AIR FORCE

QUALIFICATION TRAINING PACKAGE (AFQTP)

FOR

ELECTRICAL SYSTEMS
(3E0X1)

MODULE 14

ELECTRICAL FUNDAMENTALS

TABLE OF CONTENTS

MODULE 14

ELECTRICAL FUNDAMENTALS

Career Field Education and Training Plan (CFETP) references from 1 Jul 02 version.

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Supersedes AFQTP 3E0X1-13, 1 Oct 99

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Notice. This AFQTP is ***NOT*** intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

AIR FORCE QUALIFICATION TRAINING PACKAGES

FOR

ELECTRICAL SYSTEMS

(3E0X1)

<u>INTRODUCTION</u>

Before starting this AFQTP, refer to and read the "AFQTP Trainer/Trainee Guide".

AFQTPs are mandatory and must be completed to fulfill task knowledge requirements on core and diamond tasks for upgrade training. ***It is important for the trainer and trainee to understand*** that an AFQTP ***<u>does not</u>*** replace hands-on training, nor will completion of an AFQTP meet the requirement for core task certification. AFQTPs will be used in conjunction with applicable technical references and hands-on training.

AFQTPs and Certification and Testing (CerTest) must be used as minimum upgrade requirements for Diamond tasks.

<u>MANDATORY</u> minimum upgrade requirements:

Core task:
AFQTP completion
Hands-on certification

Diamond task:
AFQTP completion
CerTest completion (80% minimum to pass)

<u>Note</u>: *Trainees will receive hands-on certification training on diamond tasks when equipment becomes available either at home station or at a TDY location.*

Put this package to use. Subject matter experts under the direction and guidance of HQ AFCESA/CEOF revised this AFQTP. If you have any recommendations for improving this document, please contact the Career Field Manager at the address below.

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ELECTRICAL FUNDAMENTALS

MODULE 14 AFQTP UNIT 4

COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER (14.4.)

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COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

Task Training Guide

STS Reference Number/Title:	14.4., Compute for voltage, current, resistance, and power.
Training References:	Career Development Course (CDC) Electrical Systems 3E051A, Vol. 2: *Electrical and Electronic Fundamentals.*
Prerequisites:	1. **Possess as a minimum a 3E031 AFSC.** 2. **Review CDC Electrical Systems 3E051A, Vol. 2.**
Equipment/Tools Required:	None.
Learning Objective:	Given scenario, compute for voltage, current, resistance, and power.
Samples of Behavior:	Follow the required steps to compute for voltage, current, resistance, and power.
Notes:	

COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

1. Background: In order for current to flow, two things are essential: there must be a source of electrical power (voltage) and there must be a complete circuit. The source of voltage can be a battery, a generator, or some other device. The complete circuit means that there must be a complete path from the source through the load and a return back to the source. In this unit we discuss the relationship of voltage, current, and resistance, and the application of Ohm's law.

2. Ohm's law application.

2.1. There is a definite relationship among the voltage, current, and resistance of any circuit or part of a circuit. If the voltage is increased, the current increases proportionately if resistance stays the same. If the resistance is increased, the current decreases proportionately if voltage stays the same.

NOTE:
A German scientist, George Simon Ohm, developed a law for the quantities of a circuit as follows: 1 volt is the pressure required to force 1 ampere of current through a resistance of 1 ohm.

2.2. Ohm's law, simply stated, is as follows: "For any circuit or part of a circuit, the current in amperes is equal to the electromotive force in volts divided by the resistance in ohms."

2.3. This means that, if you know the voltage and resistance, you can determine the current by dividing the voltage value by the resistance.

2.4. This relationship is expressed by the following equation: *Current = Voltage/Resistance.*

2.5. You can also find the values of voltage and resistance if you know any two of the other values. The following equations show this: *Resistance = Voltage / Current; Voltage = Current x Resistance.*

2.6. Using the symbols for current (I), voltage (E), and resistance (R), you can state ohms law as follows: E = I x R; I = E / R; R = E / I.

