DOCUMENT RESUME

ED 190 884		CE 026 569
TITLE	Military Curricula for Vocational & Technical Education. Basic Electricity and Electronics Individualized Learning System. CANTRAC A-100-0010. Module Seven: Combination Circuits and Voltage Dividers. Study Booklet.	
INSTITUTION	Chief of Naval Education and Training Support, Pensacola, Fla.: Ohio State Univ., Columbus. National Center for Research in Vocational Education.	
REPORT NO	NAVEDTRA-34258-7	
PUB DATE	Mar 77	
NOTE	109p.: For related documents see CE 026 560-593.	
EDRS PRICE	MF01/PC05 Plus Postage.	
DESCRIPTORS	*Electric Circuits: *Electricity: *Electronics: Individualized Instruction: Learning Activities: Learning Modules: Postsecondary Education: Programed Instruction: *Technical Education	
IDENTIFIERS	Military Curriculum Project	

ABSTRACT

This individualized learning module on combination circuits and voltage dividers is one in a series of modules for a course in basic electricity and electronics. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instructional and curriculum development in a civilian setting. Three lessons are included in the module: (1) Solving Complex Circuits, (2) Voltage Reference, and (3) Voltage Dividers. Each lesson follows a typical format including a lesson overview, a list of study resources, the lesson content, a programmed instruction section, and a lesson summary. (Progress checks are provided for each lesson in a separate document, CE 026 562.) (LRA)

NAVEDTRA 34258-7

CHIEF OF NAVAL EDUCATION AND TRAINING

MARCH 1977

Military Curricula for Vocational & Technical Education

BASIC ELECTRICITY AND ELECTRONICS INDIVIDUALIZED LEARNING SYSTEM.

MODULE SEVEN. COMBINATION CIRCUITS AND VOLTAGE DIVIDERS.

STUDY BOOKLET.

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

Agriculture	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Occupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
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The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

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The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

OVERVIEW

MODULE SEVEN

Combination Circuits and Voltage Dividers

In this module, you will learn to apply the rules you learned for series and parallel circuits to more complex circuits called series-parallel circuits. You will discover the utility of a common reference when making reference to voltage values and learn how to obtain a required voltage from a voltage divider network.

For you to more easily learn the above, this module has been divided into the following three lessons:

TURN TO THE FOLLOWING PAGE AND BEGIN LESSON I.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

MODULE SEVEN

LESSON I

Solving Complex Circuits

Study Booklet

OVERVIEW
LESSON I

Solving Complex Circuits

In this lesson, you will study and learn about the following:

- composing and reviewing rules for series and parallel circuits
- redrawing circuits
- finding equivalent resistance
- finding total resistance
- solving for branch currents
- solving for voltage drops

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES

LESSON I

Solving Complex Circuits

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following:

STUDY BOOKLET:

- Lesson Narrative
- Programmed Instruction
- Lesson Summary

ENRICHMENT MATERIAL:

NAVPERS 93400A-1a "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U.S. Government Printing Office, 1965.

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

NARRATIVE
LESSON 1

Solving Complex Circuits

You have already learned about series circuits and parallel circuits, but you will seldom be working with either of these as separate circuits. Most networks you will encounter will be combinations of these two types. We have several names for these -- series-parallel circuits, combination circuits, or complex circuits. Your power supply is an example of a series-parallel network.

To complex circuits, you need to apply the rules for ser. cuits to the circuit components wired in series and the r for parallel circuits to the circuit components in paralle.. For this reason, let's compare and review the rules for series and parallel circuits.

Comparison and Review of Rules for Series and Parallel

	SERIES	PARALLEL
Current	Common $I_T = I_1 = I_2 = I_3 = \ldots$	Equal to sum of branch currents (Kirchhoff's Current Law). $I_T = I_1 + I_2 + I_3 + \ldots$
Voltage	Sum of voltage drops equals applied voltage (Kirchhoff's Voltage Law). $E_a = E_1 + E_2 + E_3 + \ldots$	Common $E_a = E_1 = E_2 = E_3 = \ldots$
Resistance	Resistances are additive. $R_T = R1 + R2 + R3 + \ldots$	Total resistance is the equivalent resistance as seen by the source and is always smaller than the smallest branch resistance. Solved by: 1) Reciprocal method: $R_T = \frac{1}{1/R1 + 1/R2 + 1/R3}$

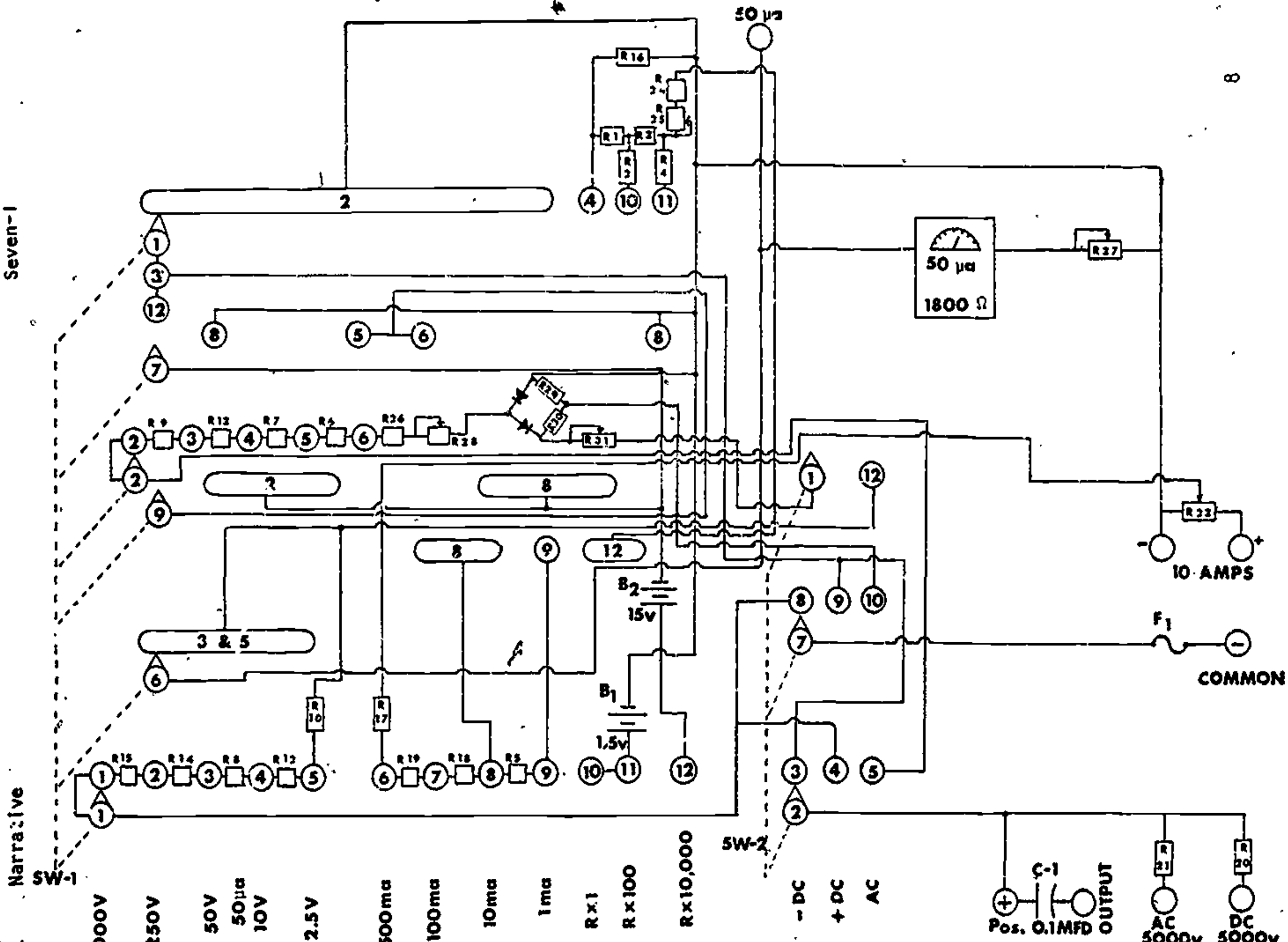
(CONTINUED NEXT PAGE)

		2) Equal Branches: $R_T = \frac{\Omega \text{ one resistor}}{\text{number of branches}}$ 3) Product Over Sum: $R_T = \frac{R1 \times R2}{R1 + R2}$ R_T is always less than the smallest resistor. Branch resistance controls branch current.
Power	P_T is equal to the sum of power consumptions of individual resistances.	Same as for series: $P_T = P_1 + P_2 + P_3 + \ldots + P_n$

Redrawing

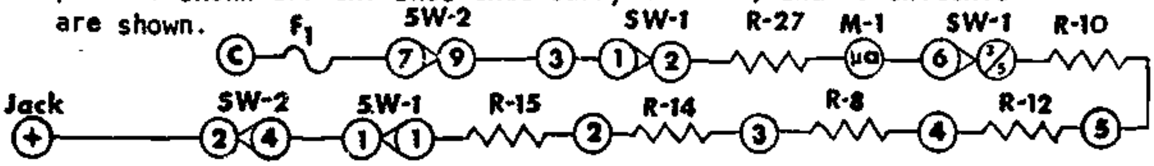
You will often find that a circuit in an instruction book or blueprint is hard to use because it shows many sections of the system which do not concern you at the moment. You may have to redraw the section you are concerned with to get a better idea of how it works. A good way to do this is to follow the electron flow through the network, drawing each part or junction as you proceed.

An overall schematic of the Simpson Model 260-5P multimeter is on the next page.


50 μa
R16
R24
R25
R1
R2
R3
R4
2
Seven-1
50 μa
1800 Ω
R27
R9
R13
R7
R6
R26
R28
R29
R30
R31
3 & 5
R15
R14
R8
R12
R10
R17
R19
R18
R5
B2
15v
B1
1.5v
10 AMPS
F1
COMMON
SW-2
SW-1
Narrative
1000V
250V
50V
50μa
10V
2.5V
500ma
100ma
10ma
1ma
R×1
R×100
R×10,000
− DC
+ DC
AC
C-1
R21
R20
Pos.
0.1MFD
OUTPUT
AC
5000v
DC
5000v

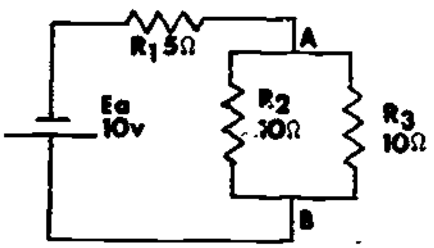
If your meter is inoperative on the 1000 VDC range only, there is no need to check all the components in the meter. Here is a drawing showing only the 1000 VDC section.

This schematic was drawn by starting at the common (-) jack (assuming the meter was set up for +DC, 1000 v operation) and by tracing the current path through the circuits. The only components shown are the ones that carry current, and no switches are shown.



It is usually helpful to reduce a section to its simplest form. This process is sometimes called complex-circuit reduction or simplification.

This schematic illustrates a series-paralle circuit. Observe that R1 is in series with the source. However, R2 and R3 are not directly in series. They make up a parallel network within the configuration. To see this, trace the path of current from the source through R1 to point A. At point A, current divides between the two branches of the parallel network, and then comes together again at point B and continues to the source.



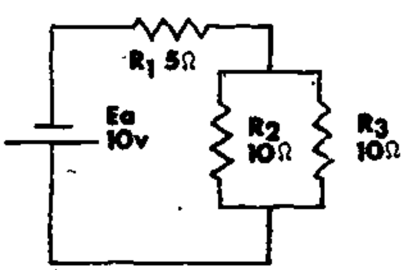
Finding Parallel Equivalent Resistance

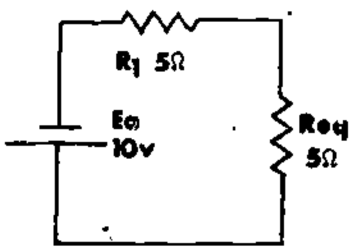
To solve for total circuit resistance, we first need to find the equivalent resistance of the parallel network.

What is the R_{eq} of R2 and R3? ____________________

By using the equal branch method you found that $R_{eq} = \frac{R}{n} = \frac{10}{2} = 5\ \Omega$.

Now that you know the equivalent resistance of the parallel branches, you can simplify the complex circuit and redraw it in this manner:

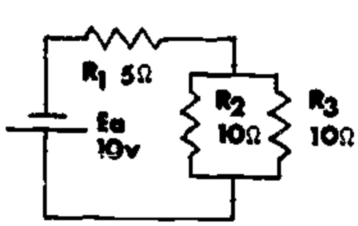


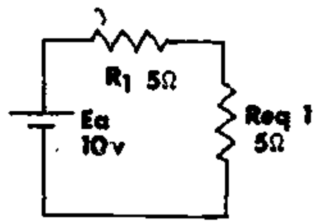


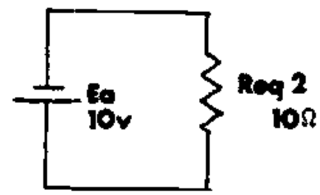
Notice that the R_{eq} in the reduced circuit represents the equivalent resistance of the parallel branches. Now the combination circuit has been simplified to a series circuit with two resistances.

Finding Total Resistance

You can further reduce the circuit to a circuit with one resistance. This can be accomplished by adding the two resistances in series to combine them into one representative resistance value, which is total resistance of the complex circuit -- 10 ohms.







You have now redrawn the complex circuit twice.

Once the circuit is reduced to its simplest form, it is a simple matter to solve a series-parallel circuit for other values.

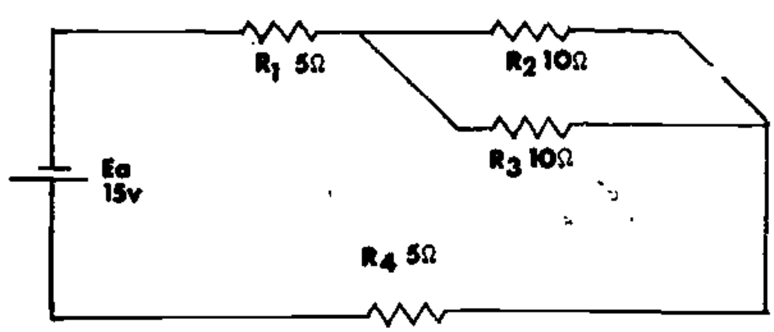
What is I_T for the circuit above? ______________________

By Ohm's Law, you found that $I_T = \frac{E_a}{R_T} = 1a$

Observe that you have taken three steps toward solving for quantities in the complex circuit.

1. Find R_{eq} of the parallel network and redraw the circuit to reflect R_{eq}.
2. Find total resistance and reduce circuit to its simplest form.
3. Find total current by using Ohm's Law.

See if you can follow the three steps to solve for total current in the series-parallel circuit below.

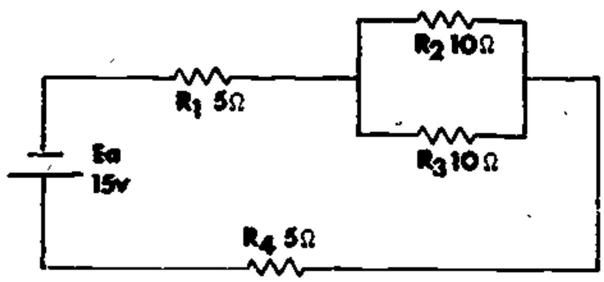


You must first decide which resistors are directly in series with the source. That is, through which resistors does total current flow? ________ ________

You can see by tracing the path of current from the negative terminal that total current flows through R1 and R4. Current divides, however, through the parallel network, so that total current does not flow through R2 or R3.

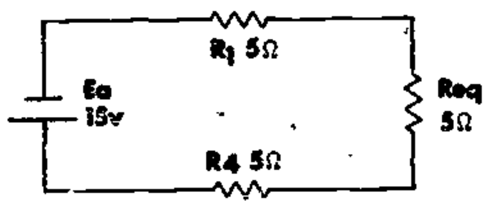
Step 1.

Find R_{eq} of the parallel network and redraw the circuit to reflect R_{eq}. R_{eq} = ________________



You could have calculated R_{eq} (R2 and R3) by the equal resistors method -- dividing 10 ohms by the number of branches, 2; $R_{eq} = 5\ \Omega$.

The redrawn circuit looks like this:



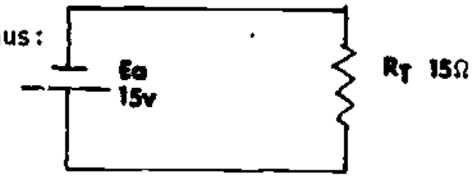
Step 2.

Find the total resistance (equivalant resistance) of the total circuit, and reduce the complex circuit to its simplest form.

R_T = ________

Recall that in a series circuit $R_T = R1 + R_{eq} + R4$.

Thus:



$R_T = 5\Omega + 5\Omega + 5\Omega = 15\Omega$

Having found total resistance, and knowing the applied voltage, you can calculate total current.

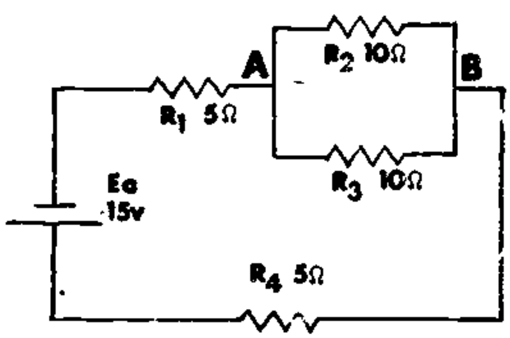
Step 3.
Applying Ohm's Law, find total current. I_T = __________

$$I_T = \frac{E_a}{R_T} = \frac{15\ v}{15\ \Omega} = 1a$$

After you have completed these three steps, you can solve for branch currents through the parallel network and voltage drops across individual resistors.

Solving for Branch Currents

Sometimes we can solve for branch currents when we know total current by tracing the path of current flow. Again looking at our complex circuit, let's solve for I_{R2} and I_{R3}.

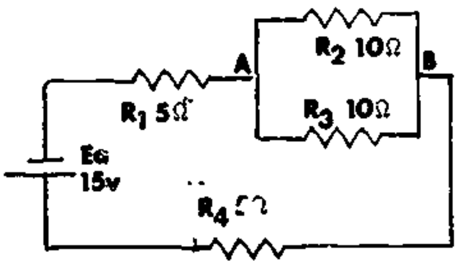


We know that total current from the negative terminal of the source is 1 amp. Therefore, 1 amp of current flows through R1. At point A, current divides and flows through the two parallel branches. Because R2 and R3 are equal, current divides equally so that .5 amp flows through each branch. Thus I_{R2} = .5 a and I_{R3} = .5 a. Then at point B, the two branch currents of .5 amp each unite to become total current of 1 amp again. One amp flows through R4 and back to the source.

