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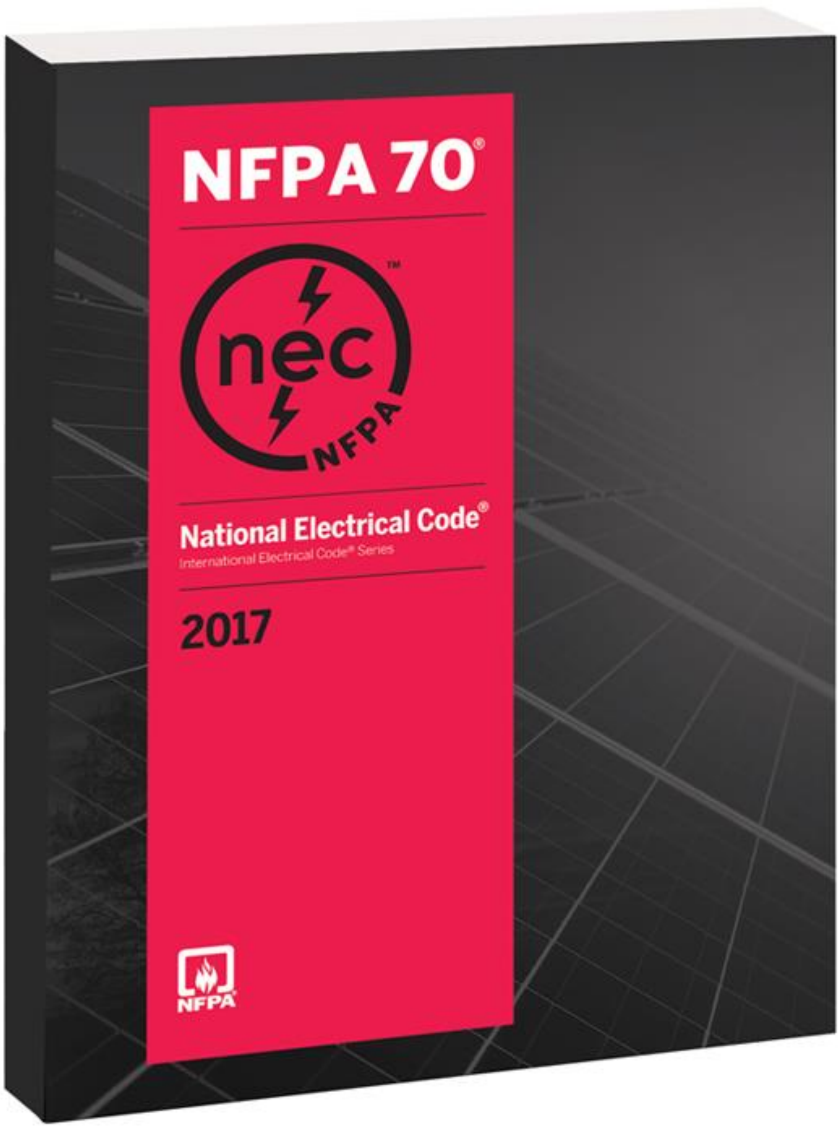
Electrical Examination Preparation Highlights and Workbook

Based on the



1.0 Introduction on How To Get The Best Grade On Your Exam

The material in this workbook is intended to supplement the computer exam prep software programs of Prep At Home LLC. The book is structured to assist the student to study and prepare for their electrical Contractor, Master, or Journeyman examination. Please note that you will not be allowed to use this workbook while you are taking your state.

This book is dedicated to providing information that will help you best the best grade possible on the state examination. This workbook contains mathematics and basic electrical formulas which play a large role in the state examination, along with articles from the National Electrical Code® ("code") that are commonly used on the exam. There are also practice questions that pertain to these specific articles. The practice questions should be used to test your knowledge of the code, and basic electrical concepts. Once you have answered all of the questions, you should then look up the correct answers to the questions located in Appendix 1, and correct any questions you may have missed. These questions and answers should be reviewed several times to insure through understanding of the subject material. The course instructor will be able to answer any questions you may have on the material contained herein.

2.0 Preparation and Study Recommendations

Dedication is the key to success. Failing to prepare is preparing to fail, therefore, below is a list of techniques that can help you get the best grade possible with your preparation and studying for your upcoming state examination.

- **Support.** You need encouragement in your studies and support from your loved ones and employer. To properly prepare for your exam, you should study until the material on which you will be tested is thoroughly understood.
- **Communication With Your Family.** Good communication with your family members is very important. Studying every night and on weekends may cause tension. Get their support, cooperation, and encouragement during this preparation time. Be sure to plan some special time with family to help your relationships.
- **Stress.** Stress can really take the wind out of you. It takes practice, but get into the habit of relaxing before you begin your studies. Doing some type of exercise such as stretching or walking. Close your eyes for a couple of minutes; deliberately relax the muscle groups that are associated with tension, such as the shoulders, back, neck, and jaw. Take several slow deep breaths.
- **Attitude.** Maintaining a positive attitude is extremely important. Being positive helps give your motivation, and keeps you from getting discouraged or frustrated.
- **Reducing Eye Strain.** Your eyes will be under additional stress because of prolonged, near-vision reading, which can result in headaches, fatigue, etc. Your work area should be brighter than the rest of the room. Don't read under a single lamp in a dark room. Sit straight up, chest and shoulders back, and weight over the seat so both eyes are an equal distance from what you are reading.
- **Getting Organized.** You should not waste time looking around for your study materials. Keep everything you need together (i.e. in one backpack). It is very important that you study in a private area. Assuming that your home is busy, the dining room table is not a good study location.

- **Time Management.** Time management and planning is very important. On paper, write a plan for each day, and do your best to stick to that plan. Dedicate a certain time and place for studying. Your plan should include the tasks that you intend to complete in that day. Do not include tasks that you would *like* to get done, but should be scheduled for another day.
- **Class Participation.** In the classroom, pay attention to everything the instructor lectures. If he is taking the time to bring up a fact, that fact is important in preparing for your exam. If you do not understand a point or did not hear what was said, ask for clarification. If you still do not understand bring up the point after class to the instructor (or a possibly classmate).
- **Study Partners.** Studying with a partner can make learning more enjoyable. You can push and encourage each other. You are more likely to study if someone else is depending on you. Students who study together perform above average because they try different approaches and explain their solutions to each other.

