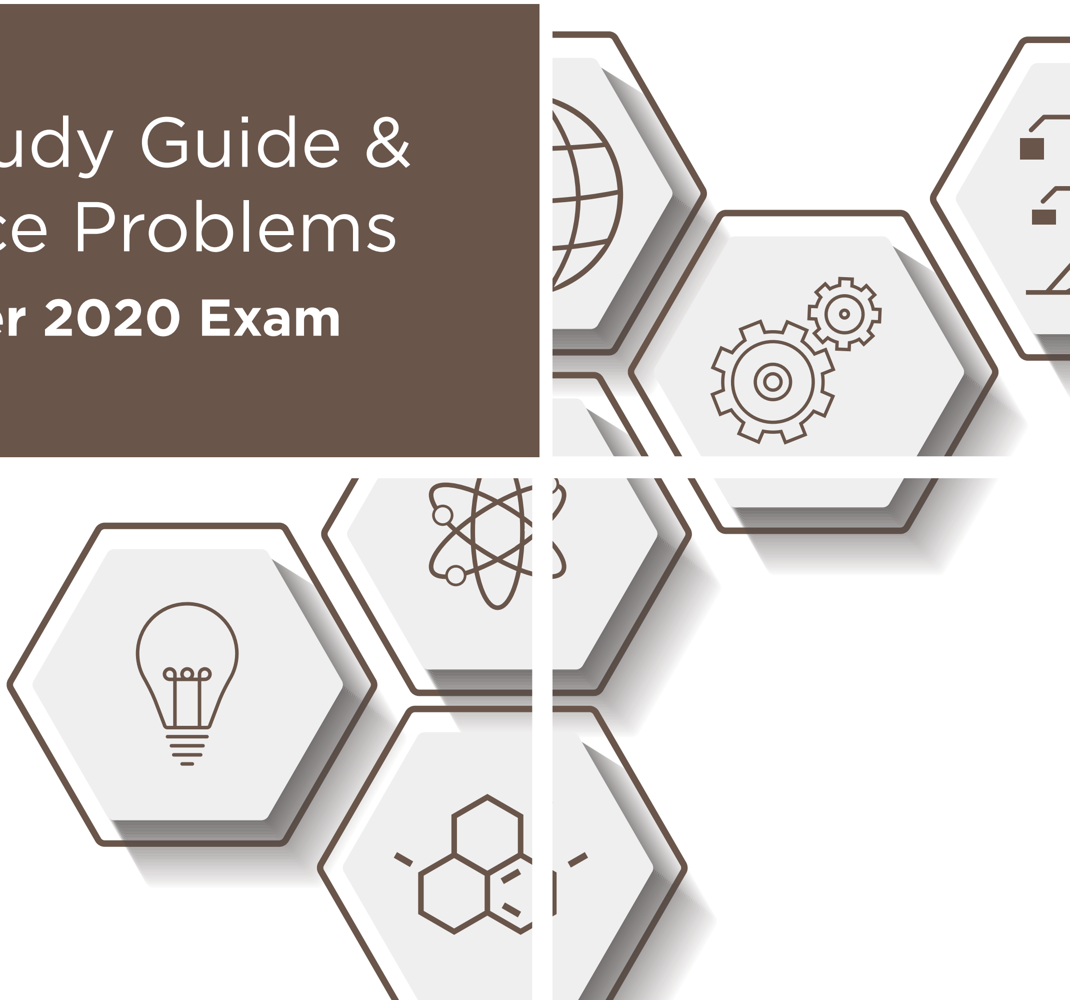
Other Disciplines

FE

Textbook & Full Exam

Technical Study Guide & 250+ Practice Problems

Updated October 2020 Exam



Learn the key concepts and skills necessary to pass the FE Exam

Engineering Pro Guides

by **Justin Kauwale, P.E.**

Other Disciplines FE Exam: Textbook & Full Exam

by Justin Kauwale, PE

Published by Engineering Pro Guides, LLC
Honolulu, HI 96815

www.engproguides.com

October 2020 Edition

ISBN 978-1-7329987-7-3 (ebook)

Other Disciplines FE Textbook & Practice Exam

How to pass the FE Other Disciplines exam

Table of Contents

0 - Introduction

How to Study for and Pass the FE Exam

Section 0.0 - 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. The first step towards obtaining your P.E. is passing the Fundamentals of Engineering (F.E.) Exam. Both tests are administered by the National Council of Examiners for Engineering and Surveying (NCEES). The FE Exam is a year round computer based test that can be taken as early as your senior year in college or with at least 3 years of engineering-related work experience. Once passed, the FE Exam will certify you as an Engineering in Training (EIT). With enough experience after passing the EIT, you will become eligible for the PE 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 textbooks that outline how to pass the FE & PE exams.

In the FE exam you will not be able to bring in any outside reference material. You will be given the *NCEES FE Exam Reference Handbook*, which contains all the necessary equations, tables, and graphs that you will need to solve each problem. The *NCEES FE Exam Reference Handbook* will be provided as a searchable electronic pdf during the test. The key to passing the FE exam is understanding the key concepts and skills that are tested on the exam and becoming familiar with using this handbook to solve each problems in approximately 2-3 minutes. Although the

NCEES handbook provides the necessary equations for the exam, knowing how to apply them and which equations to use requires an understanding of the concepts and practice of the skills. The FE Exam is available for 6 disciplines plus a generic engineering discipline. This textbook teaches you the key concepts and skills required to pass the Other Disciplines F.E. Exam in a single document.

1.1 Exam Format

How is the exam formatted?

The FE exam format and additional exam day information can be found on the NCEES Examinee Guide (https://ncees.org/exams/examinee-guide/). The entire exam period is about 6 hours, with 2 minutes for signing agreements, 8 minutes for tutorials, and one break up to 25 minutes. You will have a total of 5 hours 20 minutes of actual exam time to solve 110 problems, which equates to about 2.9 minutes per problem if spread out evenly. The test is broken up into two sessions. The length of each session is determined by the number of problems, 55 problems per session, and not the time. So, you could spend more or less than half the time on the first session, and the remaining 5 hours 20 minutes will be allotted for the second session. Since the first session doesn't have a halfway time limit, it is very important to keep watch of the clock to make sure you have enough time for the second session. Before each session is completed, you are allowed to go back to problems that you may have skipped or want to check in that session. However, once the first session is completed and submitted, you are no longer allowed to revisit the questions in that session. There is a 25 minute break in between the sessions. You are allowed to take less than a 25 minute break or no break at all, but this does not increase the time you have to answer exam questions. No points are deducted for incorrect answers, so be sure to provide an answer for all questions, even if it is a guess. The final results are scaled based on the exam difficulty. There are five types of question formats that could be presented on the exam.

1. Multiple Choice (4 choices) – Select one option, *majority of questions in the exam*
2. Multiple Answers – Select multiple answers that are correct
3. Select by Clicking – Click on a point on a graph, etc.
4. Drag and Drop – Matching, sorting, labeling, etc.
5. Fill in the Blank – Type in the answer

The types of questions and number of questions per topic will be based on the outline provided by NCEES, discussed in the next section. These topics will not be labeled on the test. Finally, the NCEES Examinee Guide states that there will be some questions that will not be scored in the exam. These are questions that are tested for their quality and possible use in future exams. Your final results will be given to you 7-10 days after you take the exam.

1.2 Key Concepts and Skills

How are the key concepts and skills determined?

The key concepts and skills tested in the sample exams and taught in this technical study guide were first developed through an analysis of the topics and information presented by NCEES. The above factors related to timing is considered. The Other Disciplines FE exam will focus on the following topics as indicated by NCEES. (https://ncees.org/engineering/fe/):

1 **Mathematics (8-12 questions)**
   i) *Analytic Geometry and trigonometry*
   ii) *Differential equations*
   iii) Numerical methods (e.g., algebraic equations, roots of equations, approximations, precision limits, convergence)
   iv) *Linear Algebra (e.g., matrix operations)*
   v) *Single-variable calculus*

2 **Probability and Statistics *(6-9 questions)***
   i) *Estimation (e.g., point, confidence intervals)*
   ii) *Expected value and expected error in decision making*
   Sample distributions and sizes (e.g., significance, hypothesis testing, non-normal distributions)
   iii) *Goodness of fit (e.g., correlation coefficient, standard errors, R2)*

3 **Chemistry *(5-8 questions)***
   i) *Oxidation and reduction (e.g., reactions, corrosion control)*
   ii) Acids and bases (e.g., pH, buffers)
   iii) Chemical reactions (e.g., stoichiometry, equilibrium, bioconversion)

4 **Instrumentation and Controls *(4-6 questions)***
   i) Sensors (e.g., temperature, pressure, motion, pH, chemical constituents)
   ii) Data acquisition (e.g., logging, sampling rate, sampling range, filtering, amplification, signal interface, signal processing, analog/digital [A/D], digital/analog [D/A], digital)
   iii) Logic diagrams

5 **Engineering Ethics and Societal Impacts *(5-8 questions)***
   i) Codes of ethics (e.g., identifying and solving ethical dilemmas)
   ii) Public protection issues (e.g., licensing boards)
   iii) Societal impacts (e.g., economic, sustainability, life-cycle analysis, environmental, public safety)depreciation, discounted cash flow, decision trees)

6 **Safety, Health and Environment *(6-9 questions)***
   i) Industrial hygiene (e.g., carcinogens, toxicology, exposure limits, radiation exposure, biohazards, half-life)
   ii) Basic safety equipment (e.g., pressure-relief valves, emergency shutoffs, fire prevention and control, personal protective equipment)
   iii) Gas detection and monitoring (e.g., O_2, CO, CO_2, CH_4, H_2S, radon)
   iv) Electrical safety
   v) Confined space entry and ventilation rates

vi) Hazard communications (e.g., SDS, proper labeling, concentrations, fire ratings, safety equipment)

7 **Engineering Economics *(6-9 questions)***

i) Time value of money (e.g., present worth, annual worth, future worth,
ii) rate of return)
iii) Cost analysis (e.g., incremental, average, sunk, estimating)
iv) Economic analyses (e.g., break-even, benefit-cost, optimal economic life)
v) Uncertainty (e.g., expected value and risk)
vi) Project selection (e.g., comparison of projects with unequal lives, lease/buy/make, depreciation, discounted cash flow, decision trees)

8 **Statics *(9-14 questions)***

i) Vector analysis
ii) Force systems (e.g., resultants, concurrent, distributed)
iii) Force couple systems
iv) Equilibrium of rigid bodies (e.g., support reactions)
v) Internal forces in rigid bodies (e.g., trusses, frames, machines)
vi) Area properties (e.g., centroids, moments of inertia, radius of gyration, parallel axis theorem)
vii) Static friction
viii) Free-body diagrams
ix) *Weight and mass computations (e.g., slug, lbm, lbf, kg, N, ton, dyne, g, g_c)Static friction*