2.7. Look at Figure 1, to see Ohm's law in a circular representation.

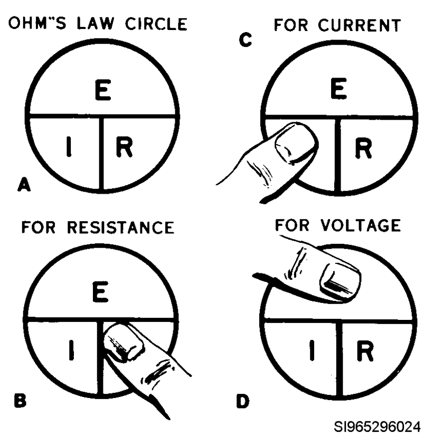

Figure 1, Ohm's Law Circle

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2.8. To use the circle, simply cover the value you wish to determine.

2.9. Use the remaining values in the formula to determine the unknown.

2.10. Here is an example; a circuit has an applied voltage of 120 volts and a resistance of 20 ohms.

2.10.1. To find the current flow, simply apply Ohm's law as follows: I = E / R.

2.10.2. Next enter the known values: I = 120 / 20 = 6 amps.

3. Application of Ohm's law to direct current –series circuits.

3.1. A series circuit is defined as "a circuit that has only one path of current flow."

3.2. Figure 2 shows the arrangement of a series circuit.

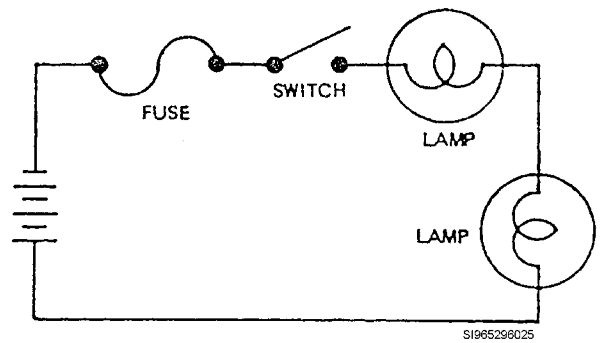

Figure 2, Arrangement of Units in a Series Circuit

3.3. Each electrical circuit has certain operating characteristics. The three characteristics of a series circuit are as follows:

3.3.1. Total resistance is the sum of the individual resistors ($R_T = R_1 + R_2 + R_3$ + etc.).

3.3.2. Same current flows in each part of the circuit ($I_T = I_1 = I_2$ = etc.).

3.3.3. Applied voltage divides among the resistors according to their resistance ($E_T = E_1 + E_2$ + etc. and $E_1 = IR_1$; $E_2 = IR_2$.). The sum of the voltage drops in each resistor equals the applied voltage. (Et=E1+E2+E3+etc.)

3.4. Knowing these characteristics along with Ohm's law, you will be able to compute for voltage, current, and resistance.

3.5. Using Figure 3 as an example: it has a 120-volt source of power, a fuse, a switch, and two 30-ohm resistors in series.

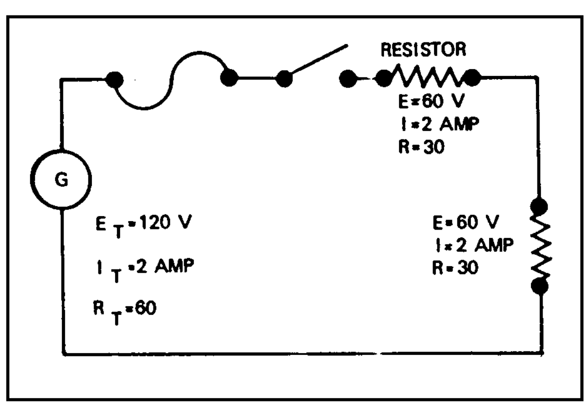

Figure 3, Series circuit with equal resistors

3.5.1. Since the total resistance of a series circuit is equal to the sum of the resistors, then the total resistance for this circuit is 30 ohms plus 30 ohms, or a total of 60 ohms. (R_T = 60).

3.5.2. You were already given the total voltage (120 volts). Knowing the total voltage and the total resistance, you can now find the total current flow by using Ohm's law.

3.5.2.1. I = E / R = 120 / 60 = 2 amperes

3.5.3. Since the same current flows in each part of a series circuit, a current of 2 amps flows through each of the two resistors.