3.0 Test Day Recommendations

Being prepared for an exam means more than just knowing electrical concepts, formula calculations, and the NEC. Being successful on taking exams is a learned process that takes practice and involves strategies. The following are our recommendations for the type of examination you will soon be taking.

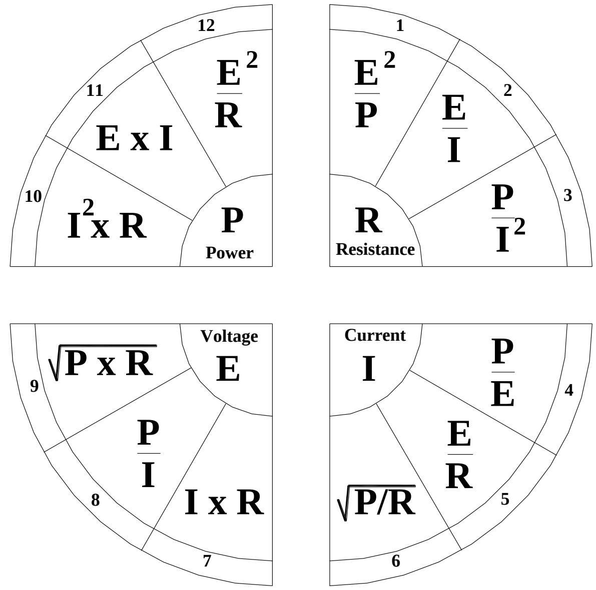
- **Relax.** This is easier said than done, but it is very important. You must make a deliberate effort to relax. Make sure you're comfortable; remove clothes if you are hot, or put on a jacket if you are cold. Make sure you have rested, and that you are not hungry.
- **Be Prepared.** Make sure you have everything needed several days before the exam. The night before the exam is not the time to be out buying Code books, calculators, and other study materials.
- **Understand The Question.** To answer a question correctly, you must first understand the question. One word in a question can totally change the meaning of it. Carefully read every word of every question. Many of the questions are worded tricky in order to confuse what the questions is really asking. Questions will many times give more information than you require to solve the problem, commonly referred to as "fluff". You may not agree, or have not calculated exactly the same numbers that are given as answers to the question, however, remember that the directions will state to answer the "BEST" possible answer.
- **Skip The Difficult Questions.** Contrary to popular belief, you do not have to answer one question before going on to the next one. This could result in not having enough time to answer the easy questions, and on most of the exams the first few questions are considerably harder than the rest of the test. The following strategy should be used to avoid getting into this situation.
  - ✓ **First Pass:** Answer the questions you know from the top of your head. This information could be from this workbook, course lecture, or practical experience. It should only take as long to answer these type of questions as it takes to read them. If you do not know the correct choice immediately during this first pass through the examination, simply skip it!
  - ✓ **Second Pass:** Start at the beginning of the exam and answer the questions that you are simple Ohm's Law calculations or information that you can look up in your NEC quickly. This would be using articles that you are familiar with, such as commonly used tables. If you can't find the answer, go on to the next question. Don't get stuck or guess at this point.

- ✓ **Third Pass:** At this point you have gone through the test twice. Check how much time is left to take the exam and subtract 20 minutes (for guessing) and determine the amount of time left per each question. Spend the remaining time equally on each question. Again, do NOT get stuck!
- ✓ **Guessing:** If you have not answered all the questions after the three previous passes, make an educated guess. You should only need 10-20 minutes for guessing. Never leave a question unanswered. The answer "none of the above" is usually not the correct answer, however, "all of the above" can be a good guess. Avoid selecting the highest or lowest number when guessing. You may also select the best answer using the process of elimination, meaning: some of the answers are obviously wrong given your knowledge of the subject.

Test Recommendation Summary

- Continuously review information that you are told will be on the exam, such that you can quickly answer or reference your code book to answer.
- Don't try to "cram" information that you do not understand the night before the exam, if you don't know it by then.
- Make sure everything is ready and packed the night before the exam.
- Get sufficient sleep, and have a good meal before the exam.
- Take all your reference material. Let the proctors tell you what you can't use.
- Be at the exam site early, being in a rush will make you nervous.
- Bring you identification.
- Determine the time per question remaining for the exam.
- Be sure you are marking the answer in the correct spot on the answer sheet.
- Read each question carefully.
- Try to stay relaxed (take deep breaths, read, etc.)
- Don't get stuck on any one question.
- Skip questions that look difficult or lengthy. These type of questions are structured to devour your time and get you frustrated. Only answer difficult questions on the third pass through the exam, or if time runs out, simply guess.

4.0 Common NEC Articles and Examples



Tab and highlight ALL the following in your codebook

220	Calculations and Tables
T220.12	General lighting
T220.42	Lighting and derating
T220.54	Household Dryer derating
T220.55	Household Range derating
240.6	Standard Rating of Fuses
T250.66	Electrode grounding conductors
T250.122	Equipment grounding conductors
T300.5	Direct burial requirements
T310.15	Ampacity of Conductors
T430.52	Motor Overcurrent Protection
T430.248	Motor FLC single-phase
T430.250	Motor FLC three-phase
	Nameplate – overcurrent size
	Tables – branch or feeder conductors

Chapter 9, Table 5 area conductors, then Table 4 size conduit.
Chapter 9, Table 8, Resistance of conductors.
Annex C, Conduit fill (same size only).
Annex D, Examples (examples 1 and 2 are important), load calculations.

