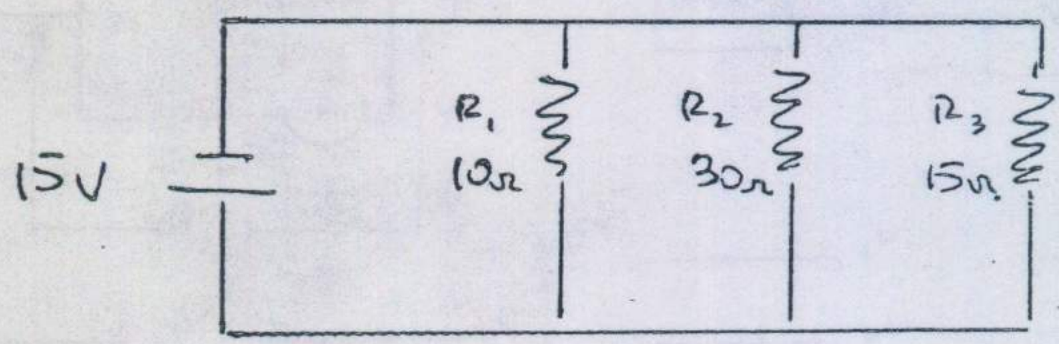
V_1 = ________

V_2 = ________

V_3 = ________

A = ________

(2)



A ______ A_1 ______ A_2 ______ A_3 ______

1. Sometimes you hear someone say a particular appliance uses up electricity. What is it that the appliance uses up and what becomes of it?

2. Does electric current flow out of a battery or through a battery? Does it flow into a light bulb or through a light bulb? Explain.

3. Why do wires heat up when they carry an electric current?

4. What condition is necessary for a sustained flow of electric charge through a conducting medium?

5. A string of 20 christmas lights wired in series draws 1.7 amp when connected to a 125 volt line. What is the power used by the 20 lights? What is the resistance of a single bulb?

$R_T = \frac{125\text{ Volts}}{1.7\text{ amps}} = \frac{73.53\,\Omega}{20\text{ bulbs}} = 3.68\,\Omega/\text{bulb}$

$P = 212.5\text{ watts}$

If you wanted to make a circuit using only 5 bulbs connected to a 125-volt line, what resistance would have to be connected in series with the 5 bulbs?

$5 \times 3.68\,\frac{\Omega}{\text{bulb}} = 18.4\,\Omega$ $\qquad 73.5\,\Omega - 18.4\,\Omega = 55.1\,\Omega$

Need $R_T = \frac{\mathcal{E}}{I_T} = \frac{125\text{ Volts}}{1.7\text{ amp}} = 73.5\,\Omega$

6. What is the resistance of an electric frying pan that draws 11 amperes when connect to a 110-volt circuit?

7. A toaster uses 1600 watts when plugged into a 120 volt line. If it takes 2 minutes to toast a slice of bread and it costs 7.5 cents/kilowatt-hour, how much does it cost to do this?

8. Suppose we have three resistors, R1 = 12 ohms, R2 = 6 ohms, and R3 = 4 ohms. What is the total resistance of these 3 resistors when connected in (a) series (b) parallel?

9. When the three resistors identified in problem 8 are connected in series, find
   a. the current in the circuit if the emf is 12 volts
   b. find the potential difference across each resistor
   c. Find the power supplied to or by each circuit element.