3.5.4. Use Ohm's law again to see how the voltage divides among the resistors.

3.5.4.1. $E_1 = I \times R_1 = 2 \times 30 = 60$ volts

> **NOTE:**
> This is the same for each resistor since the resistance is the same in both resistors.

3.6. Figure 4 shows how voltage divides among unequal resistors in a series circuit. Note that the unit with the most resistance uses most of the voltage.

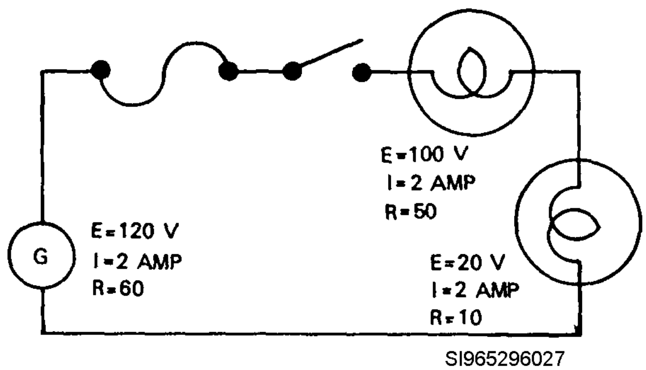

Figure 4, Series Circuit with Unequal Resistors

4. Application of Ohm's law to direct current-parallel circuits.

4.1. Parallel circuits are circuits in which the components are arranged in such a manner that the current divides between them.

4.2. Unlike a series circuit, a parallel circuit has two or more paths for current to flow.

4.3. The characteristics of a parallel circuit are:

4.3.1. The same voltage is applied across each branch, ($E_T = E_1 = E_2$ = etc.).

4.3.2. The total current in a parallel circuit is equal to the sum of the current flow in the individual branches. ($I_T = I_1 + I_2 + I_3$ + etc.).

4.3.3. The total resistance of a parallel circuit is equal to the applied voltage divided by the total current and is always less than the smallest individual resistance.

4.4. When the total current is unknown and several resistors of equal value are connected in parallel, you can find the combined or joint resistance by dividing the resistance of one resistor by the number of resistors connected in parallel.

4.4.1. For example, if two 10-ohm resistors are connected in parallel, the joint resistance offered by the combination is 5 ohms (10 / 2).

4.5. To state this as a rule: The combined resistors of equal value connected in parallel are equal to one resistance value divided by the number of connected resistors.

4.6. All equipment you use in electrical circuits does not have the same resistance.

4.7. Therefore, when you connect different pieces of equipment in a parallel circuit, they do not draw the same current. Two unequal resistors connected in parallel are shown in Figure 5.

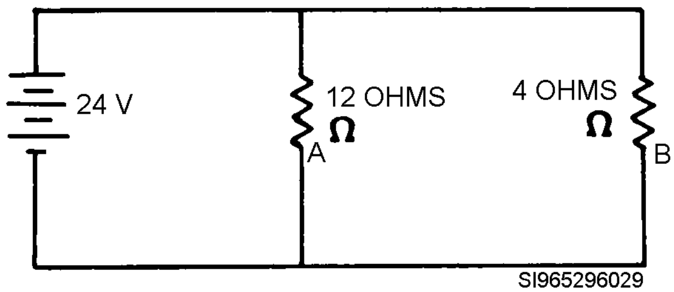

Figure 5, Two Unequal Resistors Connected in Parallel

4.8. In this case, the current through the parallel connected resistor A is $I_A = E / R_A = 24 / 12 = 2$ amps.

4.9. The current through resistor B is $I_B = E / R_B = 24 / 4 = 6$ amperes.

4.10. The current is equal to the sum of the currents in the branches ($I_T = 6A + 2A = 8$ amperes).

4.11. Ohm's law then gives the joint resistance offered by the current as $R_J = E / I_T = 24 / 8 = 3$ ohms.

4.12. You could not use the rule for resistors of equal value in parallel circuits for this circuit because the individual resistors, A and B, are not equal in value.

4.13. For such cases, another rule has been developed for the calculation of joint resistance: The joint resistance of two resistors in parallel is equal to their product divided by their sum. (R_J = product / sum)

4.14. If you substitute the values from the circuit in Figure 5, you have $R_J = (12 \times 4) / (12 + 4) = 48 / 16 = 3$ ohms.