$\text{Current}_{(3\phi)} = P / (E \times \sqrt{3})$ **√3 = 1.732 (used for *all* three-phase formulas)**

$\text{Power}_{(3\phi)} = E \times I \times \sqrt{3}$

$$Vd = \frac{\sqrt{3} \times K \times L \times I}{CM}$$ Where:

(3-phase)
(1-phase) use a 2 *in place of* √3

Vd = Voltage drop on the conductor
I = Current draw
L = Length of the conductor (between the source and load)
K = 12.9 for copper (21.2 Aluminum)
CM = circular mils (Chap 9 Table 8)
√3 = 1.732

L = (Vd x CM) / (2 x K x I) solve for the max length between source and load

1 HP = 746 watts

Total Resistance in Series (simply add them up): $R_T = R_1 + R_2 + R_3 + R\ldots$

Total Resistance in Parallel (***only 2*** *resistors)*: $$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

Total Resistance in Parallel (***three or more*** *resistors)*: $$R_T = \frac{1}{1/R_1 + 1/R_2 + 1/R_3 + 1/R\ldots}$$

5.0 Seminar and Webinar Questions

1. A dwelling has 3,000 sq-ft of heated space, with a 600 sq-ft garage, and 1,000 sq-ft unfinished habitable space for future use. When calculating the service conductor size for this dwelling unit using the standard calculation method, what is the minimum demand in volt-amperes?

   1. 6,150
   2. 7,725
   3. 12,000
   4. 16,500

   Table 220.12, Table 220.42, Annex D Examples 1, and 2. (4000 sq-ft x 3VA/sq-ft) + 3000 (small appliance) + 1500 (laundry) = 16,500 – 3,000 = 13,500 x 35% = 4725 VA + 3000 VA = 7,725VA
   While the Standard Method of derating is listed in Table 220.12; which is 100% of the first 3,000 VA, and 35% of the remainder, it is important to note that the Optional Method detailed on 220.82(B) can also be a test question; which is 100% of the first 10,000 VA, and 40% of the remainder.

Example D1(a) One-Family Dwelling

The dwelling has a floor area of 1500 ft^2, exclusive of an unfinished cellar not adaptable for future use, unfinished attic, and open porches. Appliances are a 12-kW range and a 5.5-kW, 240-V dryer. Assume range and dryer kW ratings equivalent to kVA ratings in accordance with 220.54 and 220.55.

Calculated Load *[see 220.40]*

General Lighting Load 1500 ft^2 at 3 VA/ft^2 = 4500 VA

Minimum Number of Branch Circuits Required *[see 210.11(A)]*

General Lighting Load: 4500 VA ÷ 120 V = 38 A

This requires three 15-A, 2-wire or two 20-A, 2-wire circuits.
Small-Appliance Load: Two 2-wire, 20-A circuits *[see 210.11(C)(1)]*
Laundry Load: One 2-wire, 20-A circuit *[see 210.11(C)(2)]*
Bathroom Branch Circuit: One 2-wire, 20-A circuit (no additional load calculation is required for this circuit) *[see 210.11(C)(3)]*

Minimum Size Feeder Required *[see 220.40]*

General Lighting		4,500 VA
Small Appliance		3,000 VA
Laundry		1,500 VA
	Total	9,000 VA
3000 VA at 100%		3,000 VA
9000 VA – 3000 VA = 6000 VA at 35%		2,100 VA
	Net Load	5,100 VA
Range *(see Table 220.55)*		8,000 VA
Dryer Load *(see Table 220.54)*		5,500 VA
Net Calculated Load		18,600 VA

Net Calculated Load for 120/240-V, 3-wire, single-phase service or feeder

18,600 VA ÷ 240 V = 78 A

Sections 230.42(B) and 230.79 require service conductors and disconnecting means rated not less than 100 amperes.

Calculation for Neutral for Feeder and Service

Lighting and Small-Appliance Load		5,100 VA
Range: 8000 VA at 70% *(see 220.61)*		5,600 VA
Dryer: 5500 VA at 70% *(see 220.61)*		3,850 VA
	Total	14,550 VA

Example D2(a) Optional Calculation for One-Family Dwelling, Heating Larger Than Air Conditioning *[see 220.82]*

The dwelling has a floor area of 1500 ft^2, exclusive of an unfinished cellar not adaptable for future use, unfinished attic, and open porches. It has a 12-kW range, a 2.5-kW water heater, a 1.2-kW dishwasher, 9 kW of electric space heating installed in five rooms, a 5-kW clothes dryer, and a 6-A, 230-V, room air-conditioning unit. Assume range, water heater, dishwasher, space heating, and clothes dryer kW ratings equivalent to kVA.

Air Conditioner kVA Calculation

6 A × 230 V ÷ 1000 = 1.38 kVA

This 1.38 kVA [item 1 from 220.82(C)] is less than 40% of 9 kVA of separately controlled electric heat [item 6 from 220.82(C)], so the 1.38 kVA need not be included in the service calculation.

General Load

1500 ft^2 at 3 VA		4,500 VA
Two 20-A appliance outlet circuits at 1500 VA each		3,000 VA
Laundry circuit		1,500 VA
Range (at nameplate rating)		12,000 VA
Water heater		2,500 VA
Dishwasher		1,200 VA
Clothes dryer		5,000 VA
	Total	29,700 VA

Application of Demand Factor *[see 220.82(B)]*

First 10 kVA of general load at 100%		10,000 VA
Remainder of general load at 40% (19.7 kVA × 0.4)		7,880 VA
	Total of general load	17,880 VA
9 kVA of heat at 40% (9000 VA × 0.4) =		3,600 VA
	Total	21,480 VA

2. What would be the derated value for a 20,800 Watt range installed in a single family dwelling?
   1. 8.0 kW
   2. 11.6 kW
   3. 12.5 kW
   4. 20.8 kW

   One Range above 12 kW: **Table 220.55 Column C.** **Note 1 says to increase the value in Column C by 5% for every kW above 12 kW.** Therefore, 20,800 VA – 12,000 VA = 8,800 VA. So, 8,800/1,000 is 8.8 x 5% = 44%. Then multiply the value in Column C which is 8,000 VA (for the one range) by the 44%, which is 3,520 VA, and add that back to the value in Column C of 8,000 VA for a total derated value of 11,520 VA.

3. A 32-unit apartment complex has replaced the ranges. Each range is rated at 18,000 Watts. What is the calculated load?
   1. 47.0 kW
   2. 51.7 kW
   3. 56.0 kW
   4. 61.1 kW

   Multiple ranges above 12 kW: **Table 220.55** Column C states; 15 K + 1 kW for each range. Additionally, you must apply Note 1 since the ranges are above 12 kW. Therefore, 15 kW + 32 K = 47 kW, and the ranges are 18,000 – 12,000 = 6 kW above 12 kW, so 6 x 5% = 30%. Then multiply the value in Column C which is 47,000 VA (for the 32 ranges) by the 30%, which is 14,100 VA (this is our derated portion), and add back to the value from Column C of 47,000 VA for a total derated value of 61,100 VA.