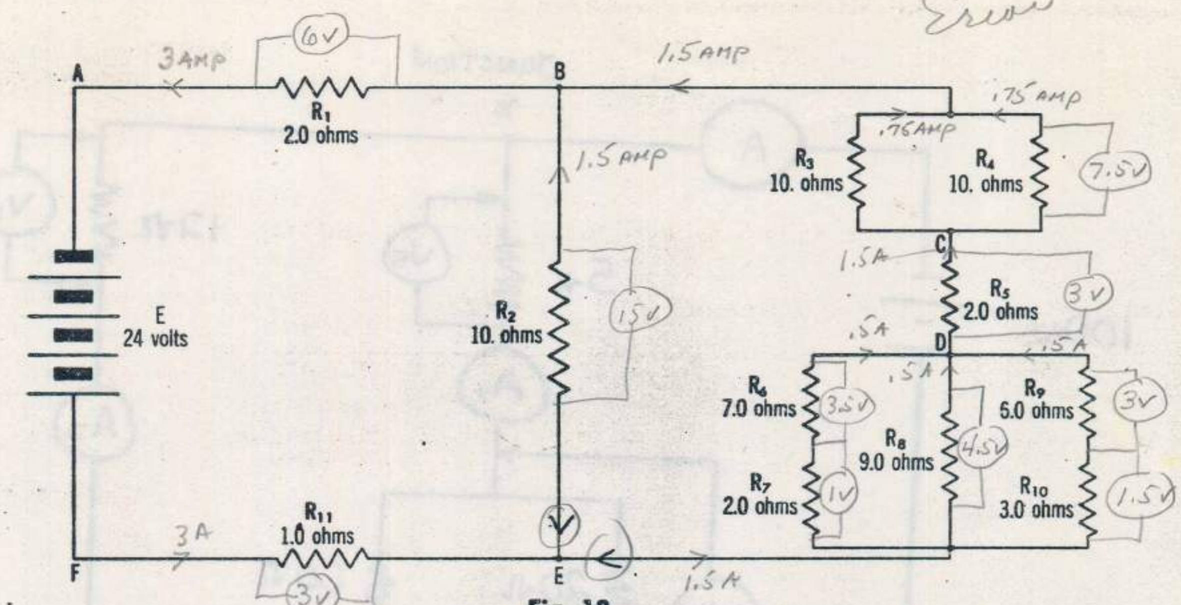
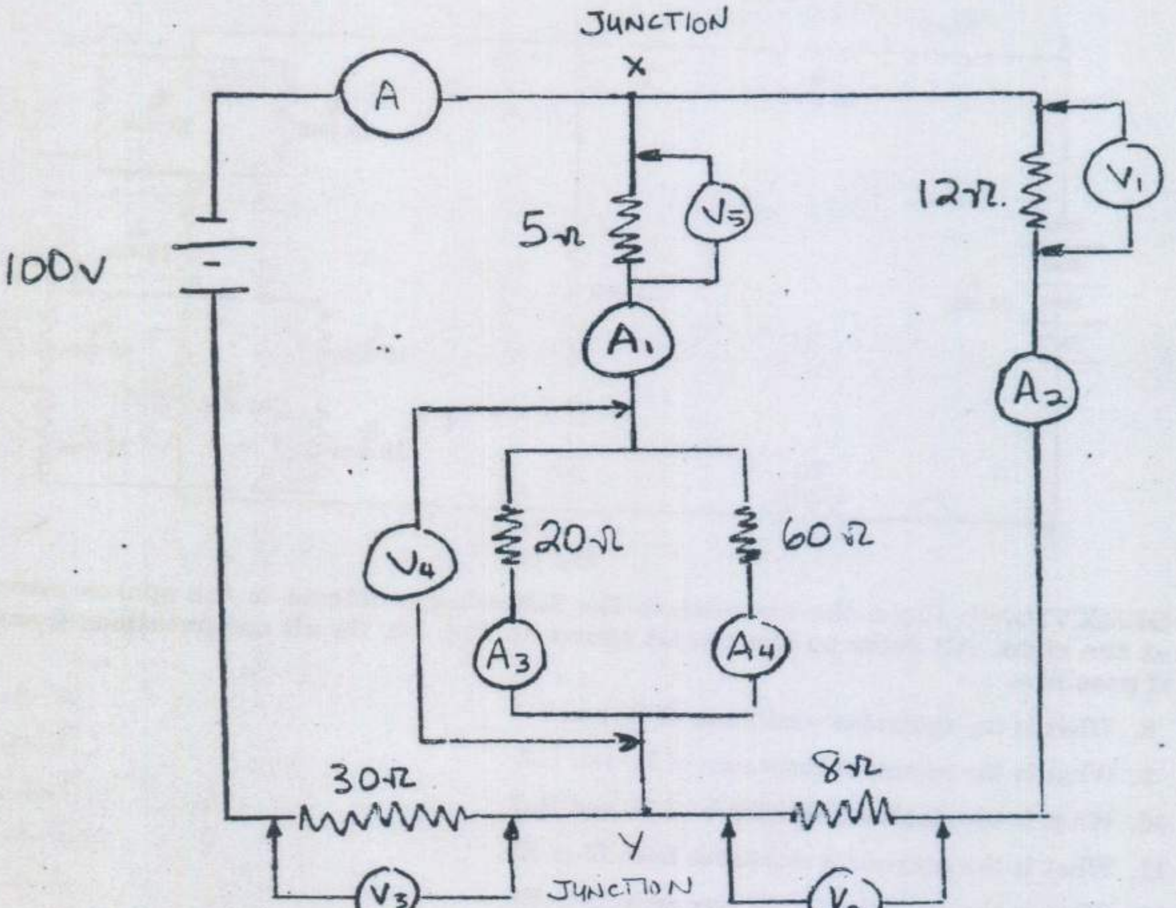


