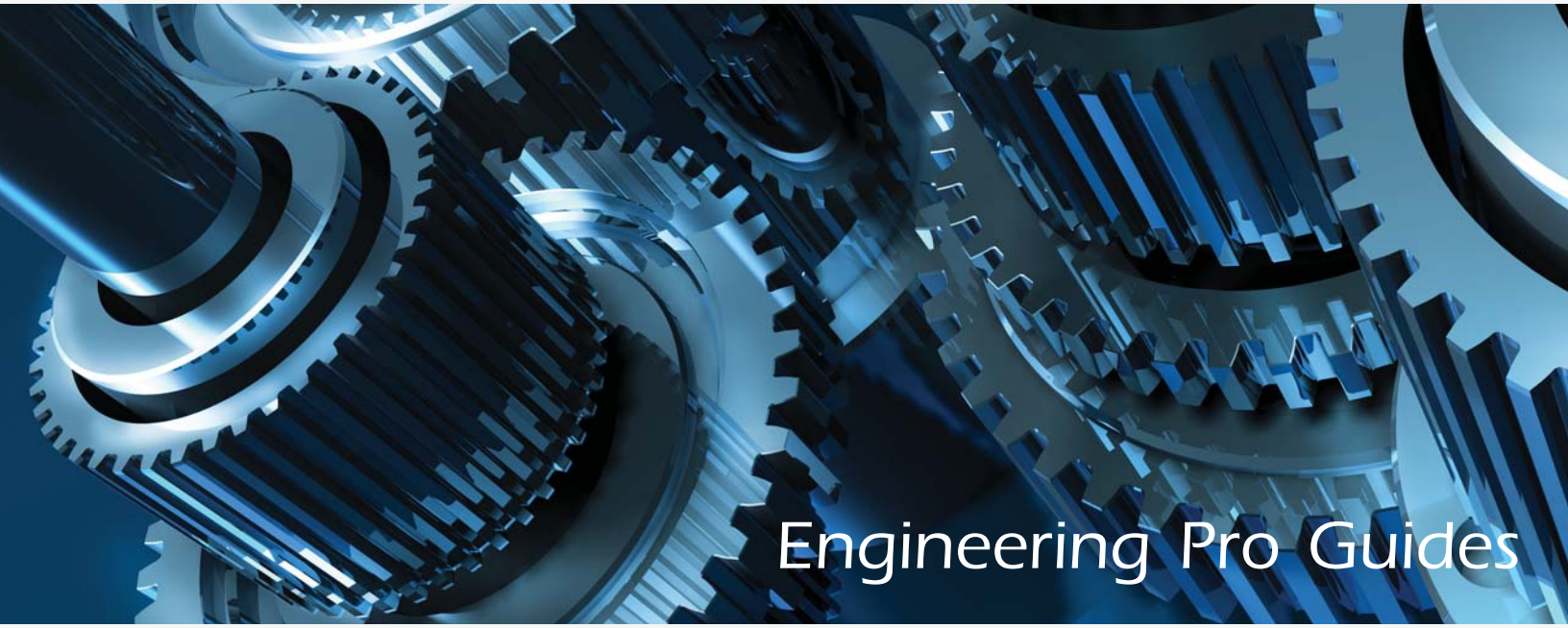
Power PE

References Exam



Electrical Power

Supplemental Code Reference Practice Problems

- 40 reference specific exam problems
- Tests NEC® and NESC® lookup for the Power PE Exam
- Practice your familiarty and speed with code references.
- Written in exam format with exam difficulty level
- Also includes detailed solutions

Justin Kauwale, P.E.

SECTION 1
INTRODUCTION

Introduction

Table of Contents

1.0 INTRODUCTION

One of the most important steps in an engineer's career is obtaining the professional engineering (P.E.) license. It allows an individual to legally practice engineering in the state of licensure. This credential can also help to obtain higher compensation and develop a credible reputation. In order to obtain a P.E. license, the engineer must first meet the qualifications as required by the state of licensure, including minimum experience, references, and the passing of the National Council of Examiners for Engineering and Surveying (NCEES) exam. Engineering Pro Guides focuses on helping engineers pass the NCEES exam through the use of free content on the website, http://www.engproguides.com and through the creation of books like sample exams and guides that outline how to pass the PE exam.

The first key to passing the PE exam is to learn the key concepts and skills that are tested on the exam. There are several issues that make this very difficult. First, the key concepts and skills are unknown to most engineers studying for the exam. Second, the key concepts and skills are not contained in a single document. The technical guide teaches you the key concepts and skills required to pass the Electrical Power PE Exam. The second key is being able to navigate and understand your Power PE references. In practice, a deep understanding of your references is necessary to be a successful engineer. These references contain applicable codes and standards. Your understanding of these references is tested on the Power PE exam. The reference exam makes you familiar with the key parts of your Power PE references by pushing you to navigate your references to solve sample exam problems.

1.1 KEY CONCEPTS AND SKILLS

How are the key concepts and skills determined?

The key concepts and skills tested in this sample exam were first developed through an analysis of the topics and information presented by NCEES. NCEES indicates on their website that the PE Exam will cover an AM exam (4 hours) followed by a PM exam (4 hours) and that the exam will be 80 questions long, 40 questions in the morning and 40 questions in the afternoon. The Power Electrical PE exam will focus on the following topics, as indicated by NCEES. (http://ncees.org/engineering/pe/):

I. General Power Engineering (24 questions)

A) Measurement and Instrumentation *(4 questions)*
   1 Instrument transformers
   2 Insulation testing
   3 Ground resistance testing

B) Special Applications *(8 questions)*
   1 Lightning protection
   2 Surge protection
   3 Reliability
   4 Illumination/lighting and energy efficiency engineering
   5 Demand calculations
   6 Energy management

7 Engineering economics
8 Grounding

C) Codes and Standards *(12 questions)*
1 National Electrical Code (NFPA 70, NEC 2017)
2 National Electrical Safety Code (ANSI C2, NESC)
3 Standard for Electrical Safety in the Workplace: Shock and Burns (NFPA 70E)
4 Hazardous Area Classification (NFPA 497, 499, 30B)

II. Circuits(16 questions)

A) Analysis *(9 questions)*
1 Three-phase circuits
2 Symmetrical components
3 Per unit system
4 Phasor diagrams
5 Single phase circuits
6 DC circuits
7 Single-line diagrams