9 **Dynamics *(9-14 questions)***

i) Particle and rigid-body kinematics
ii) Linear motion (e.g., force, mass, acceleration)
iii) Angular motion (e.g., torque, inertia, acceleration)
iv) Mass moment of inertia
v) Impulse and momentum (e.g., linear, angular)
vi) Work, energy, and power
vii) Dynamic friction
viii) *Vibrations (e.g., natural frequency)*

10 **Strength of Materials *(9-14 questions)***

i) Stress types (e.g., normal, shear)
ii) Combined loading–principle of superposition
iii) Stress and strain caused by axial loads, bending loads, torsion, or transverse shear forces
iv) Shear and moment diagrams
v) Analysis of beams, trusses, frames, and columns
vi) Loads and deformations (e.g., axial-extension, torque-angle of twist, moment-rotation)
vii) Stress transformation and principal stresses, including stress-based yielding and fracture criteria (e.g., Mohr's circle, maximum normal stress, Tresca, von Mises)

viii) Material failure (e.g., Euler buckling, creep, fatigue, brittle fracture, stress concentration factors, factor of safety, and allowable stress)

11 **Materials *(6-9 questions)***
- i) *Physical (phase diagrams) properties of materials (e.g., alloy phase diagrams, phase equilibrium, and phase change)*
- ii) Mechanical properties of materials
- iii) Chemical properties of materials
- iv) Thermal properties of materials
- v) Electrical properties of materials
- vi) Material selection

12 **Fluid Mechanics *(12-18 questions)***
- i) *Fluid properties (e.g., Newtonian, non-Newtonian, liquids and gases)*
- ii) Dimensionless numbers (e.g., Reynolds number, Froude number, Mach number)
- iii) Laminar and turbulent flow
- iv) Fluid statics (e.g., hydrostatic head)
- v) Energy, impulse, and momentum equations (e.g., Bernoulli equation)
- vi) Pipe and duct flow and friction losses (e.g., pipes, valves, fittings, laminar, transitional and turbulent flow)
- vii) Open-channel flow (e.g., Manning's equation, drag)
- viii) Fluid transport systems (e.g., series and parallel operations)
- ix) Flow measurement (e.g., pitot tube, venturi meter, weir)
- x) Turbomachinery (e.g., pumps, turbines, fans, compressors)
- xi) Ideal gas law (e.g., mixtures of nonreactive gases)
- xii) Real gas law (e.g., z factor)

13 **Basic Electrical Engineering *(6-9 questions)***
- i) *Electrical fundamentals (e.g., charge, current, voltage, resistance, power, energy)*
- ii) *Current and voltage laws (e.g., Kirchhoff, Ohm)*
- iii) *AC and DC circuits (e.g., real and imaginary components, complex numbers, power factor, reactance and impedance, series, parallel, capacitance and inductance, RLC circuits)*
- iv) *Measuring devices (e.g., voltmeter, ammeter, wattmeter)*
- v) *Three-phase power (e.g., motor efficiency, balanced loads, power equation)*

14 **Thermodynamics and Heat Transfer *(9-14 questions)***
- *i) Thermodynamic laws (e.g., first law, second law)*
- *ii) Thermodynamic equilibrium*
- *iii) Thermodynamic properties (e.g., entropy, enthalpy, heat capacity)*
- *iv) Thermodynamic processes (e.g., isothermal, adiabatic, reversible, irreversible)*
- *v) Heat transfer (e.g., conduction, convection, radiation)*
- *vi) Mass and energy balances*
- *vii) Property and phase diagrams (e.g., T-s, P-h, P-v)*
- *viii) Combustion and combustion products (e.g., CO, CO_2, NO_X, ash, particulates)*

ix) *Psychrometrics (e.g., relative humidity, wet bulb)Combustion and Combustion Products*

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 fundamental principles taught in college. The test is intended for the engineer right out of college without work or practical experience. The exam will focus on fundamental engineering principles you will need during your career. However, since the Other Disciplines topic is broad, the exam will be based on the general knowledge that each General Engineer develops in school and will not include an in-depth, higher level analysis of a specific topic. The subjects listed above are the basic curriculum that General Engineers should encounter before they graduate.

(2) Second, the skill and concept must be testable in roughly 2.9 minutes per problem. There are (110) questions on the Other Disciplines FE exam and you will be provided with 5 hours 20 minutes to complete the exam. This results in an average of 2.9 minutes per problem. This criterion limits the complexity of the exam problems and the resulting solutions. For example, pressure drop calculations are common in Fluids, but the calculation is often very lengthy because of the number of steps involved, especially if a unique fluid and flow condition is used. Thus, common fluids like water/air and common pipe/duct materials are used.

(3) Third, the information and equations required to solve the problems should be in the *NCEES FE Reference Handbook.* Since you are not allowed to bring in outside resource, the Handbook and along with any information given to you in the problem should provide you with sufficient information needed to solve the problems. It is extremely unlikely that you will need an equation that is not given to you in the reference handbook. Thus, the handbook is an additional resource for understanding the types of questions that could be asked. Note that the *NCEES FE Reference Handbook* contains extraneous information for the Other Disciplines FE exam, since the same resource is used across all tested disciplines. To narrow down the relevant topics, the handbook was cross referenced with the NCEES Other Disciplines FE outline mentioned in the last section. Lastly, the solution may still require a variation of the equations in the reference handbook. Therefore it is very important to understand how to use these equations, as well as the variables and the units that the equations require.

(4) The F.E. Exam tests the background engineering concepts and skills for a practicing General Engineer and not the derivation of the topic or concept. The exam is intended to prove that the test taker is minimally competent to practice as an engineer in training and has the basic understanding of General Engineering principles. This background knowledge is necessary for the practicing engineer to understand how engineering concepts and skills are applied in the field. Therefore, the exam is less concerned with theory and more with how these concepts and skills can be applied. For example, the F.E. exam is less interested with the derivation of angular momentum equations and more with how to solve for resultant forces or final velocity conditions.

In summary, this book is intended to teach the necessary skills and concepts to develop a minimally competent, practicing General Engineer in Training, capable of passing the F.E. exam. This book and the sample exam do this through the following means:

(1) Teaching common skills, principles, and concepts in the General Engineering field.

(2) Providing sample problems that can be completed in roughly 2-3 minutes per problem.

(3) Teaching how to use and apply the equations in the *NCEES FE Reference Handbook*. Also teaching the underlying concept behind the equations in the book.

(4) Teaching the application of the skill and concept for an engineer in training.

1.3 Units

The units that are used in the F.E. Exam are the International System of Units (SI) and the United States Customary System Units (USCS). The equations in the *NCEES FE Reference Handbook* are more generic and does not necessarily differentiate between SI or USCS units. Therefore, it is very important, especially with the USCS problems, to make sure all necessary conversion factors are used and that the units cancel out to the unit of your desired final answer. Be aware of the use of the g_c conversion factor in USCS problems. See the fluids section for an explanation of the g_c term.

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 an engineer in training. 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

This book is organized into the topics as designated by the NCEES. These topics include:

- Section 0.0: Introduction
- Section 1.0: Mathematics

- Section 2.0: Probability and Statistics
- Section 3.0: Chemistry
- Section 4.0: Instrumentation and Controls
- Section 5.0: Engineering Ethics and Societal Impacts
- Section 6.0: Safety, Health and Environment
- Section 7.0: Engineering Economics
- Section 8.0: Statics
- Section 9.0: Dynamics
- Section 10.0: Strength of Materials
- Section 11.0: Materials
- Section 12.0: Fluid Mechanics
- Section 13.0: Basic Electrical Engineering
- Section 14.0: Thermodynamics and Heat Transfer

First, it is recommended that the engineer in training gather the *NCEES FE Reference Handbook*.

Second, proceed through the book 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. These problems are meant to practice the application of the skill or concept presented in the section. The problems are exam difficulty level.

Finally, set aside a five-hour twenty-minute block of uninterrupted time to complete a sample exam. Gather the NCEES FE Reference Handbook and calculator and create a test-like environment. Set a timer and proceed to take the sample exam, which can be purchased separately. Remember that the exam is around 50-60 problems each for the first and second 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.

4.0 Practice Exam Tips

Engineering Pro Guides practice exam problems 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 is not comprehensive of all concepts. Also the practice exam problems are split up throughout the entire book.

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 two hours forty minutes to simulate half of the real exam. This will give you a better indication of your status of preparation for the exam. If you are at the ending of your studying, it is recommended to couple this exam with the second section to simulate the full exam test day.

Review the exam day rules and replicate the environment for the real test as much 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 55 questions in 2 hours 40 minutes.

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

Allowed:

1. ID used for admission
2. Approved calculator (2 recommended for backup. The backup will be stored with your personal items)
3. Eyeglasses
4. Light sweater or jacket
5. Test center locker key
6. Test center provided booklet and marker
7. Test center comfort aids, approved upon visual inspection. See the *Pearson VUE Comfort Aid List* on the Pearson VUE website (includes medicine – inhaler, aspirin not in bottle, eye drops, cough drops, etc. and mobility devices – crutches, wheelchairs, etc. Tissues and earplugs must be provided by the test center.)
8. Religious head coverings

Prohibited:

1. Cell phones
2. Electronic Devices (other than approved calculator)
3. Watches
4. Wallets and Purses
5. Hats and hoods
6. Bags
7. Coats
8. Books
9. Pens, Pencils, Erasers
10. Food, Drinks
11. Weapons
12. Tobacco
13. Eyeglass cases
14. Scratch Paper (all writing devices are provided)

Most test centers will have lockers for you to store your personal items. 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/

For best use of your time, answer the questions that you know first and return to the questions that you are unfamiliar with later. On the computer based test, you are able to bookmark the answers you may want to come back to 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. *NCEES FE Reference Handbook*: It is important to understand the *NCEES FE Reference Handbook*. During times of uncertainty, this will likely lead you to your answers. Determine the key concept that is being asked in the question and refer to this reference book. Remember that the reference is searchable, so you will able to do a search by keyword (Ctrl+F). Additional tips on this resource is discussed in the next section.