Another approach to finding branch current is to first solve for the voltage drops across each resistor, then determine branch current by Ohm's Law.

Solving for Voltage Drops

Again looking at this circuit, we already know that total current is 1 amp. By ohm's Law, if 1 amp of current flows through R1 and the resistance of R1 is 5 ohms, then E_{R1} must be 5 volts. Similarly, E_{R4} is also 5 volts. Therefore, across R1 and R4, we have 10 volts dropped. We know the applied voltage is 15 volts. By subtracting 10 volts from the 15 volts, we discover the voltage drop across the equivalent resistance must be 5 volts, according to Kirchhoff's Law -- the sum of the voltage drops in series equals the applied voltage.



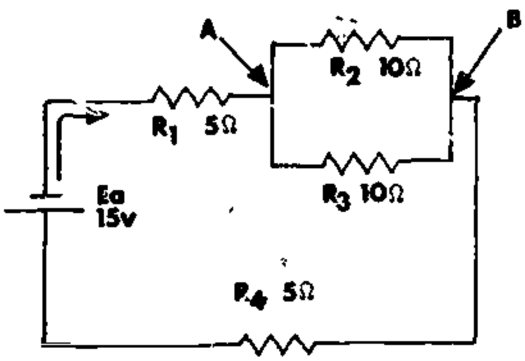
As voltage is common in a parallel circuit, what is the voltage drop across R2? ____________. Across R3? ____________

E_{R2} = 5 v, E_{R3} = 5 v. Now that you know the voltage drops, you can solve for current through each leg of the parallel network.

$$I_{R2} = \frac{E_{R2}}{R2} = \frac{5\text{ v}}{10\ \Omega} = .5\text{ a or }500\text{ ma}$$

R3 is equal to R2; therefore, I_{R3} = 500 ma.

There is another approach to find the voltage drops and current through the branches of the parallel network.



We know that current in this circuit is 1 amp until it gets to point A. At point A, current does not see two resistors of 10 ohms each; instead, it sees the equivalent resistance of 5 ohms; then voltage across the parallel network is 5 volts. $I_T \times R_{eq}$ = 5v. In a parallel network, voltage is common; therefore, E_{R2} = 5 v and E_{R3} = 5v.

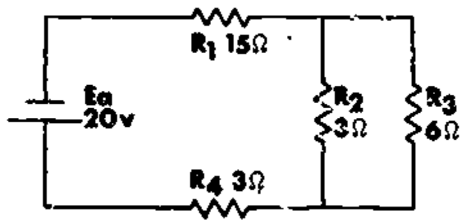
Knowing E and R of each branch in the parallel network, find I_{R2} and I_{R3}.

I_{R2} = __________

I_{R3} = __________

By using a different approach, you have again found that $\bar{I}_{R2}$ and I_{R3} are each .5 amps.

Let's solve a complex circuit with unequal resistors in the parallel network -- one 3-ohm resistor and one 6-ohm resistor.



Step One.

Find R_{eq} of R2 and R3. Redraw circuit. R_{eq} = ________

We can find R_{eq} of R2 and R3 by the reciprocal method. Recall the formula:

$$R_{eq} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}}$$

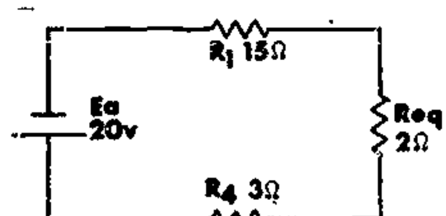
$$R_{eq} = \frac{1}{\frac{1}{3} + \frac{1}{6}} \text{ and } \frac{1}{3} = \frac{2}{6}; \text{ therefore}$$

$$R_{eq} = \frac{1}{\frac{2}{6} + \frac{1}{6}} = \frac{1}{\frac{3}{6}} = \frac{6}{3} = 2\ \Omega$$

NOTE: Recall that you can also find R_{eq} of R2 and R3 by the product over the sum method:

$$R_{eq} = \frac{R2 \times R3}{R2 + R3}$$

$$R_{eq} = \frac{3 \times 6}{3+6} = \frac{18}{9} = 2\ \Omega$$



Step Two.

Find R_T. Redraw circuit. R_T = ______

Once you find the R_{eq}, you can add the values of the two resistors and the R_{eq} to find R_T = 20 Ω.

Step three.

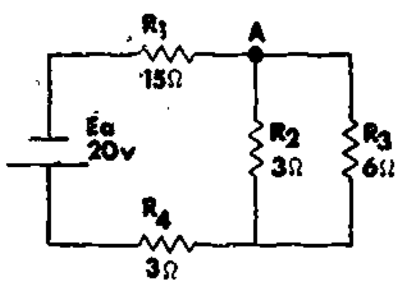
Find I_T. I_T = ______

By Ohm's Law, if R_T is 20 ohms, and E_a is 20 volts, then $I = \frac{20v}{20\Omega} = 1a$.

Now to solve for circuit voltage drops and branch current, we can use either of the two procedures we discussed previously.

The Voltage Drop Approach

This approach adds up the voltage drops across resistances directly in series with the source, then subtracts this total from the amount of applied voltage. The remainder then is the voltage drop across the equivalent resistance as shown below.



$E = IR$

$E_{R1} = 1a \times 15\Omega$

$E_{R1} = 15v$

$E_{R4} = 1a \times 3\Omega$

$E_{R4} = 3v$

$E_{R1} + E_{R4} = 15v + 3v = 18v$

$E_a = 20v$; thus $20v - 18v = 2v$ drop across R_{eq}.

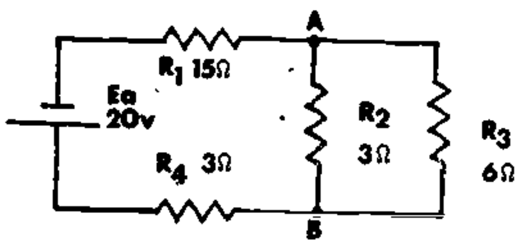
Voltage is common in a parallel network: E_{R2} is 2 volts: therefore, E_{R3} is 2 volts. Then we can find branch currents in this manner.

Current through <u>R2</u>: $I = \frac{E}{R}$ or $I_{R2} = \frac{2v}{3\Omega}$

$I_{R2} = .667a$ or 667ma

Current through <u>R3</u>: $I_{R3} = \frac{2v}{6\Omega} = .3a$ or 333 ma

The alternative approach solves first for voltage across the equivalent resistance, then accordingly solves for branch currents in the parallel network.



Here, current sees the equivalent resistance of the parallel circuit -- 2 ohms. Voltage across

$R_{eq} = E = IR$

$E = 1a \times 2\Omega$

$E = 2v$

Thus, the voltage drop across <u>R2</u> is 2 volts and across <u>R3</u> is 2 volts.

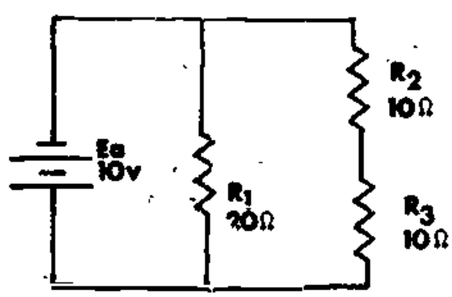
Then you can figure current through the resistors in parallel:

$I_{R2} = \frac{2v}{3\Omega} = 667$ ma $\qquad I_{R3} = \frac{2v}{6\Omega} = 333$ma

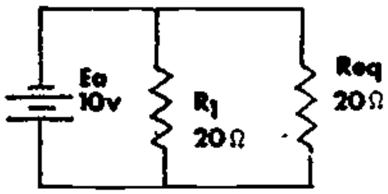
As you can see, using either method, we can solve the complex circuits.

Another Configuration

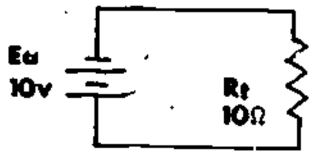
The first step in solving a complex circuit is to reduce the circuit to a basic circuit. Let's look at another series-parallel configuration and see how we go about solving it. Notice that in this circuit, <u>R2</u> and <u>R3</u> are in series within a parallel branch.



To reduce this circuit, it is necessary first to determine the equivalent of R2 and R3. Resistances in series are additive; therefore, resistance in the second branch of the parallel network is 20 ohms, and we can redraw the circuit in this way.



Then we can further reduce the network to a basic series circuit by finding the equivalent resistance of the parallel network, and redrawing the circuit. After we have reduced the circuit to a basic series circuit, we can apply Ohm's Law and rules for series and parallel to solve for any quantity in the complex circuit.



Practice

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1. By the methods you have just learned, find the following quantities in this circuit.

R_T = ______

I_T = ______

E_{R1} = ______

E_{R2} = ______

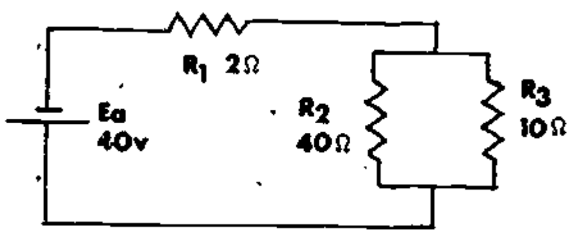
E_{R3} = ______

I_{R1} = ______

I_{R2} = ______

I_{R3} = ______

P_T = ______

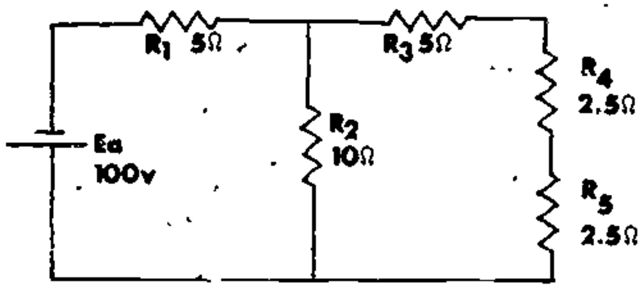


Recall that redrawing the circuit helps to understand it and solve it.

Answers begin on page 19

Practice

2.



Note: This configuration is a little more complex than those you have previously worked. Ask yourself whether R3 is in parallel or in series with R4 and R5. The question to ask is: How many paths are there for current flow?

Reduce the circuit. Solve for:

R_T. ______ E_{R5}. ______

I_T. ______ I_{R2}. ______

E_{R1}. ______ I_{R3}. ______

E_{R2}. ______ I_{R4}. ______

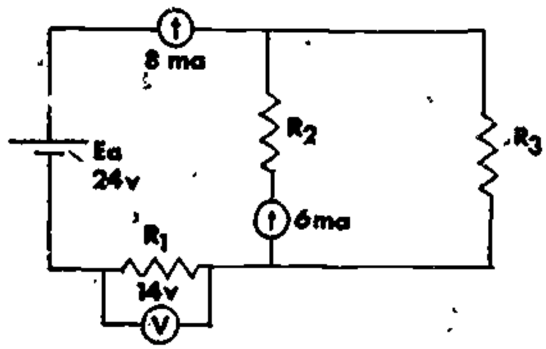
E_{R3}. ______ I_{R5}. ______

E_{R4}. ______

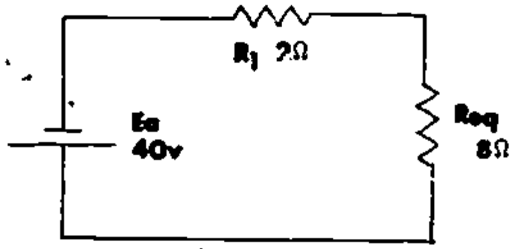
Practice

3. Using rules for series and parallel circuits and methods you have just learned, you can solve for any quantity in a complex circuit even when resistance values are unknown. Solve for R3.

R3 = ______



1. Reduction:



R_T = 10Ω

I_T = 4a

E_{R1} = 8v

E_{R2} = 32v

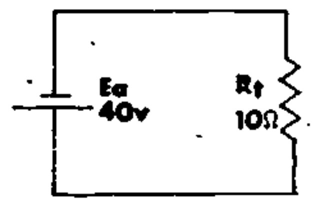
E_{R3} = 32v

I_{R1} = 4a

I_{R2} = .8a

I_{R3} = 3.2a

P_T = 160w



2. Redraw to:

R_T = 10Ω

I_T = 10a

E_{R1} = 50v

E_{R2} = 50v

E_{R3} = 25v

E_{R4} = 12.5v

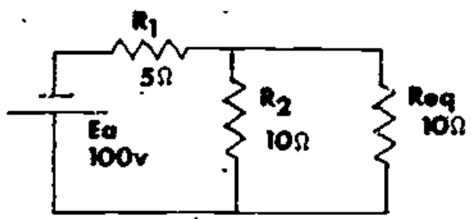
E_{R5} = 12.5v

I_{R2} = 5a

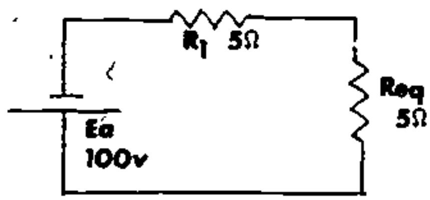
I_{R3} = 5a

I_{R4} = 5a

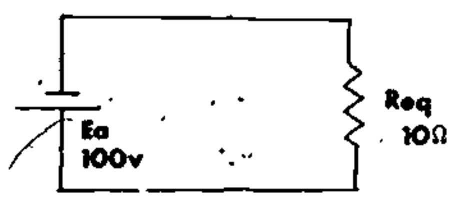
I_{R5} = 5a



(adding in series R3, R4, and R5)



(finding equivalent of parallel network)



(adding equivalent resistance + R1)

3. You know that:

   $E_a = 24v$

   $E_{R1} = 14v$

   therefore, the voltage drop across the parallel network must be 10 volts.

If there is a total current of 8ma and current through <u>R2</u> is 6ma, then current through <u>R3</u> = 2ma.

If $I_{R3} = 2ma$, and

$E_{R3} = 10v$,

then R3 = 5kΩ

AT THIS POINT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON I

Solving Complex Circuits

TEST FRAMES ARE 17, 34, AND 38. AS BEFORE, GO FIRST TO TEST FRAME 17 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

---

1. A series-parallel circuit is a circuit which contains elements of both series and parallel circuits. There is a portion of the circuit which has source voltage divided among loads, and there is at least two junctions where currents divide and/or combine.

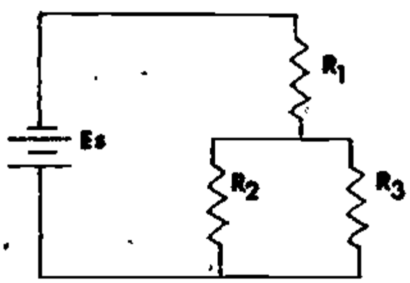
A circuit which is made up of both series and parallel sections is called a ________________ circuit.

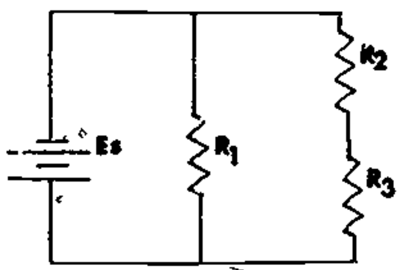
- -

(series-parallel)

---

2. The simplest form of a series-parallel circuit requires three resistors (or some other load devices), and these three components may be arranged in either of two ways to meet our definition.





The components making up the parallel network of circuit A are ____________ and ____________.

- -

(R2, R3)

---

3. The series network of circuit B in frame 2 is composed of ____________ and ____________.

- -

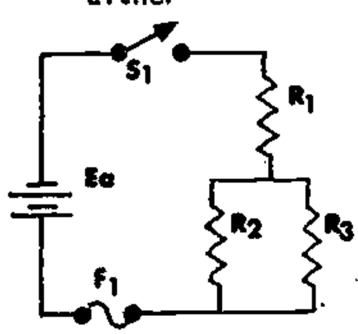
(R2, R3)

---

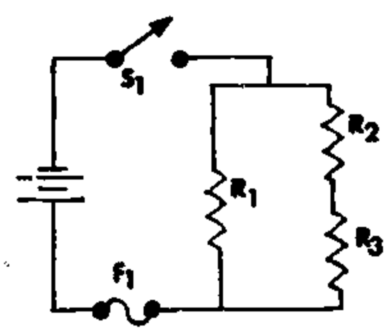
4. Draw a schematic diagram of a series-parallel circuit consisting of a source, a switch, a fuse, three resistors and the wiring to connect them so that the fuse and switch control current through all three resistors in the series-parallel connection. Label all components with appropriate circuit symbols.

- -

Either



or



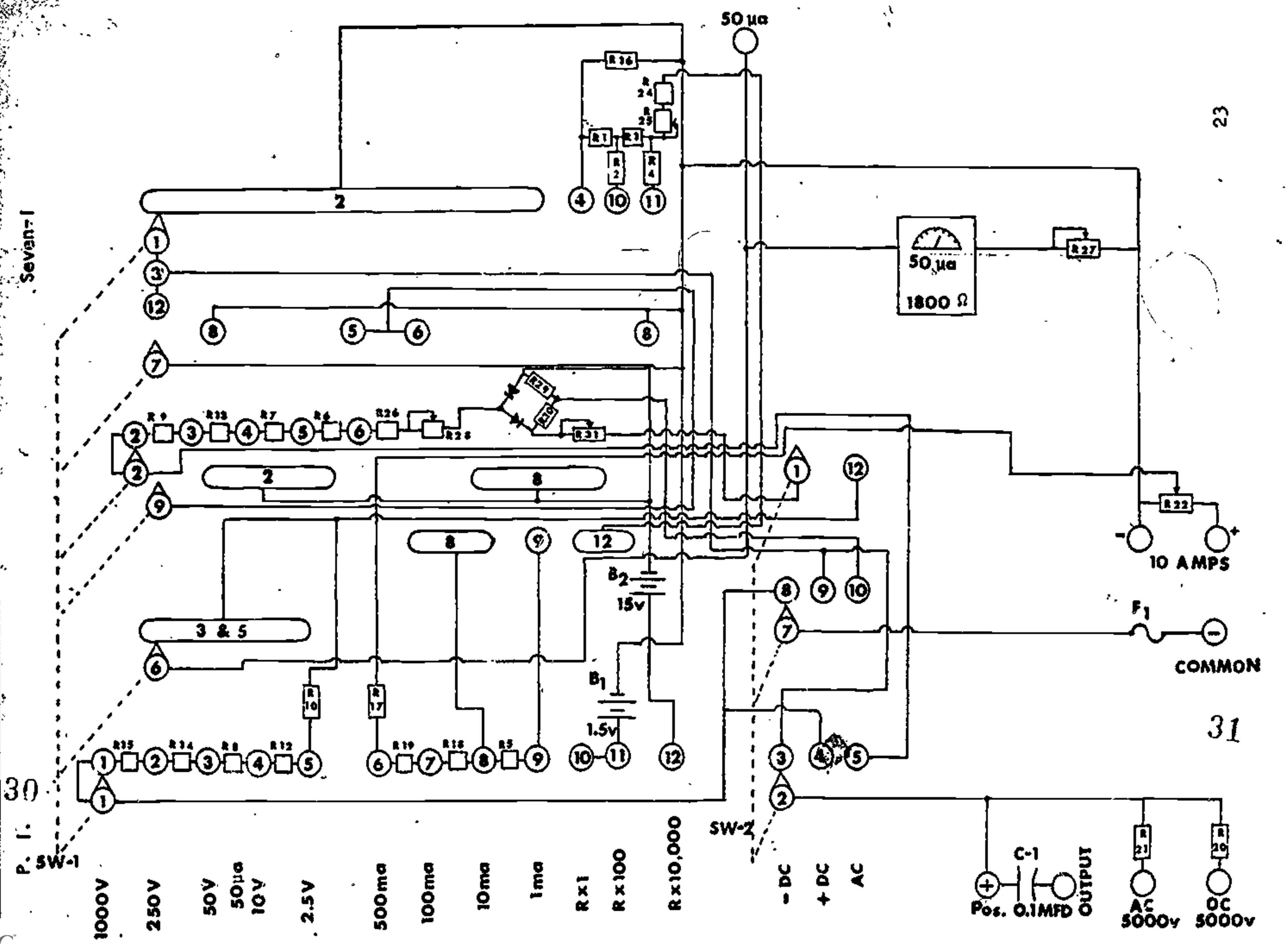
5. Actual circuits are complicated and seldom follow neat patterns. For this reason, you must learn to systematically trace the current path to simplify the circuit schematic.