B) Devices and Power Electronic Circuits *(7 questions)*
1 Battery characteristics and ratings
2 Power supplies
3 Relays, switches and PLCs
4 Variable speed drives

III. Rotating Machines and Electromagnetic Devices (16 questions)

A) Rotating Machines *(8 questions)*
1 Induction and Synchronous Machines
i) Generator/motor applications
ii) Equivalent circuits and characteristics
iii) Motor starting
iv) Electrical machine theory

B) Electric Power Devices *(8 questions)*
1 Transformers
2 Reactors
3 Testing
4 Capacitors

IV. Transmission and Distribution (High, Medium and Low Voltage) (24 questions)

A) Power System Analysis *(11 questions)*
1 Voltage drop
2 Voltage regulation
3 Power factor correction and voltage support
4 Power quality
5 Fault current analysis

6 Transformer connection
7 Transmission line models

Power System Performance

8 Power flow
9 Load sharing parallel generators or transformers
10 Power system stability

B) Protection *(13 questions)*

1 Overcurrent protection
2 Protective relaying
3 Protective devices (e.g., fuses, breakers, reclosers)
4 Coordination

Next, each of these broad topics were investigated and filtered for concepts and skills that met the following criteria:

(1) First, the concept and skill must be *commonly encountered* in the Power Engineering field of study. For example: Voltage drop, phasor diagrams, three-phase power, NEC and transmission analysis are regular occurrences in the Power Engineering field.

(2) Second, the skill and concept must be testable in roughly *6 minutes per problem*. There are (40) questions on the morning exam and you will be provided with 4 hours to complete the exam. The same is true for the afternoon portion of the exam. This results in an average of 6 minutes per problem. This criterion limits the complexity of the exam problems and the resulting solutions. For example, power flow calculations are common in the Power Engineering field, but the calculation is often very lengthy because of the number of steps involved, especially if the circuit is complex. Thus, the exam uses simple circuits and the math required to solve the problems is also very simple.

(3) Third, the key concepts and skills must be used or be known by practicing electrical engineers in the Power field. This criterion is similar to the first criterion. However, this criterion filters the concepts and skills further by limiting the field to material encountered and used by *practicing engineers*. The Power Engineering field is vast and there are many different avenues an engineer can take. Two diverging paths are those engineers involved in research and those who practice. Research engineers are pushing the boundaries of the field and are highly focused in their specific area of the field. The Professional Engineering Exam does not cover emerging technologies or highly focused material.

(4) The PE Exam must test the *principle or application* of the skill and concept and not the background knowledge of the topic or concept. The exam also does not cover background information on the NCEES topics. The PE Exam is meant to prove that the test taker is minimally competent to **practice** in the Electrical Engineering field. The exam is less concerned with theory and more with the principle or application of the theory, skill or concept. For example, the PE Exam is less concerned with the theory of thyristors or magnetic flux and more with the performance of a rectifying circuit and the voltage output of a transformer.

In summary, this book is intended to teach the necessary skills and concepts to develop a minimally competent, practicing professional engineer in the Electrical Engineering Power field, capable of passing the PE Exam.

1.2 Units

The primary units that are used in the PE Exam are United States Customary System Units (USCS). As such, this guide focuses exclusively on the USCS. However, it is recommended that the test taker have a conversion book, because certain areas of the PE Exam may use the International System of Units (SI).

2.0 Disclaimer

In no event will Engineering Pro Guides be liable for any incidental, indirect, consequential, punitive or special damages of any kind, or any other damages whatsoever, including, without limitation, those resulting from loss of profit, loss of contracts, loss of reputation, goodwill, data, information, income, anticipated savings or business relationships, whether or not Engineering Pro Guides has been advised of the possibility of such damage, arising out of or in connection with the use of this document or any referenced documents and/or websites.

This book was created on the basis of determining an independent interpretation of the minimum required knowledge and skills of a professional engineer. In no way does this document represent the National Council of Examiners for Engineers and Surveying views or the views of any other professional engineering society.

3.0 How to use this Book

All of the following three books should be used together, (1) Power PE Technical Study Guide, (2) Power PE Full Exam and the (3) Power PE References Exam.

The Power PE Technical Study Guide book is organized into the topics as designated by the NCEES, but in a more logical order. These topics include:

1. Introduction
2. Circuit Analysis
3. Devices and Power Electronic Circuits
4. Rotating Machines
5. Electromagnetic Devices
6. Transmission and Distribution
7. Power System Performance
8. Protection
9. Measurement and Instrumentation
10. Special Applications
11. Codes & Standards
12. Cheat Sheets

First, it is recommended that the engineer in training gather the recommended references presented in the following section.

Second, proceed through the Power PE Technical Study Guide in the order designated. Go through and first read the material of the section, then complete the practice problems designated for that section. If you have trouble with the practice problems, review the material and then read the solutions. The problems at the end of each section are slightly easier and more straightforward than the typical problems you would find on an actual PE Exam. These problems are meant only to practice the application of the skill or concept presented in the section.

Following the completion of each of the sections, it is recommended that you determine if you are unconfident with any of the NCEES topics. If you are not confident then please go back and revisit the section.

Next, set aside an eight-hour block of uninterrupted time to complete a full exam. Gather your references and calculator and create a test-like environment. Set a timer and proceed to take the sample exam presented at the end of this book. Remember that the exam is only 40 problems for both the morning and afternoon sessions and does not encompass all the possible items that can appear on an exam, but it should give you an idea of your level of readiness for the exam.

Finally, go through the Power PE References exam. This exam is only 40 questions and contains only exam problems that require you to lookup the answers in your references.

4.0 Sample Exam Tips

Engineering Pro Guides sample exams can be used in multiple ways, depending on where you are in your study process. If you are at the beginning or middle, it can be used to test your competency, gain an understanding and feel for the test format, and help to highlight target areas to study. If you are at the end, it can be used to determine your preparedness for the real exam. Remember that the questions are a sample of the many topics that may be tested and are limited to fit a full exam length and therefore are not comprehensive of all concepts.

Because the exam is written to be similar to the difficulty and format of the NCEES exam, it is recommended that the test be completed in one sitting and timed for four hours to simulate the real exam. This will give you a better indication of your status of preparation for the exam. If you are at the end of your studying, it is recommended to couple this exam with the PM section to simulate the full exam test day.