4.15. There is also another method of finding the joint resistance of several resistors in parallel. It is called the reciprocal method. As you have seen, you can use the product-over-sum method with only two resistors at one time. If the circuit has five or six resistors in parallel, this could be a lengthy procedure.

4.16. Instead you can use the reciprocal method to find the joint resistance of any number of resistors in one operation. The rule is the joint resistance of a parallel circuit is equal to the reciprocal of the reciprocals of the individual resistances.

4.16.1. $R_J = 1/ [(1 / R_1) + (1 / R_2) + (1 / R_3)] = 1 / (1/2 + 1/3 + 1/6) = 1 / (.5 + .33 + .17) = 1$ ohm

5. Application of Ohm's law to series-parallel circuits.

5.1. Series-parallel circuits consist of groups of parallel resistors in series with other resistors. Any leg of a parallel group can consist of two or more resistors in series.

5.2. You can analyze series-parallel circuits by using the same rules we applied to series circuits and to parallel circuits. To make this application, reduce the series-parallel circuit to an equivalent, series or parallel circuit.

5.3. Work only one part first; use the laws that apply to that part of the circuit.

5.4. First, replace each group of parallel resistors with its equivalent single resistance.

5.5. Then, treat the entire circuit as a series circuit.

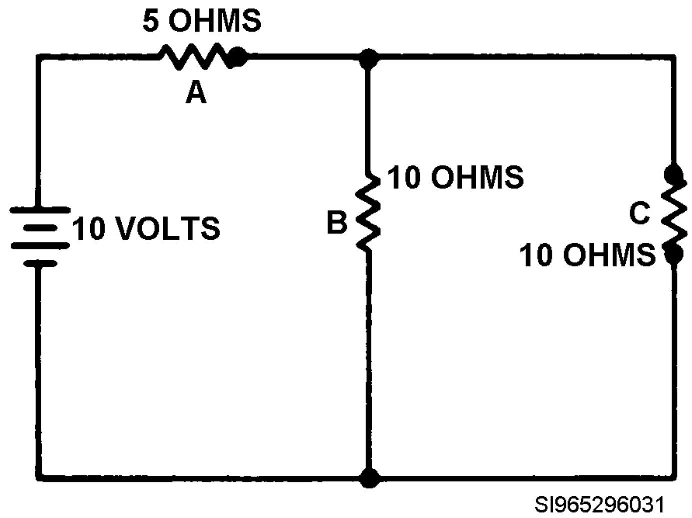

Figure 6, Simple Series-Parallel Circuit

5.6. Figure 6 shows an example of a series-parallel circuit.

5.7. The first step is to reduce the two parallel resistors B and C to an equivalent single resistance.

5.8. Since B and C are equal, you can divide 10 by 2. This gives you 5 ohms as the joint resistance of the parallel branch.

5.9. The circuit is now a series circuit of two 5-ohm resistors.

5.10. Obtain the total resistance by adding the resistance A to the equivalent of B and C. This gives you 5 plus 5, or 10 ohms, as the resistance of the entire circuit.

5.11. Knowing this, you can calculate the total current by applying Ohm's law:

5.11.1. $I_T = E_T / R_T = 10 / 10 = 1$ ampere

5.12. This 1 ampere flows through resistor A, producing a voltage drop of 5 volts.

5.13. Since the two parallel resistance's have the same value, the 1 ampere of current divides equally between the two. The IR drop across B equals ½ x 10, or 5 volts, and across C is 5 volts.

5.14. By following one complete path around the circuit, you can see that the sum of the voltage drops is equal to the applied voltage.

5.14.1. Starting from the positive side of the battery, there is a 5-volt drop in resistor A, another 5-volt drop in resistor B, and thus back to the battery.