4. Given. A Service has conductors of 250 kcmil copper, with a driven ground rod as its only means of grounding. What copper grounding electrode conductor size would be required?
   1. 1/0 AWG
   2. 2 AWG
   3. 6 AWG
   4. 8 AWG

   Table 250.66 Note, that the grounding electrode conductor size is based on the size of the service entrance conductors. Be careful if the questions state copper or aluminum for each conductor, and to use the proper column. 2 AWG.

5. According to the NEC, what size copper grounding electrode conductor would be required for a service built with 380 ampere rated THHN insulated copper conductors?
   1. 1/0 AWG
   2. 2 AWG
   3. 3 AWG
   4. 4 AWG

   Use **Table 310.15(B)(16)** for the 380 Amp THHN service, gives a 400 kcmil copper service conductor, then use **Table 250.66** to size the # 1/0 copper grounding electrode conductor.

6. What MINIMUM size copper bonding jumper is allowed for a circuit with an overcurrent protective device rated at 15 amperes?

1. 8 AWG
2. 10 AWG
3. 12 AWG
4. 14 AWG

Table 250.122 Note, that the size of the equipment grounding conductor (or bonding jumper) is sized according to the overcurrent protection for that branch circuit. The size of the service is not relative to question. 14 AWG.

7. In a residential dwelling location, direct buried cables that are GFCI protected at 20 amperes must be installed a minimum of how many inches below grade?

1. 8
2. 12
3. 18
4. 24

Table 300.5 Note, this table is used for several different types of questions. 12 inches.

8. What is the ampacity of three # 1 THW copper conductors at 86 degrees F in a raceway?

1. 100 amperes
2. 115 amperes
3. 130 amperes
4. 150 amperes

Table 310.15(B)(16) gives 130 amperes, then derate for temperature using Table 310.15(B)(2)(a) which is a multiplier of 1.00 in this case. Therefore, 130 amperes x 1.00 = 130 amperes.

Important Note: Use **Table 310.15(B)(2)(a)** when correcting ampacities from **Tables 310.15(B)(16)** and 310.15(B)(17), both of which are based on an ambient temp of 86 degrees F. However, use 310.15(B)(2)(b) when correcting ampacities from Tables 310.15(B)(18), 310.15(B)(19) and 310.15(B)(20), all of which are based on an ambient temp of 104 degrees F.

9. What would be the ampacity of each conductor in a raceway given that there are four (4), #1 THW copper conductors at 132 degrees Fahrenheit?

1. 60 amperes
2. 75 amperes
3. 115 amperes
4. 130 amperes

Table 310.15(B)(16) gives 130 amperes, then derate for temperature using **Table 310.15(B)(2)(a)** which is a multiplier of 0.58, then derate for the number of conductors (four) using Table **310.15(B)(3)(a)** which is 80%. Therefore, 130 A x 0.58 x 0.80 = 60 amperes.

10. What is the size of the secondary current of a 75 kVA transformer, given a three phase 480 V primary, and a three phase 120/208 V secondary?

1. 156 amperes
2. 208 amperes
3. 360 amperes
4. 362 amperes

Ohm's Law: I = P/(E x √3) = 75,000 / (208 x 1.732) = 208.18 amps. Try this on a simple non-programmable calculator to make sure you can handle the 1.732 in the denominator. 208 amperes.

Important Note: As a testing candidate, you should be given the Ohm's Law formula wheel shown in Section 4 by the testing agency administering the examination. You may need to ask for the formula wheel, prior to starting your exam. These formulas are tricky from memory, but using the wheel, these become easy questions to answer if you take your time, choose the proper formula, and calculate carefully.

11. Assume a kitchen is added to a church with a total load of 54,000 VA. What would be the MINIMUM size THW copper conductors for this 3-phase, 120/208 Volt service?

1. 1 AWG
2. 1/0 AWG
3. 2/0 AWG
4. 3/0 AWG

Ohm's Law: I = P/(E x √3) = 54,000 / (208 x 1.732) = 149.89 amps, then use **Table 310.15(B)(16)**, 1/0 AWG.

12. What would be the full load current rating of a single phase 115 volt 1/2 HP motor?

1. 4.4 amps
2. 5.8 amps
3. 7.2 amps
4. 9.8 amps

Table 430.248 Full Load Current in Single-Phase Motors. 9.8 amperes.

13. What size THW copper conductors are required for a continuous duty, 208 V, 30 HP, motor with a nameplate rating of 74 amperes?

1. # 2 AWG
2. # 3 AWG
3. # 4 AWG
4. # 6 AWG

Table 430.250 Tricky, however, do NOT use the nameplate rating, even though it is given in the question.) 88 amps x 125% = 110 amperes, then use Table 310.15(B)(16). 2 AWG.

14. What part of the motor circuit is sized according to the current rating marked on the motor <u>nameplate</u>?

1. Branch circuit conductors
2. Branch circuit short-circuit fuse
3. Separate motor <u>overload</u> protection device
4. Feeder overload protection

430.6 (A)(1). Separate motor overload protection shall be based on the motor nameplate current rating. Overload protection.

15. Conductor ampacity for general motor applications and branch circuits shall be based on what?
    1. The actual current rating marked on the motor nameplate
    2. The full-load current in amperes given in the NEC motor tables
    3. The actual current based on the actual load
    4. The locked-rotor current

    430.6 (A)(2). Tables shall be used to determine the ampacity of conductors… instead of the actual current rating marked on the motor nameplate. Tables Values.