Review the exam day rules and replicate the environment for the real test as close as possible, including the type of calculator you may use and the acceptable references. Keep a watch or clock next to you to gauge your pace for 40 questions in 4 hours.

Based on the NCEES website, the following are general rules for exam day.

Allowed:

1. Snacks that are not disruptive to others
2. Watches and small clocks
3. Religious head coverings

4. Two straight edges: e.g. ruler, scale, protractor, triangle
5. Approved references
6. Approved calculator (2 recommended for backup)
7. Eyeglasses
8. Non-electronic magnifying glass
9. (Units conversion book is also recommended)

Prohibited:

1. Cell phones
2. Hats and hoods
3. Slide charts, wheel charts, drafting compasses
4. Weapons
5. Tobacco
6. Personal Chairs
7. Eyeglass/Magnifying glass cases
8. Scratch Paper (all writing must be done in the exam booklet)

For additional references on exam day policies, exam day processes, and items to bring on your exam day, review the NCEES Examinee Guide:

http://ncees.org/exams/examinee-guide/

Similar to the NCEES exam, the tested topics are presented in a random order. For best use of your time, answer the questions that you know first and return to the questions that you are unfamiliar with later. Once all the known questions are answered, go through the test again and attempt to answer the remaining questions by level of difficulty. If time allots, review your answers.

If you are stuck on a question, seek the following avenues.

1. Study Guide: It is important to understand your study guides and indices. During times of uncertainty, these will likely lead you to your answers. Determine the key concept that is being asked in the question and refer to your indices or pre-tabbed sections.

2. Process of Elimination: There are only four possible choices for each question. Ask yourself if there is an answer that does not make sense and eliminate it. Further narrow down the answer that are derived from equations or concepts that you know are not right and are instead meant to deceive the test taker. See if there are answers that are similar or separated by something like a conversion error. This may be an indication that the correct equation was used.

3. Educated Guess: Remember that there is no penalty for wrong answers. Hopefully with the process of elimination you are able to narrow down as many answers as possible and are able to create an educated guess.

4. Rules of Thumb: Rules of thumb can be used to not only speed up time, but to help lead you in the right direction.

5. If the time is almost up and there are still unanswered questions remaining, determine whether it makes sense to check for mistakes on the problems you do know how to solve, or to tackle the unanswered problems.

Typical Exam Verbiage/Design:

1. Most Nearly: Due to rounding differences, the exam answers will not match yours exactly and in fact may not closely resemble your answer. NCEES uses the term "most nearly" to test your confidence in your solution. When the question prompts you with "most nearly", choose the answer that most closely matches yours, whether it be greater than or lesser to your value.

2. Irrelevant Information: The exam is intended to test your overall understanding of concepts. At times the question will include unnecessary information that is meant to misdirect you.

3. Deceiving Answers: NCEES wants to know that you are able to determine the appropriate methods for the solutions. There are answers that were intentionally produced from wrong equations to mislead the test taker. For example, you may forget a 1/2 in the formula, $KE = (1/2)MV^2$ and there would be two answers each off by a factor of 1/2.

4. Do Not Overanalyze: The exam questions are meant to be completed in 6 minutes. Therefore, they are intended to be written as straight forward as possible. Do not be tempted to overanalyze the meaning of a question. This will only lead you down the wrong path.

Review the Solutions:

Once the sample test is completed, grade your results. Measure your aptitude in speed, concept comprehension, and overall score. If your score is above the 75% range then you are in good shape. This 75% score is only applicable if you have prepared completely for the exam. If you are just starting out, then please do not be worried about a low score. This number is also just a range; there is no finite score to determine passing the test. Instead, NCEES calibrates the results against practicing professional engineers. See this page http://ncees.org/exams/scoring-process/ for a better understanding of how NCEES grades the scores.

Review the answers that you got wrong and use the solutions as a learning tool on how to address these types of problems. Compare the types of questions you are missing with the NCEES outline of topics and determine where you should focus your studying. Finally, repeat as many practice problems as you can to get a better grasp of the test and to continually improve your score.

5.0 RECOMMENDED REFERENCES

The following references are recommended to be reviewed prior to the exam and should be used during the exam. When reviewing these references, make sure you first understand the content. These references do not go into depth on explaining the equations or concepts but are simply references. If you require more background information on any of the information in these references, then you may need to research that information on the internet. Secondly, you should be very familiar with the indices of these references and should be able to navigate the references to find information quickly. This may require you to insert tabs into the references. Once you have completed these two tasks then you should be ready to use these references during the exam. (Tip: It is helpful to have the indices of your references printed separately to allow you to have both the index and the reference material open at the same time, making for quicker searches.)

Complete List of References for the Power PE Exam		
by	Engineering Pro Guides	www.engproguides.com
Engineering Pro Guides provides a power technical study guide that teaches the key concepts and skills necessary to pass the Power PE Exam. If you have any suggestions to this list, please email me Justin at contact@engproguides.com		
Topic 2.0	**Circuit Analysis**	**9 of 80 problems**
	Three-Phase Circuit Analysis	Power System Analysis
	Symmetrical Components	Power System Analysis
	Per Unit Analysis	Power System Analysis
	Phasor Diagrams	Power System Analysis
Topic 3.0	**Devices and Power Electronic Circuits**	**7 of 80 problems**
	Battery Characteristics/Ratings	Flooded Lead Acid Batteries
		Sealed Gel Cell Batteries
		Sealed AGM Batteries
		Lithium Batteries
	Power Supplies (inverters, UPS)	Selection and Sizing of Batteries for UPS Backup