5.14.2. Follow only one path at a time in tracing through a circuit.

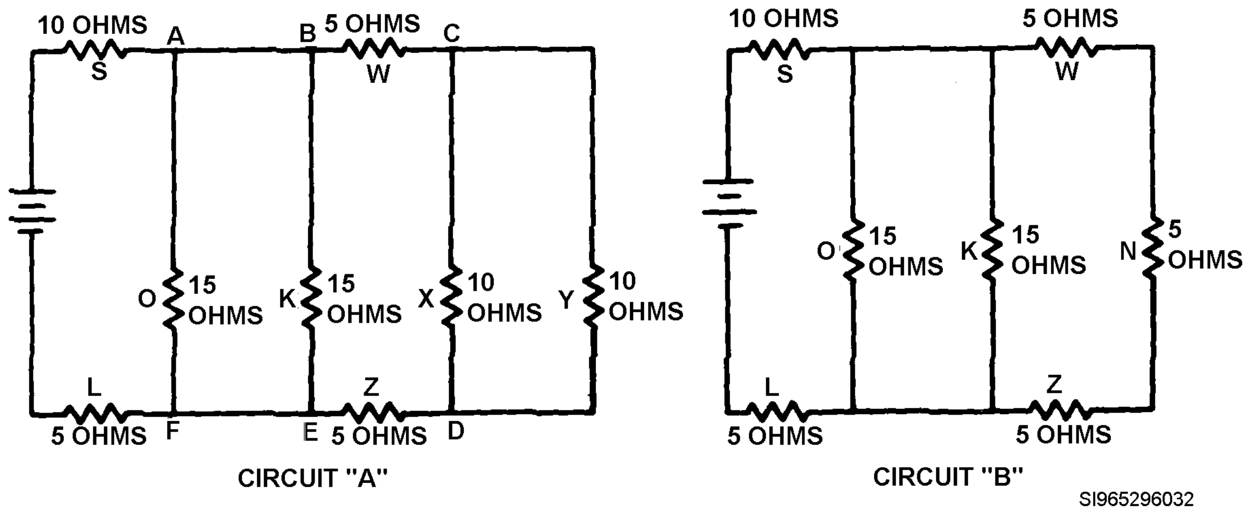

Figure 7, Solving Series-Parallel Circuits Simplified

5.15. As you will see In Figure 7, a series-parallel circuit that involves more steps.

5.16. Combine resistor X and Y of circuit A and represent them with resistance N of circuit B.

5.17. Circuit B is the equivalent circuit of circuit A in Figure 7.

5.18. X and Y are equal and in parallel; therefore, their joint resistance is as follows: N = 10/2 = 5 ohms.

5.19. Combine resistors W, N, and Z (Circuit B of Figure 7) into a simple resistor M of circuit C in Figure 8.

5.20. W, N, and Z are in series; therefore, the resistance of M equals 15 ohms (5+5+5=15).

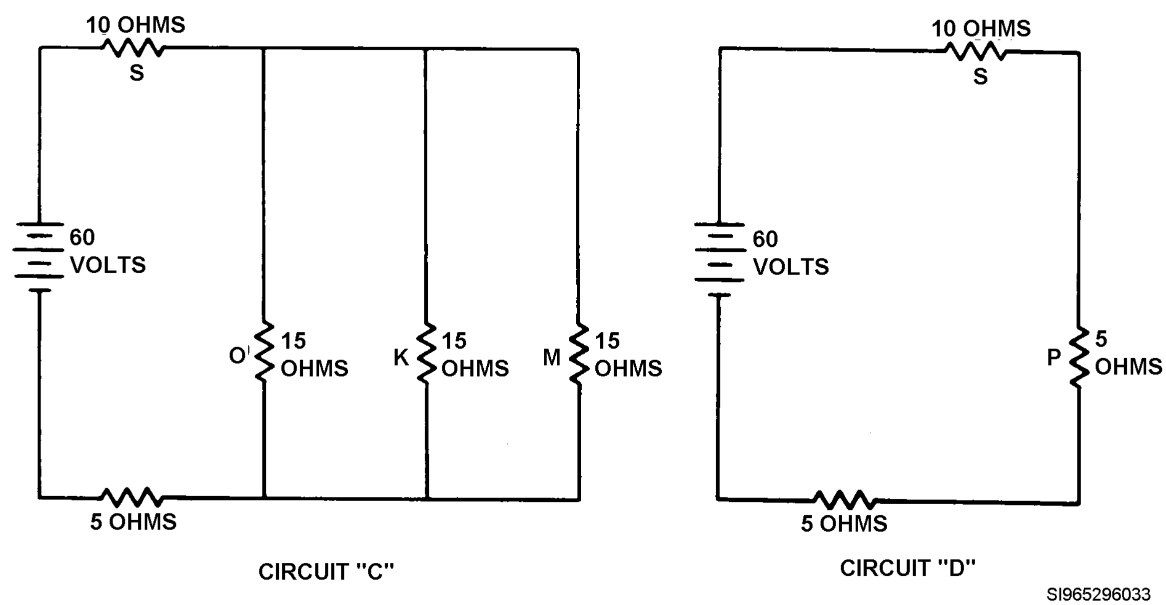

Figure 8, Solving Series-Parallel Circuits by Simplified Equivalent Circuits

5.21. Combine resistors O, K, and M, of circuit C in Figure 8, into a simple resistance P of circuit D of Figure 8. Since resistors O, K, and M are equal and in parallel, treat them as follows: P = 15/3 = 5 ohms.

5.22. Combine resistors S, P, and L (circuit D, Figure 8), which are in series. The combined or joint resistance (R_J) of the whole circuit equals 20 ohms (10+5+5).

5.23. Find the total current (I_T) of the circuit as follows: $I_T = E / R_T = 60/20 = 3$ amperes.

5.24. Find the voltage drop across S (circuit C, Figure 8) as follows: $E_S = I_T \times R_S = 3 \times 10 =$ 30 volts.

5.25. Find the voltage drop across L (circuit D, Figure 8) as follows: $E_L = I_T \times R_L = 3 \times 5 = 15$ volts.

5.26. Find the voltage drop across equivalent resistance P (equivalent of O, K, M, circuit C) as follows: $E_P = E_T - E_S - E_L = 60 - 30 - 15 = 15$ volts.

5.27. The voltage drop across each parallel branch is equal. Find the current in resistor O as follows: $I_O = E_O / R_O = 15 / 15 = 1$ ampere.

5.28. At point A of circuit A, Figure 7, there are two paths for the current flow. In a parallel circuit, the total current equals the sum of the currents in the branches.

5.29. Therefore, the current flowing from point A to point B equals $I_T - I_O$, or 3 – 1 = 2 amperes.

5.30. The voltage drop across parallel resistors is equal, so the voltage drop across K is 15 volts. The current is I = E / R = 15 / 15 = 1 ampere.