2. Process of Elimination: In most questions, 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. 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 may not match yours exactly and in fact may not even 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 less than 3 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 you 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 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. 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 NCEES FE Reference Handbook

As previously mentioned, the *NCEES FE Reference Handbook* is the only reference material you will have during the exam. Therefore, it is very important to use this reference book when doing practice problems. You should become familiar with the layout of the book, how to apply the equations, what the variables mean, what units the equations are in, and where to find common constants, tables, and graphs. The *NCEES FE Reference Handbook* can be purchased as a hardcopy on the NCEES website or downloaded a free pdf of the latest version from your *MyNCEES* account. I would recommend studying from the pdf to become familiar with using the reference book electronically with the search (Ctrl+F) options. The index will not be provided during the real exam, but the table of contents bookmarks will be provided. When studying, notice how the Handbook is organized and how it is broken out by subject, then by discipline. Take some time go browse through the entire reference handbook to see where different equations are located. Realize that some of the Other Disciplines FE questions may overlap with other disciplines, like Civil, Mechanical and Electrical.

5.1 Unit Conversion

The first section of the *NCEES FE Reference Handbook* has a list of typical unit conversions as well as common constants, such as the universal gas constant, gravity, Stefan-Boltzmann constant.

5.2 Tables and Graphs

It is important to be able to quickly navigate through the *NCEES FE Reference Handbook* and know where the common tables are used across multiple subjects.

The following are examples of common tables or graphs that you should be aware of.

- Hazard Assessment Diamond, GHS Pictograms – *Safety*
- Trigonometric Identities, Derivatives/Integrals – *Mathematics*
- Probability Distribution Tables – *Engineering Probability and Statistics*
- Periodic Table - Chemistry
- Area Moment of Inertia & Centroid – *Statics*
- Mass Moment of Inertia & Centroid – *Dynamics*
- Modulus of Elasticity – *Material Properties*
- Metal Densities – *Material Properties*
- Coefficient of Thermal Expansion – *Material Properties*
- Beam Deflection – *Mechanics of Materials*
- Steam Tables – *Thermodynamics*
- Specific Heat Capacities – *Thermodynamics*
- Z-factor chart – *Thermodynamics*
- Critical temperatures and pressures for gases – *Thermodynamics*
- Water Properties – *Fluid Mechanics*
- Moody Diagram/Roughness Coefficients – *Fluid Mechanics*
- Drag Coefficients – *Fluid Mechanics*
- Hazen-Williams Coefficients – *Civil Engineering*
- Beam Analysis (additional) – *Civil Engineering*
- Buckling – *Civil Engineering*
- Mechanical Application – *Mechanical Engineering*

6.0 Past Exams

6.1 Pass Rates on Survey vs. NCEES

The NCEES website indicates that 75% of Other Disciplines FE test takers pass the exam. These pass rates only include first time test takers that have attended an accredited engineering program and took the test within 12 months of graduation.

6.2 Estimated Cut Score

Since the exam is weighted, the cut score is not clearly defined and is never posted by NCEES. The general online consensus is that the passing rate is about 60% correct. Our goal with this book is to get you to a score of at least 70%. You should be able to obtain at least this amount to increase your confidence of passing.

1 - Mathematics

STUDY GUIDE
www.engproguides.com

Section 1.0 – Mathematics

Table of Contents

1.0 INTRODUCTION

Mathematics accounts for approximately 8 to 12 questions on the Other Disciplines FE exam. The topics covered in this section include Analytic Geometry, Trigonometry, Differential Equations, Numerical Methods, Linear Algebra and Single Variable Calculus. At first glance, these topics seem very vast and daunting. But you should not be worried because you will most likely only need to know the equations that are shown in the NCEES FE Reference Handbook as they relate to General Engineering.

Section 1.0 Mathematics (8 to 12 Problems)		
NCEES Outline Value	Engineering Pro Guides	
	Section 1.0	Introduction
1A	Section 2.0	Analytic Geometry & Trigonometry
1B	Section 3.0	Differential Equations
1C	Section 4.0	Numerical Methods (e.g., algebraic equations, roots of equations, approximations, precision limits, convergence)
1D	Section 5.0	Linear Algebra (e.g., matrix operations)
1E	Section 6.0	Single Variable Calculus
	Section 7.0	Practice Exam Problems

2.0 Analytic Geometry & Trigonometry

Analytic geometry uses algebra to characterize various geometric objects such as shapes, lines and points.

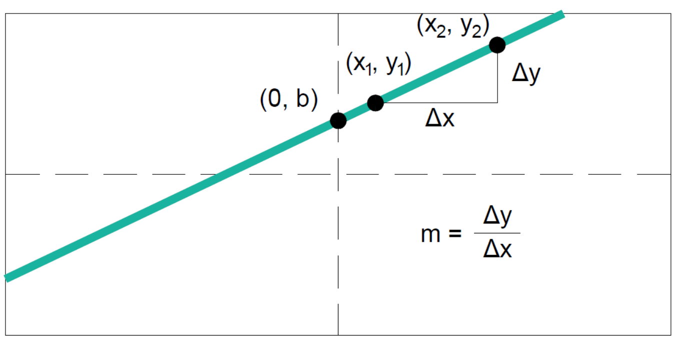


Figure 1: The slope of a line can be found with the difference between the y-values and x-values of two points.

2.1 Find Line Equation Given Two Points

If you are given two points, then you can follow the process below to produce an equation for the line.

First solve for slope, “m”, where the slope is equal to the change in y over the change in x.

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

Next, solve for the y-intercept, "b", using the following equation for a line. To solve for "b", plug in the value of the slope, "m", and one of the (x, y) points along the line. Then solve for the y-intercept, "b".

$$y - intercept\ equation\ for\ line \rightarrow\ y = mx + b$$

$$y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right) * x_1 + b$$

Finally, replace "b" in the equation and you will have found the equation of the line.

2.2 Parallel and Perpendicular Lines

Another skill you should have is being able to calculate the equation for lines that are parallel or perpendicular to each other. Parallel lines share the same slope.

$$Parallel\ Lines \rightarrow m_1 = m_2$$

You can then find the equation of one line that is parallel to another by determining the offset between the lines. Add the offset to the y-intercept of one line to find the equation of the other line.

$$Line\ 1 \rightarrow y = m_1 x + b$$

$$Line\ 2 \rightarrow y = m_2 x + (b + offset); where\ m_1 = m_2$$

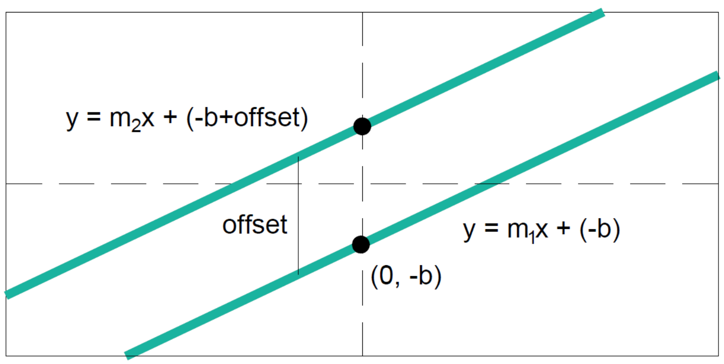


Figure 2: Parallel lines have the same slope and never intersect.

Perpendicular lines have inverse, negative slopes.

$$Perpendicual\ Lines \rightarrow -\frac{1}{m_1} = m_2$$

Find the slope of the perpendicular line, then solve for the new y-intercept, "b_2", by substituting one of the (x, y) coordinates on the line.

7.0 Practice Exam Problems

7.1 Practice Problem 1 – Calculus

What is the integral of the function below from 0 to 90 degrees?

$$\int_{0\ deg}^{90\ deg} 10 * \sin(\theta)\ d\theta$$

(a) 0

(b) 1

(c) π

(d) 10

7.2 Practice Problem 2 – Calculus

What is the integral of the function below from 1 to 2?

$$\int_{1}^{2} \ln(x) dx$$

(a) 0.39

(b) 1.01

(c) 1.77

(d) 2.00

8.0 Practice Exam Problems

8.1 Solution 1 – Calculus

Use the integral equations from the *NCEES FE Reference Handbook*.

$$\int_{0\,deg}^{90\,deg} 10 * \sin(\theta)\, d\theta = -10\cos(\theta)\big|_{0\,deg}^{90\,deg}$$

$$= -10 * \cos(90\text{deg}) - (-10 * \cos(0\text{ deg}))$$

$$= 0 - (-10 * 1) = 10$$

The correct answer is most nearly, (d) 10.

8.2 Solution 2 – Calculus

$$\int_{1}^{2} \ln(x)\, dx = x(\ln(x) - 1)\big|_{1}^{2}$$

$$= 2 * (\ln(2) - 1) - 1 * (\ln(1) - 1)$$

$$= -0.614 + 1 = 0.386$$

The correct answer is most nearly, (a) 0.39

8.3 Solution 3 - Calculus

First, integrate the function.

$$\int v(t)\, dt = \frac{1}{2}t^2 * 10 + 2t$$

$$x(t) = \int v(t)\, dt = 5t^2 + 2t$$

Then evaluate from 0 to 3 seconds.

$$x(0) = 5(0)^2 + 2(0) = 0\, ft$$

$$x(3) = 5(3)^2 + 2(3) = 51\, ft$$

$$\Delta x = x(3) - x(0) = 51 ft$$

The correct answer is most nearly (b) 50 ft.

2 – Probability & Statistics

STUDY GUIDE
www.engproguides.com

Section 2.0 – Probability and Statistics

Table of Contents

1.0 INTRODUCTION

Probability and Statistics accounts for approximately 6 to 9 questions on the Other Disciplines FE exam. This section focuses on the following NCEES Outline topics, Estimation, Expected Value and Expected Error in Decision Making, Sample Distribution and Sizes and Goodness of fit.

Probability Distribution involves applying a mathematical formula to describe the probability of a measured variable occurring at a certain value. This is useful for characterizing the measured output of any mechanical system property when you are taking a sample of a larger number. For example, you measure the weight of 100 products, but this is only a sample of the 10,000 products that are produced. A probability distribution will help to characterize all 10,000 products.

Regression curve fitting involves measuring a variable as a function of another variable, then plotting the data points and assigning a mathematical formula to approximate the function. This is useful in predicting how a change in one variable will affect another.

Section 2.0 Probability and Statistics (6 to 9 Problems)		
NCEES Outline Value	**Engineering Pro Guides**	
	Section 1.0	Introduction
2A	Section 2.0	Estimation (e.g., point, confidence intervals)
2B	Section 3.0	Expected value and expected error in decision making
2C	Section 4.0	Sample distributions and sizes (e.g., significance, hypothesis testing, non-normal distributions)
2D	Section 5.0	Goodness of fit (e.g., correlation coefficient, standard errors, R^2)
	Section 6.0	Practice Exam Problems

2.0 ESTIMATION

Estimation is the process of finding the population mean. The population mean is the mean of the entire data set. The entire data set could be all of the products produced at a plant or it could be the entire world population. Let's say that you wanted to find the mean height of every person in the world. You would not be able to measure every single person in the world, but you could take a sample and then find the mean height of the people in that sample set. This mean is called the sample mean or the point estimate.

$$\bar{x} = sample\ mean\ or\ point\ estimate;\ \ \bar{u} = population\ mean;$$

2.1 CONFIDENCE INTERVAL

The confidence interval describes the level of trust in the point estimate (sample mean) in representing the population mean. Towards the ending of the Engineering Probability & Statistics section of the FE Reference Handbook are the following two equations, which will be discussed in the following two examples. These equations allow you to create a range that corresponds to a certain level of confidence. The equation states, there is an X% confidence that the population mean is within this range. These equations can be

Example 1: Confidence Interval of Population Mean with Normal Distribution (known population mean)

A sample set of 10 temperature measurements of a product resulted in a sample mean of 65 and a standard deviation of 5.2. The population standard deviation is 3.1. What are the 90% and 80% confidence intervals?