	Relays, Switches and PLCs	Fundamentals of Power System Protection
	Variable Speed Drives (rectifiers, capacitor, THD)	Electrical Machines, Drives and Power Systems (6th Edition)
Topic 4.0	**Rotating Machines**	**8 of 80 problems**
	Synchrnous Motor/Generator	Electrical Machines, Drives and Power Systems (6th Edition)
	Induction Motor/Generator	Electrical Machines, Drives and Power Systems (6th Edition)
	Equivalent Circuits for all 4 Types	Electrical Machines, Drives and Power Systems (6th Edition)
	Speed-Torque Motors/Generators	Electrical Machines, Drives and Power Systems (6th Edition)
	Motor Starting	Electrical Machines, Drives and Power Systems (6th Edition)
Topic 5.0	**Electromagnetic Devices**	**8 of 80 problems**
	Transformers	Electrical Machines, Drives and Power Systems (6th Edition)
	Equivalent Circuit	Electrical Machines, Drives and Power Systems (6th Edition)
	Autotransformer	Electrical Machines, Drives and Power Systems (6th Edition)
	Transformer Arrangements	Electrical Machines, Drives and Power Systems (6th Edition)
	Transformer Banks	Electrical Machines, Drives and Power Systems (6th Edition)
	Short Circuit Test and Open Circuit Test	Electrical Machines, Drives and Power Systems (6th Edition)
Topic 6.0	**Transmission and Distribution**	**11 of 80 problems**
	Voltage Drop	Power System Analysis

	Voltage Regulation	Power System Analysis
	Power Factor Correction and Voltage Support	Power System Analysis
	Power Quality	Electrical Machines, Drives and Power Systems (6th Edition)
	Fault Current Analysis	Power System Analysis
	Grounding	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
	Transformer Connections	Power System Analysis
	Transmission Line Models (Short, Medium, Long)	Power System Analysis
Topic 7.0	**Power System Performance**	**(Subset of Transmission & Distribution)**
	Power Flow	Power System Analysis
	Parallel Generators	Synchronous Generators
	Parallel Transformers	http://www.facilitiesnet.com/whitepapers/pdfs/schneiderelectric_111711.pdf
		Loading Considerations when Paralleling Transformers
	Power System Performance	Power System Analysis
Topic 8.0	**Protection**	**13 of 80 problems**
	Overcurrent Protection	Power System Analysis
	Protective Relaying	Fundamentals of Power System Protection
	Protective Devices (fuses, breakers, reclosers)	Fundamentals of Power System Protection
	Coordination	How to Read a TCC
		Selective Coordination
		Circuit Breaker Characteristic Trip Curves and

		Coordination
		IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)
Topic 9.0	**Measurement and Instrumentation**	**4 of 80 problems**
	Instrument Transformers	http://www.gegridsolutions.com/products/manuals/ITITechInfo.pdf
	Wattmeters	http://www.newtons4th.com/wp-content/uploads/2010/03/APP014-3-Phase-2-Wattmeter-Explained.pdf
	VOM Metering	http://support.fluke.com/find-sales/Download/Asset/1260898_6116_ENG_M_W.PDF
	Insulation Testing	https://www.instrumart.com/assets/Megger-insulationtester.pdf
		IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
		http://www.weschler.com/_upload/sitepdfs/techref/gettingdowntoearth.pdf
	Ground Resistance Testing	http://www.fluke.com/fluke/inen/solutions/earthground/
Topic 10.0	**Special Applications**	**8 of 80 problems**
	Lightning and Surge Protection	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
	Reliability	http://testguy.net/content/256-6-Common-Substation-Bus-Schemes-Every-Test-Tech-Should-Know
	Illumination Engineering	http://www.holophane.com/education/fund_pdf/HL-862.pdf
		http://aesl.hanyang.ac.kr/class/are141/zonal%20

		cavity%20ratio%20method.pdf
		http://www.lightingassociates.org/i/u/2127806/f/tech_sheets/lighting_fundamentals_1.pdf
	Demand/Energy Management Calculations	Understanding kW and kWh
	Engineering Economics	Economics Factors
		Compound Interest Tables
Topic 11.0	**Codes and Standards**	**12 of 80 problems**
	National Electric Code (NEC)	NEC 2014 (Handbook)
	National Electrical Safety Code (NESC)	2017 National Electrical Safety Code (NESC)
	Standard for Electrical Safety in the Workplace: Shock and Burns	NFPA 70E
	Hazardous Area Classification	NFPA 497, 499, 30B

Please see the below link to the online version of this spreadsheet for any updates. You can also read below about a majority of the different references. If you have any suggestions or questions on the list, please email Justin at contact@engproguides.com or you can comment on the online version of the spreadsheet.

Link: http://www.engproguides.com/powerreferences.html

5.1 NFPA 70, NEC HANDBOOK, 2014 EDITION

By National Fire Protection Association

The NEC does not apply from the service point to the utility. The National Electrical Safety Code, or NESC, is the governing code from the utility to the service point. The service point is typically the point of connection to a utility system. The user loads could include an industrial motor, a residential receptacle, a parking lot light and many other types of loads.

However, the NEC does not apply in specialty areas like ships, aircrafts, vehicles and mobile homes. For example, the NEC would apply to the wires and outlets of an electric vehicle charging station but it would not apply to the inner electrical system of the electric vehicle. The NEC also does not apply to other specialty areas like mines, railways, communications utilities and electric utilities.

The NEC does apply to more typical applications like residential, industrial, commercial, educational, institutional, retail, assembly, factory, storage and other building type applications.

The purpose of the NEC is to provide the minimum requirements to promote a safe installation. Design electrical engineers must ensure that their designs meet these requirements at a minimum. The NEC does not tell electrical engineers how to design.

The following is an outline of the code. The following sections will provide an overview of each chapter and the important sections that may be on the exam.

- Chapter 1: General
- Chapter 2: Wiring and Protection
- Chapter 3: Wiring Methods & Materials
- Chapter 4: Equipment for General Use
- Chapter 5: Special Occupancies
- Chapter 6: Special Equipment
- Chapter 7: Special Conditions
- Chapter 8: Communication Systems
- Chapter 9: Tables

If you do not already have the NEC 2017, then you should purchase your own copy.

Amazon Link[1]: National Electric Code 2017

Topics Covered: 10.0 Codes & Standards

5.2 Schaum's Outline of Basic Electricity

By Milton Gussow

This book is great as a refresher to electrical engineering 101 and is succinct such that you can use it as a resource during the exam, in the event you need to look up a formula. However, if you are comfortable with circuits and devices then you should not need this book. You can also find most of this information online.