5.31. Since a current of 2 amperes flows from point A to point B and 1 ampere of current flows through resistor K, the current through W must be 1 ampere (2 – 1).

5.32. At C the current divides again. Since the resistances X and Y are the same, the current divides equally, with ½ ampere going through each resistor.

5.33. Voltages across X and Y are the same. E = I x R = ½ x 10 = 5 volts.

5.34. At C to D of circuit A (Figure 7) the two currents of ½ ampere join and 1 ampere flows through Z. Voltage drop across Z is 5 volts. (E = I x R = 1 x 5 = 5)

5.35. At point E, the currents through Z and K join and 2 amperes (1 + 1) flow through E to F.

5.36. At point F, the current flowing through O joins the current flowing from point E to F and 3 amperes flow through L. Recall that these 3 amperes is equal to the total current.

6. Determine power in a DC circuit.

6.1. To determine the power in a DC electrical circuit, use the power formula P = E x I.

6.2. For example, a circuit with an applied voltage of 120 volts and a current flow of 10 amperes consumes 120 volts x 10 amperes, or 1,200 watts.

6.3. You can also find the power in a DC circuit if you know the resistance (R) by using the following formula: $P = E^2 / R$ or $P = I^2R$.

NOTE:
Many of the ideas you absorbed in your study of DC circuits are applicable to AC circuits. The constant changing of the direction and the magnitude of alternating current cause those features that you found to be different. The rules and equations for DC circuits apply to AC circuits having resistive load elements alone. This includes load elements such as lamps, resistors, and heating elements. When the AC circuit contains reactive load elements, we must consider them also because the current through a reactive component is not in phase with the applied voltage. We must take the effect of this out-of-phase condition into account when we calculate values in AC circuits.

7. ***To perform this task, follow these tasks:***

Step 1: Using ohms law compute for voltage.

1.1. In a circuit where total resistance and current are known use formula E=IR.

1.2. In a series circuit, first find voltage at each resistor using formula E1=IR1. Then find total voltage using formula ET=E1+E2+ect.