On the following page is a schematic of the Simpson 260-5P multimeter. You can see that the current path through the circuit is not readily apparent. We will follow a step-by-step procedure through the schematic and redraw one of the many possible current paths.

What is the purpose for redrawing a complicated schematic diagram?

- -

(To simplify the schematic and make it more easily understood.)



Seven-I

23

30

31

6. Look at the schematic in frame 5. At the bottom you see the positions of both the Range Selector (SW1) and the Function Switch (SW2). Directly above the 1000 v and the -DC positions you see a number of switch contacts represented by and connected by dotted lines.

When the switch position is changed, the contacts ganged by the dotted lines move in the same direction at the same time. The schematic indicates both switches in the fully counterclockwise position.

Rotate the Function Switch one position clockwise and list the numbers of the contacts moved and the direction moved (left or right). ____________________

(Contacts 1, 7, and 2 each move one position to the right.)

7. One more thing about the switch contacts and we will get started.

The switch contacts designated by are movable, you see contacts designated by or , these contacts remain stationary as the switch position is changed. Note that the movable contacts touch different stationary contacts when the switch is moved.

Indicate by number the movable contacts of the Range Selector in the 1000 v position and the non-moving contacts which they touch.

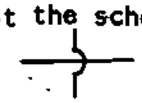
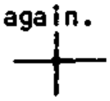
(1,3 and 12 touch 2; 7 touches none; 2 touches 2; 9 touches none; 6 touches 3 and 5; 1 touches 1)

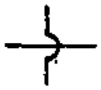
8. All of this simply means that if two switch contacts are touching, current can flow from one to the other.

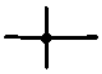
In frame 6, the function switch was rotated clockwise, to the +DC position. Indicate by number the movable contacts and the contacts they touch.

(1 touches none; 7 touches 9; 2 touches 4)

(Remember this because as we go through the schematic the Function Switch is to be in the +DC position.)

9. Take a look at the schematic again. Notice conductors crossing in two ways:  and 

 indicates a crossing but no connection.

 indicates __________________.

(a connection)

---

10. Let's set up the conditions of the circuit.

    1. Range Switch - 1000 v position.
    2. Function Switch - + DC position.
    3. Starting Point - Common (-) jack.

(You could pick any point to start. We selected this point since we are tracing current, and electrons will enter at this point.)

With the common (-) jack as the starting point, the first component the electrons enter is ____________.

(Fuse F1)

---

11. Drawing the circuit as we go, we have:

The current is now at movable contact No. 7 of the Function Switch. Where does it go from there? ________________

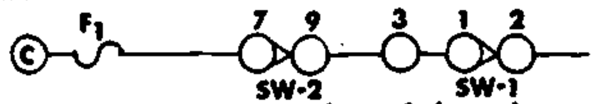
(Contact No. 9 of the Function Switch)

12. Now you have a decision to make. Does the current go to the right or to the left at the junction? Let's take a look at the conductor going to the right.

Can current flow through this conductor? ______________
Why? ______________________________

(No. Contact No. 3 of the Function Switch is open.)

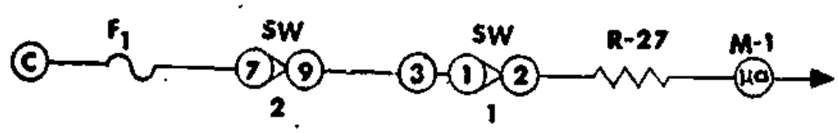
13. So we go to the left, and we have this much of the schematic redrawn.

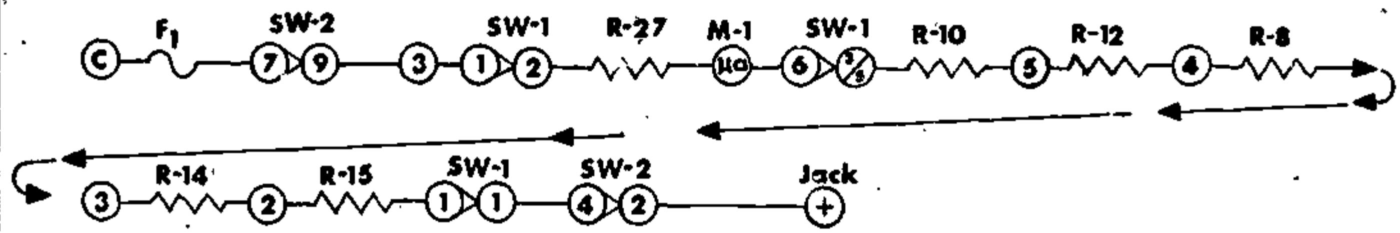


The current comes to a series of junctions. What is the next component through which it flows? ______________

(R-27. All the other conductors end at open switch contacts.)

14. From here the current flows through the meter movement. Complete the tracing of the circuit and complete the circuit below.



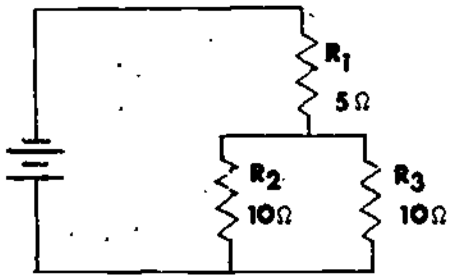


(If your circuit doesn't agree with this one and you cannot determine the problem upon re-examination of the schematic, check with your learning supervisor.)

The purpose for all of this is to get you to think and see the importance of following a logical process when dealing with complicated circuits. You will not be required to solve anything nearly so complicated in this school, although you will in later training schools.

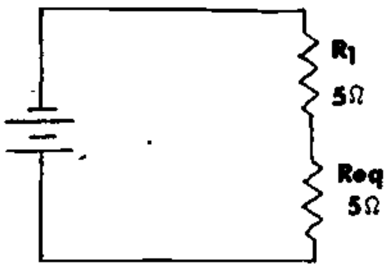
Now let's get back to a simple series-parallel circuit; but remember: WORK IN A SYSTEMATIC MANNER AND FOLLOW THE CURRENT.

15. If the values of all the load devices in a series-parallel group are known, the value of an equivalent resistor may be found by combining the methods used for series connections with those used for parallel circuits. To further understand this process, follow these steps:



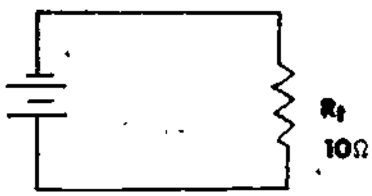
First, let's find the equivalent resistance for the parallel portion of our circuit.

$R_{eq} = \frac{R}{n} =$ ______________



The circuit can be redrawn to show R_1 in series with the R_{eq} of R2 and R3 found above. We can now reduce this series circuit to its equivalent resistance which is R_T.

$R_T =$ ______________

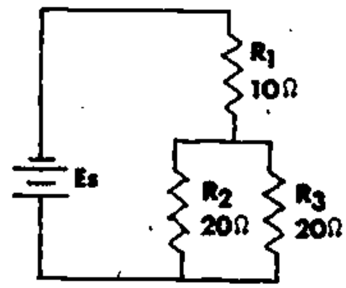


You have now found that the resistance is equal to 10 ohms, and we can replace the entire series-parallel network with a single equivalent resistance of 10 ohms.

This is known as <u>complex circuit reduction</u> or <u>simplification</u>.

15. cont'd.

Simplify the circuit below and redraw.



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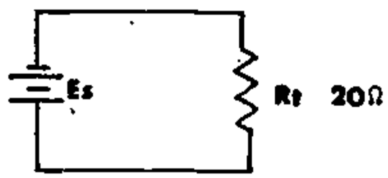
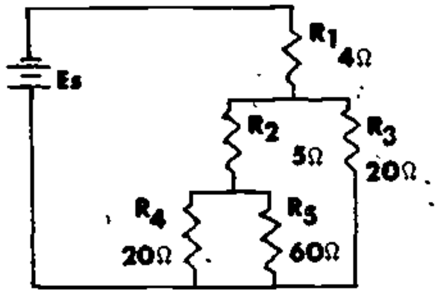
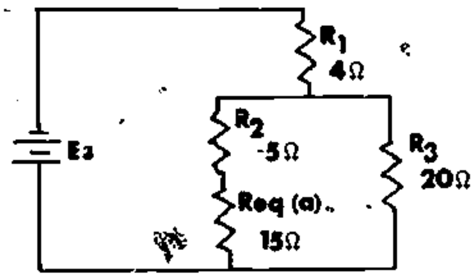


16. Now a rather complex circuit will be used to demonstrate most of the situations which you might meet in practical work. Examining the circuit below, you can see that it is made up of groups of series and parallel networks. Let's work this problem through to its simplest form.



Find $R_{eq(a)}$ [i.e., R4 and R5]:

$R_{eq(a)}$ = ______________

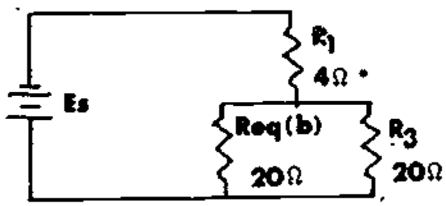


Find $R_{eq(b)}$ [i.e., R2 and $R_{eq(a)}$]:

$R_{eq(b)}$ = ______________

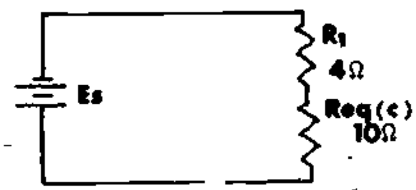
Find $R_{eq(c)}$ [i.e., R3 and $R_{eq(b)}$]:

$R_{eq(c)}$ = ______________

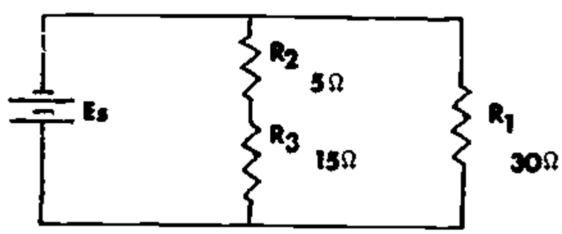


Find R_T. (R_{eq} of the entire circuit.)

R_T = ______________

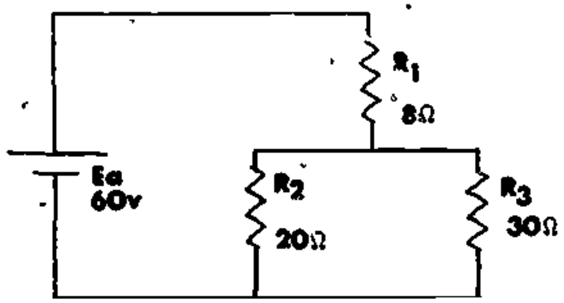


Now find the total resistance for the following circuit.



(12 Ω)

17. Redraw this circuit, first to show a series circuit with RI and R_{eq} (R2 and R3), then redraw again to show a series circuit with one resistor (include ohmic value).



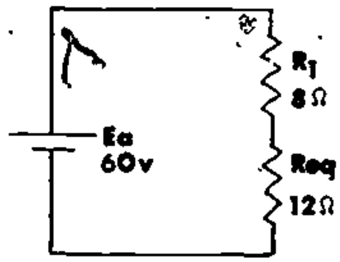
Circuit Reduction 1

Circuit Reduction 2

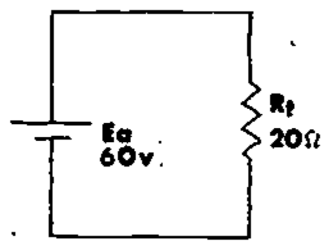
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 17

1



2



IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 34. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 17 AGAIN.

---

18. Since these circuits are part series and part parallel, this seems like a good place to review these circuits. Fill in the blanks in each of the following statements about a <u>series</u> circuit with the word or phrase which completes it.

1. There is/are __________ path(s) for current.
2. Current is ____________ throughout the circuit.
3. The equivalent resistance is equal to the ____________ of the individual resistances.
4. The ____________ across each load device is proportional to its resistance.
5. The sum of all the voltage drops around a circuit is equal to __________.
6. Total power dissipated in the circuit is equal to the sum of the ______________________________.

(1. one; 2. the same; 3. sum; 4. voltage, voltage drop, potential difference, etc.; 5. source voltage; 6. power dissipated in each individual load device.)

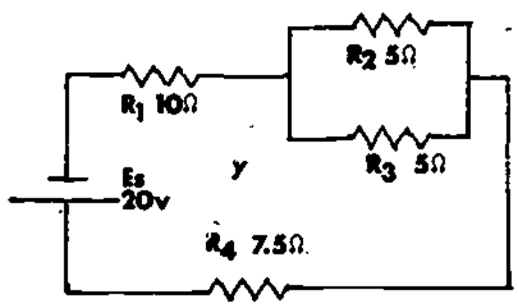
19. In a parallel circuit:

1. There is/are ______________________ current path(s).
2. ______________ is the same for each branch of the circuit.
3. ______________ in any branch is inversely proportional to the resistance of the branch.
4. Total current equals the sum of the ______________.
5. Total resistance equals the reciprocal of the sum of the reciprocals of the ______________________.
6. Total power dissipated is equal to the sum of the ______ ______________________________.

- -

(1. more than one; 2. voltage or potential difference; 3. current; 4. branch currents; 5. resistances of each branch; 6. power dissipated by each resistor)

20. In this series-parallel circuit, which resistors have total current flowing through them?



- -

(R1 and R4; the current is split between R2 and R3)

21. Find the equivalent resistance of the parallel network in frame 20. ______________.

- -

(2.5 Ω)

22. R_T of the circuit in frame 20 is ______________________.

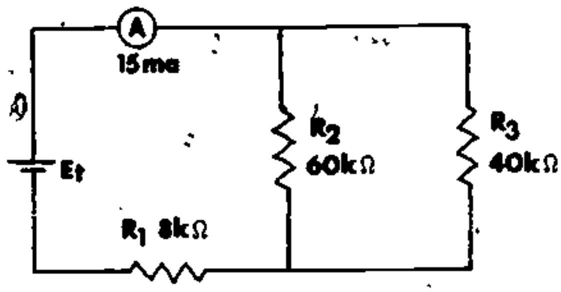
- -

(20 Ω)

23. Since you know E_s and R_T, find I_T using Ohm's Law. ________

(1 a)

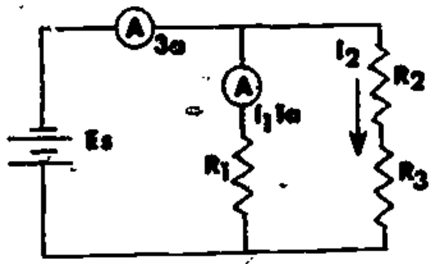
24. Solve for E_T.



E_T = ________

(480 v)

25. Kirchhoff's Current Law may be applied to series-parallel circuits and often provides the clue needed to answer a circuit problem. In this circuit, I_T and I_1 are given, so finding I_2 is a simple application of Kirchhoff's Current Law:



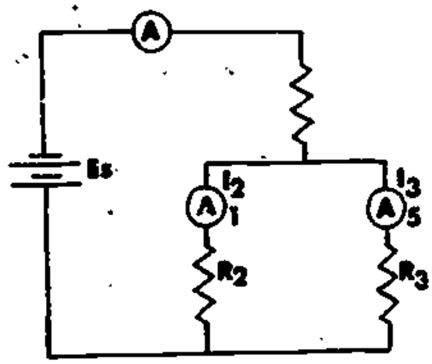
$I_T - I_1 - I_2 = 0$

$3a - 1a - I_2 = 0$

$2a - I_2 = 0$

$I_2 = 2a$

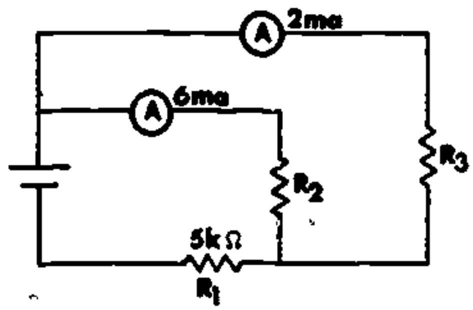
Find total current.



$I_T =$ ________

(6 a)

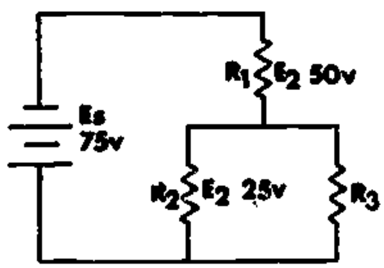
26. Solve for E_{R1}.



E_{R1} = ________

(40 v)

27. Kirchhoff's Voltage Law applies to the series portion of a series-parallel circuit in exactly the same way it applies to a straight series circuit. In the diagram below, the source voltage is divided as shown by the brackets E_1 and E_2.