Amazon Link[Error! Bookmark not defined.]: Schaum's Outline of Basic Electricity

Topics Covered: 2.0 Circuit Analysis and 3.0 Devices and Power Electronic Circuits

5.3 Schaum's Outline of Electrical Power Systems

By Cheng Liu, Giles Ranald, Jack Evett

[1] Justin Kauwale is a participant in the Amazon Services LLC Associates Program, an affiliate advertising program designed to provide a means for sites to earn advertising fees by advertising and linking to amazon.com

This book covers the transmission and distribution topic along with the power flow topics. You will need another resource for the parallel generators, parallel transformers, protection and grounding.

Amazon Link[Error! Bookmark not defined.]: Schaum's Outline of Electrical Power Systems

Topics Covered: 6.0 Transmission & Distribution and 7.0 Power System Performance

5.4 Electric Machines, Drives and Power Systems

By Theodore Wildi

This book covers generators, motors and transformers. It also provides more information on three phase circuits, power and very good information on equivalent circuits for the previously mentioned equipment. Finally the book also covers Devices and Power Electronics since these items are used heavily in drives and controls for machines.

Amazon Link[Error! Bookmark not defined.]: Electrical Machines, Drives and Power Systems (6th Edition)

Topics Covered: 3.0 Devices and Power Electronic Circuits, 4.0 Rotating Machines and 5.0 Electromagnetic Devices

5.5 Power System Analysis

By John J. Grainger

This book is similar to the previous book in that it covers some transformers and machines, but not in as much detail as the previous book. This book covers the various types of transmission lines and also includes protection topics like symmetrical and unsymmetrical faults. Finally, the book covers power flow which is under the topic of Power System Performance.

Amazon Link[Error! Bookmark not defined.]: Power System Analysis

Topics Covered: 6.0 Transmission and Distribution, 7.0 Power System Performance and 8.0 Protection

5.6 Fundamentals of Power System Protection

By Y.G. Paithankar and S.R. Bhide

This book explains various protection methods by system and protection type, such as over-current protection, distance protection, protection of transmission lines, transformers, generators, busbars, etc. It also gives diagrams of the various protection configurations and describes the components that are used in protection schemes.

Amazon Link[Error! Bookmark not defined.]: Fundamentals of Power System Protection

5.7 Online Articles

1. Instrument Transformer Basic Technical Information and Application http://www.gegridsolutions.com/products/manuals/ITITechInfo.pdf

This article covers everything you need to know to answer instrument transformers type questions.

Topics Covered: 9.0 Measurement and Instrumentation – Instrument Transformers

2. 3 Phase 2 Wattmeter Power Measurements
http://www.newtons4th.com/wp-content/uploads/2010/03/APP014-3-Phase-2-Wattmeter-Explained.pdf

This article provides a great explanation on the phasors and how a 3 phase power system can be measured with 2 watt meters. The other scenarios are provided in this book.

Topics Covered: 9.0 Measurement and Instrumentation – Wattmeters

3. VOM Metering aka Digital Multi Meters (DMM)
http://support.fluke.com/find-sales/Download/Asset/1260898_6116_ENG_M_W.PDF

VOM metering is basically an older name for the current digital multi meters that are used heavily in the electrical industry.

Topics Covered: 9.0 Measurement and Instrumentation – VOM Metering

4. Insulation Testing
https://www.instrumart.com/assets/Megger-insulationtester.pdf

A megger is the common name for the equipment used to test insulation. This article provides background information on the equipment and also the process to test insulation under various scenarios.

Topics Covered: 9.0 Measurement and Instrumentation – Insulation Testing

5. Ground Resistance Testing
http://www.weschler.com/_upload/sitepdfs/techref/gettingdowntoearth.pdf

“A Practical Guide to Earth Resistance Testing” by Megger®. This guide has a comprehensive explanation of the various methods and equipment used for ground resistance testing.

Topics Covered: 9.0 Measurement and Instrumentation – Ground Resistance Testing

6. Bus Arrangements
http://testguy.net/content/256-6-Common-Substation-Bus-Schemes-Every-Test-Tech-Should-Know

This website has information on the common bus arrangements that are used to enhance reliability of an electrical power distribution system.

Topics Covered: 10.0 Special Applications – Reliability

5.8 IEEE Color Books

By IEEE

The IEEE Color Books contain a lot of information that is used in nearly all of the recommended references. There are 13 volumes and each book is given a color as shown in the list below. For the purposes of the exam you should only get the items in **bold**.

Red Book™— IEEE STD 141™-1993 (R1999), Recommended Practice for the Electric Power Distribution for Industrial Plants

Green Book™— IEEE STD 142™-2007, Recommended Practice for Grounding of Industrial and Commercial Power Systems

This book will help you understand the purpose of grounding and the different approaches to grounding. There is also information on lightning protection in this book.

Topics Covered: 10.0 Special Applications – Lighting/Surge Protection

Gray Book™— IEEE STD 241™-1990 (R1997), Recommended Practice for Electrical Power Systems in Commercial Buildings

Buff Book™— IEEE STD 242™-2001, Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

This book will help you to understand short circuit calculations, time current coordination graphs and different approaches to the protection of various types of equipment like motors, generators, transformers, buses and conductors.

Brown Book™— IEEE STD 399™-1997, Recommended Practice for Industrial and Commercial Power Systems Analysis

This book provides background on the various power system analysis studies. This analysis includes power flow and harmonics. If you need more background information on these items, then this book should be of help.

Orange Book™— IEEE STD 446™-1995 (R2000), Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

Gold Book™— IEEE STD 493™-2007, Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems

White Book™— IEEE STD 602™-2007, Recommended Practice for Electrical Systems in Health Care Facilities

Bronze Book™— IEEE STD 739™-1995 (R2000), Recommended Practice for Energy Management in Industrial and Commercial Facilities

Yellow Book™— IEEE STD 902™-1998, Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems

Blue Book™— IEEE STD 1015™-2006, Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems

Emerald Book™— IEEE STD 1100™-2005, Recommended Practice for Powering and Grounding Electronic Equipment

Violet Book™— IEEE STD 551™-2006, Recommended Practice for Short-Circuit Calculations in Industrial and Commercial Power Systems

5.9 National Electrical Safety Code© (NESC©)

By NESC©

There are two main products published by the NESC and they include the actual code and a handbook that provides a walkthrough on how to apply the NESC in practice. Although the handbook is more descriptive and provides figures and diagrams to better explain the code, the actual code is more useful for electric utility engineers. For the exam, you will need the code not the handbook. You should have a general idea of what is in this code and when it is applied. A link is provided below for your use to provide more background information on the code.