Fig. 18

DIRECTIONS: Place the answers to the following problems in the spaces provided at the right. All refer to the circuit shown in Fig. 18. Do all computations mentally if possible.

8. What is the equivalent resistance of R_3 and R_4? ....5 Ω....8
9. What is the combined resistance of R_6 and R_7? ....9 Ω....9
10. What is the combined resistance of R_9 and R_{10}? ....9 Ω....10
11. What is the equivalent resistance from D to E? ....3 Ω....11
12. What is the equivalent resistance from B to E? ....5 Ω....12
13. What is the total resistance of the external circuit (from A to F)? ....8 Ω....13
14. What is the total current in the external circuit? ....3 amp....14
15. What potential drop occurs across R_1? ....6V....15
16. What is the drop in potential from B to E? ....15V....16
17. How much current is in R_2? ....1.5A....17
18. How much current is in R_5? ....1.5A....18
19. What is the potential drop from B to C? ....7.5V....19
20. What is the current in R_3? ....0.75 A....20
21. What is the voltage drop across R_5? ....3V....21
22. What is the current in each branch of the circuit from D to E? ....0.5A....22
23. What is the potential drop across R_6? ....3.5V....23
24. What potential drop occurs across R_7? ....1V....24
25. What is the potential drop across R_8? ....4.5V....25
26. What is the sum of the potential drops across R_9 and R_{10}? ....4.5....26
27. Find the sum of the potential drops from A to B, B to E, and E to F. ....24V....27
28. What resistance is in parallel with R_2? ....10 Ω....28.
29. What is the sum of all currents between B and E? I_T ....3 amp....29
30. Does Ohm's law apply to each part of the circuit as well as to the circuit as a whole? ....Yes....30



R_T ____________

A ____________

V_1 ____________

V_2 ____________

V_3 ____________

V_4 ____________

V_5 ____________

V_{XY} ____________

A_1 ____________

A_2 ____________

A_3 ____________

A_4 ____________

1. Distinguish between an **ampere** and a **volt.**

Ampere - current = $\frac{charge}{time}$

4

Volt - potential (energy) = $\frac{Energy}{charge}$

2. If a 60-watt and a 100-watt bulb are connected in series in a circuit, through which bulb will the greatest current flow? What if they are connected in parallel? Explain.

(6)

3 (a) $I_{60} = I_{100}$ ∴ in series same

Which has greatest R?