Use the following equation to determine the confidence interval.

$$\bar{x} - Z_{\frac{a}{2}}\left(\frac{\sigma}{\sqrt{n}}\right) \leq\ \ \bar{u} \leq \bar{x} + Z_{\frac{a}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$$

$$\sigma = population\ standard\ deviation, n = number\ of\ samples;$$

$$Z_{a/2} = probability\ from\ normal\ distribution$$

You will need to either go to the normal distribution table and navigate to the W(x) column or on the next page from the above equation is the following table. These values tell you the number of standard deviations from the population mean in the positive and negative direction and the corresponding probability that a value will be in that range.

Confidence Interval	$Z_{a/2}$		Probability W(x) (from Normal Distribution Table)	x (-x to x) # of standard deviations
80%	1.2816		0.8	1.2816
90%	1.6449		0.9	1.6449
95%	1.96		0.95	1.96
96%	2.0537		0.96	2.0537
98%	2.3263		0.98	2.3263
99%	2.5758		0.99	2.5758

For an 80% confidence interval the equation results in the following range.

3 – Chemistry

STUDY GUIDE
www.engproguides.com

Section 3.0 – Chemistry

Table of Contents

1.0 Introduction

Chemistry accounts for approximately 5 to 8 questions on the Other Disciplines FE exam. This section covers oxidation, reduction, acids, bases and chemical reactions. This book makes the assumption that you have taken a college/university, so it will not teach you all of the basics of chemistry. It will only teach you what you need to know for the FE exam. The FE reference handbook provides insight into what you need to know for the FE exam. The handbook has a section called Chemistry & Biology, so you will have to filter out the biology information from this section. The handbook shows the periodic table, pH equations, bioconversion equations and some basic definitions. The chemistry/biology section in the handbook also has a list of electrochemistry half reactions. There are some topics in the handbook that are for the Chemistry FE exam and not covered in the Other Disciplines FE exam. These topics include the organic chemistry topic.

Section 3.0 Chemistry (5 to 8 Problems)		
NCEES Outline Value	**Engineering Pro Guides**	
	Section 1.0	Introduction
3A	Section 2.0	Oxidation and reduction (e.g., reactions, corrosion control)
3B	Section 3.0	Acids and bases (e.g., pH, buffers)
3C	Section 4.0	Chemical reactions (e.g., stoichiometry, equilibrium, bioconversion)
	Section 5.0	Practice Exam Problems

1.1 Molarity & Molality

The NCEES FE Reference handbook has some basic definitions that you should be familiar with and should be able to use to solve the problems.

Molality is a property of a solution and is defined as the number of moles of solute per mass of solvent. The solute is the substance that dissolves. The solvent is the substance that the solute dissolves into. Dissolving the solute into the solvent will create a solution. The SI units which are the units that you will use on the FE exam for Chemistry is moles per kilogram. Molality is more often used for concentration rather than molarity, because the volume can change as a function of temperature and pressure. The mass of the solution will remain constant.

Molarity is a property of a solution and is defined as the number of moles of the solute per volume of the solvent. The units used for molarity are moles per liter.

As an example, please see the calculations for molarity and molality.

Given a solution of HCL dissolved in 2 liters of water. The concentration of the solution is 100 mg/L of HCl.

$$Find\ the\ molar\ mass\ of\ HCl \rightarrow H\ \left[1\frac{g}{mol}\right] \&\ Cl\ \left[35.5\frac{g}{mol}\right] \rightarrow HCl \rightarrow 36.5\ \left[\frac{g}{mol}\right] \rightarrow\ 36{,}500\ \left[\frac{mg}{mol}\right]$$

$$Find\ the\ Molarity \rightarrow \frac{mol\ of\ HCl}{Liters\ of\ H_2O}\frac{100\frac{mg}{L}}{36{,}500\ \left[\frac{mg}{mol}\right]} =\ 0.00274\frac{mol}{L} = 2.74\ x\ 10^{-3}\ M$$

$$Find\ the\ Water\ Mass \rightarrow \rho_{H20}\left(1000\frac{grams}{Liters}\right) * 2\ Liters =\ 2{,}000\ g = 2\ kg$$

$$Find\ the\ Molality \rightarrow \frac{mol\ of\ HCl}{kg\ of\ H_2O} = \frac{\left(0.00274\frac{mol}{L}\right) * 2\ L}{2\ kg\ of\ H_2O} = 0.00274\frac{mol}{kg}$$

1.2 Chemical Substances, Compounds & Elements

A chemical substance is a matter with a consistent composition. A chemical substance can either be a compound or an element. An element consists of one atom, which is the basic unit of matter of an element. The periodic table of elements is provided to you in the FE Handbook and you will need to be able to navigate this table and to be able to answer questions on this table.

1.2.1 Periodic Table of Elements

The periodic table of elements contains all of the known elements. It is important for you to understand some of the basics of the periodic table, like the organization of the elements and also how to read and interpret each element's data.

The periodic table is organized from top left to right in order of the element's atomic number. The atomic number is the number of protons in the nucleus of an atom. The nucleus is the center of the atom and it is where the protons and neutrons are contained. The protons and neutrons account for the mass of the element.

Columns: The columns are each given a number and often these columns are called groups. The columns are labeled by a number.

Groups 1, 2 and 13-18: Each of those numbers relate to the number of valence electrons. The valence electrons are the electrons that are on the outer orbit of the nucleus. These valence electrons indicate the reactivity of an element. Those in groups 1, 2, 16 & 17 are more reactive while those in 18 and 13-15 will not be as reactive. Groups 1 & 2 correspond to having 1 & 2 valence electrons. Groups 13-18 corresponds to 3-8 valence electrons respectively.

Groups 3-12: These groups are called the transition metals and typically will have 2 valence electronics, but it is a little bit more complicated. There is a subshell but this discussion is outside of the scope of the FE exam.

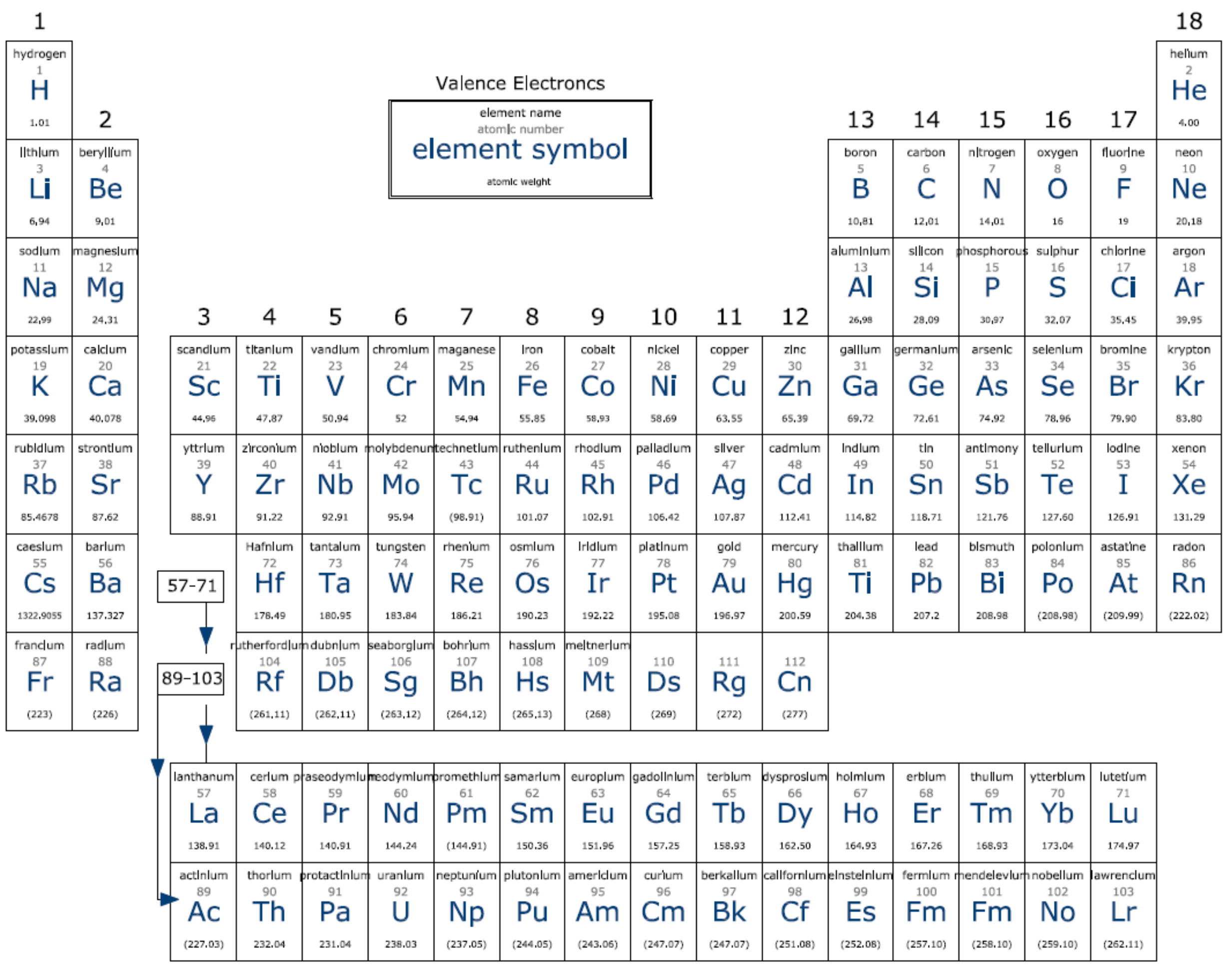


Figure 1: This figure shows the periodic table of elements. For the chemistry part of the FE Other Disciplines exam, you need to be knowledgeable of this table and will need to know how to use the values on the table to solve problems.