$E_s - E_1 - E_2 = 0$

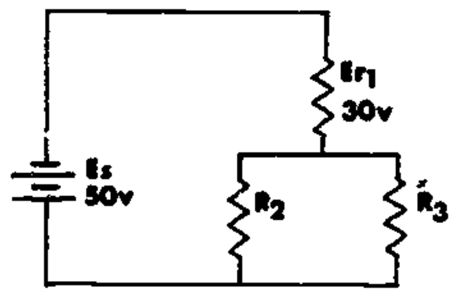
$75v - 50v - E_2 = 0$

$E_2 = 25$ v

What will the voltage drop across R3 be? E_{R3} = ________

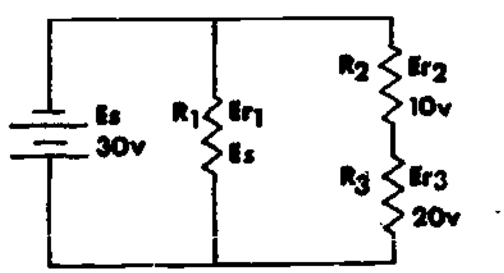
(25 v)

28. What is the value of E_{R3} in this circuit? E_{R3} = ________

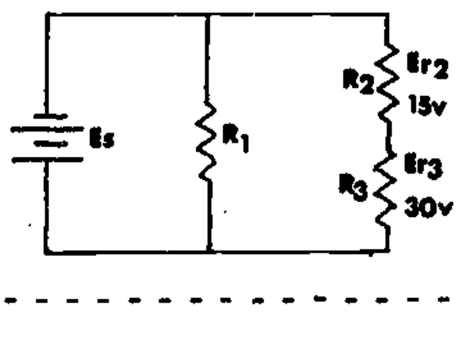


(20 v)

29. The second configuration of the series-parallel circuit is just as easily solved when Kirchhoff's Voltage Law is applied. In this case, one circuit loop contains only one resistor and full source voltage appears across it. The other loop has two resistors in series across source voltage. In the second loop, starting a Kirchhoff's Voltage Law equation in the lower left corner, $E_s - E_{R2} - E_{R3} = 0$ or $30V - 10V - 20V = 0$. (The equation for the first load, R1, is $E_s - E_{R1} = 0$.)



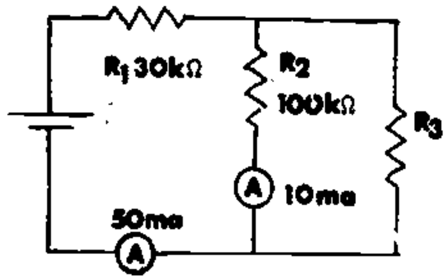
Find the voltage across R1 in the circuit shown below.



E_{R1} = ________

(45 v)

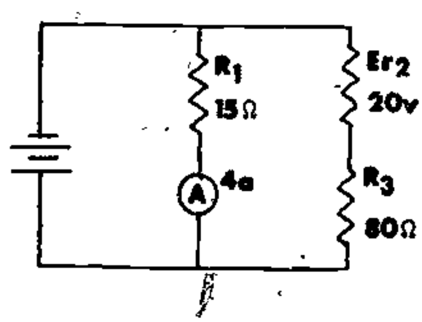
30. Solve for R_T.



R_T = ________

(50 kΩ)

31. Using the methods learned, solve the following circuit for E_{R3}.

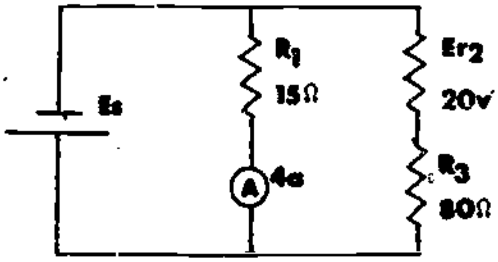


E_{R3} = ________

(40 v)

46

32. Find the current through R2.



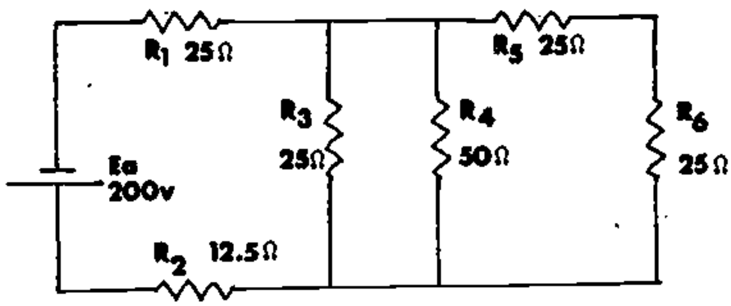
I_{R2} = ______

(0.5 or 500 ma)

33. Find the value of R2 in frame 32. ______

(R2 = 40 Ω)

34. Solve for E_{R6}. E_{R6} = ______



(THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWER - TEST FRAME 34

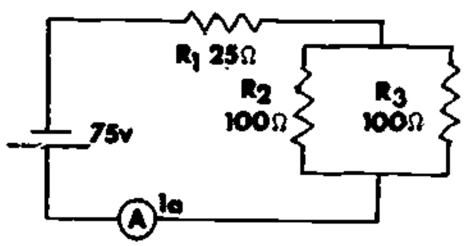
$E_{R6} = 25$ v

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 38. OTHERWISE, GO BACK TO FRAME 18 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 34 AGAIN.

35. Power can be found in series-parallel circuits in the same manner that it is found in series and parallel circuits. The formulas are $P = EI$, $P = I^2R$, $P = \frac{E^2}{R}$ and $P_t = P_1 + P_2 + \ldots + P_n$.

Always be certain that the current and voltage you use are for the component you are working with.

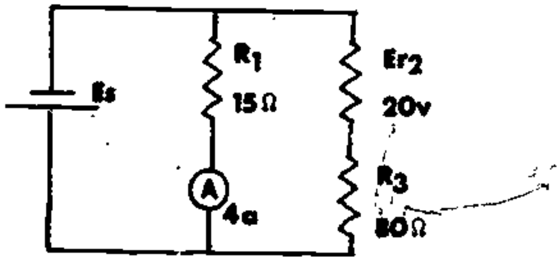
Find the power expended in R2 in the circuit below.



$P_{R2} =$ ________

(25 W)

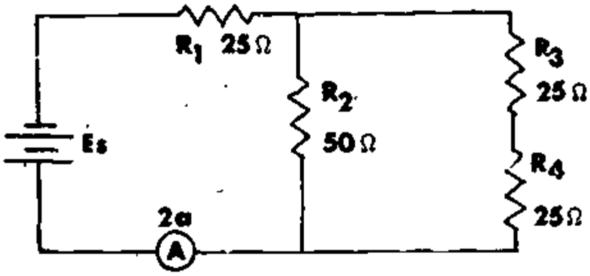
36. Now see if you understand what you have learned. Solve this circuit for R, I, P and E (total and for each component). Place values in blocks below.



	R	I	P	E
Total				
R1	15 Ω	4 a		
R2				20 v
R3	80 Ω			
R_{eq} 2&3				

	R	I	P	E
Total	13.3 Ω	4.5 a	270 w	60 v
R1	15 Ω	4 a	240 w	60 v
R2	40 Ω	0.5 a	10 w	20 v
R3	80 Ω	0.5 a	20 w	40 v
R_{eq} 2&3	120 Ω	0.5 a	30 w	60 v

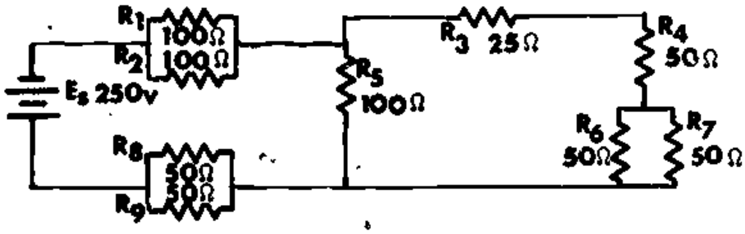
37. Now let's try another problem. As you have seen, keeping your figures in a block aids you in knowing what you are looking for and what you already have.



	R	I	P	E
Total		2 a		
R1	25 Ω	2 a		
R2	50 Ω			
R3	25 Ω			
R4	25 Ω			
R_{eq} 3 & 4				
R_{eq} R2,3&4				

	R	I	P	E
Total	50 Ω	2 a	200 w	100 v
R1	25 Ω	2 a	100 w	50 v
R2	50 Ω	1 a	50 w	50 v
R3	25 Ω	1 a	25 w	25 v
R4	25 Ω	1 a	25 w	25 v
R_{eq} 3 & 4	50 Ω	1 a	50 w	50 v
R_{eq} 2,3&4	25 Ω	[illegible] a	100 w	50 v

38. Solve the following complex problem.



Remember to break the circuit down to its simplest form.

	R	I	P	E
Total				250 v
R1	100 Ω			
R2	100 Ω			
R3	25 Ω			
R4	50 Ω			
R5	100 Ω			
R6	50 Ω			
R7	50 Ω			
R8	50 Ω			
R9	50 Ω			
R_{eq} 1 & 2				
R_{eq} 8 & 9				
R_{eq} 6 & 7				
R_{eq} 3, 4, 6 & 7				
R_{eq} 3, 4, 5, 6 & 7				

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN ON THE NEXT PAGE.)

ANSWERS - TEST FRAME 38

	R	I	P	E
Total	125 Ω	2 a	500 w	250 v
R1	100 Ω	1 a	100 w	100 v
R2	100 Ω	1 a	100 w	100 v
R3	25 Ω	1 a	25 w	25 v
R4	50 Ω	1 a	50 w	50 v
R5	100 Ω	1 a	100 w	100 v
R6	50 Ω	0.5 a	12.5 w	25 v
R7	50 Ω	0.5 a	12.5 w	25 v
R8	50 Ω	1 a	50 w	50 v
R9	50 Ω	1 a	50 w	50 v
R_{eq} 1 & 2	50 Ω	2 a	200 w	100 v
R_{eq} 8 & 9	25 Ω	2 a	100 w	50 v
R_{eq} 6 & 7	25 Ω	1 a	25 w	25 v
R_{eq} 3, 4, 6 & 7	100 Ω	1 a	100 w	100 v
R_{eq} 3, 4, 5, 6 & 7	50 Ω	2 a	200 w	100 v

IF ANY OF YOUR ANSWERS ARE <u>INCORRECT</u>, GO BACK TO FRAME 37 AND TAKE THE PROGRAMMED SEQUENCE.

IF YOUR ANSWERS ARE CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, GO ON TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

SUMMARY
LESSON 1

Solving Complex Circuits

So far you have studied series and parallel circuits. These simple circuits are found in numerous electrical devices. However, in our modern society, most networks you will encounter will be more complex; they will consist of combinations of series and parallel configurations. Complex circuits are also called series-parallel, or combination circuits.

In this lesson, we will develop some of the techniques that will enable you to solve complex circuits. Since most of what we have to build on are the rules for series and parallel circuits, let us review these important relationships.

In a series circuit, we found that:

$$I_T = I_1 = I_2 = I_3 = \ldots$$

$$E_a = E_1 + E_2 + E_3 + \ldots \quad \text{(Kirchhoff's Voltage Law)}$$

$$R_T = R1 + R2 + R3 + \ldots$$

However, in a parallel circuit, we found that:

$$I_T = I_1 + I_2 + I_3 + \ldots \quad \text{(Kirchhoff's Current Law)}$$

$$E_a = E_1 = E_2 = E_3 = \ldots$$

$$R_T = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots \frac{1}{Rn}}$$

The last relationship simplifies under certain special conditions. We saw that if all of the branch loads are of equal resistance:

$$R_T = \frac{\text{resistance of one resistor}}{\text{number of branches}}$$

We also saw that for a two-branch circuit:

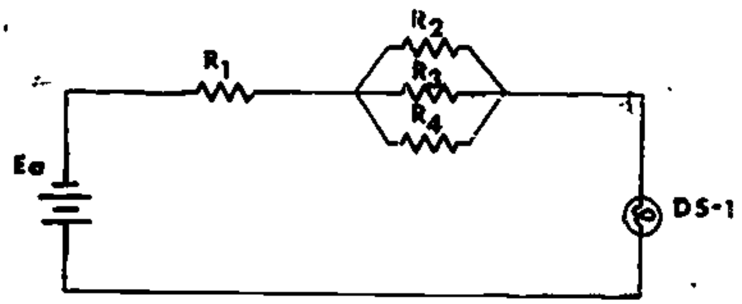
$$R_T = \frac{R1 \times R2}{R1 + R2}$$

We note that in all parallel circuits, R_{eq} is always less than the smallest resistor.

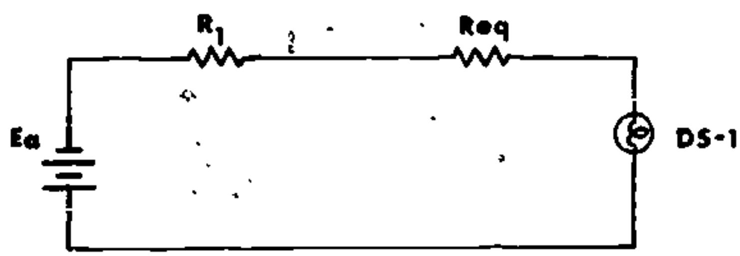
For both series and parallel circuits, the total power consumed is:

$$P_T = P_1 + P_2 + P_3 + \ldots P_n.$$

In this lesson, you will be confronted with complex circuits. It is helpful to redraw such circuits before analysis. In the circuit shown below, an equivalent resistance, R_{eq}, for the parallel network can first be found:



and then the series circuit analyzed.



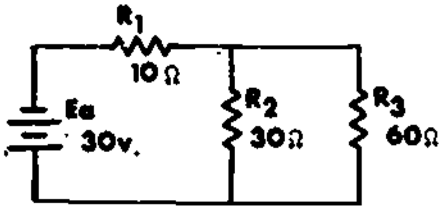
Determining I_T in the above circuit enables a determination of the voltage drop across the parallel group of resistors represented by R_{eq}. Once we have this drop, we can go back to the original network and find each of the branch currents from Ohm's Law.

You may sometimes have information which gives all but one of the potential difference values across the elements or groups of elements in the series part of the circuit. Here Kirchhoff's Voltage Law can be used to find the missing voltage, and the balance of the circuit can be solved, using Ohm's Law.

You will often find that the circuit diagrams for a system contain more information than you need for a specific problem. It may help if you redraw the section you are concerned with so that you can better see the functions of these parts. One good way to redraw some part of a system is to follow the path of electron flow through the components, drawing each one as you go. Be sure to include all the components and junctions involved.

Try these practice problems to see if you have mastered the above approaches.

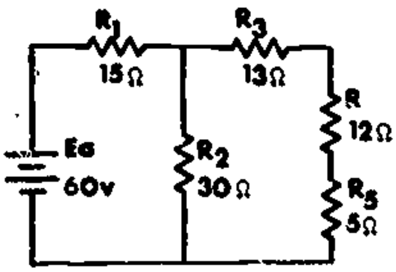
1\.



Simplify the circuit and find:

R_T.	____	I_{R1}.	____
I_T.	____	I_{R2}.	____
E_{R1}.	____	I_{R3}.	____
E_{R2}.	____	P_T.	____
E_{R3}.	____		

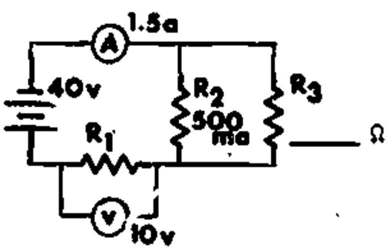
2\.



Simplify the circuit and find:

R_T.	____	E_{R5}.	____
I_T.	____	I_{R2}.	____
E_{R1}.	____	I_{R3}.	____
E_{R2}.	____	I_{R4}.	____
E_{R3}.	____	I_{R5}.	____
E_{R4}.	____		

3\.



Solve for R3. ________

Answers:

1. R_T = 30 Ω I_{R1} = 1a

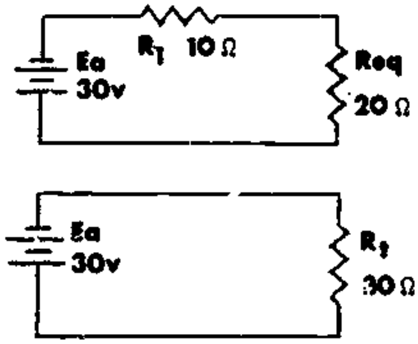
   I_T = 1a I_{R2} = 667 ma

   E_{R1} = 10 v I_{R3} = 333 ma

   E_{R2} = 20 v P_T = 30 w

   E_{R3} = 20 v

Simplification:



2. R_T = 30 Ω

   I_T = 2a

   E_{R1} = 30 v

   E_{R2} = 30 v

   E_{R3} = 13 v

   E_{R4} = 12 v

   E_{R5} = 5 v

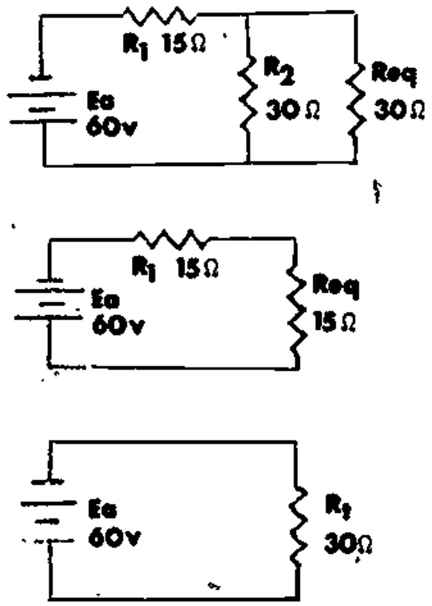
   I_{R2} = 1 a

   I_{R3} = 1 a

   I_{R4} = 1 a

   I_{R5} = 1 a

Simplification:



3. R3 = 30 Ω

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

MODULE SEVEN
LESSON II

Voltage Reference

Study Booklet

OVERVIEW
LESSON II

Voltage Reference

In this lesson you will study and learn about the following:

- why we study voltage reference
- negative and positive voltage
- point of reference
- ground
- ground as common
- polarity of circuit components
- obtaining negative and positive voltages

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON II

Voltage Reference

To learn the material in this lesson, you have the option of choosing according to your experience and preferences, any or all of the following:

STUDY BOOKLET:

- Lesson Narrative
- Programmed Instruction
- Lesson Summary

ENRICHMENT MATERIAL:

NAVPERS 93400A-1a "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U.S. Government Printing Office, 1965.

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

NARRATIVE
LESSON II

Voltage Reference

Why We Study Voltage Reference

In your work in the electrical field, you will discover that some circuit components such as electronic tubes and transistors require what we call negative voltage to operate them.

Some circuits then, often complex configurations, are designed to supply both positive and negative voltages.

Negative and Positive Voltage

Perhaps now you wonder if a negative voltage has any less zap than a positive voltage. The answer is that 100 volts is 100 volts, whether it is negative or positive. The direction of current flow does not affect the feeling you get when you are shocked.

Point of Reference

A positive voltage means that the point from which we are measuring has fewer negative charges (electrons) than the point to which we are measuring, a negative voltage indicates the reverse; that is, the point from which we are measuring has more negative charges (electrons) than the point to which we are measuring.