16. Given a circuit serves a 10-HP, 208-volt, 3-phase, squirrel-cage Design-B motor, with nameplate rating of 37 amps. What is the maximum permitted operational setting of an adjustable inverse-time breaker?
    1. 30.8 amps
    2. 35.7 amps
    3. 77.0 amps
    4. 92.5 amps

    Table 430.52 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices. 37A x 250% = 92.5 amps (do NOT use ... Table 430.250)

17. What would be voltage drop for a 3 phase, 3 wire, 480V circuit assuming there is a 15 HP induction motor, in rigid conduit, a distance of 150 feet from the source, installed with # 6 AWG conductor?
    1. 1.54 volts
    2. 2.67 volts
    3. 3.09 volts
    4. 5.35 volts

    Table 430.250 gives 21 amperes for this motor, and **Chapter 9 Table 8** gives 26240 circular mils for the conductor size, therefore, applying the formula for voltage drop in three-phase circuit we get; Vd = ($\sqrt{3}$ x K x L x I) / CM = (1.732 x 12.9 x 150 feet x 21 amps) / 26240 circular mils = 2.68 Volts.

18. If the maximum voltage drop of the circuit is only 3 volts, and there are 9 amperes flowing in the circuit. What is the approximate max circuit length for a # 12 AWG, single-phase, copper conductor?
    1. 0 - 150 feet
    2. 151 - 250 feet
    3. 251 - 350 feet
    4. 351 - 450 feet

    Chapter 9 Table 8 gives 6530 circular mils for the # 12 AWG conductor, therefore, applying the formula for distance based on a voltage drop we have; Length = (Vd x CM) / (2 x K x I) = (3 Volts x 6530) / (2 x 12.9 x 9 amperes) = 84.37 feet, is the exact length to drop 3 volts. Therefore, 0 - 150 feet is the best answer.

19. Given: Five (5), 400 kcmil THW conductors in a conduit raceway. What is the minimum diameter, in inches, permitted for Schedule 40 PVC conduit?
    1. 3
    2. 3-1/2
    3. 4
    4. 5

    Chapter 9, Table 5, gives a conductor area of 0.6619 x 5 conductors = 3.3095-in^2. Then use **Chapter 9, Table 4,** for Rigid PVC Conduit (PVC) Schedule 40, column for Over 2 Wires 40% - in^2 and slide down till you see at least the 3.3-in^2, which is 3.895-in^2, so we size up to a 3-1/2 inch trade size conduit.

20. A conductor enters a pull box with a 2-inch conduit on the "east" side. The conductor then makes a U turn in the box and goes out a 2-1/2 inch conduit on the same side. What is the MINIMUM distance from "east" side of the box to the opposite "west" side, in inches?

1. 12 inches
2. 15 inches
3. 17 inches
4. 20 inches

314.28(A)(2) 2.5" x 6 = 15" + 2" = 17 inches

21. What would be the required box size volume in cubic inches to provide the minimum free air space of the box was to be installed with:

- Six #14 AWG THW conductors
- Eight #12 AWG THW conductors
- Three #10 AWG THW conductors

1. 24.0 cubic inch box
2. 29.1 cubic inch box
3. 35.2 cubic inch box
4. 37.5 cubic inch box

Table 314.16(B) Volume Allowance Required per Conductor

Size of Conductor (AWG)	Free Space Within Box for Each Conductor	
	cm^3	$in.^3$
18	24.6	1.50
16	28.7	1.75
14	32.8	2.00
12	36.9	2.25
10	41.0	2.50
8	49.2	3.00
6	81.9	5.00

Table 314.16(B) Calculate the volume for each size, then add. (6 x 2 = 12) + (8 x 2.25 = 18) + (3 x 2.5 = 7.5) = 37.5 cu-in.

6.0 Homework Study Material and Questions

6.1 Mathematics and Basic Electrical Formulas

The state examination will require you to have some basic knowledge of mathematics and expect you to be able to solve word problems. You will need to understand Ohm's Law (and the reciprocals of those formulas) to solve the circuit analysis type questions. The questions given usually only require basic understanding of series and parallel circuits.

6.2 Notation

Many questions on the examination are structured to test your ability to recognize differences in notation. The most common is the letter ***k***. The letter *k* is an abbreviation for *kilo*, which represents the value 1,000. Note the following examples.

Example 1. An electric heater is rated at 6*k*W. Which value should be used in calculating the heaters load ?

(a) 6,000 volt
(b) 6.0 W
(c) 6,000 watts
(d) none of the above
Answer: (c) 6,000 watts

Example 2. What is the kVA of a 500 VA load ?

(a) 500 kVA
(b) 0.5 kVA
(c) 5,000 kVA
(d) 500 VA
Answer: (b) 0.5 kVA

Example 3. What is the VA of a 30 kVA load ?

(a) 30 kVA
(b) 300 VA
(c) 30,000 VA
(d) 3,000 VA
Answer: (c) 30,000 VA

6.3 Percentages

Some questions on the exam ask for the power factor or the efficiency of a load. The answer can either be in the form of a percent, decimal, or whole number.

For example:

125% = 1.25
0.80 = 80%
100% = 1.00
2.25 = 225%

Example 1. Branch circuit conductors are to be sized at 125% of the motors FLC rating. If the motors FLC rating is 8 amps, the conductors must have an ampacity of at least how many amps?

(a) 6.40 amps
(b) 8.00 amps
(c) 10.00 amps
(d) 1000 amps

Answer: (c) 10 amps. Where: I = (8 amps) x 1.25

6.4 Squaring

You will be required to square a number using the calculator provided to you at the testing location. Squaring is denoted by a small "2" in the upper right corner of a variable. For example, one of the formulas for power that is required for the exam is: $\mathbf{P = I^2 \times R}$

Example 1. If the circuit current through a load is 2.5 amps, and the resistance of that load is 10 Ohms, what will be the power consumed by the load?

(a) 25.0 watts
(b) 62.5 watts
(c) 250.0 watts
(d) 625.0 watts

Answer: (b) 62.5 watts. Where: P = (2.5 amps)x(2.5 amps)x(10 Ohms)

6.5 Square Root

You may be required to take the square root of a number using the calculator provided to you at the testing location. Usually denoted by " √ ". For example, one of the formulas for power that you may need is: $\mathbf{I_{3\phi} = P/(E \times \sqrt{3})}$

Please note that the only time you should require to take the square root of a number is when the question is asking for either power or current in each circuit conductor given that the source voltage is three phase **3ϕ**.

Example 1. What is the circuit current in each leg of the ungrounded service conductors given that the load draws 24,000 VA and is operating on a source voltage of 208 volts?