4 –Instrumentation & Controls

STUDY GUIDE
www.engproguides.com

Section 4.0 – Instrumentation & Controls

Table of Contents

1.0 INTRODUCTION

Instrumentation and Controls accounts for approximately 4 to 6 questions on the Other Disciplines FE exam. This section covers the following topics, sensors, block diagrams, system response and measurement uncertainty. In the sensors topic, you must be familiar with the types of sensors that are used to measure, strain, temperature and pressure, since these are the properties that are most commonly used in mechanical engineering, unlike the pH and chemical sensors which are also shown in the *NCEES FE Reference Handbook.* Block diagrams are used to analyze a control system that consists of different functions in graphical format. You must be able to read and simplify these block diagrams for the FE exam. The system response topic focuses on how control systems respond to various inputs like step, ramp and parabolic inputs. This topic will teach you how to determine if a control system will be stable with the Routh test and how to determine the response error.

Section 4.0 Instrumentation and Controls (4 to 6 Problems)		
NCEES Outline Value	Engineering Pro Guides	
	Section 1.0	Introduction
4A	Section 2.0	Sensors (e.g., temperature, pressure, motion, pH, chemical constituents)
4B	Section 3.0	Data acquisition (e.g., logging, sampling rate, sampling range, filtering, amplification, signal interface, signal processing, analog/digital [A/D], digital/analog [D/A], digital)
4C	Section 4.0	Logic diagrams
	Section 5.0	Practice Exam Problems

2.0 SENSORS

The sensors that you need to know for the FE exam are those sensors that convert a physical measurement into an electrical signal. Typically, the physical measurement changes a circuit's resistance, which in turn changes the measured voltage, assuming that current remains constant. Others change the voltage directly, like in a thermocouple.

2.1 TEMPERATURE SENSORS

There are two main types of temperature sensors that you need to know for the FE exam, (1) Thermocouple and (2) Resistance Temperature Detector.

The thermocouple uses a composite of two dissimilar metals that creates a voltage as a function of temperature. As the temperature increases, the thermoelectric effect occurs and this effect creates a voltage difference between the two sides of the composite. There are wires that are connected to the opposite sides of the composite that measure the voltage. The voltage increases as the temperature of the composite temperature increases.

The resistance temperature detector works off the basic concept that as a metal increases in temperature its resistance decreases. Thus if the current is maintained constant, then the voltage drop through a metal will decrease as the resistance increases, which increases when the temperature decreases. When the temperature increases, the resistance decreases, which decreases the voltage drop.

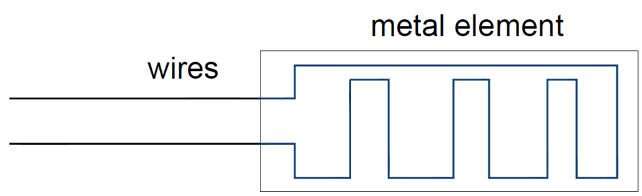


Figure 1: In a resistance temperature sensor, the metal element becomes more conductive as its temperature increases. This reduces the resistance which decreases the voltage drop.

2.2 Strain Gauge

A strain gauge is similar to the resistance temperature detector. A strain gauge consists of a foil-like element with a circuit running through it. This element is placed on a component that will undergo strain. As the component lengthens, the strain gauge will lengthen as well. This will cause the circuit wires within the strain gauge to become narrow, which will increase the resistance of the strain gauge.

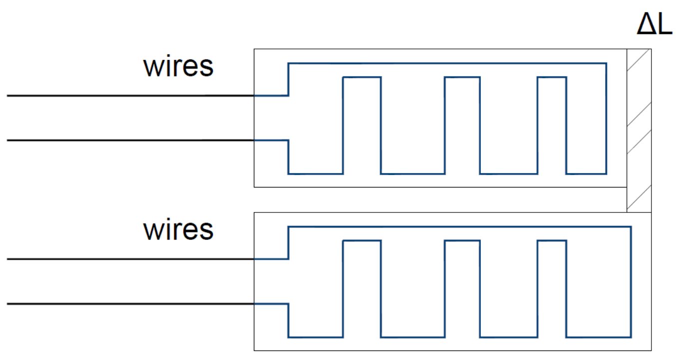


Figure 2: A strain gauge will measure the change in length of a component by measuring the change in resistance of the wires within the strain gauge.

The wires are connected to a Wheatstone bridge to measure the change in resistance. The change in resistance will correspond to a change in length of the component. This change in length can then be used to calculate strain. The ratio between the change in length of the strain gauge and the measured change in resistance is shown as the gauge factor. This gauge factor is pre-measured for each type of strain gauge. Typically the gauge factor is around 2.

$$Gauge\ Factor = G = \frac{\Delta R / R_0}{\Delta L / L_0} = \frac{\Delta R / R_0}{\varepsilon}$$

$$\varepsilon = strain; \Delta R = change\ in\ resistance\ (\Omega); R_0 = original\ resistance\ (\Omega)$$

$$\Delta L = change\ in\ length\ (m); R_0 = original\ length\ (m); \varepsilon = strain$$

5 – Engineering Ethics & Societal Impacts

STUDY GUIDE
www.engproguides.com

Section 5.0 – Ethics and Professional Practice

Table of Contents

1.0 INTRODUCTION

Ethics and Professional Practice accounts for approximately 5 to 8 questions on the Other Disciplines FE exam. The NCEES outline provides the following topics on its outline, Codes of Ethics, Public Protection Issues and Societal Impacts. There is no readily available or commonly used content that covers these topics, except for what is shown on the NCEES website and the *NCEES FE Reference Handbook*. In addition, the topics cover concepts that are open for interpretation. These two facts make it very difficult to fairly test this topic.

Section 5.0 Engineering Ethics and Societal Impacts (5 to 8 Problems)		
NCEES Outline Value		**Engineering Pro Guides**
	Section 1.0	Introduction
5A	Section 2.0	Codes of ethics (e.g., identifying and solving ethical dilemmas)
5B	Section 3.0	Public protection issues (e.g., licensing boards)
5C	Section 4.0	Societal impacts (e.g., economic, sustainability, life-cycle analysis, environmental, public safety)
	Section 5.0	Practice Exam Problems

1.1 CODES OF ETHICS

There are a couple of things you can do to prepare for questions on ethics.

(1) The first can be found in the *NCEES FE Reference Handbook*. There are about 8 pages on Ethics. This section covers the Codes of Ethics, Intellectual Property and the NCEES Model Law and Model Rules.

(2) The second is to read through the Model Law. The model law is published by NCEES and it is on the NCEES website. The link is shown below. The model law has very general regulations to govern engineering for the purposes of keeping the public safe. It is important to note that these laws are only ideas and it is up to each authority having jurisdiction like your State board to come up with their own laws.

NCEES Publications Website: https://ncees.org/about/publications/

Model Law Website: https://ncees.org/wp-content/uploads/Model_Law_2018.pdf

(3) You should also read through the Model rules. The model rules are published by NCEES and it is on the NCEES website. The link is shown below. The model rules complement the model laws. One key section in the model rules is the Rules of Professional Conduct.

Model Rules Website: https://ncees.org/wp-content/uploads/Model_Law_2018.pdf

6 – Safety, Health & Environment

STUDY GUIDE
www.engproguides.com

Section 6.0 – Safety, Health & Environment

Table of Contents

1.0 INTRODUCTION

Safety, Health & Environment accounts for approximately 6 to 9 questions on the Other Disciplines FE exam. The Safety section in the FE Handbook contains information on safety labels, brief descriptions of industrial hygiene topics like carcinogens, a chemical compatibility chart, a corrosion chart, EPA standard values for intakes, vaporization of flammable liquids equations, ergonomics, noise data, electrical safety, flammability limits tables, toxicity tables and a few other general safety topics like risk, hazard and confined spaces.

The FE handbook does not include information on gas detection and monitoring techniques, so it seems like that topic in this exam will focus on the flammability and toxicity tables. The exam could also focus on general knowledge on gas detection/monitoring equipment, which will be discussed in this section. The FE Handbook also does not include information on basic safety equipment like pressure relief valves, emergency shutoffs, fire prevention, and personal protective equipment. This means that the questions on this subtopic will focus on general knowledge of the common concepts and terms. This information will also be provided in this section.

An adjacent FE Handbook section that you will need to be familiar with is the Environmental Engineering section. There are formulas on half-life and radiation that you may need to use.

Section 6.0 Safety, Health & Environment (6 to 9 Problems)		
NCEES Outline Value	Engineering Pro Guides	
	Section 1.0	Introduction
6A	Section 2.0	Industrial hygiene (e.g., carcinogens, toxicology, exposure limits, radiation exposure, biohazards, half-life)
6B	Section 3.0	Basic safety equipment (e.g., pressure-relief valves, emergency shutoffs, fire prevention and control, personal protective equipment)
6C	Section 4.0	Gas detection and monitoring (e.g., O_2, CO, CO_2, CH_4, H_2S, radon)
6D	Section 5.0	Electrical safety
6E	Section 6.0	Confined space entry and ventilation rates
6F	Section 7.0	Hazard communications (e.g., SDS, proper labeling, concentrations, fire ratings, safety equipment)
	Section 8.0	Practice Exam Problems

2.0 INDUSTRIAL HYGIENE

Industrial hygiene is the study of predicting, recognizing, evaluating and ultimately controlling various factors that can arise in the workplace that could cause people to get sick or hurt and that could cause damage to the environment. This study covers carcinogens (things that cause cancer), toxic substances, flammable substances, radioactive substances and much more. Industrial hygiene covers air contaminants, dusts, fumes, mists, fibers and gases. It also covers

7 – Engineering Economics

STUDY GUIDE
www.engproguides.com

Section 7.0 – Engineering Economics

Table of Contents

1.0 INTRODUCTION

Engineering Economics accounts for approximately 6 to 9 questions on the Other Disciplines FE exam. As an engineer, you will be tasked with determining the course of action for a design. Often times this will entail choosing one alternative instead of several other design alternatives. You need to be able to present engineering economic analysis to your clients in order to justify why a certain alternative is more financially sound than other alternatives. The following topics will present only the engineering economic concepts that you need for the FE exam and does not present a comprehensive look into the study of engineering economics. For the FE exam you are required to know the following concepts shown in the table below. Applicable equations for these topics can be found in the Engineering Economics section of the *NCEES FE Reference Handbook*.