For example, if you place your voltmeter probes across a 12-volt battery, you get a meter reading of about 12 volts. This means that the negative terminal is 12 volts more negative than the positive terminal, or that the positive terminal is 12 volts more positive than the negative terminal. The voltage is considered negative or positive depending on the location of your reference point.

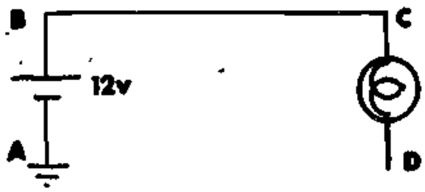
Reading across the battery, we indicate 12 volts positive with respect to the negative terminal. Or, we indicate 12 volts negative with respect to the positive terminal.

In this lesson we will learn how to establish a common reference point in a circuit to supply the amount and polarity of voltage required for particular loads.

Ground

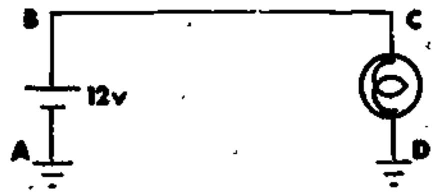
To understand how ground can be a common reference point in a circuit, you first need to be familiar with what is meant by ground.

Frequently, in pieces of electrical equipment, the complete path for electron flow is not supplied by wires. Instead, a wire from the source may be attached to the metal chassis or case of the equipment as schematically indicated here.

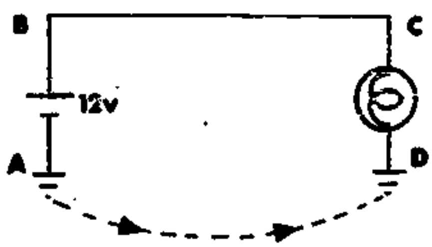


Notice the symbol at point A which indicates the wire is attached or grounded to the chassis. is

one schematic symbol used for ground.

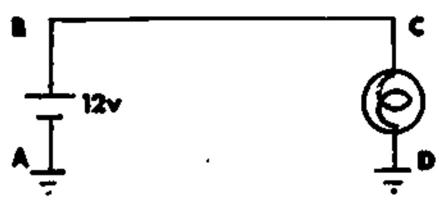


Now the circuit can be grounded to the chassis at point D as shown. At first glance, it may appear as if the circuit is open between points A and D, but this is not so. In this case the ground symbols indicate that the path for current flow is completed by the metal chassis itself.



Thus current flows through the metal chassis from point A to D and through the circuit. A common example of wiring that is grounded in this manner is the wiring in your automobile.

Let's see how ground relates to other parts of the circuit. If you were to take a voltmeter reading from ground (point A) to point B in this circuit, you would read a 12-volt difference in potential. Point B would be 12 volts more positive than ground (point A) because ground (point A) is connected directly to the negative terminal of the battery.

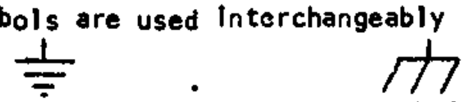


In other words, in this schematic at ground, or chassis, we have the same potential as we have at the negative terminal of the battery.

Similarly, ground at point D is at the same potential as ground at point A. If you measured voltage from ground (point D) to point C, you would have 12 volts across the load.

Equipment may be grounded to the chassis at almost any point on the circuit that the manufacturer chooses.

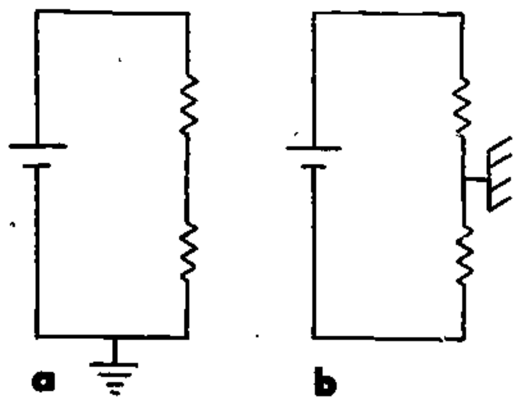
NOTE: These two symbols are used interchangeably throughout this lesson



to represent a reference point. The symbol that looks like a "rake" is most commonly used to show a connection point to chassis.

Ground as Common

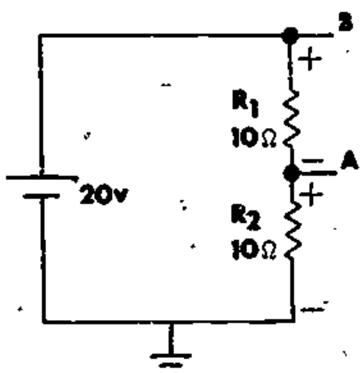
Ground is not always used to complete the circuit. Sometimes it is used as a common reference point as shown in the two schematics below.



Notice that figure (b) shows ground with a forked symbol like this .

This symbol is frequently used to represent chassis or common reference. All voltages are measured with respect to the common point.

In such cases the chassis or common is almost always considered to be at zero potential. (If a metal chassis is not at zero potential, we say it is <u>floating</u>.)



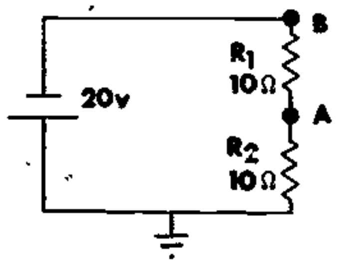
If a technician were measuring the output voltage of this circuit, he would clip one voltmeter probe on the chassis itself, and then move the other probe to the points he wished to measure with respect to the chassis. With the second probe at point A, he would measure a difference in potential of 10 volts. (Observe that the voltage drops across <u>R1</u> and <u>R2</u> would both be 10 volts.) Notice that point A is 10 volts positive with respect to the chassis.

Now if the technician moved the probe to point B, he would read a 20-volt difference in potential. With respect to the chassis, point B is 20 volts positive.

Polarity of Circuit Components

Observe in the circuit we have just been measuring that <u>R1</u> and <u>R2</u> are labeled according to polarity. You will recall that the end of the load that current enters is designated as <u>negative</u>. The end from which current leaves is designated as <u>positive</u>.

Label the polarity of the resistors in this schematic.



The polarity signs should be the reverse of what they were in the preceding schematic because current is flowing in the opposite direction now.

With respect to chassis, what do you think the voltage and polarity would be at point A? ________
. . . . at point B? ________

Point A is 10 volts negative with respect to the common reference because ground is now on the positive side of the source, and point A is 10 volts less positive than chassis. Point B is 20 volts negative with respect to the common reference.

Obtaining Negative and Positive Voltages

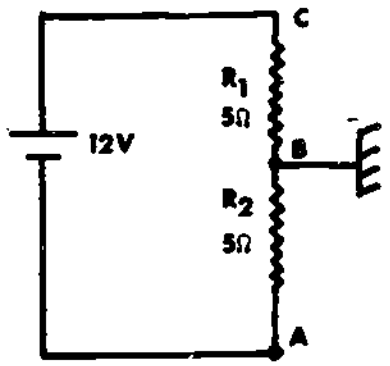
Let's see now how we can get both negative and positive voltages from the same circuit.

In the following schematic, what will the voltmeter measure across R1? Across R2? Across both R1 and R2?

R1 = ________
R2 = ________
R1 + R2 = ______

Of course R1 will be 6 volts and R2 will be 6 volts. Across R1 and R2 together the meter will measure 12 volts.

Now take the same circuit and add ground as a reference at point B, then read voltages.



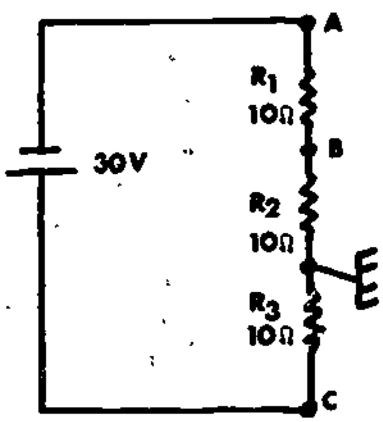
Suppose we place chassis ground at point B. With reference to the chassis, we find that point A is 6 volts negative because point A is in a more negative position in the circuit than is the chassis.

Now if we measure from the common reference to point C, the meter will again indicate 6 volts. At point C, however, it is 6 volts positive with respect to chassis.

You have seen how the same circuit can supply both positive and negative voltages with respect to a reference point -- in this case a -6 volts and a +6 volts.

Always remember, as you measure toward the negative terminal from the reference point, your voltage will be negative with respect to common zero reference. As you are measuring away from the negative terminal, your voltage will be positive with respect to common reference.

Study this schematic, then:



1. determine the voltage drop across each resistor.

2. state the voltage at points A, B, and C, and whether they are negative or positive with respect to chassis.

At point A _____

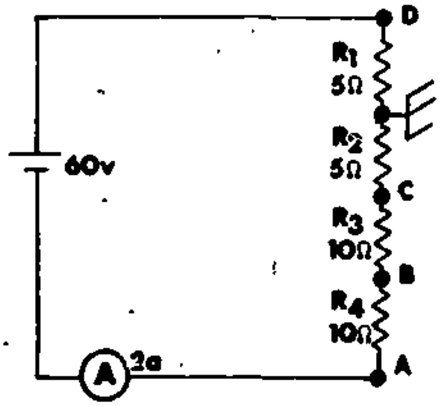
At point B _____

At point C _____

You should have determined from what you have learned about voltage reference that point A is 20v negative with respect to chassis, point B is 10v negative, and point C is 10v positive.

In the next lesson you will learn how networks are designed to supply loads that require these positive and negative voltages.

Practice



With respect to the chassis, what is the voltage at:

point A? ________

point B? ________

point C? ________

point D? ________

Answer - Point A = -50v Point B = -30v Point C = -10v
Point D = +10v

AT THIS POINT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON II

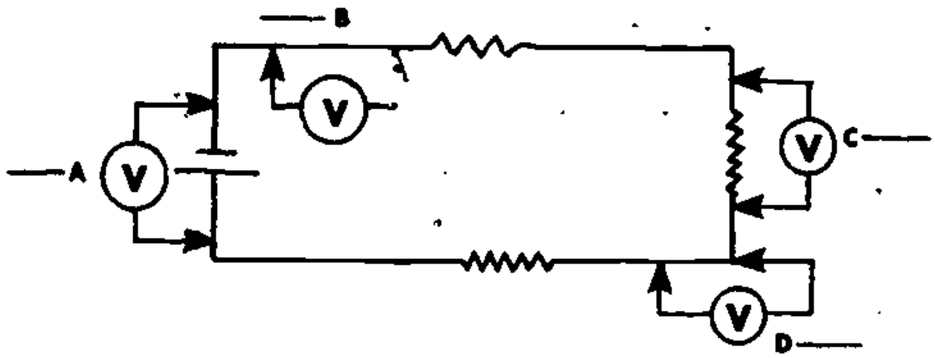
Voltage Reference

THE TEST FRAME IS 24. AS BEFORE, GO FIRST TO TEST FRAME 24 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

---

1. You will recall that to measure a voltage there must be a difference in potential.

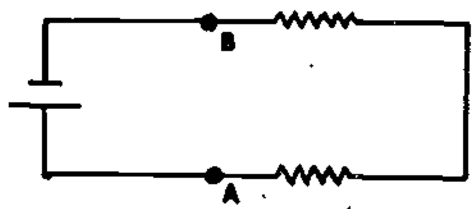
   Select the meter or meters measuring a difference of potential.



(A, C)

2. To have a difference of potential, one point must be more or less negative than another point.

   Point A is ________ negative than point B.
   more/less



(less)

3. When measuring voltage in a circuit, we measure a point against a reference.

   The point in a circuit against which other points are compared is known as a/an ________________.

(reference)

4. Most electronic equipment uses the chassis as a common point of reference.

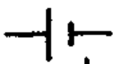
   When measuring voltage in a piece of electronic equipment you use the ________________________ as a reference.

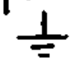
(chassis)

5. The schematic symbol for a reference point is a series of parallel lines in the shape of an arrow head.

   Which of the following is the symbol for a reference point?

   ____ a. 

   ____ b. 

   ____ c. 

   ____ d. 

(c)

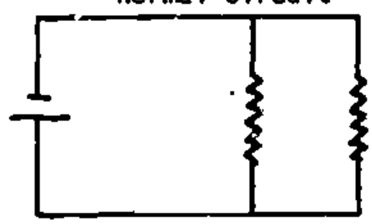
6. This common reference point is known as ground.

   Draw the schematic symbol for ground.

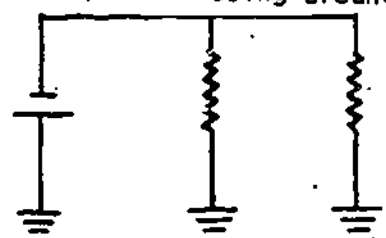
()

7. Using ground as a common point makes the drawing of a schematic much simpler as shown below.

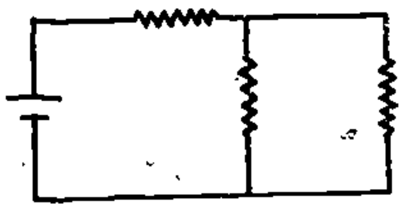
Normal Circuit

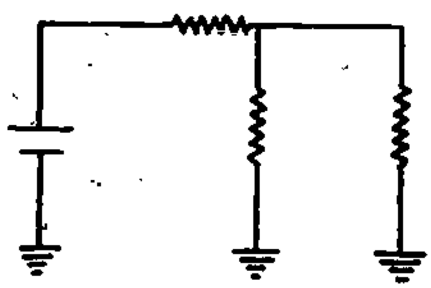


Using Ground

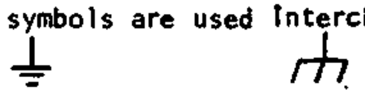


Redraw the following circuit using ground as a common point.





NOTE: These two symbols are used interchangeably throughout this lesson



to represent a reference point. The symbol that looks like a "rake" is most commonly used to show a connection point to chassis.

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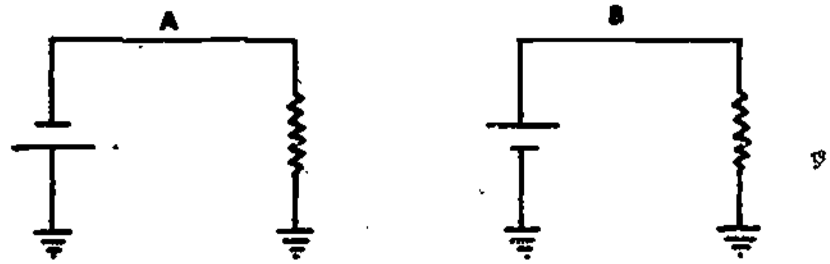
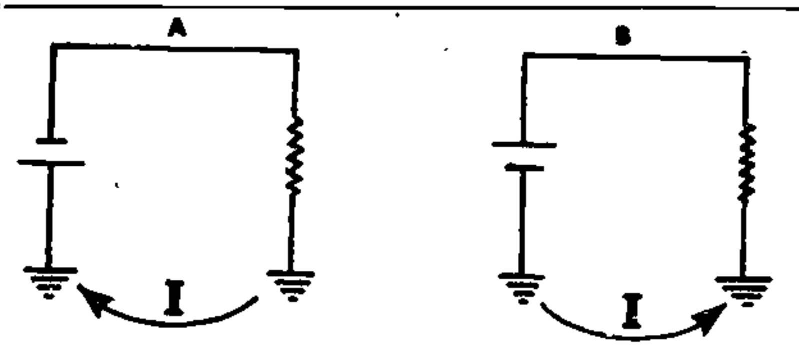
8. Current actually flows through the chassis between the ground connections.

With arrows show the direction of current flow through the chassis in the below circuits.



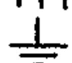
- -

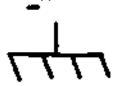


9. Another schematic symbol frequently used for chassis grounds looks like a garden rake.

Select the schematic symbols for ground.

____ a. 

____ b. 

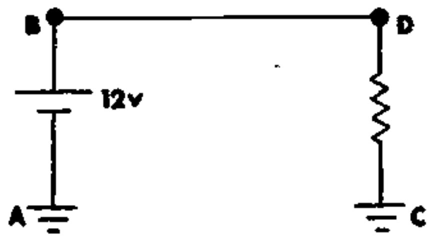
____ c. 

____ d. 

- -

(b, c)

10. Let's discuss another use of ground connections.



If you read voltage from ground (point A) to point B you will read 12 volts. Point B will be 12 v positive in respect to ground (point A) because ground (point A) is on the negative side of the battery.

Point D would measure what voltage with respect to ground (point C)?

____

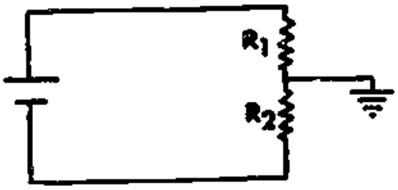
(12v positive)

11. What is the difference in potential between ground (point A) and ground (point C)? ________

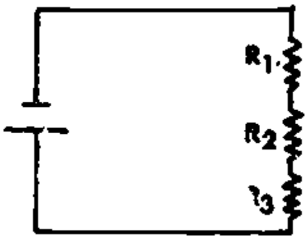
(0)

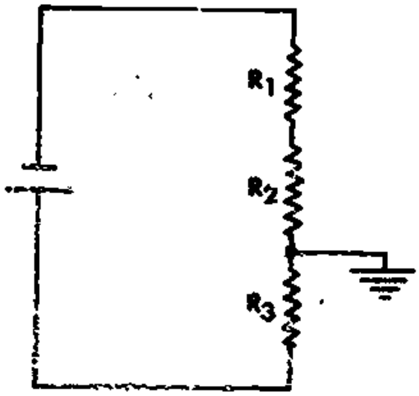
12. Since ground is used as a reference point with which all other points in a circuit are compared, it is said to be at zero potential and can be placed anywhere in the circuit.

For example:

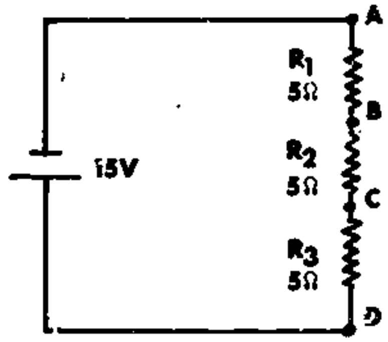


Draw ground as a reference between R2 and R3.





13. Now let's see how moving our reference affects the voltage in a circuit.



In the above circuit you can see that each resistor drops 5v.

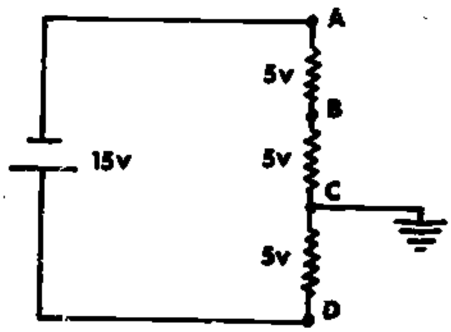
Measuring the voltage between points A and C, you would read ____v.