(a) 67 amps
(b) 115 amps
(c) 200 amps
(d) none of the above

Answer: (a) 67 amps. Where $I_{3\phi}$ = 24,000/(208 volts x 1.732)

6.6 Electrical Circuit Concepts and Examples

An electric circuit consists of a power source, circuit conductors, and a load. For current to travel in the circuit, there must be a complete path from one terminal of the power source, through the conductors and the load, and then back to the other terminal of the power source.

In any completed circuit, it takes a force to push the electrons through the power source, conductor, and load. The two most common types of power sources are direct current and alternating current. The polarity from a direct current power source never changes; that is, the current flows out of the negative terminal of the power source always in the same direction. An alternating current power source produces a voltage and current that has a constantly changing polarity and magnitude at a constant frequency. Alternating current (AC) flow is produced by a generator or an alternator.

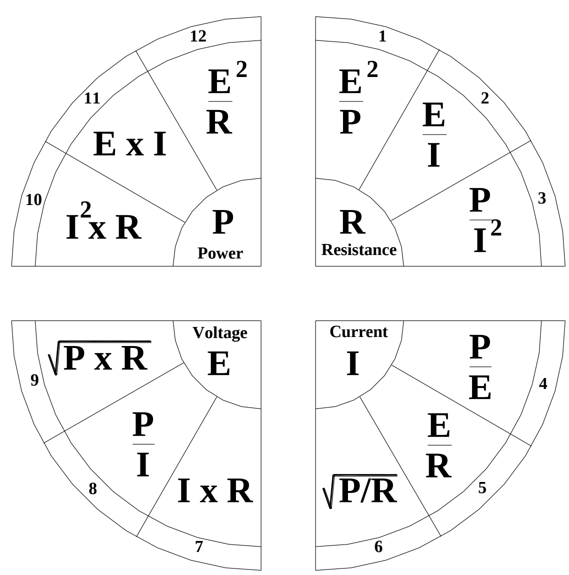
Inside a direct current power source (such as a battery) the electrons travel from the positive terminal to the negative terminal; however, outside of the power source, electrons travel from the negative terminal to the positive terminal. The opposition of current flow is dependant on the conductors resistance. The values for resistance of conductors per 1,000 feet is located in Chapter 9 Table 8 of the NEC. Observing the table, you should notice that as the cross sectional area of the conductors increases (wire gets bigger), the resistance of that conductor decreases proportionally.

6.7 Electrical Circuit Formulas

The Formula Wheel is commonly used to calculate an unknown value, such as, resistance, current, voltage, or power in a circuit analysis type problem. When calculating an unknown value, the question should always give you two constants that are a fixed value. If you can apply the proper formula to the word question given, you stand a very good chance of calculating the value of the answer correctly.

The circuit value definitions and the Ohms Law Formula Wheel are shown below:

- **Resistance** - The opposition to the flow of electrons. The unit of measure is the ohm, and is abbreviated by the letter R.
- **Current** - The movement of electrons through a conductor, measured in amperes. Amperes is abbreviated by the letters I, A, or amps.
- **Voltage** - Electron pressure is called electromotive force. The practical unit of electric pressure. The pressure will produce a current of one ampere against a resistance of one ohm. The unit of measure is the volt, and is abbreviated by the letter E or V.
- **Power** - The rate of work that can be produced by the movement of electrons. The unit of measure is the watt. Power can be abbreviated by the letter P, W, or VA.



6.7.1 Solving for Resistance

Example 1. What is the resistance of a circuit that has a voltage 240 V and a load of 5000 W ?

Answer: $R = E^2 / P = (240\ V)^2 / (5000\ W) = 11.52$ Ohms

Example 2. What is the resistance of a circuit that has a source of 120 V and draws 6 Amps of current ?

Answer: $R = E / I = (120\ V) / (6\ A) = 20$ Ohms

6.7.2 Solving for Current

Example 1. What is the current in amperes flowing in a circuit that has a source of 120 V and a resistance of 10 Ohms ?

Answer: $I = E/R = (120\ V) / (10\ ohms) = 12$ Amps

Example 2. What is the current flowing in a circuit that has a 1000 W load and is operating on a voltage of 120 V ?

Answer: $I = P/E = (1000\ W) / (120\ V) = 8.33$ Amps

6.7.3 Solving for Voltage

Example 1. What is the voltage of a circuit that has a load of 1440 Watts and a current draw of 12 Amps ?

Answer: $E = P / I = (1440\ W) / (12\ A) = 120$ Volts

Example 2. What is the voltage of a circuit that has a current draw of 12 Amps and a circuit resistance of 10 Ohms ?

Answer: $E = I \times R = (12\ A) \times (10\ Ohms) = 120$ Volts

6.7.4 Solving for Power

Example 1. What is the power of a circuit that has a voltage of 460 V with 15 Amps of current flow ?

Answer: $P = E \times I = (460\ V) \times (15\ A) = 6900\ W$

Example 2. What is the power of a circuit that has a current of 25 Amps and a resistance of 5 Ohms ?

Answer: $P = I^2 \times R = (25\ A)^2 \times (5\ ohms) = 3125$ watts

Example 3. What is the power of a circuit that has a voltage of 240 V and a resistance of 10 Ohms ?

Answer: $P = E^2 / R = (240\ V)^2 / (10\ ohms) = 5760\ VA$

6.8 Circuit Analysis Using Ohms Law

The state exam will require you to know the basics of Ohm's Law and circuit analysis. On the exam you may see series, parallel, and combination circuit questions. This section will describe the subject matter required to succeed on this portion of the exam. If you feel that you need additional practice questions beyond those given in this workbook, there is a vast body of resources available on this topic at your local library, bookstore. The "internet" can also provide some excellent examples that would help your understanding. Use the formulas given in Section 5.1 of this workbook to solve the following questions.

6.8.1 Series Circuits

A series circuit is one that has all of the loads "in-line" or "end-to-end" with the supply voltage, refer to Figure 1 below.