1.3. In a parallel circuit, first find total current using formula IT=I1+I2+ect. Then find total resistance using formula RJ=E/IT. Place these totals in formula E=ITRJ.

Step 2: Using ohms law compute for current.

2.1. In a circuit where total resistance and voltage are known use formula I=E/R.

2.2. In a series circuit first find total resistance using formula RT=R1+R2+ect. Then find total voltage using formula ET=E1+E2+ect. Then find total current using formula I=ET/RT.

2.3. In a parallel circuit, first find current at each resistor using formula IA=E/RA. Then find total current using formula IT=I1+I2+ect.

Step 3: Using ohms law compute for resistance

3.1. In a circuit where total current and voltage are known use formula R=E/I.

3.2. In a series circuit find the totals of voltage and current using formulas ET=E1+E2+ect and IT=I1=I2=ect. Then find total resistance using formula RT = ET/ IT.

3.3. In a parallel circuit, find the totals of voltage and current using formulas ET=E1= E2=ect and IT=I1+I2+ect. Then find total resistance using formula RT = ET/ IT.

Step 4: Determine power in a circuit

4.1. To determine power in a simple DC electrical circuit, use the power formula P = E x I.

4.2. For example, a circuit with an applied voltage of 120 volts and a current flow of 10 amperes consumes 120 volts x 10 amperes, or 1,200 watts.

4.3. You can also find the power in a DC circuit if you know the resistance (R) by using the following formula: $P = E^2 / R$ or $P = I^2R$.

REVIEW QUESTIONS
FOR
COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

QUESTION	ANSWER
1. In mathematical equations, what is the symbol for current?	a. "C". b. "I". c. "E". d. "R".
2. A direct current-series circuit has two or more paths for current to flow.	a. True. b. False.
3. In a direct current-series circuit the same current flows in each part of the circuit.	a. True. b. False.
4. A method of finding the joint resistance of several resistors in parallel is called the _______ method.	a. Parallel b. Ohm's c. Sum d. Reciprocal
5. What formula is used to determine the power in a DC circuit?	a. P = I x R. b. P = I / E. c. P = E x I. d. P = E x R.

COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

PERFORMANCE CHECKLIST

INSTRUCTIONS:

The trainee must satisfactorily perform all parts of the task without assistance. Evaluate the trainee's performance using this checklist.

DID THE TRAINEE….?	YES	NO
1. Properly apply Ohm's law to compute for voltage		
2. Properly apply the power formula to compute power		
3. Properly apply Ohm's law to compute for current		
4. Properly apply Ohm's law to compute for resistance		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

Air Force Civil Engineer

QUALIFICATION TRAINING PACKAGE (QTP)

REVIEW ANSWER KEY

FOR

ELECTRICAL SYSTEMS

(3E0X1)

MODULE 14

ELECTRICAL FUNDAMENTALS

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COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER
(3E0X1-14.4.)

QUESTION	ANSWER
1. In mathematical equations, what is the symbol for current?	b. “I”.
2. A direct current-series circuit has two or more paths for current to flow.	b. False.
3. In a direct current-series circuit the same current flows in each part of the circuit.	a. True.
4. A method of finding the joint resistance of several resistors in parallel is called the ________ method.	d. Reciprocal
5. What formula is used to determine the power in a simple DC circuit?	c. P = E x I.

MEMORANDUM FOR HQ AFCESA/CEOF
139 Barnes Drive Suite 1
Tyndall AFB, FL 32403-5319

FROM:

SUBJECT: Qualification Training Package Improvement

1. Identify module.

   Module # and title____

2. Identify improvement/correction section(s):

______ STS Task Reference	_______ Performance Checklist
______ Training Reference	_______ Feedback
______ Evaluation Instructions	_______ Format
______ Performance Resources	_______ Other
______ Steps in Task Performance	

3. Recommended changes--use a continuation sheet if necessary.

   ____
   ____
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4. You may choose to call in your recommendations to DSN 523-6392 or FAX DSN/Commercial 523-6488 or (850) 283-6488 or email ceof.helpdesk@tyndall.af.mil.

5. Thank you for your time and interest.

YOUR NAME, RANK, USAF
Title/Position