Amazon Link[1]: NESC 2017

5.10 NFPA 70E, 497, 499 & 30B

By National Fire Protection Association

5.1.1 NFPA 70E

The Standard for Electrical Safety in the Workplace includes requirements to prevent accidents from electrical systems in the field. Included in the appendix are the arc flash boundary calculations, used to determine safe distances during an arc flash. There are two safety terms that you should be familiar with for the exam, (1) Electric Shock and (2) Arc Flash.

Electric Shock: Electric shock is also known as electrocution. This occurs when an electric current passes through the body. Electric shock can occur through either direct contact with a conductor or indirect contact (no touching). A human can feel approximately 1 mA (AC) or 5 mA (DC). The minimum amount of current that can seriously injure a person is around 1 amp.

Arc Flash: In an arc flash, electricity is conducted from a high voltage point to a low voltage point, like ground through the air. The energy released in this arc is huge. The temperatures of the arc can exceed tens of thousands of degrees Celsius and can also result in an explosive blast. An arc most commonly occurs when a circuit breaker is opened. The sudden break in electricity will cause high voltage on one side of the circuit and no voltage on the other side, with air in-between. This potential difference causes an arc to occur, which is typically contained within the circuit breaker device.

Amazon Link[1]: NFPA 70E

5.1.2 NFPA 497 – Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

This document provides recommendations, and not code requirements, for hazardous classifications in chemical process areas. It is intended to be used in conjunction with Article 500 of the NEC (NFPA 70E) to assist in identifying more specific hazardous classifications. Once the hazard class, division, and zone can be defined with the assistance of NFPA 497, then the NEC is referred to for the particular electrical installation requirements.

NFPA 497 specifically refers to Class I hazards, which include flammable or combustible liquids, gases or vapors. Table 4.4.2 Selected Chemicals provides a list of various Class I chemical properties to assist with classifications for more specific applications. Chapter 5 provides direction on classifying the division and zone of the hazardous location. At the end of Chapter 5 are figures for various hazardous location offsets. In addition to class, division, and zones, there are also group definitions for Class I combustible materials. This is defined in Section 3.3.5 of NFPA 497 and Article 500.6 Material Groups of the NEC.

5.1.3 NFPA 499 – Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

NFPA 499 is also a recommendation and not a code requirement. This document is similar in intent and layout to NFPA 497, except it assists with defining Class II hazardous locations, which contains combustible dust.

Chapter 4 of this document identifies what is considered combustible dust and whether it is hazardous. ASTM E1226, ASTM E2021, and ASTM E1491 are standard test methods used to determine whether dust is combustible and will ignite. Combustible groups and zone groups are defined in Section 4.4.

Table 5.2.3 Selected Combustible Dust provides a list of combustible dust by chemical name with their associated groups and ignition temperatures.

Finally, Chapter 6 assists with identifying the hazardous division, zone, and class of the location containing the combustible dust. Similar to NFPA 497, the end of Chapter 6 provides figures of hazardous location offsets from the hazardous source.

5.1.4 NFPA 30B – Code for the Manufacture and Storage of Aerosol Products

NFPA 30B is a code requirement to protect against fire hazards from aerosol products. This standard also refers to the NEC (NFPA 70) for electrical installation requirements.

Only a few parts of the code refer to electrical installations in these areas. For aerosols, it is important to note that sources of ignition include static electricity and electrical arcs and sparks. This document can be used for the classification of hazardous locations with respect to aerosol facilities.

In section 5.5, the flammable propellant charging and pump rooms of aerosol manufacturing facilities shall be defined as a Class I, Division 1 or Class I, Zone 1 location. If vacuum pumps used for propellant charging are located outside the charging room, then the location 5ft from the vacuum pump is considered Class I, Division 2 or Class I, Zone 2. Additional qualifications and variations are provided in the subsequent paragraphs. To prevent static electricity, the code also requires that all equipment that play a role in the manufacturing of aerosol be bonded and grounded. Laboratory Hoods that contain aerosol will also be considered Class I, Division 1.

SECTION 2
QUESTIONS

QUESTION 1

An overhead line will have a support structure located on a sidewalk of a city street. What is the minimum clearance required between the support structure and the street. Assume the support structure is 20 ft tall and completely perpendicular to the street. The support structure is protected by a re-directional curb.

(A) No clearance required

(B) 6 inches

(C) 18 inches

(D) 3 feet

QUESTION 2

Three 13.2 KV phase to phase, conductors are run at a height of 20 feet above the ground. The conductors are run near a swimming pool. If the pool water level is at ground level, then what is the minimum clearance between the pool water and the conductors? Assume the conductors are open supply conductors.

(A) 3 feet

(B) 7.6 feet

(C) 12 feet

(D) 25 feet

QUESTION 3

Three supply cables, each with metallic shields, are installed in an underground trench. What is the minimum depth of these cables? Assume the cables are operated at a design phase to phase voltage of 900 V. Also assume that frost is not a concern and no other supplemental protection is provided for the cables. The depth of the cables is measured from the surface, which equals final grade.

(A) 0 inches

(B) 24 inches

(C) 30 inches

(D) 42 inches

QUESTION 4

A new driven rod shall serve as the grounding electrode for a small substation. The substation is located in an area where frost is not a concern and the bedrock is located at a depth of 100 ft below finished grade. What is the minimum depth required for the driven rod?

(A) 3 feet

(B) 8 feet

(C) 12 feet

(D) 24 feet

QUESTION 33

A 480V 3-phase, 100 kW, 60 Hz, 2,300 RPM, generator is rated at 150 amps at 480 volts. What amperage should be used to find the size of the conductors from the generator terminals? Assume the generator is not inherently designed to prevent overload and an overcurrent relay is not provided.

(A) 128 A

(B) 150 A

(C) 173 A

(D) 211 A

QUESTION 34

A 25 HP, 460 V, 60 HZ, 3PH, AC induction motor is served by a panel that is located 100 feet from the motor. The motor is operated continuously. The running amps value is 25 A. According to NEC, what is the voltage drop from the panel to the pump? Assume (3) 10 AWG copper conductors in a steel conduit and a 0.8 lagging power factor.