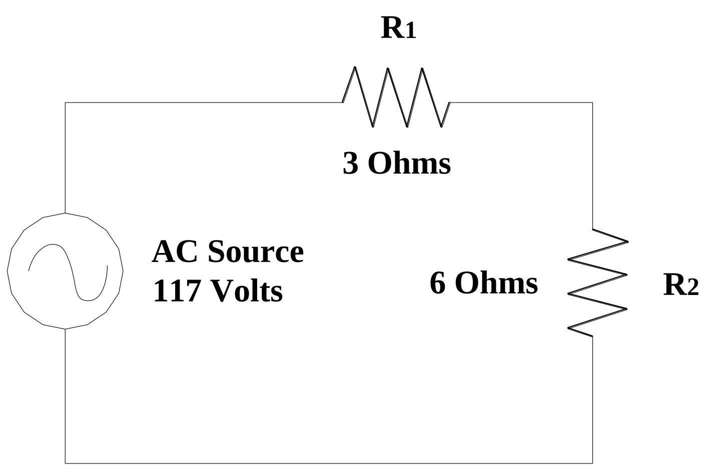


Figure 1. Series Circuit

In a series circuit you should note that the circuit current has only one path for current flow. This means that the current that is flowing through each load of a series branch has the same value. There are some important rules that should be understood about series circuits, a few of which are listed below.

Rule 1. The total resistance in a series circuit is the sum of the individual resistors in that branch. The formula for calculating R_T is:

$$R_T = R_1 + R_2 + R_3 + R\ldots$$

Rule 2. The current is constant throughout the series branch.

Rule 3. The sum of the voltage drops in a series branch is equal to the source voltage of that branch.

Given the series circuit shown in Figure 1, calculate the following.

Example 1. What is the total resistance (R_T) of the circuit?
(Hint: Here you would simply add up all the resistors in the series branch to find the total resistance.)

Example 2. What is the total current (It) in the circuit?

Example 3. What is the voltage across R_2.

Answers to: Example 1. = 9.0 ohms
Example 2. = 13.0 amps
Example 3. = 78.0 volts

6.8.2 Parallel Circuits

A parallel circuit is one that has all of the loads "across" the supply voltage, refer to Figure 2 shown below.

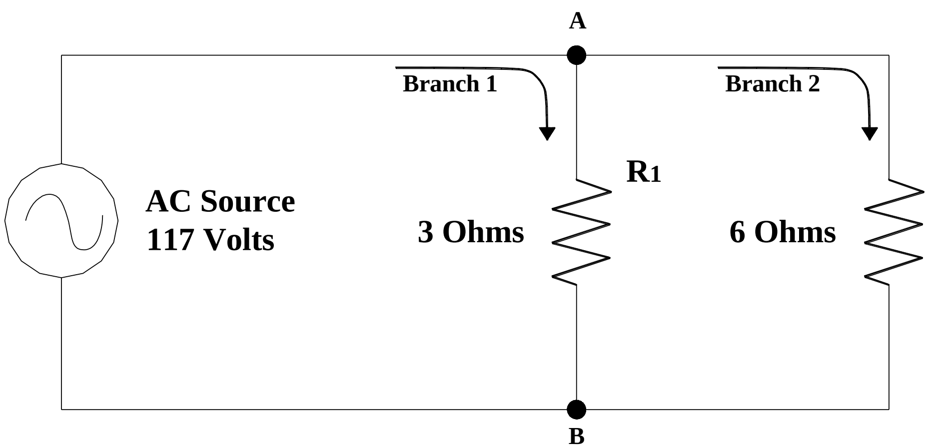


Figure 2. Parallel Circuit

In the parallel circuit shown above, you should note that the circuit current has multiple paths for current to flow. The total circuit current divides up at node A, some of the current flows through "Branch 1" and the remainder of the current flows through "Branch 2", ultimately the total current combines at node B to return to the source.

Because all the loads on the circuit are in parallel, they will all have the same voltage across them. However, the current through each load could be different depending on the value of each individual load. There are some important rules that should be understood about parallel circuits, some of which are listed below.

Rule 1. The total resistance in a parallel circuit will always be less than the lowest-value resistor in the parallel branch. One of the formulas for calculating R_T is:

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

(only 2 resistors)

Rule 2. The voltage is constant throughout the parallel branch, the same value as the source voltage.

Rule 3. The total current available to a parallel branch will divide up in the parallel branches and combine again to flow back into the source.

Given the parallel circuit shown in Figure 2, calculate the following.

Example 1. What is the total resistance (R_T) of the circuit?
(Caution! The total resistance for a parallel branch is NOT calculated the same as a series circuit!)

Example 2. What is the voltage across R_2.

Example 3. What is the current through R_2?

Example 4. What is the power consumption of R_1?

Answers to: Example 1. = 2.0 ohms
Example 2. = 117 volts
Example 3. = 19.5 amps
Example 4. = 4.6 kW

An AC circuit is one that has at least one Hot and Neutral conductor. The conductor insulation is usually black and white respectively. An important issue to note is that of a "balanced load". A balanced load is a circuit that has the multiple loads that are drawing the same current for each load. In a balanced circuit, there will be NO current flowing in the neutral conductor. However, given that the loads on a branch are un-balanced, the difference in the current draw between Branch 1 and Branch 2 would be flowing through the neutral conductor. There will be many questions on the exam that will test your understanding of this concept. This subject will be covered in more detail in the lecture portion of this course.

6.9 Supplemental Electrical Circuit Questions

These questions should all be **easily** understood prior to taking the required examination. Working thorough these questions can assist each student to gauge his/her knowledge of general electrical subject material. It also gives the student a better understanding of what subject areas may require more preparation and study time. Use the answer key at the end of this section to grade your understanding of this material.