Section 7.0 Engineering Economics (6 to 9 Problems)		
NCEES Outline Value	Engineering Pro Guides	
	Section 1.0	Introduction
7A	Section 2.0	Time value of money (e.g., present worth, annual worth, future worth, rate of return)
7B	Section 3.0	Cost analysis (e.g., incremental, average, sunk, estimating)
7C	Section 4.0	Economic analyses (e.g., break-even, benefit-cost, optimal economic life)
7D	Section 5.0	Uncertainty (e.g., expected value and risk)
7E	Section 6.0	Project selection (e.g., comparison of projects with unequal lives, lease/buy/make, depreciation, discounted cash flow, decision trees)
7F	Section 7.0	Practice Exam Problems

2.0 Time Value of Money

2.1 Future and Present Value

Before discussing interest rates, it is important that the engineer understands that money today is worth more than that same value of money in the future, due to factors such as inflation and interest. This is the time value of money concept. For example, if you were given the option to have $1,000 today or to have $1,000 ten years from now, most people will choose $1,000 today, without understand why this option is worth more. The reason $1,000 today is worth more is because of what could have done with that money; in the financial world, this means the amount of interest that could have been earned with that money. If you took $1,000 today and invested it at 4% per year, you would have $1,040 dollars at the end of the first year.

$$\$1{,}000\ x\ (1+.04) = \$1{,}040$$

- If you kept the $1,040 in the investment for another year, then you would have $1,081.60.

$$\$1{,}040\ x\ (1+.04) = \$1{,}081.60$$

- At the end of the 10 years the investment would have earned, $1,480.24.

$$\$1{,}000\ x\ (1+.04)x(1.04)x(1.04)\ \dots\dots = \$1{,}000\ x\ (1.04)^{10} = \$1{,}480.24$$

- An important formula to remember is the Future Value (FV) is equal to the Present Value (PV) multiplied by (1+interest rate), raised to the number of years.

$$PV\ x\ (1+i)^{10} = FV$$

8 - Statics

STUDY GUIDE
www.engproguides.com

Section 8.0 – Statics

Table of Contents

1.0 INTRODUCTION

Statics accounts for approximately 9 to 14 questions on the Other Disciplines FE exam. These questions can cover statics, but not dynamics. The statics topic on the NCEES exam is similar to a common statics college engineering class. Statics is the study of components at equilibrium, which means the components are at rest or at zero acceleration. This topic includes vectors, free body diagrams, moments, reaction forces, first moment of area, static friction and second moment of area. These concepts and skills are used to solve problems on pulleys, cables, springs, beams, trusses, frames, etc.

The *NCEES FE Reference Handbook* Statics section has some basic equations for the topics below, but it does not explain the skills and concepts necessary to use these equations. You should learn the skills and concepts presented in this section and go through the handbook to confirm that you know how to use the basic equations. You may also need to know some of the Mathematics equations like law of cosines and other trigonometry equations presented in the Mathematics section.

Section 8.0 Statics (9 to 14 Problems)		
NCEES Outline Value	**Engineering Pro Guides**	
	Section 1.0	Introduction
8A	Section 2.0	Vector Analysis
8B	Section 3.0	Force systems (e.g., resultants, concurrent, distributed)
8C	Section 4.0	Force couple systems
8D	Section 5.0	Equilibrium of rigid bodies (e.g., support reactions)
8E	Section 6.0	Internal forces in rigid bodies (e.g., trusses, frames, machines)
8F	Section 7.0	Area properties (e.g., centroids, moments of inertia, radius of gyration, parallel axis theorem)
8G	Section 8.0	Static Friction
8H	Section 9.0	Free-body diagrams
8I	Section 10.0	Weight and mass computations (e.g., slug, lbm, lbf, kg, N, ton, dyne, g, gc)
	Section 9.0	Practice Exam Problems

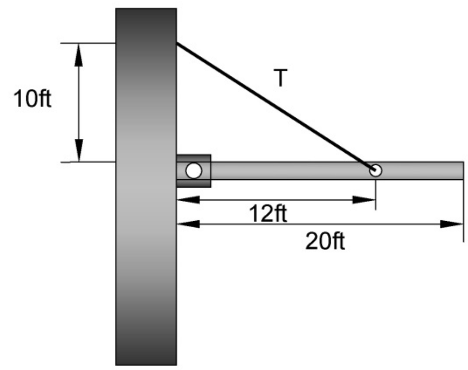
2.0 VECTOR ANALYSIS

As previously stated, statics is the study of mechanical components at equilibrium, which means the components have zero acceleration or are at rest. The material presented on statics focuses on the key equations and skills necessary to complete the possible problems within this topic on the FE exam.

10.0 PRACTICE EXAM PROBLEMS

10.1 PRACTICE PROBLEM 1 – BALANCING MOMENT

A beam of weight 100 lbs is supported by a tension cable. The dimensions are shown in the diagram below. What is the tension in the cable?



(A) 100 LBS

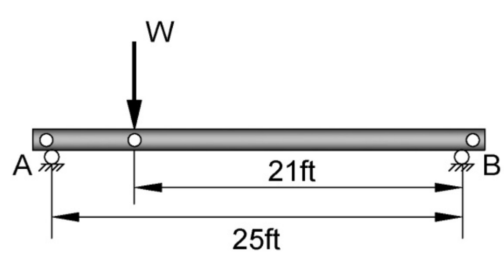
(B) 130 LBS

(C) 160 LBS

(D) 190 LBS

10.2 PRACTICE PROBLEM 2 – BALANCING MOMENT

A beam has a weight of 450 lbs and there is a point load of 150 lbs as shown in the figure below. What is the reaction force at point A?



(A) 100 LBS

(B) 150 LBS

(C) 250 LBS

(D) 350 LBS

11.0 SOLUTIONS

11.1 SOLUTION 1 – BALANCING MOMENT

This problem is solved by balancing the moment about the fulcrum. The moment about this point must be equal to zero. The force due to gravity occurs at the center of the beam at 10 ft from the fulcrum. The tension has a vertical component and a horizontal component. The horizontal component is not included in the moment equilibrium equation since it does not cause rotation.

$$\sum M_{fulcrum} = 0$$

$$\sum M = 0 = -100lbs * 10ft + Tsin(\theta) * 12ft$$

The angle theta is found through the following equation.

$$tan(\theta) = \frac{10\ ft}{12\ ft} \rightarrow 39.8°$$

Insert theta and solve for T.

$$0 = -100lbs * 10ft + Tsin(39.8°) * 12ft$$

$$T = 130\ lbs$$

The correct answer is most nearly, **(B) 130 LBS**.

11.2 SOLUTION 2 – BALANCING MOMENT

First, balance the moment about A. The weight of the beam occurs at the center of the beam.

$$\sum M_A = 0$$

$$\sum M = 0 = -150lbs * 4ft - 450lbs * 12.5ft + R_B * 25ft$$

Solve for reaction at B.

$$R_B = \frac{150lbs * 4ft + 450lbs * 12.5ft}{25\ ft} = 249\ lbs$$

Next balance all the forces in the Y-direction. Since the beam is not moving or accelerating, then the sum of the forces should be equal to zero.

$$0 = R_A + R_B - Weight - Point\ Load$$

$$0 = R_A + 249\ lbs - 450\ lbs - 150\ lbs$$

9 – Dynamics

STUDY GUIDE
www.engproguides.com

Section 9.0 – Dynamics, Kinematics and Vibrations

Table of Contents

1.0 INTRODUCTION

Dynamics, Kinematics and Vibrations accounts for approximately 9 to 14 questions on the Other Disciplines FE exam. This section first discusses, (1) particles and (2) rigid bodies. Particles are a single mass subject and rigid bodies consist of a collection of particles into a solid body that does not deform. The kinematics, work, energy, impulse and momentum and kinetics equations first focus on a single mass subject. You may be familiar with problems that had a block moving down a hill or a ball being thrown. These types of problems covered particles. Problems on rigid bodies are those that contain mechanical components like cams where one part of the body moves relative to another part of the body. The Other Disciplines exam does not seem to focus on those mechanical components.

Kinematics covers the movement, speed and acceleration of particles and rigid bodies. This includes radial movement and movement due to gravity. Kinetics builds upon kinematics by including force and energy, which also transitions into the work-energy topic. Lastly, this section covers friction and impulse-momentum.

Section 9.0 Dynamics, Kinematics & Vibrations (9 to 14 Problems)		
NCEES Outline Value	Engineering Pro Guides	
	Section 1.0	Introduction
9A	Section 2.0	Particle and rigid-body kinematics
9B	Section 2.1	Linear motion (e.g., force, mass, acceleration)
9C	Section 2.2	Angular motion (e.g., torque, inertia, acceleration)
9D	Section 3.0	Mass moment of inertia
9E	Section 4.0	Impulse and momentum (e.g., linear, angular)
9F	Section 5.0	Work, energy, and power
9G	Section 8.0	Dynamic friction
9H	Section 9.0	Vibrations (e.g., natural frequency)
9I	Section 10.0	Practice Exam Problems

2.0 PARTICLE & RIGID BODY KINEMATICS

Kinematics type problems will be centered on finding one of these three variables, (1) the distance traveled by an object, (2) the velocity of an object or (3) the acceleration of an object at any given time or location. If a problem asks for one of these three variables and forces are not involved, then most likely the solution will be found using the equations presented in the kinematics topic.

Within the topic of kinematics you may encounter problems with either linear motion or angular motion. Linear motion is the movement of an object within the x-y-z plane in either a straight line or a curve. Curve type movement is typical of projectiles and straight line movement is typical of vehicles, sliding blocks, pistons and springs. Angular motion is the circular movement of an object about an axis, within the x-y-z plane. This type of movement is typical of gears, pumps, fans and any other equipment that rotates about an axis.

3.0 LINEAR MOTION

Linear motion is the movement of an object from one location to another, while angular motion is the movement about an axis. You will need to be familiar with the three forms of linear motion: (1) displacement, (2) velocity and (3) acceleration.

3.1.1 Linear Displacement

The first variable in linear motion is displacement.

$$x(t)$$

$$Constant\ velocity \rightarrow x_f = x_i + vt; a = 0;$$

On the FE exam, you can use the following equations to help you solve any kinematics problems for the distance (x_f) when there is constant acceleration.

Solving for Distance with Uniform Acceleration (a; V_i ; x_i = 0)			
$x_f = x_i + V_i t + \frac{1}{2}at^2$	$x_f = \frac{(V_f + V_i)t}{2}$	$x_f = \frac{(V_f^2 - V_i^2)}{2a}$	$x_f = V_f t - \frac{1}{2}at^2$

3.1.2 Linear Velocity

The instantaneous velocity at a time (t) is the derivative of the position.

$$v(t) = \frac{dx}{dt};\ \ Units \rightarrow \frac{m}{s}\ or\ \frac{ft}{s}$$

The average velocity of an object can be found by dividing the change in position over a specific time interval.

$$Average\ velocity = \frac{\Delta x}{\Delta t}$$

On the FE exam, you can use the following equations to help you solve any kinematics problems for the specific scenario of uniform acceleration.