(A) 5.1 V

(B) 10.2 V

(C) 14.4 V

(D) 20.9 V

QUESTION 35

A sensitive 3-PH, 60 HZ, AC, motor has a NEC determined full load current rating of 50 A to be used for the conductor. The motor is located 150 ft from the panel. The voltage at the panel is 460 V and the required voltage at the motor is greater than 437 V. What is the minimum size copper conductor at 75 °C?

(A) 10 AWG

(B) 8 AWG

(C) 6 AWG

(D) 4 AWG

QUESTION 36

Which of the following is not an essential electrical system branch required for hospital life safety and effective operation during normal power interruptions, per the NEC?

(A) Life Safety Branch

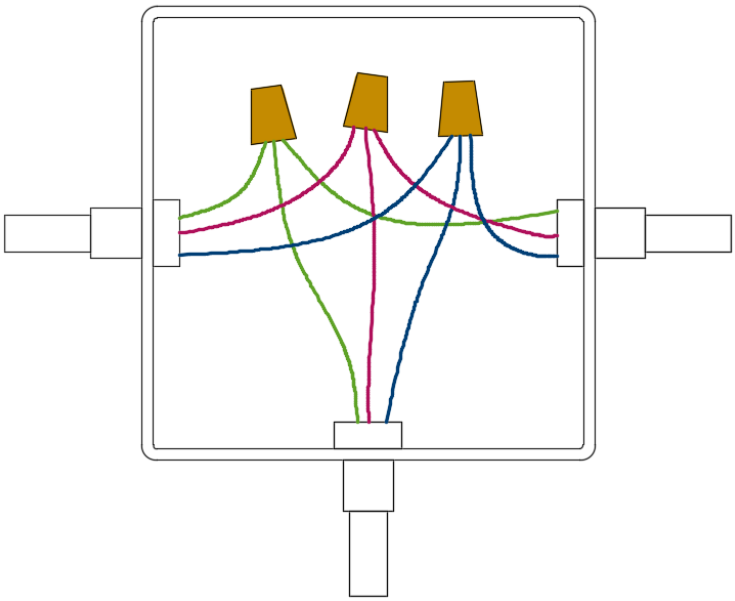
(B) Critical Branch

(C) Emergency Branch

(D) Equipment Branch

QUESTION 39

All conductors in the junction box below are size #10 AWG. What is the minimum standard box size for the installation below?



(A) 4” x 1-1/4” square

(B) 4” x 1-1/2” square

(C) 4-11/16” x 1-1/4” square

(D) 4-11/16” x 1-1/2” square

QUESTION 40

A construction project shall require temporary power and lighting. According to the NEC, what is the maximum amount of days that the temporary power installation can be installed?

(A) 30 days

(B) 60 days

(C) 90 days

(D) No maximum days, the temporary power shall be removed immediately after construction.

SECTION 3
SOLUTIONS

SOLUTION 1

An overhead line will have a support structure located on a sidewalk of a city street. What is the minimum clearance required between the support structure and the street. Assume the support structure is 20 ft tall and completely perpendicular to the street. The support structure is protected by a re-directional curb.

(A) No clearance required

(B) 6 inches

(C) 18 inches

(D) 3 feet

First, navigate to **NESC Part 2: Safety Rules for Overhead Lines** and find the section on clearances for support structures. Depending on your edition of the NESC, this section may be numbered **231. Clearances of supporting structures B. From streets, roads and highways**. This section indicates if there is a re-directional curb, support structures require a minimum of 6 inches of clearances from streets, roads and highways.

The correct answer is most nearly, **(B) 6 inches**.

SOLUTION 2

Three 13.2 KV phase to phase, conductors are run at a height of 20 feet above the ground. The conductors are run near a swimming pool. If the pool water level is at ground level, then what is the minimum clearance between the pool water and the conductors? Assume the conductors are open supply conductors.

(A) 3 feet

(B) 7.6 feet

(C) 12 feet

(D) 25 feet

First, navigate to **NESC Part 2: Safety Rules for Overhead Lines** and find the table on clearances of wires, conductors, cables or unguarded rigid live parts over or near swimming pools. Depending on your edition of the NESC, this table may be numbered **Table 234-3**. This section indicates that open supply conductors, over 750 V to 22 kV must have a clearance of 7.6 meters in any direction from the water level, edge of pool, base of diving platform or anchored raft. This distance converts to 24.9 feet.

The correct answer is most nearly, **(D) 25 feet**.

SOLUTION 12

An escalator motor has an FLA of 58A and an LRC of 200 A. Based on the **2017** version of the NEC, what is the maximum size for the overload protection for the motor? Assume a separate overload device shall be provided. The motor does not have a service factor, nor does it have a marked temperature rise.

(A) 58 A

(B) 66.7 A

(C) 72.5 A

(D) 200 A

According to **NEC 207, Chapter 6 Special Equipment, Article 620 Elevators, Dumbwaiters, Escalators, Moving Walks, Platform Lifts and Stairway Chairlifts, 620.61 Overcurrent Protection (B) Overload Protection for Motors.** Motor and branch circuit overload protection shall conform to **Article 430, Part III and (B)(1) through (B)(4).**

(B)(2) Duty Rating on Escalator Motors indicates that escalator motors shall be rated as continuous and should be protected against overload in accordance with 430.32.

Part III refers to articles, 430.31 through 430.44.

In 430.32, Continuous Duty Motors, (A) More than 1 Horsepower, (1) Separate Overload Device, the device shall be selected to trip or shall be rated at no more than the following percent of the motor nameplate full-load current rating: 115% for all other motors.

$$115\% * Full\ Load\ Current\ Rating \rightarrow\ 115\% * 58\ FLA = \ 66.7\ A$$

To protect a motor from an overload, the motor nameplate full-load current is used to select the overload protection rather than the full load current values from Tables 430.248 through 430.250, which are used to select the feeder and branch circuit wiring.

The correct answer is most nearly **(B) 66.7 A.**

SOLUTION 13

According to the **NEC 2017**, which of the following conduit materials is suitable for an exterior, wet environment, where the conduit may be subject to physical damage and where the conduit will be exposed?

(A) High Density Polyethylene Conduit

(B) Flexible Metal Conduit

(C) Liquidtight Flexible Metal Conduit

(D) Stainless Steel Rigid Metal Conduit

Chapter 3 Wiring Methods and Materials outlines the permitted and non-permitted uses for various conduit materials.