1. What is the kW of a 75-watt load?
   (a) 75 kW (b) 7.5 kW (c) .75 kW (d) .075 kW

2. The output VA of a transformer is 100 VA. The transformer efficiency is 90 percent. What is the transformer input?
   (a) 90 watts (b) 110 watts (c) 100 watts (d) 125 watts

3. When changing a percent value to a decimal or whole number, simply move the decimal point two places to the ____ .
   (a) right (b) left (c) depends (d) none of these

4. The decimal equivalent for 75 percent is ____ .
   (a) .075 (b) .75 (c) 7.5 (d) 75

5. The decimal equivalent for 225 percent is ____ .
   (a) 225 (b) 22.5 (c) 2.25 (d) .225

6. The decimal equivalent for 300 percent is ____ .
   (a) .03 (b) .3 (c) 3 (d) 30.0

7. Given. An overcurrent protection device (breaker or fuse) is required to be sized no less than 115 percent of the load. If the load is 20 amperes, the overcurrent protection device would have to be sized at no less than ____ .
   (a) 20 amps (b) 23 amps (c) 17 amps (d) 30 amps

8. The maximum continuous load on an overcurrent protection device is limited to 80 percent of the device rating. If the device is rated 90 amperes, the maximum continuous load is ____ amperes.
   (a) 72 (b) 90 (c) 110 (d) 125

9. The feeder demand load for an 8-kW load, increased by 20 percent is ____ kVA.
   (a) 6.4 (b) 8.0 (c) 9.6 (d) 16.0

10. A continuous load requires an overcurrent protection device sized no smaller than 125 percent of the load. What is the maximum continuous load permitted on a 100-ampere overcurrent protection device?
    (a) 100 amps (b) 125 amps (c) 80 amps (d) 110 amps

11. What is the power consumed in watts of a No. 12 conductor that is 100 feet long and has a resistance of 0.2 ohm, the current in the circuit is 16 amperes ?
    (a) 75 watts (b) 50 watts (c) 100 watts (d) 200 watts

12. The numeric equivalent of 4^2 is ____ .
   (a) 2 (b) 8 (c) 16 (d) 32

13. The numeric equivalent of 12^2 is ____ .
   (a) 3.46 (b) 24 (c) 144 (d) 1,728

14. What is the square root of 1,000 ?
   (a) 3 (b) 32 (c) 100 (d) 500

15. The square root of the number 3 is ____ .
   (a) 1.732 (b) 9 (c) 729 (d) 1.50

16. The sum of 5, 7, 8 and 9 is approximately ____ .
   (a) 20 (b) 25 (c) 30 (d) 35

17. What is the current in amperes of a three-phase, 18-kW, 208-volt load ?
   (a) 12 amps (b) 50 amps (c) 86 amps (d) 150 amps

18. An electric circuit consists of the ____ .
   (a) power source (b) conductors (c) load (d) all of these

19. The Ohm's law formula, I = E / R demonstrates that current is ____ proportional to the voltage, and ____ proportional to the resistance.
   (a) indirectly, inversely (b) inversely, directly
   (c) inversely, indirectly (d) directly, inversely

20. In an alternating current circuit, which factors oppose current flow?
   (a) resistance (b) capacitance (c) induction reactance (d) all of these

21. The opposition to current flow in an alternating current circuit is called ____ and is often represented by the letter Z.
   (a) resistance (b) capacitance (c) induction (d) impedance

22. What is the voltage drop of two No.12 conductors supplying a 16-ampere load, located 100 feet from the power supply? Where the current in the circuit is 16 amps, and the resistance of the conductors is 0.4 ohm.
   (a) 1.6 volts (b) 3.2 volts (c) 6.4 volts (d) 12.8 volts

23. What is the resistance of the circuit conductors when the conductor voltage drop is 7.2 volts and the current flow is 50 amperes?
   (a) 0.14 ohm (b) 0.3 ohm (c) 3 ohms (d) 14 ohms

24. What is the power loss in watts for a conductor that carries 24 amperes and has a voltage drop of 7.2 volts?
   (a) 175 watts (b) 350 watts (c) 700 watts (d) 2,400 watts

25. What is the power consumed of a 10-kW heat strip rated 230 volts, connected to a 115-volt circuit?
   (a) 10 kW (b) 2.5 kW (c) 5 kW (d) 20 kW

26. The total resistance of two No. 12 conductors, 150 feet long is 0.6 ohm, and the current of the circuit is 16 amperes. What is the power loss of the conductors?
    (a) 75 watts (b) 150 watts (c) 300 watts (d) 600 watts

27. What is the conductor power loss for a 120-volt circuit that has a 3 percent voltage drop and carries a current flow of 12 amperes? The load operates 24 hours per day, 365 days each year.
    (a) 43 watts (b) 86 watts (c) 172 watts (d) 722 watts

28. What is the power of a 10-kW heat strip rated 240 volts, when connected to a 208-volt circuit?
    (a) 7.0 kW (b) 7.6 kW (c) 8.0 kW (d) 11.0 kW

29. kVA is equal to ____ .
    (a) 100 VA (b) 1,000 volts (c) 1,000 watts (d) 1,000 VA

30. If the contact resistance of a connection increases and the current remains the same, the voltage drop across the connection will ____ .
    (a) increase (b) decrease (c) remain the same (d) cannot be determined

31. To double the current of a circuit when the voltage remains constant, the R (resistance) must be .
    (a) doubled (b) reduced by half (c) increased (d) none of these

32. To calculate the power consumed by a resistive appliance, one needs to know ____ .
    (a) voltage and current (b) current and resistance
    (c) voltage and resistance (d) any of these

33. The number of watts of heat given off by a resistor is ____ , if 10 volts is applied to a 5 ohm resistor.
    (a) 500 (b) 250 (c) 50 (d) 20

34. When a lamp that is rated 500-watts at 115 volts is connected to a 120-volt power supply, the current of the circuit will be ____ amperes.
    (a) 3.8 (b) 4.5 (c) 2.7 (d) 5.5

35. A 1,500-watt heater rated 230 volts is connected to a 208-volt supply. The power consumed for this load is ____ watts.
    (a) 1,625 (b) 1,750 (c) 1,850 (d) 1,225

36. The total resistance of a circuit is 12 ohms; the load is 10 ohms, and the wire 2 ohms. If the current of the circuit is 3 amperes, then the power consumed by the circuit conductors is ____ watts.
    (a) 28 (b) 18 (c) 90 (d) 75

6.9.1 Answer Key for Supplemental Electrical Circuit Questions

The following is a list of answers to the questions given in Section 6.9 of this document.

1. D
2. B
3. B
4. B
5. C
6. C
7. B
8. A
9. C
10. C
11. B
12. C
13. C
14. B
15. A
16. C
17. B
18. D
19. D
20. D
21. D
22. C
23. A
24. A
25. B
26. B
27. A
28. B
29. D
30. A
31. B
32. D
33. D
34. B
35. D
36. B