---

(10)

14. With ground at point C, what voltage would you read between points A and C?

____ v



---

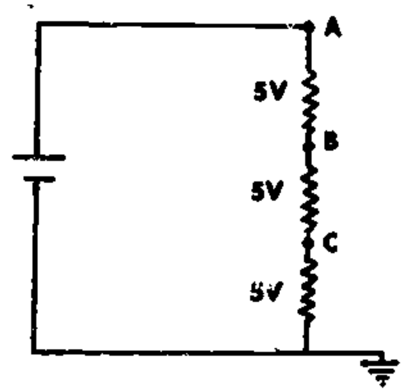
(10)

15. What voltage would you measure between point A and D in the illustration in frame 14? __________v

---

(15)

16. As you can see, the ground does not affect the voltage drop across the resistor. But it does allow us to have positive and negative voltage.



In the circuit above, since the reference (ground) is at the most negative point in the circuit all voltages measured will be positive.

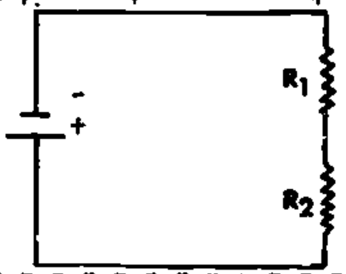
If the ground were moved to point A, what would be the polarity of the voltages measured? ____________

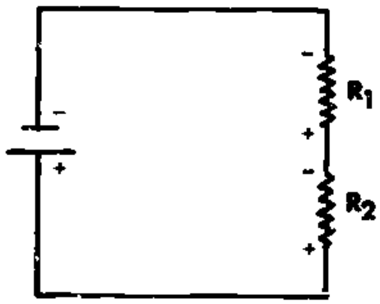
(negative)

17. To aid you in understanding what polarity you have at any point in a circuit, you must assign polarities to the circuit component.

(Remember that a negative polarity is assigned to the end of a component where current enters, and a positive polarity is assigned to the end where current leaves.)

Label the polarity of the components in the following circuit.

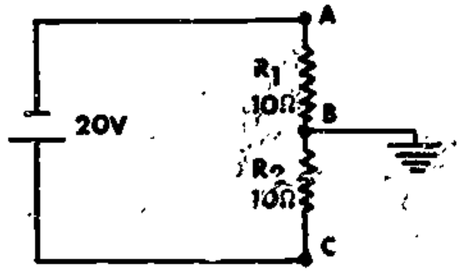




Note: Even though the lower end of R1 is marked + and the upper end of R2 is labeled - they are at the same potential.

---

18. Now let's take the previous circuit and place a ground between R1 and R2.



Using ground as a reference, what is the magnitude and polarity of the voltage at point A? __________

(-10v)

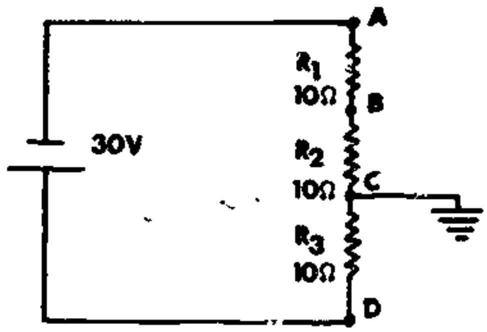
19. Refer to the illustration in frame 18. What is the magnitude and polarity of the voltage at point C? ____________

(+10v)

20. In the illustration in frame 18, what is the voltage between point A and C? ____________

(20v)

21. Use the following schematic for frames 21 through 23.



As you can see, polarity of voltage can only be stated with respect to a reference. In the above circuit, ground is the reference.

What is the polarity and magnitude of the voltage at point A? ______

(-20v)

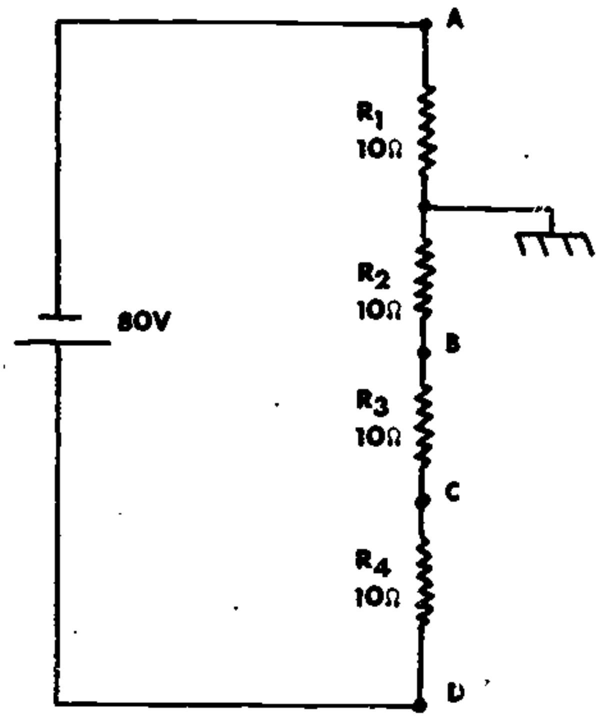
22. Determine the voltage polarity and magnitude at point D. ________

(+10v)

23. Determine the voltage polarity and magnitude at point B. ________

(-10v)

24. State the voltage and polarities as indicated with reference to ground.



a. Point A ____

b. Point B ____

c. Point C ____

d. Point D ____

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 24

a. -20v

b. +20v

c. +40v

d. +60v

IF ANY OF YOUR ANSWERS IS INCORRECT, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE.

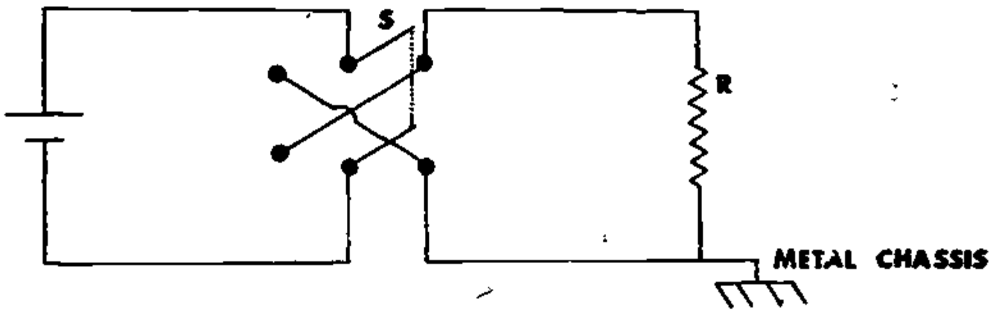
IF YOUR ANSWERS ARE CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

SUMMARY
LESSON II

Voltage Reference

In your work with complex circuits, you will find that some points in a circuit require a positive voltage, and others require a negative voltage or potential difference. Basically, a negative voltage is merely a difference in potential observed from a different point, whereas a positive voltage means that the point from which we are measuring has fewer negative charges (electrons) than the point to which we are measuring. A negative voltage indicates the reverse; that is, the point from which we are measuring has more negative charges (electrons) than the point to which we are measuring.

Consider the circuit below.

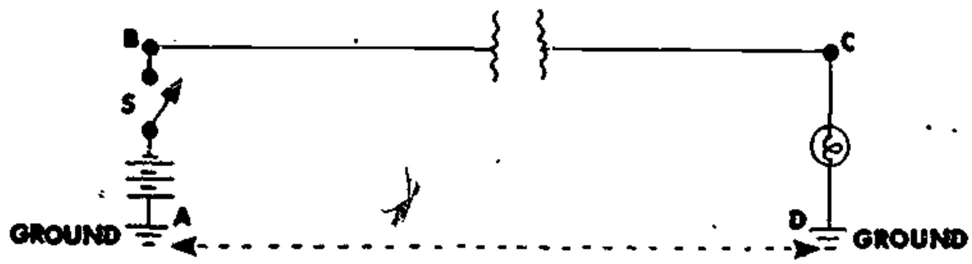


Two new elements are included. One is labeled S, and is a double-pole, double-throw switch; the other is the metal chassis that the circuit rests on. Note that if S is thrown to the right, the top of the resistor is positive with respect to the end connected to the metal chassis. However, if S is thrown to the left, the top of the resistor is negative with respect to the other end. If E were 100 volts and you touched one hand to each end of R you would receive as great a shock from the positive voltage (S to the right) as you would from a negative potential difference (S to the left).

There are advantages to establishing a common reference point in a circuit such as the metal chassis point shown above.

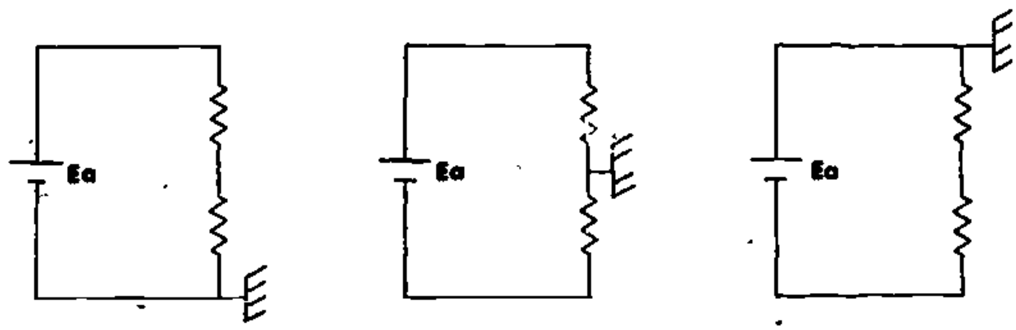
Historically, one of the earliest and most often used references of this type was the earth itself, or ground. Consider a type of telegraph system shown at the top of the next page.

Every time S is closed and opened, the light bulb at the other end flashes. Note that the circuit may be quite long, and only one wire is used, thus saving on materials. Effectively, when S is closed, electron current flows from the cell through the switch, long wire and lamp to the ground at point D to point A, completing the circuit.



(In actual practice, all that is necessary is that electrons flow from the earth into the circuit at point A and to the earth from the circuit at point D.)

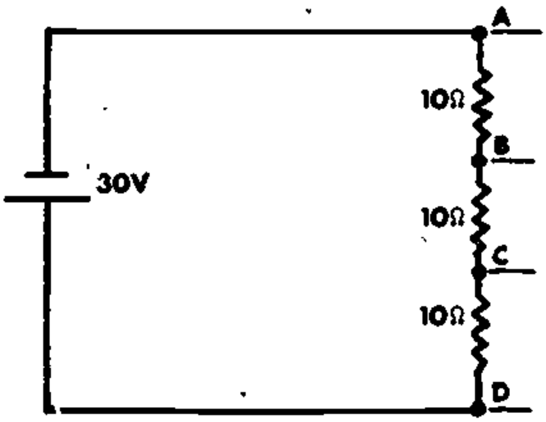
As already mentioned above in our double-pole, double-throw switch experiment, ground itself is not always used to complete the circuit. Sometimes the metal chassis on which a circuit rests is used as a reference point, or artificial ground. It can be placed at many different points as shown in the simple case below.



By definition we usually consider the earth, or the local metal chassis or common connection point, to be at zero potential. (If a metal chassis is not at zero potential, we say it is floating.)

The three figures shown above can be used by design technicians by applying the strategy in reverse. Depending on where the ground is placed, we can obtain various sources of negative or positive potential.

In the circuit shown at the top of the next page, where would you place the common or ground connection to make point A 10 volts negative with respect to the chassis?

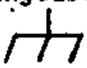


Answer - Since there are 30 volts applied to an R_T of 30Ω, each resistor has a voltage drop of 10 volts across it. Since we desire point A to be 10 volts negative with respect to the chassis, we would place the common chassis connection at point B.

Where would we place it if we wanted point A to be 30 volts negative with respect to the chassis? How could we make point A 20 volts positive with respect to the chassis?

Answer - The common chassis connection would be placed at point D; point A could be made 20 volts positive by placing the connection to the chassis at point C, after reversing the leads to the battery, thus changing its polarity with respect to the rest of the circuit.

NOTE: These two symbols are used interchangeably throughout this lesson



to represent a reference point. The symbol that looks like a "rake" is most commonly used to show a connection point to chassis.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

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BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

MODULE SEVEN

LESSON III

Voltage Dividers

Study Booklet

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OVERVIEW
LESSON III

Voltage Dividers

In this lesson you will study and learn about the following:

- -voltage supply
- -no load conditions
- -load conditions
- -designing a voltage divider

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES

LESSON III

Voltage Dividers

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following:

STUDY BOOKLET:

Lesson Narrative

Programmed Instruction

Lesson Summary

ENRICHMENT MATERIAL:

NAVPERS 93400A-1a "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U.S. Government Printing Office, 1965.

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

NARRATIVE
LESSON III

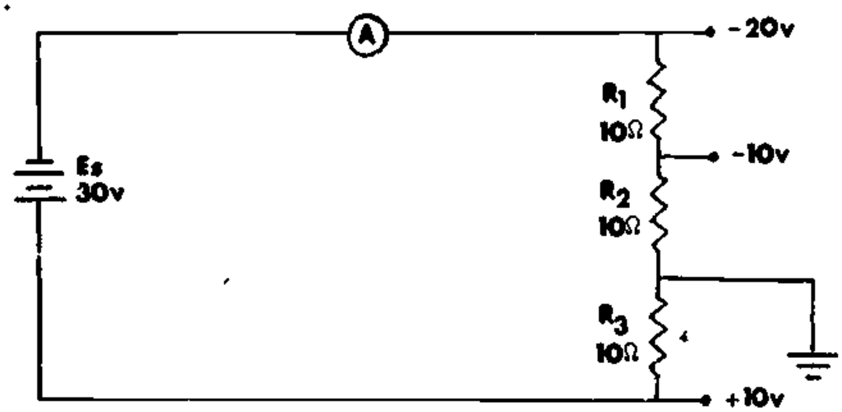
Voltage Dividers

A Voltage Supply

When we need specified voltages or a specific voltage magnitude and polarity to operate components or equipment, we often construct a circuit which is called a voltage divider. A power supply frequently contains a voltage divider. A voltage divider is a series-parallel circuit.

No Load

Let's design a voltage divider to provide three voltages from a 30-volt battery. The voltages wanted are -20 volts, -10 volts, and +10 volts. This circuit should provide these outputs very nicely.



Load Conditions

Now look at what happens when you use one of these outputs to operate a load. Assume you need +10 volts to operate a 10-ohm load. When the load is connected between the +10-volt connection and ground, it is in parallel with R3. Solving this complex circuit for load voltage shows that it is less than 10 volts.

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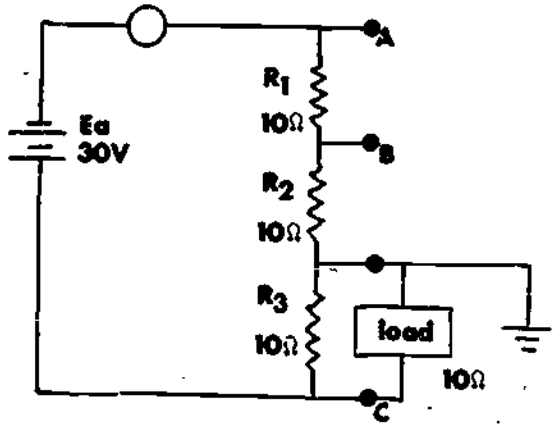


Find: R_{eq} of R3 and load ____

I_T ____

E_{LOAD} ____

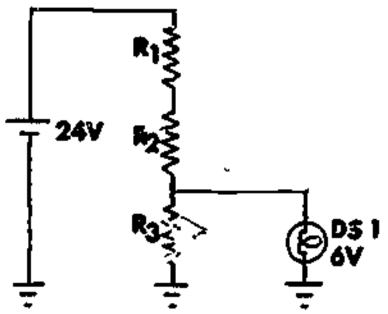
R_{eq} is 5 Ω; I_T = 1.2 a; E_{LOAD} = 6 v

You can now see that designing a voltage divider without considering the load resistance (or current) does not work.

Designing a Voltage Divider

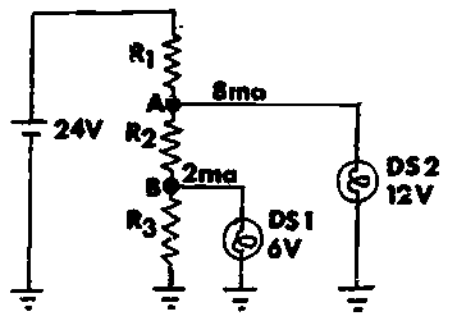
Assume we begin by knowing only that we have a series circuit with three resistors and an applied voltage of 24 volts. We want to furnish voltage to two lamps, a 12-volt lamp and a 6-volt lamp. The 12-volt lamp will draw 8 milliamps of current; the 6-volt lamp, 2 milliamps.

We need to find what value of resistors will do the job.



We plan to add the 6-volt lamp across R3 because it requires less voltage than the 12-volt lamp.

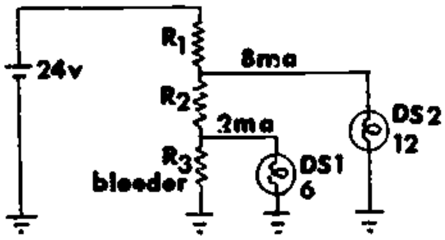
Note: The schematic shows the new branch running to chassis (grounded to the chassis) where current makes a complete path through the metal case. It could also be drawn with a line indicating connecting wires.



Now we add the 12-volt lamp across R2 and R3 as shown. It is also grounded to the chassis.

The 6-volt lamp draws 2 milliamps, so we can write that on the horizontal line as shown. The 8 milliamps that the 12-volt lamp draws is written on the proper line.

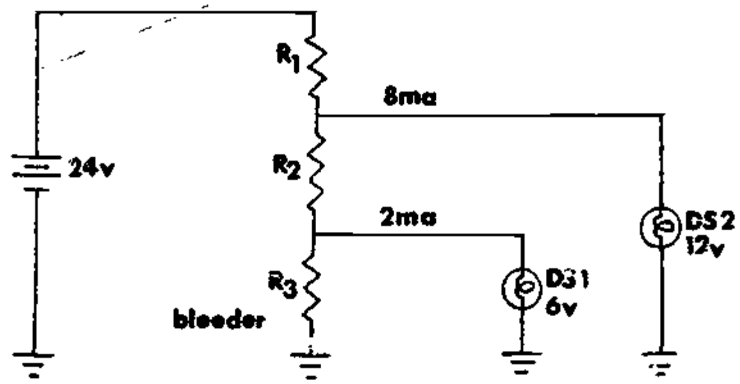
Notice that we now have a voltage divider consisting of R1, R2, and R3. The lamps, DS1 and DS2, are the load resistances. One of the divider resistors has none of the load current flowing through it. This resistor is designated the bleeder resistor.