3 (b) $V_{60} = V_{100}$ $I = \frac{P}{V} = \frac{100\,watt}{V}$ vs $\frac{60\,watt}{V}$ ∴ Current greater in 100 watt

3. Why are household appliances almost never connected in series?

(3) In series - must share potential ($\frac{energy}{charge}$

One out all out

Least V drop in last one

4. Which will do the least damage, plugging a 110-volt rated appliance in a 220-volt circuit or into a 110-volt circuit? Explain.

4 110 volt $I = \frac{V}{R}$ => $I \propto V$

5. The damaging effects of electric shock results from the amount of current that flows in the body. Why, then, do we see signs that read, "**Danger, High Voltage**", rather than "**Danger,** High Current"?

4

Potential Causes the current

↳ There even if no current.

6. What current flows through a 60-watt bulb connected to a 120-volt circuit?

4

$V = 120\,volt$ $P = IV$ $I = \frac{P}{V} = \frac{60\,watt}{120\,volt}$ = 0.5 amps = I

$P = 60\,watt$

$I =$

7. If you double the resistance of a heater operated on 110 volts, what will happen to the heat output?

4

P $P = \frac{V^2}{R}$ Power is $\frac{1}{2}$

V

R

Cannot read.

3. Will short out outlets - Blow a circuit

Each have 1/2 the volts

Current same - not all need same.

Not enough energy for last appliance

Almost never because of amount of resistance needed in circuit.
↳ have hot wires

Because V α I

Used more often - be a greater of them all being on at once

Easier to blow out a fuse

In series use a tremendous amount of voltage

Each appliance has a different amount of volts to use

Voltage have be the same through each circuit

Current not distributed as well.

If 1 appliance overloads the voltage it will burn out

beginning voltage broke down comes back = beg. voltage

R's add up - circuit not handle all current

Never in series - require much more resistance

As light bulb → current split equally.

$P = IV$

$P = I^2 R$

$P = \frac{V^2}{R}$

4. Not able to use excess energy.

220 - give too much flow cause it to blow

110 V appliance does not have high enough R for that outlet

Appliance <u>might</u> overheat

" only draw $\frac{1}{2}$ max voltage

Most appliance run off 220 V line

into 110 volt line → less R

into 220 - less stress on line

220 - too much energy - appliance not enough R to cope w/ excess energy

Get twice as much power

for 220 - take longer to blow a fuse

More V ⇒ more I ⇒ moves faster

Appliance only draw 110 volts if plugged into either 110-220

5. Current may not always be going through the wire

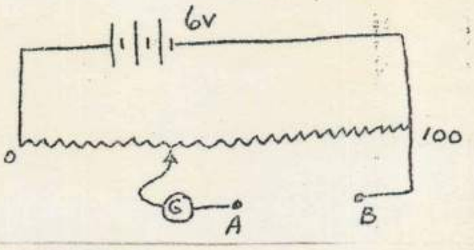
but the voltage is always connected to it.

Current carries the charges

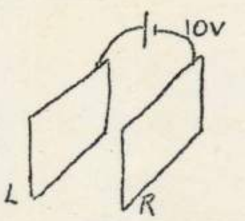
Voltage is how much is applied

Voltage turned into current.

The slide wire potentiometer has 100 divisions. If a 1.5 volt battery is connected between A and B, what will the slider setting be for a null reading on the galvanometer? Draw in the battery with appropriate connections for balance.



Two metal plates 0.03 cm apart in an evacuated region are connected to a battery. If a micromicrocoulomb of charge is taken from the R plate to the L, then it will receive a potential energy increase of:



Suppose this charge manages to get free of the left plate and accelerates to the right, experiencing a force, F. Write an expression for energy of motion that will be given to the charge.________________________________.

Explain briefly why these two answers represent the same amount of energy.__________

Calculate the electric field between the plates.