Solving for Velocity with Uniform Acceleration (a; V_i ; x_i = 0)			
$V_f = V_i + at$	$V_f = \frac{2x_f}{t} - V_i$	$V_f = \frac{x_f}{t} + \frac{1}{2}at$	$V_f = \sqrt{V_i^2 + 2ax_f}$

3.1.3 Linear Acceleration

10 – Strength of Materials

STUDY GUIDE
www.engproguides.com

Section 10.0 – Strength of Materials

Table of Contents

1.0 INTRODUCTION

Mechanics of Materials accounts for approximately 9 to 14 questions on the Other Disciplines FE exam. Mechanics of Materials questions basically will cover calculating the stress or strain due to different loadings, like axial loads, bending loads, torsional loads and shear loads. In addition, you will have to calculate the displacement, shear force and moments for beams and the buckling forces and stresses in columns.

The equations shown in the *NCEES FE Reference Handbook* on Mechanics of Materials is comprehensive and all of these equations are fairly simple and easy to use. This means that the equations do not have any complex math. After going through this section, you should be familiar with the different types of loadings and all the equations within the handbook and should be able to quickly recognize when to use each equation for each problem.

Section 10.0 Strength of Materials (9 to 14 Problems)		
NCEES Outline Value	**Engineering Pro Guides**	
	Section 1.0	Introduction
10A	Section 2.0	Stress Types (e.g., normal, shear)
10B	Section 3.0	Combined loading–principle of superposition
10C	Section 4.0	Stress and strain caused by axial loads, bending loads, torsion, or transverse shear forces
10D	Section 5.0	Shear and moment diagrams
10E	Section 6.0	Analysis of beams, trusses, frames, and columns
10F	Section 7.0	Loads and deformations (e.g., axial-extension, torque-angle of twist, moment-rotation)
10G	Section 8.0	Stress transformation and principal stresses, including stress-based yielding and fracture criteria (e.g., Mohr's circle, maximum normal stress, Tresca, von Mises)
10H	Section 9.0	Material failure (e.g., Euler buckling, creep, fatigue, brittle fracture, stress concentration factors, factor of safety, and allowable stress)
	Section 10.0	Practice Exam Problems

2.0 STRESS TYPES

Stress is described as the internal force acting upon a specific cross sectional area within an object. The equation below shows that stress is equal to the force divided by the area. The units of stress are in "psi" or "kips" for imperial units and Megapascal for SI units.

$$\sigma = \frac{F}{A}$$

$$Stress\ (Pa) = \sigma = \frac{Load\ (N)}{Area\ (m^2)}\ \text{[SI Units]}$$

$$Stress\ (psi) = \sigma = \frac{Load\ (lbf)}{Area\ (in^2)}\ \text{[English Units]}$$

You may encounter both sets of units on the FE exam, so you should be familiar with both and should commit these conversions to memory.

SI Units	*Imperial Units*	*Conversion*
Megapascal(MPa) *1 Pascal(Pa) = 1 N/m²* *Kilo (103), Mega (106), Giga (109)*	*lb/in²(psi)*	*1 MPa = 145 psi*
	Kip/in²(ksi) [kip = 1,000 lb]	*7 MPa = 1 ksi*

The strength of a material with respect to stress is the maximum stress that a material can withstand before failing. For brittle materials, failure occurs at ultimate stress.

$$Brittle \rightarrow \sigma_{ultimate};$$

For ductile materials, the maximum stress for a design *could be* the yield stress, because an object will no longer perform to design if it passes the yield strength and becomes permanently deformed.

$$Ductile \rightarrow \sigma_{yield};$$

On the FE exam, you should be careful to make sure you use the correct maximum stress for the correct type of material and situation. The following two graphs illustrate the difference between the yield stress and ultimate stress for brittle and ductile materials.

11 – Materials

STUDY GUIDE
www.engproguides.com

Section 11.0 – Materials

Table of Contents

1.0 INTRODUCTION

Materials accounts for approximately 8 to 12 questions on the Other Disciplines FE exam. This section works in conjunction with *Section 10 Strength of Materials*.

There are a few pages on Material Properties & Processing in the *NCES FE Reference Handbook* that you should be familiar with in order to pass the FE exam. However, in order to use those pages you need to understand the concepts and skills presented in this section.

Section 11.0 Materials (8 to 12 Problems)		
NCEES Outline Value	**Engineering Pro Guides**	
	Section 1.0	Introduction
11A	Section 2.0	Physical (phase diagrams) properties of materials (e.g., alloy phase diagrams, phase equilibrium, and phase change)
11B	Section 3.0	Mechanical properties of materials
11C	Section 4.0	Chemical properties of materials
11D	Section 5.0	Thermal properties of materials
11E	Section 6.0	Electrical properties of materials
11F	Section 7.0	Material selection
	Section 8.0	Practice Exam Problems

2.0 PHYSICAL PROPERTIES

During the exam you will need to be able to find and use material properties to complete many problems. You should be very familiar with your resources and where to find these material properties. As you go through these descriptions of the important material properties, look through the *NCEES FE Reference Handbook* so you can become familiar with the available properties and the units.

2.1 DENSITY

The density of a substance is its mass per unit volume, basically how heavy is something in one cubic foot or one cubic meter.

$$density, \rho = \frac{mass}{Volume}\left[\frac{lbm}{ft^3}, \frac{lbm}{in^3}, \frac{kg}{m^3} or \frac{g}{cm^3}\right]$$

Common Conversion Factors:

$$1\frac{lbm}{ft^3} = 0.000578\frac{lbm}{in^3}$$

$$1\frac{kg}{m^3} = 0.001\frac{g}{cm^3} = 0.0624\frac{lb}{ft^3}$$

The density is typically used to calculate the overall weight of a material based on its volume. The table below lists densities of common metals. You may find that different sources have varying densities for metal alloys. Therefore, it is likely that the test will provide you with the density values when referencing an alloy to avoid possible discrepancies.

Material	**Density (lb/in^3)**
Aluminum Base	
Aluminum (Pure)	0.097
Aluminum 6061	0.098
Copper Base	
Copper (Pure)	0.323
Cupronickel, 30%	0.323
Commercial Bronze, 90%	0.318
Bronze (Aluminum, 9%)	0.276
Yellow Brass	0.306
Naval Brass	0.304
Nickel Base	
Nickel	0.321
Monel	0.305
Cast Iron/Steel Base	
Gray Cast Iron	0.250
Ductile Iron	0.250
Cast Steel, 3% Carbon	0.250
Stainless Steel	
304SS	0.290
316SS	0.290
Titanium	
Titanium (Pure)	0.163
Zinc	
Zinc (Pure)	0.258
Other	
Water	$3.6\text{x}10^{-5}$ (0.0624 lb/ft^3)

Specific volume is the inverse of density and is measures as a volume per unit mass.

$$specific\ volume, v = \frac{1}{\rho}\left[\frac{ft^3}{lb}\ or\ \frac{m^3}{kg}\right]$$

2.2 Melting Point

The melting point is the temperature at which a solid will turn into a liquid at atmospheric pressure. An alloy may have two melting points, solidus and liquidus. *Solidus* is the

12 – Fluid Mechanics

STUDY GUIDE
www.engproguides.com

Section 12.0 – Fluid Mechanics

Table of Contents

1.0 INTRODUCTION

Fluid mechanics accounts for 12 to 18 problems on the Other Disciplines FE Exam. The topics range from college fluid mechanics topics like fluid properties, fluid statics, energy, impulse, momentum, internal flow, external flow and compressible flow to the topics that are more often used in practice like incompressible flow, power, efficiency, performance curves and scaling laws for fans, pumps and compressors. As you go through this section, you should also check the fluids topics within the *NCEES FE Reference Handbook*.

Section 12.0 Fluid Mechanics (12 to 18 Problems)		
NCEES Outline Value	**Engineering Pro Guides**	
	Section 1.0	Introduction
12A	Section 2.0	Fluid properties (e.g., Newtonian, non-Newtonian, liquids and gases)
12B	Section 3.0	Dimensionless numbers (e.g., Reynolds number, Froude number, Mach number)
12C	Section 4.0	Laminar and turbulent flow
12D	Section 5.0	Fluid statics (e.g., hydrostatic head)
12E	Section 6.0	Energy, impulse, and momentum equations (e.g., Bernoulli equation)
12F	Section 7.0	Pipe and duct flow and friction losses (e.g., pipes, valves, fittings, laminar, transitional and turbulent flow)
12G	Section 8.0	Open-channel flow (e.g., Manning's equation, drag)
12H	Section 9.0	Fluid transport systems (e.g., series and parallel operations)
12I	Section 10.0	Flow measurement (e.g., pitot tube, venturi meter, weir)
12J	Section 11.0	Turbomachinery (e.g., pumps, turbines, fans, compressors)
12K	Section 12.0	Ideal gas law (e.g., mixtures of nonreactive gases)
12L	Section 13.0	Real gas law (e.g., z factor)
	Section 14.0	Practice Exam Problems

2.0 FLUID PROPERTIES

During the exam you will need to be able to find and use fluid properties to complete many problems. You should be very familiar with the *NCEES FE Reference Handbook* and where to find these fluid properties. As you go through these descriptions of the important fluid properties, look through the handbook and you will see that the only fluids mentioned in the handbook with all of these properties are air and water. This should give you an indication that most of the

13 – Basic Electrical Engineering

STUDY GUIDE
www.engproguides.com

Section 13.0 – Basic Electrical Engineering

Table of Contents

1.0 INTRODUCTION

Basic Electrical Engineering accounts for approximately 6 to 9 questions on the Other Disciplines FE exam. These questions can cover the following NCEES outline topics: KCL, KVL, series & parallel equivalent circuits, Thevenin & Norton theorems and node & loop analysis. These topics are all techniques that you can use to simplify complex DC (direct current) circuits. Each of these techniques are discussed in detail with example problems in this section. The next three topics from the NCEES outline are waveform analysis, phasors and impedance. These topics are most often covered under AC (alternating current) circuits.

The Electrical and Computer Engineering section of the *NCEES FE Reference Handbook* has all of the basic equations you need to solve any circuit analysis problem, like KCL, KVL series, parallel, etc. However, it is recommended that you read through the following section, complete the practice problems and commit the common equations to memory. This will save you a lot of time on the many easy questions that should come out of this topic, which can then be used for the more complex questions.