(A) High Density Polyethylene Conduit – Article 353 High Density Polyethylene Conduit, 353.12 Uses Not Permitted: HDPE conduit shall not be used (1) where exposed.

(B) Flexible Metal Conduit – Article 348 Flexible Metal Conduit, 348.12 Uses Not Permitted: FMC shall not be used (1) in wet locations.

(C) Liquidtight Flexible Metal Conduit - Article 350 Liquidtight Flexible Metal Conduit, 250.12 Uses Not Permitted: LFMC shall not be used (1) where subject to physical damage.

(D) Stainless Steel Rigid Metal Conduit is suitable for wet environments and is sufficiently strong enough to withstand physical damage. It is also suitable for an exposed environment, unlike HDPE which is susceptible to damage due to UV.

The correct answer is most nearly, **(D) Stainless Steel Rigid Metal Conduit.**

SOLUTION 14

According to the **NEC 2017**, what is the difference in minimum burial depth for direct buried 277 V conductors versus conductors installed in rigid metal conduits, when designing the underground conductors for a parking lot?

(A) 0 inches

(B) 6 inches

(C) 18 inches

(D) 24 inches

*According to **NEC 2017** **Table 300.5 Minimum Cover Requirements, 0 to 1000 volts, Nominal, Burial in Inches**, the minimum burial depths for direct burial and RMC in a parking lot, there is no difference between direct buried conductors versus installing in rigid metal conduits.*

The correct answer is most nearly, **(A), 0 inches.**

SOLUTION 22

What is the minimum load requirement for 2 duplex, 1 triplex and 2 quad receptacles connected to a single circuit?

(A) 840 VA

(B) 900 VA

(C) 1260 VA

(D) 1800 VA

Find the receptacle outlet requirements in **NEC Article 220.14 (I) Receptacle Outlets.** The minimum loads are as follows:

Outlet Type	Minimum Load per Outlet	Qty	Minimum Load Subtotal
Duplex	180 VA	2	360 VA
Triplex	180 VA	1	180 VA
Quad	360 VA	2	720 VA
		TOTAL	**1260 VA**

The correct answer is most nearly **(C) 1260 VA**

SOLUTION 23

For a fuel storage facility, which of the following is not true for electrical installations within regions where gasoline vapor will be present?

(A) Conduit seals are required within 10ft of the hazardous zone boundary.

(B) Seals are not required for conduit entering an enclosure when the circuit breaker is part of a nonincendive circuit.

(C) Sealing compounds are required for Type MI cable termination.

(D) Conductors in a seal shall have a cross sectional area not greater than 20% of that of the rigid metal conduit with the same trade size.

Since the installation is concerning volatile flammable gases or vapors, this installation falls within a Class I, Division 1 location.

Navigate to **Article 501, Class I Locations** of the NEC. Answer (A) is true, and is found in paragraph 501.15 (A) (4) Class I, Division 1 Boundary. Answer (B) is true. This is found in paragraph 501.15 (A) (1) (1), Exception d. Answer (C) is found under paragraph 501.15 Sealing and Drainage and is also true.

The correct answer is most nearly **(D).** Under Paragraph 501.15 (C) (6) Conductor or Optical Fiber Fill the cross sectional area permitted in a seal shall not exceed 25% of the conduit.

SOLUTION 34

A 25 HP, 460 V, 60 HZ, 3PH, AC induction motor is served by a panel that is located 100 feet from the motor. The motor is operated continuously. The running amps value is 25 A. According to NEC, what is the voltage drop from the panel to the pump? Assume (3) 10 AWG copper conductors in a steel conduit and a 0.8 lagging power factor.

(A) 5.1 V

(B) 10.2 V

(C) 14.4 V

(D) 20.9 V

First, find the full load current value, which is based on the motor horsepower and Table 430.250 Full-Load Current, Three Phase Alternating Current Motors. Even though the running amps is given, the table must be used to find the full load current. The conductor should be based on this full load current. The table value corresponding to 25 HP, 460 V induction motor gives a full load current value of 34 A.

$$Full\ load\ current = 34\ A$$

430.22 Single Motor indicates that conductors that supply a single motor used ina continuous duty application shall have an ampacity of not less than 125% of the motor full load current rating as determined by the previous table.

$$Full\ load\ current = 125\% * 34\ A = 42.5\ A$$

Next, you need to find the resistance in the conductors.

$$X_L = 0.063\ ohms\ per\ 1{,}000\ ft; X_R = 1.2\ ohms\ per\ 1{,}000\ ft$$

Use these values and the length to calculate the impedance. Make sure to use 1X the length because there is no return path, since the load is three phase.

$$Z = 1 * 100\ ft * \left(\frac{1.2}{1000} + j\frac{.063}{1000}\right) = .12 + j.0063$$

Finally use the following equation to find the voltage drop.

$$V = IZ$$

But you know that the current has a phase angle because of the power factor. Assume that the voltage phase angle is 0 degrees.

$$\theta = cos^{-1}(0.80) = 36.9°$$

You also know that the current lags the voltage, thus there should be a negative in front of the angle, since the voltage angle is 0 degrees.

$$V = 42.5\ A \angle -36.9° * (.12 + j.0063)$$

$$V = 42.5\ A\angle -36.9° * 0.12 \angle 3°$$

$$V = 5.1 \angle -33.9°$$

The correct answer is most nearly, **(A) 5.1 V.**

SOLUTION 40

A construction project shall require temporary power and lighting. According to the NEC, what is the maximum amount of days that the temporary power installation can be installed?

(A) 30 days

(B) 60 days

(C) 90 days

(D) No maximum days, the temporary power shall be removed immediately after construction.

The correct answer is most nearly, **(D) No maximum days, the temporary power shall be removed immediately after construction.** This excerpt can be found in Article 590.3(A) Temporary Installations.

SECTION 4
CONCLUSION

4.0 Conclusion

If you have any questions on this sample exam or any other Engineering Pro Guides product, then please contact:

Justin Kauwale at contact@engproguides.com

Hi. My name is Justin Kauwale, the creator of Engineering Pro Guides. I will be happy to answer any questions you may have about the PE exam. Good luck on your studying! I hope you pass the exam and I wish you the best in your career. Thank you for your purchase!