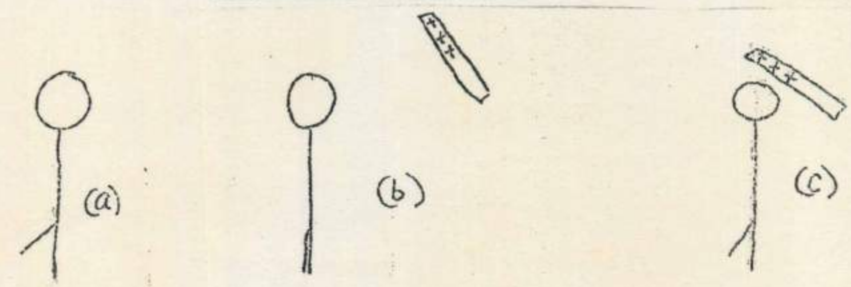


Fig. (a) shows an electroscope.

A positively charged rod is brought near the electroscope as shown in (b) and then nearer but never allowed to touch as shown in (c). What charge is on (1) the ball and (2) the leaves in each of the three cases? Justify your answer briefly.

Write an operational definition of "charged object".

---

1. Sometimes you hear someone say a particular appliance uses up electricity. What is it that the appliance uses up and what becomes of it?

2. Does electric current flow out of a battery or through a battery? Does it flow into a light bulb or through a light bulb? Explain.

3. Why do wires heat up when they carry an electric current?

4. What condition is necessary for a sustained flow of electric charge through a conducting medium?

5. A string of 20 christmas lights wired in series draws 1.7 amp when connected to a 125 volt line. What is the power used by the 20 lights? What is the resistance of a single bulb?

If you wanted to make a circuit using only 5 bulbs connected to a 125-volt line, what resistance would have to be connected in series with the 5 bulbs?

6. What is the resistance of an electric frying pan that draws 11 amperes when connect to a 110-volt circuit?

$I = 11$ amps
$V = 110$ volt

$R = \frac{V}{I} = \frac{110 \text{ volt}}{11 \text{ amps}} = 10\Omega$

7. A toaster uses 1600 watts when plugged into a 120 volt line. If it takes 2 minutes to toast a slice of bread and it costs 7.5 cents/kilowatt-hour, how much does it cost to do this?

$P = 1600$ Watts
$V = 120$ Volt
$t = 2$ MIN
$7.5¢/kw \cdot hr$

$1600 \text{ watts} \times 2 \text{ min} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ kw}}{1000 \text{ watts}} = .05\bar{3} \text{ kw} \cdot \text{hr} \times = 0.4$ cents

8. Suppose we have three resistors, R1 = 12 ohms, R2 = 6 ohms, and R3 = 4 ohms. What is the total resistance of these 3 resistors when connected in (a) series (b) parallel?

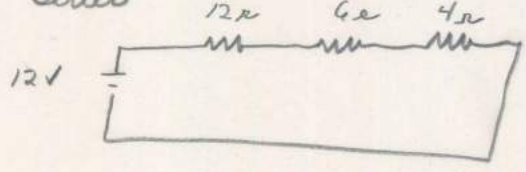
$R_1 = 12\Omega$
$R_2 = 6\Omega$
$R_3 = 4\Omega$

(a) $R_T = R_1 + R_2 + R_3 = 12\Omega + 6\Omega + 4\Omega = 22\Omega$

b $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = 2\Omega$

9. When the three resistors identified in problem 8 are connected in series, find
a. the current in the circuit if the emf is 12 volts
b. find the potential difference across each resistor
c. Find the power supplied to or by each circuit element.

Series



a. $I_T = \frac{\mathcal{E}}{R_T} = \frac{12 \text{ volt}}{22\Omega} = 0.55$ amp

b. 12Ω = 6.55 volt
6Ω 3.27 volt
2.18 volt

$.55 \text{ amp}^2 \times 12\Omega$

c. $P = I^2 R \times R$ 3.57
~~1.79~~ 1.8
~~4.30~~ 1.19