In this network, R3 is the bleeder resistor.

There are three steps to follow in order to design this voltage divider network once the load voltages and currents have been determined.

Step One: Determine Bleeder Current.



Current drawn by the bleeder resistor is usually 10% (1/10) of the value of the sums of the load currents unless stated otherwise.

$I_{DS1} + I_{DS2} \times 10\% = I_{R3}$

$8ma + 2ma \times 10\% = 1ma$

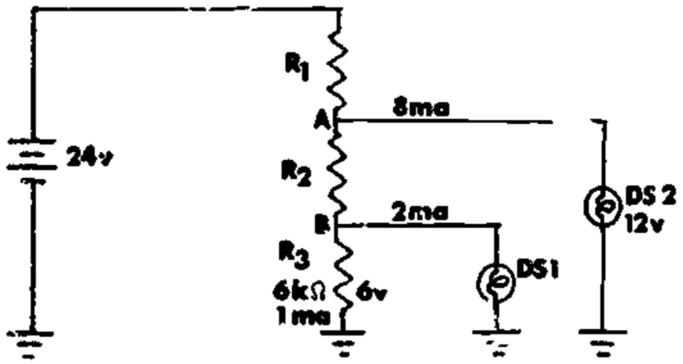
Also, we know that the bleeder resistor, R3 is in parallel with the 6 volt load. If we need 6 volts across the load, then, E_{R3} must be 6 volts.

Using Ohm's Law, determine the resistance value of the bleeder resistor.

R_3 = ______________

Bleeder resistor is determined to be 6 kilohms.

Step Two: Determine the Needed Value of R2.



Now we need to know what value resistor to use for R2. We can solve for R2 by Ohm's Law if we know the current through this resistor and the voltage drop across R2.

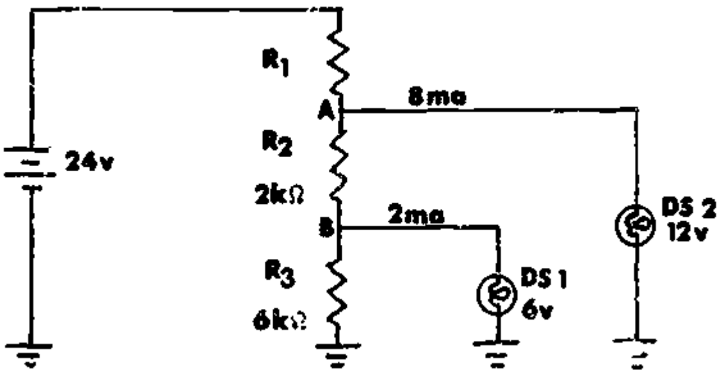
At point B, current through DS1 (2 ma) joins current through R3 (1 ma) for a total of 3 milliamps flowing through R2. Looking at the schematic we see that the 12 volts to supply the second load is tapped off across both R2 and R3. We know that the voltage across R3 is 6 volts. For the voltage across R2 and R3 to equal 12 volts, the voltage across R2 must also be 6 volts.

If E_{R2} is 6 volts and I_{R2} is 3 milliamps, what is the value of R2? ______________

You should have found that R2 needs to be 2 kilohms.

Step Three: Determine the Needed Value of R1.

We find the value of R1 in the same way we solved for R2 -- determine I_{R1} and E_{R1} and apply Ohm's Law.



Recall that we have 3 milliamps going through R2. At point A, this current joins with the 8 milliamps through the second load to be a total of 11 milliamps through R1. Then I_{R1} = 11 milliamps.

Voltage drops across R2 and R3 equal 12 volts. The applied voltage is 24 volts; therefore, the remaining 12 volts must be dropped across R1. Then E_{R1} = 12 volts.

By Ohm's Law $R1 = \dfrac{12\ v}{11\ ma} = \dfrac{12\ v}{11 \times 10^{-3}\ a} = 1.1\ k\Omega$

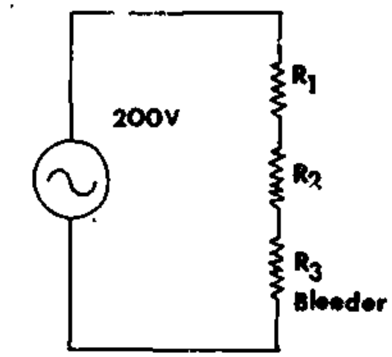
R1 needs to be a 1.1 kΩ resistor.

We have designed a voltage divider that will actually supply 6 volts to DS1 and 12 volts to DS2 by following these four steps:

1. Determine bleeder current.
2. Determine the value of R3.
3. Determine the value of R2.
4. Determine the value of R1.

If the circuit had more or fewer resistors, there would be more or fewer steps, of course. The objective is to determine the correct value needed for each resistor in the circuit to supply output voltages as required by the loads.

Now see if you can design a voltage divider for the following:



a 50-volt lamp that draws 5 milliamps and a 100-volt lamp that draws 15 milliamps.

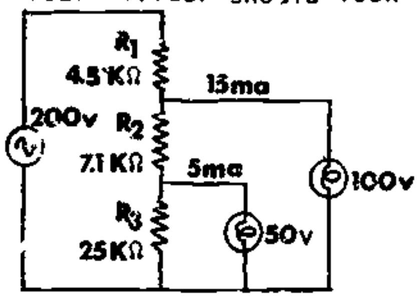
Bleeder I = ____________

R3 = ____________

R2 = ____________

R1 = ____________

Your divider should look like this:

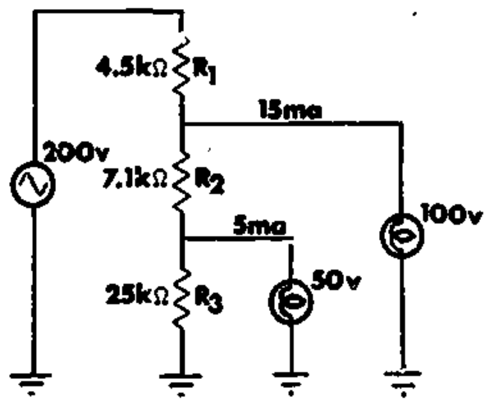


Bleeder I = 2 ma

I_{R3} = 2 ma

E_{R3} = 50 v

or this:



$I_{R2} = 7$ ma

$E_{R2} = 50$ v

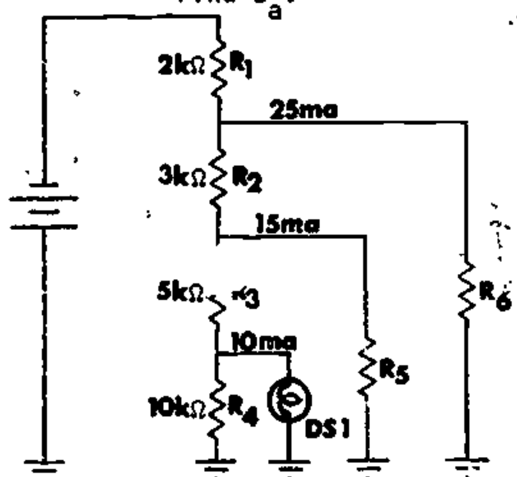
$R2 = 7.14$ kΩ

$E_{R1} = 100$ v

$I_{R1} = 22$ ma

$R1 = 4.5$ kΩ

By working out the quantities for the voltage divider below, find E_a.



Load Current = 50 ma

Bleeder I = 5 ma

$E_{R4} =$

$E_{R3} =$

$E_{R2} =$

$E_{R1} =$

$E_a =$

Your answers should be:

$E_{R4} = 50$v

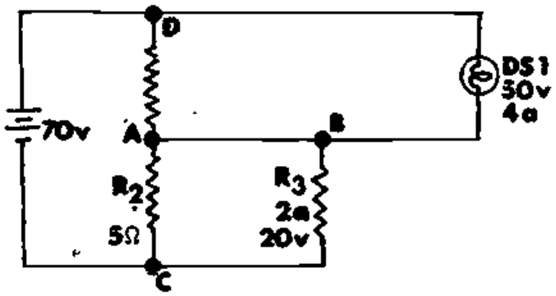
$E_{R3} = 75$v

$E_{R2} = 90$v

$E_{R1} = 110$v

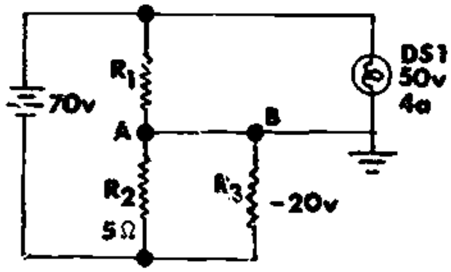
$E_a = 325$v

Now suppose you need to design a voltage divider to supply both a negative and a positive voltage. Your procedures are the same as for designing any other voltage divider, except for locating ground.



Indicate the placement of chassis ground necessary in this circuit to obtain a negative 20v at point C and a positive 50v at point D.

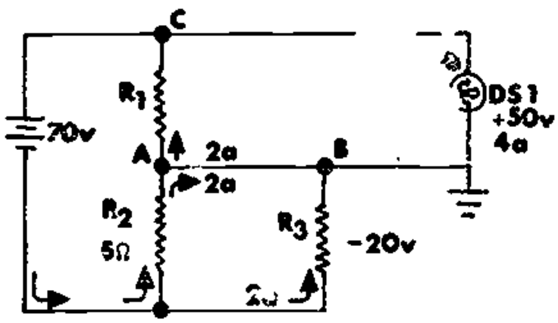
In order to get a -20 volt output and a +50 volt output you should have placed your reference as shown below:



Solve for the value of R1 in the circuit shown above.

R1 = ________

To solve for R1, you must determine current thru R2. If 50V is dropped across DS1, then E_{R2} must be 20V. R2 has a resistance of 5Ω; so I_{R2} = 4 amp.

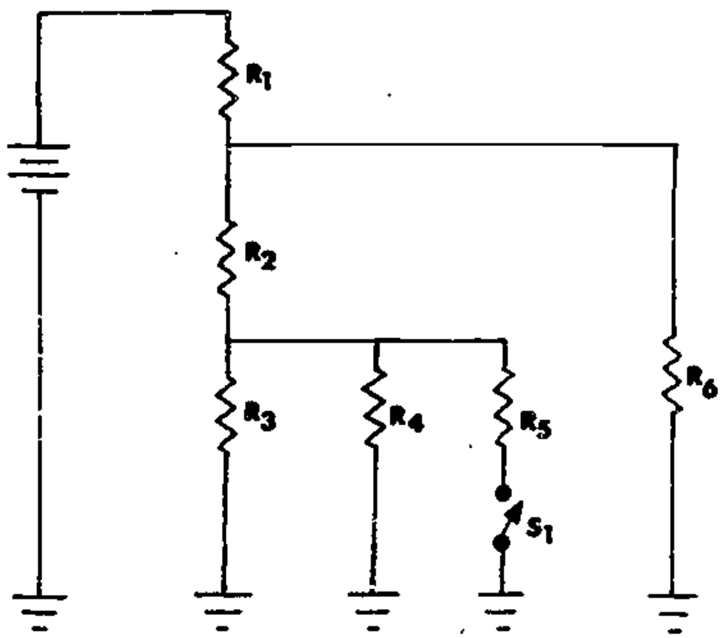


DS1 draws 4 amps. It gets 2 amps from the current flowing through load R3. At point B the 2 amps flowing through R3 join with 2 amps of the 4 amps flowing through R2. The other 2 amps from R2 flow through R1.

I_{R1} then is 2 amps and E_{R1} must be 50 volts to supply the load.

By Ohm's Law, we can calculate that R1 = $\frac{50\ v}{2\ a}$ or 25 Ω.

Problem



If switch S1 is closed, what will happen to the following:

(indicate with arrows) I_T ____
R_T ____
P_T ____

Answers: I_T ↑

R_T ↓

P_T ↑

AT THIS POINT YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON III

Voltage Dividers

TEST FRAMES ARE 15, 23 AND 28. AS BEFORE, GO FIRST TO TEST FRAME 15 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

---

1. Recall that different polarities of voltage can be obtained by varying the common reference in the circuit.

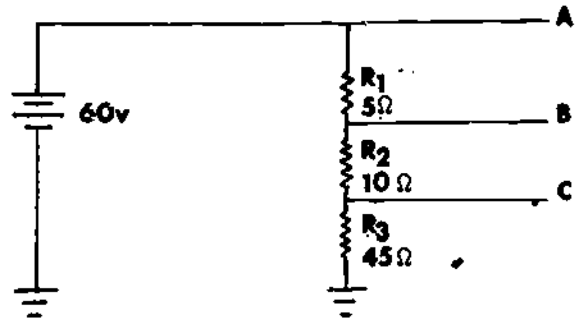
   The common reference point in a circuit is called a __________ and its symbol is ______________.

(ground; ⏚)

---

2. As you have already learned, a series circuit can provide various voltages depending upon where the voltage is taken from.

   How many voltages could be provided by the following circuit? Assume ground is always part of the load circuit. __________



(three)

3. Refer to the previous diagram. What is the voltage magnitude and polarity at points A, B, and C with no loads connected?

_____ A.
_____ B.
_____ C.

(A. +60v; B. +55v; C. +45v)

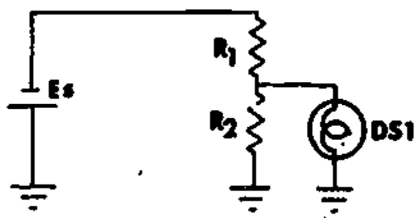
4. As you can see, various magnitudes and polarities of voltage can be supplied by a simple series circuit. This is the purpose of a voltage divider.

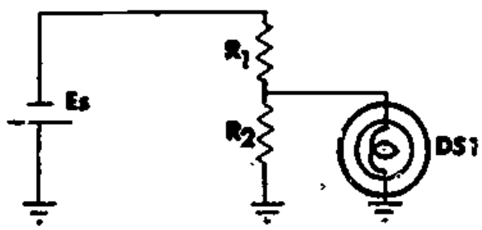
State the purpose of a voltage divider (in your own words).

(To supply various polarities and magnitudes of voltages.)

5. In its simplest form, a voltage divider consists of a simple series-parallel circuit. The parallel portion contains the load (DS1) being supplied.

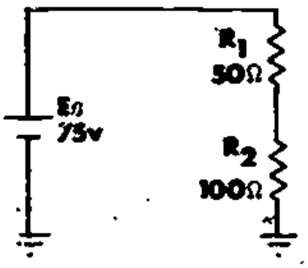
Circle the load in the following:





6. First let's take a look at the series portion of a voltage divider.

Solve for:



a. I_T . ________________

b. E_{R1} . ________________

c. E_{R2} . ________________

d. I_{R1} . ________________

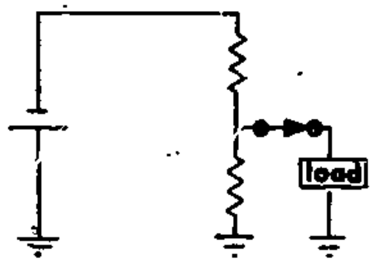
e. I_{R2} . ________________

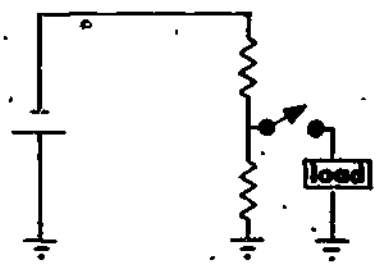
(a. 0.5a or 500ma; b. 25v; c. 50v; d. 0.5a; e. 0.5a)

7. This condition with no load connected is known as the no-load condition.

Which of the following diagrams shows the no-load condition?

____ A ____ B

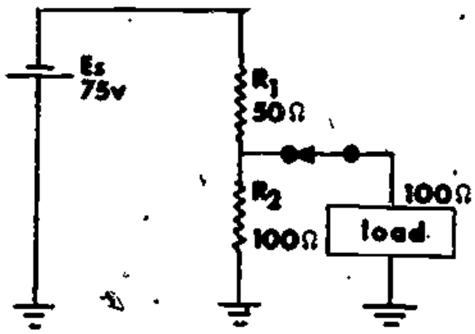




(B)

8. Using the same circuit, let's see what happens when a load is attached.

Solve for:



a. I_T. ______

b. E_{R1}. ______

c. E_{R2}. ______

d. E_{LOAD}. ______

e. I_{R1}. ______

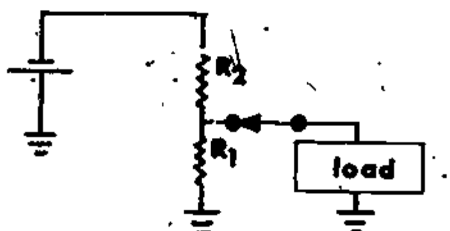
f. I_{R2}. ______

g. I_{LOAD}. ______

(a. 0.75a or 750 ma; b. 37.5v; c. 37.5v; d. 37.5v; e. 750ma; f. 375ma or 0.375a; g. 375ma or 0.375a)

9. As you have seen, connecting a load to a voltage divider changes the output voltage.

Use arrows to show what happens when the load is connected.



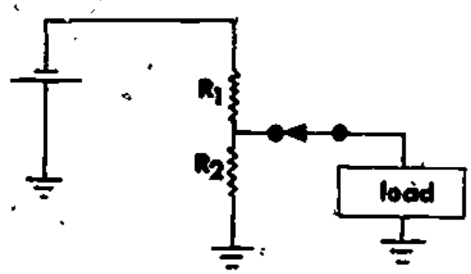
a. I_T ______

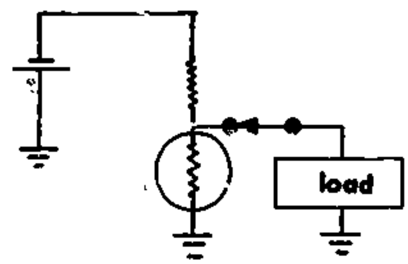
b. E_{R1} ______

(a. ↑; b. ↓)

10. The resistor R2 in the below circuit is known as the bleeder resistor.

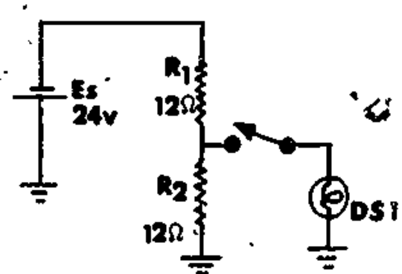
Circle the bleeder resistor.





11. The bleeder resistor is a resistor in the voltage divider network through which none of the load current flows.

Solve for the current flowing through the bleeder resistor under no-load condition.



I_{R2} = ______

(1 amp)

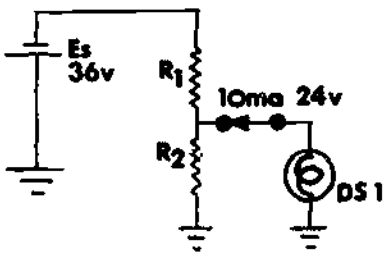
96

12. We have discovered that the voltage available at a given point under no-load conditions is not the same as the voltage at the same point when a load is attached. (Note: This is true only when there is a resistor through which the load current will flow between the point where the load is attached and the source.) It becomes apparent then that a voltage divider must be designed to supply a given load.

Let's see how this is done by designing a voltage divider to supply a load drawing 10 ma requiring a voltage of 24 v.

First the current through bleeder resistor R2 is determined by knowing that I_{R2} usually is 10% of the value of the sum of the load currents unless stated otherwise.

Second, find the resistance value of bleeder resistor R2.



Find I_{R2}.

Find I_T.

Find R_2.

(I_T = 11 ma) First, 10% of 10 ma = 1 ma. Next came the need to use your knowledge that current in parallel branches join and are added to become total current.

$$I_T = I_{R2} + \text{load current}$$

$$I_T = 1 \text{ ma} + 10 \text{ ma} = 11 \text{ ma}$$

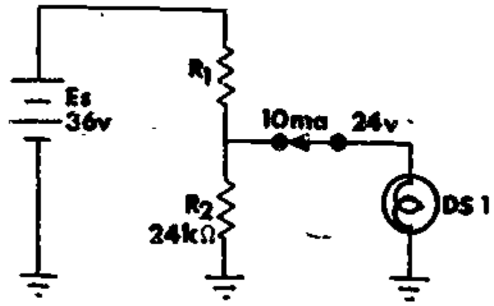
(R_2 = 24 KΩ) You had to do a little thinking here. You had to first remember that the branch voltages in a parallel network are the same. Then you had to use Ohm's Law to find R_2.

$$R_2 = \frac{24\text{v}}{1 \text{ ma}}$$

$$R_2 = 24\text{K}\Omega$$

13. Kirchhoff's Voltage Law ($E_s - E_{R1} - E_{R2} = 0$) enables you to find the voltage drop across R1.

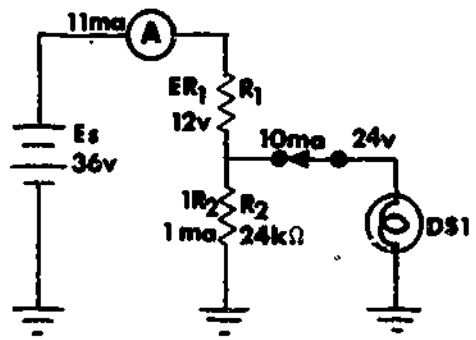
Solve for E_{R1}:



E_{R1} ____________

(12v)

14. Knowing I_T and E_{R1} enables you to determine the value of R1, solve for R1:

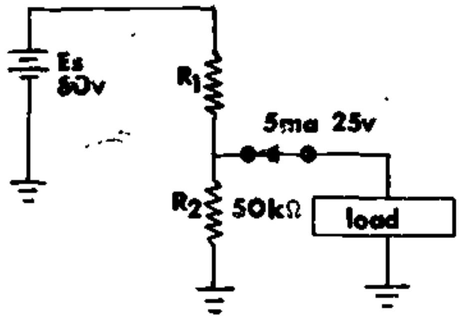


R1 ____________

(1,090 Ω)

98

15. Determine the value of resistance for <u>RI</u> to supply the indicated load.



RI = ________

- -

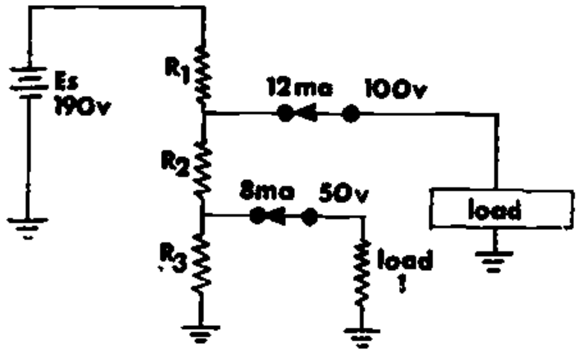
(THIS IS A TEST FRAME. COMPARE YOU ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 15

10 kΩ

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO TO TEST FRAME 23. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 15 AGAIN.

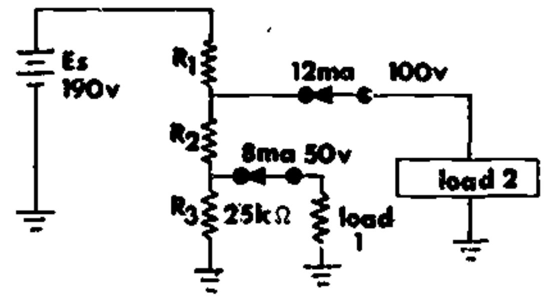
16. You will work with voltage dividers which are used to supply more than one load. They are solved in the same way as the simple voltage divider you just solved. Let's go through one step by step.



R3 = ________

(25 kΩ)

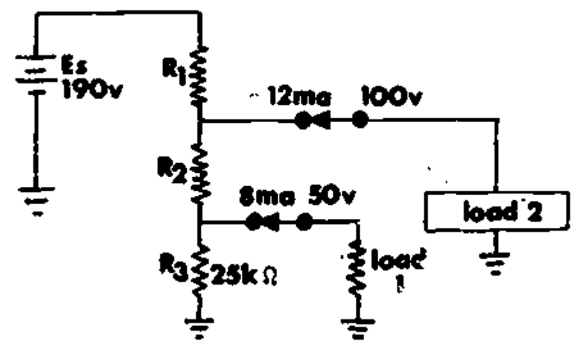
17. You now know the bleeder current and the current though load 1.



I_{R2} = ________

(10 ma)

18. The voltage drop across R2 can be determined by application of Kirchhoff's Voltage Law.



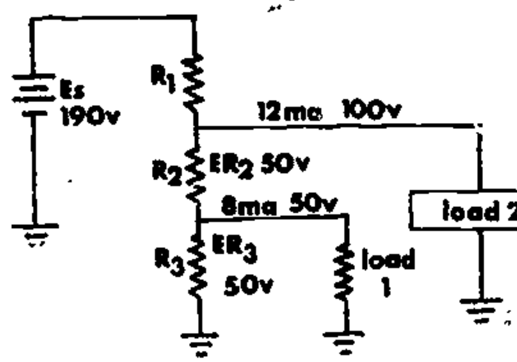
E_{R2} = ________

($E_{R2} = E_{LOAD\,2} - E_{LOAD\,1}$

$E_{R2} = 100\text{ v} - 50\text{ v}$

$E_{R2} = 50\text{ v}$)

19.

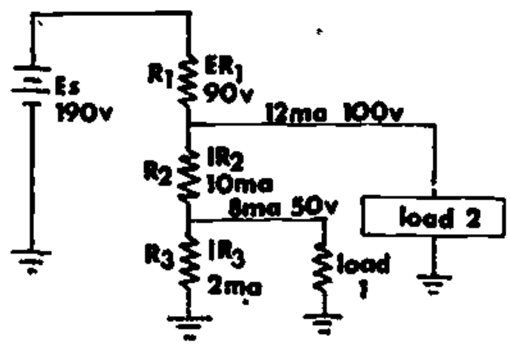


Solve for E_{R1}

E_{R1} ________

(90 v; E_a - E_{LOAD} 2)

20. Using the current through R2 and LOAD 2, total circuit current can be found.



Solve for I_T

I_T = ________

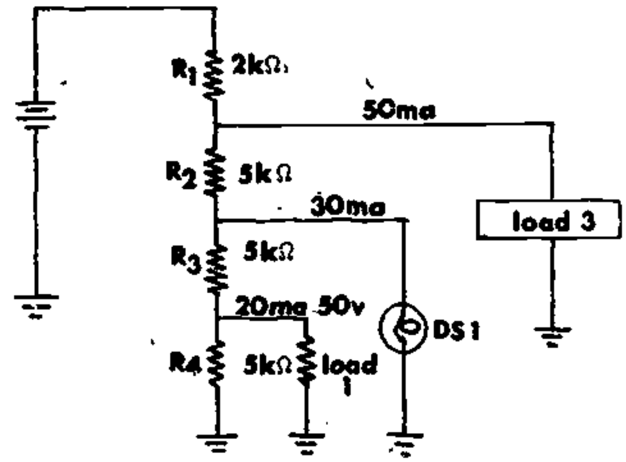
(22 ma)

21. Now solve for the value of R1, using the information in the above circuit.

R1 = ________

(4 kΩ)

22. Solve:



a. Bleeder I =

b. E_{R4} =

c. E_{R3} =

d. E_{R2} =

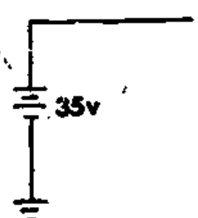
e. E_{R1} =

f. E_a =

(a. 10ma; b. 50v; c. 150v; d. 180v; e. 220v; f. 600v)

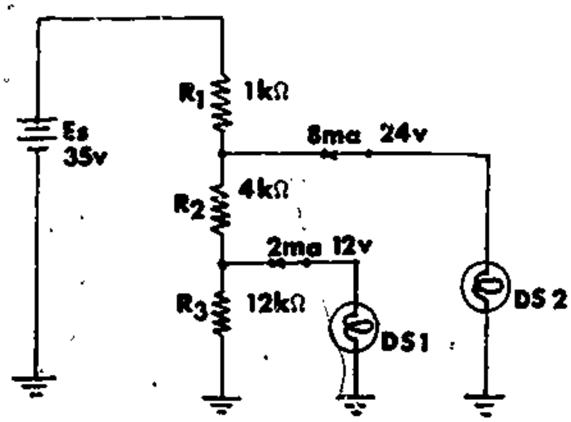
23. Using the partial schematic below, design a voltage divider schematic having a source voltage of 35v that will furnish:

DS1, a 12v lamp drawing 2 ma, and
DS2, a 24v lamp drawing 8 ma.



(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

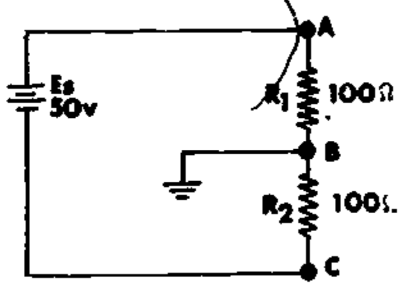
ANSWERS - TEST FRAME 23



IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO TO TEST FRAME 28. OTHERWISE, GO BACK TO FRAME 16 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 23 AGAIN.

24. As you learned earlier both positive and negative voltages may be obtained from a single voltage divider by placing a ground in the circuit as a reference.

Solve for voltage and polarity.

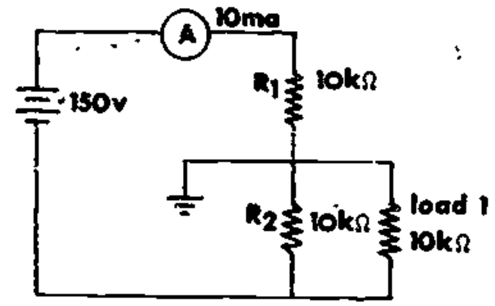


Point A ________

Point C ________

(E_{R1} = +25v; E_{R2} = -25v)

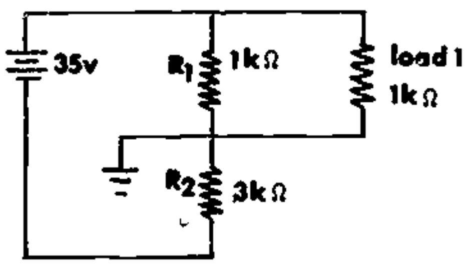
25. Solve for the magnitude and polarity of voltage with respect to ground.



$E_{LOAD\ 1}$ = ________

($E_{LOAD\ 1}$ = -50v)

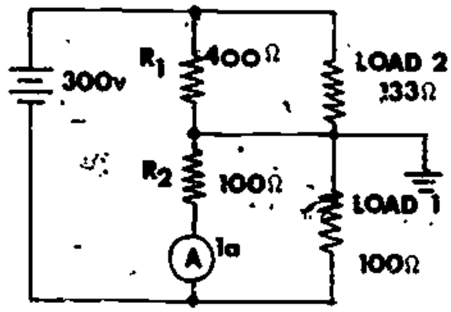
26. Solve for magnitude and polarity of voltage with respect to ground.



$E_{LOAD\ 1}$ = ________

(E_{RL} = +5v)

27. Using the methods learned, solve the following for magnitude and polarity with respect to ground:



$E_{LOAD\ 1}$ = ____________

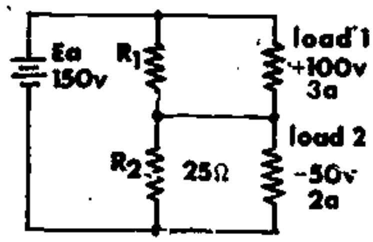
$E_{LOAD\ 2}$ = ____________

- -

(E_{RL1} = -100v; E_{RL2} = +200v)

28. In the schematic below, determine the value of R1 and indicate the placement of ground required to supply the loads as indicated.

-50v load (2 amps), and
+100v load (3 amps)



R1 = ____________

- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

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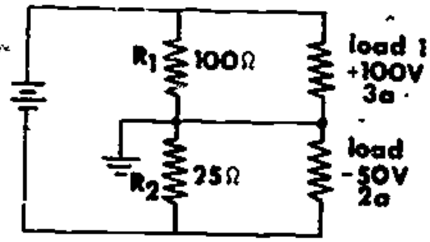
ANSWERS - TEST FRAME 28



R1 = 100 Ω

IF ANY OF YOUR ANSWERS IS INCORRECT, GO BACK TO FRAME 24 AND TAKE THE PROGRAMMED SEQUENCE.

IF YOUR ANSWERS ARE CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, YOU HAVE MASTERED THE MATERIAL AND ARE READY TO TAKE THE MODULE TEST. SEE YOUR LEARNING SUPERVISOR.

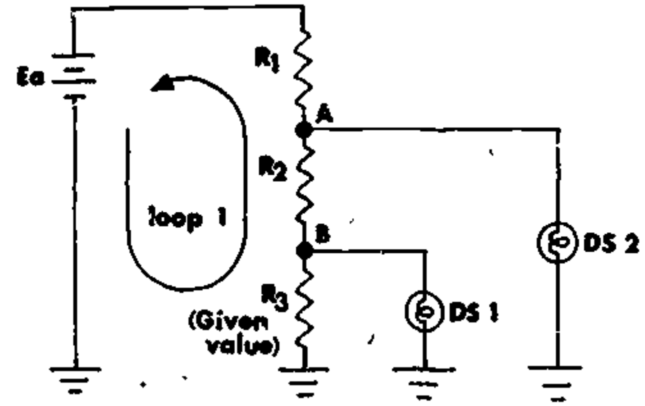
IF YOU DECIDE NOT TO TAKE THE PROGRESS CHECK AT THIS TIME, OR IF YOU MISSED ONE OR MORE QUESTIONS, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU HAVE ANSWERED ALL THE PROGRESS CHECK QUESTIONS CORRECTLY. THEN SEE YOUR LEARNING SUPERVISOR AND ASK TO TAKE THE MODULE TEST.

SUMMARY
LESSON III

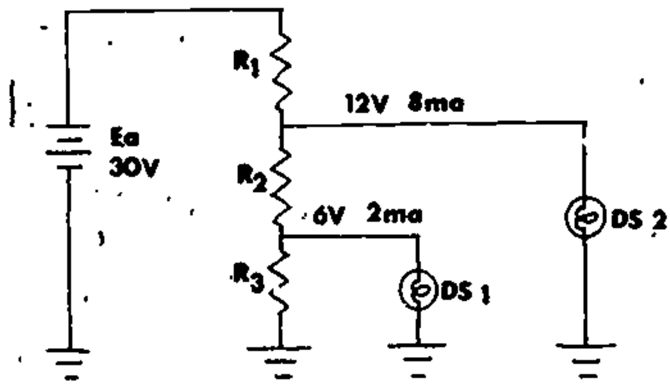
Voltage Dividers

When voltage of a specific magnitude and polarity is needed to operate components or equipment, we often construct a circuit called a voltage divider. It is usually a series-parallel circuit.

Let us consider the values for a voltage divider needed to supply voltage and current for two small loads, DS1 and DS2. The circuit may look like this:



First, we must determine the load requirements. For this example, DS1 is a 6-volt lamp which draws 2 milliamps and DS2 is a lamp that requires 12-volts and draws 8 milliamps. The applied voltage (E_a) is 30 volts, and IR_3 usually is 10% (1/10) of the value of the sums of I_{DS1} and I_{DS2} unless stated otherwise.



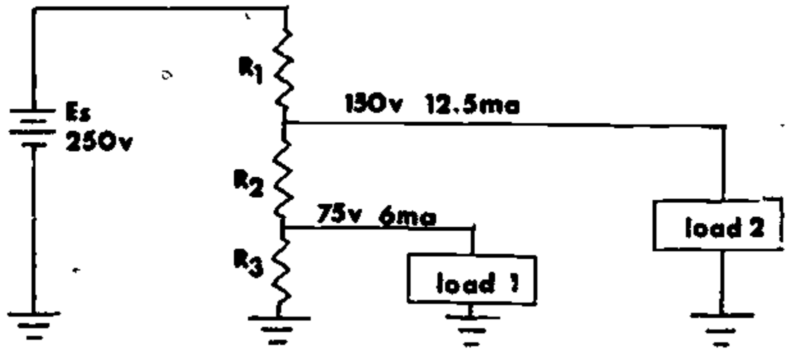
From this information, you can find I_{R3} (1 ma) and R3 (6 kilohms) by using Ohm's Law. I_{R2} must be the sum of I_{R3} and I_{DS1} (3 ma). E_{R2} is equal to the difference of E_{DS2} and E_{R3}. Using Ohm's Law, R2 is found to be 2 kilohms. I_{R1} is the sum of I_{R2} and I_{DS2} (11 ma) and E_{R1} equals 30 v - 12 v (18 v). So R1 must be 1636 ohms (a 1700 ohms resistor would be used.

Because the current flowing through R3 does not flow through the loads, it is called bleeder current. R3 is called the bleeder resistor.

To review the procedures in finding the values for a voltage divider, the following steps are used.

1. Determine the load requirements, source voltage, and bleeder resistance (current).
2. Calculate the resistance needed to provide the voltage for the second load.
3. Repeat step 2 for each additional load.
4. After the divider resistor value for the last load is found, subtract that load voltage from the source voltage. Using Ohm's Law and total current, find the resistance value needed to drop this difference.

Apply this method to find <u>R1</u> in the circuit shown below:



R1 = 5 KΩ

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.