Section 13.0 Basic Electrical Engineering (6 to 9 Problems)

NCEES Outline Value	Engineering Pro Guides' Topic	
	Topic 1.0	Introduction
13A	Topic 2.0	Electrical fundamentals (e.g., charge, current, voltage, resistance, power, energy)
13B	Topic 3.0	Current and voltage laws (e.g., Kirchhoff, Ohm)
13C	Topic 4.0	AC and DC circuits (e.g., real and imaginary components, complex numbers, power factor, reactance and impedance, series, parallel, capacitance and inductance, RLC circuits)
13D	Topic 5.0	Measuring devices (e.g., voltmeter, ammeter, wattmeter)
13E	Topic 6.0	Three-phase power (e.g., motor efficiency, balanced loads, power equation)
	Topic 7.0	Practice Exam Problems

2.0 Electric Fundamentals

2.1 Charge

An electric charge, Q, describes the number of electrons or protons there are. It can be positive (protons) or negative (electrons) and is measured in Coulombs (C). For example, one electron has -1.6×10^{-19} C of charge and one proton has $+1.6 \times 10^{-19}$ C. The movement of electrons is the foundation of how electricity works. It is unlikely that charge itself will be tested. It is more important to understand how charge is used to describe other concepts like current, power, voltage, and energy.

2.2 Current

Current, I, is the movement of charge and is more specifically defined as the rate at which charge flows. It is represented in terms of Amps, where one amp is equal to the movement of one Coulomb of charge per second.

$$Current, I(Amps) = \frac{Charge\ (C)}{Time\ (\text{sec})}$$

$$I = \frac{dq}{dt} \quad \rightarrow \quad Charge, Q = \int_{t1}^{t2} i(t)\, dt$$

For steady flow, current can be calculated as:

$$I\ (Amps) = \frac{\Delta Q}{\Delta t}$$

One characteristic to distinguish is that current flows in the opposite direction of electrons. Current flows from positive to negative, see the green arrow in the figure below, start at the positive end of the battery, loop around the circuit and end at the negative end. Electrons on the other hand are attracted to positive charge, so it will flow from negative to positive, as shown in red below.

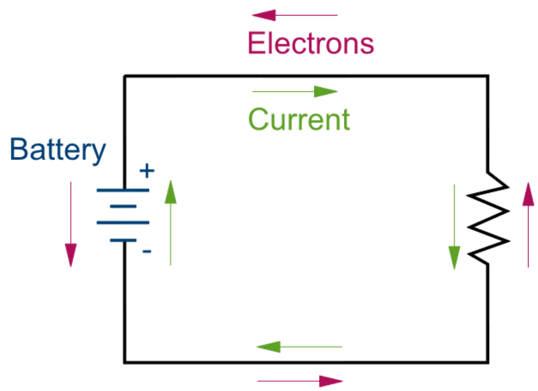


Figure 1: Current flows in a circuit from the positive end of the battery to the negative, as shown in green, while electrons flow from negative to positive.

Direct current (DC) is the supply of current in one direction. As mentioned previously, current flows from the positive voltage terminal to the negative terminal in a circuit. Current is deemed positive when it flows in this direction. Current is considered negative when it flows from a negative terminal to a positive terminal. DC current is a constant source and does not switch between negative and positive. The simplest example of a DC source is a battery.

Alternating current (AC) is able to supply current in both directions, positive to negative and negative to positive. This is shown in the graph below, where the current can be positive (above the 0-axis) or negative (below the 0-axis). Alternating current is what is supplied by the electric company to buildings. Alternating current is further discussed in the Alternating Circuits topic.

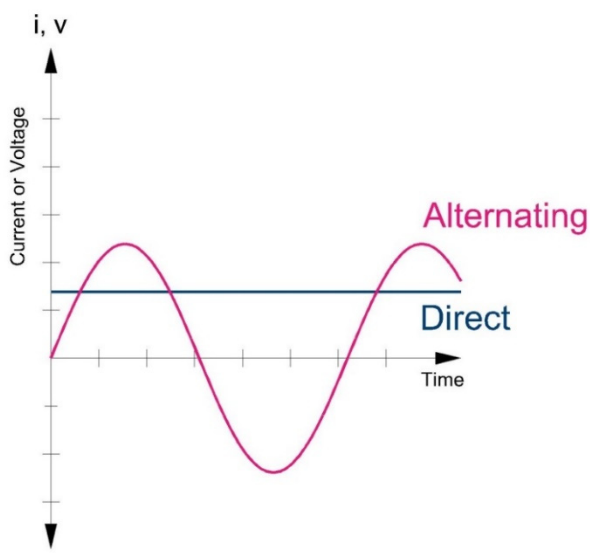


Figure 2: In an AC circuit, current can alternate its flow from positive to negative. In a DC circuit, current is constant.

14 – Thermodynamics & Heat Transfer

STUDY GUIDE
www.engproguides.com

Section 14.0 –Thermodynamics & Heat Transfer

Table of Contents

1.0 INTRODUCTION

Thermodynamics & Heat Transfer accounts for approximately 9 to 14 questions on the FE Other Disciplines exam. Thermodynamics & Heat Transfer is one of the largest topics on the FE Other Disciplines Exam. The following list is the outline of the Thermodynamics & Heat Transfer topics that can appear on the exam. This section will go into detail on the key concepts and skills that are necessary under each topic. Following, the key concepts and skills there will be problems that you can use to test your understanding of the concepts and skills.

Section 14.0 Thermodynamics & Heat Transfer (9 to 14 Problems)		
NCEES Outline Value	Engineering Pro Guides	
	Topic 1.0	Introduction
14A	Topic 2.0	Thermodynamic laws (e.g., first law, second law)
14B	Topic 3.0	Thermodynamic equilibrium
14C	Topic 4.0	Thermodynamic properties (e.g., entropy, enthalpy, heat capacity)
14D	Topic 5.0	Thermodynamic processes (e.g., isothermal, adiabatic, reversible, irreversible)
14D	Topic 6.0	Power Cycles
14D	Topic 7.0	Refrigeration Cycles
14E	Topic 8.0	Heat transfer (e.g., conduction, convection, radiation)
14F	Topic 9.0	Mass and energy balances
14G	Topic 10.0	Property and phase diagrams (e.g., T-s, P-h, P-v)
14H	Topic 11.0	Combustion and combustion products (e.g., CO, CO2, NOX, ash, particulates)
14I	Topic 12.0	Psychrometrics (e.g., relative humidity, wet bulb)
	Topic 13.0	Practice Exam Problems

2.0 THERMODYNAMICS LAWS

There are three main laws of thermodynamics as shown below. But you don't need to understand the theory behind these thermodynamic laws, you just need to be able to apply these laws to the thermodynamic problems as shown throughout the remaining topics in this section.

1st Law of Thermodynamics: The first law of thermodynamics is the conservation of energy, which was briefly discussed in the previous topic.

2nd Law of Thermodynamics: The second law is that entropy always increases.

3rd Law of Thermodynamics: The third law is that the entropy of a system approaches zero as the temperature approaches absolute zero.

15 – Full Exam

STUDY GUIDE
www.engproguides.com

1.0 FULL EXAM PROBLEMS

Total time for the 110 questions is 5 hours and 20 minutes.

-- START SESSION 1 –

1.1 PROBLEM 1 – MATHEMATICS

Convert the following value to polar form.

$$5 + \sqrt{-49}$$

(a) $8.6\angle 55°$

(b) $5 + 7\angle 50°$

(c) $8.6\angle - 55°$

(d) $5\angle - 55°$

1.2 PROBLEM 2 – MATHEMATICS

Find the product of the following two vectors, a & b.

$$a = 5 + 6i;\ \ b = \sqrt{2} - 7i;$$

(a) $56\angle 28°$

(b) $49\angle 14°$

(c) $56\angle - 28°$

(d) $49\angle - 14°$

1.5 PROBLEM 5 – MATHEMATICS

The following a-b-c triangle has sides and an angle shown below. What is the length of the remaining side?

$$a = 20; B = 75°; c = 30;$$

(a) 23

(b) 27

(c) 31

(d) 990

1.6 PROBLEM 6 - MATHEMATICS

Find the inflection point of the following equation.

$$y = e^x - 5x^2$$

(a) (2.3, -16.5)

(b) (-2.3, -16.5)

(c) (16, 2)

(d) (2.3, 0)

1.13 Problem 13 - Probability & Statistics

A fair, 6-sided die is rolled 9 times. What is the probability that a 4 is rolled only once?

(a) 0.15

(b) 0.35

(c) 0.66

(d) 0.81

1.14 Problem 14 - Probability & Statistics

A fair, 6-sided die is rolled 8 times. What is the probability that an even number is rolled less than 4 times?

(a) 0.03

(b) 0.10

(c) 0.22

(d) 0.36

1.22 Problem 22 – Instrumentation & Controls

A Wheatstone bridge is used to measure the change in resistance in a thermistor. The resistors all have a resistance equal to 20 ohms when the output voltage is 0 V and the input voltage is 24 V. If the variable resistor has a change of +5 ohms, then what will be the change in voltage?

(a) 1.0 V

(b) 1.5 V

(c) 3.0 V

(d) 6.0 V

1.23 Problem 23 – Instrumentation & Controls

A strain gauge has a gauge factor of 3.1. The unstrained resistance is equal to 95 ohms. There is a change in resistance of 0.08 ohms. What is the measured strain?

(a) 2.7×10^{-4}

(b) 9.7×10^{-4}

(c) 4.1×10^{-3}

(d) 6.5×10^{-2}

1.26 Problem 26 – Ethics and Professional Practice

Which of the following statements is most nearly NOT true regarding engineers issuing public statements?

(a) Engineers shall issue public statements only in an objective and truthful manner.

(b) Engineers may always express publicly technical opinions.

(c) Engineers may always issue criticisms on technical matters that are paid for by interested parties.

(d) Engineers shall issue public statements along with any pertinent information and the date indicating when it was current.

1.27 Problem 27 - Ethics and Professional Practice

Which of the following statements is most nearly true regarding public safety?

(a) Engineers may take assignments when not qualified by education or experience, as long as they disclose this information to their client.

(b) Engineers may affix their stamp to plans that have not been prepared under their direction or control.

(c) Engineers must not take assignments outside of their qualifications.

(d) Engineers may coordinate and assume responsibility for other engineers' work as long as the engineers are qualified.

1.36 PROBLEM 36 – SAFETY, HEALTH & ENVIRONMENT

Cyanides will generate toxic gas with which of the following chemicals?

(a) Acids

(b) Esters

(c) Ethers

(d) Fluorides

1.37 PROBLEM 37 – ENGINEERING ECONOMICS

A new transformer costs $5,000 and has an annual maintenance cost of $250. If the salvage value is $1000 at the end of its 20 year life, then what is the annual value of this transformer? Assume an interest rate of 5%.

(a) $620

(b) $250

(c) -$250

(d) -$620

1.38 PROBLEM 38 - ENGINEERING ECONOMICS

Background: A 200 HP pump operates for 1500 hours in the year. The motor is 90% efficient and the power factor is 0.88. Energy cost is $0.23 per kilowatt-hour and monthly demand cost is $8.90/KVA.

Problem: How much does it cost to operate the pump in one year?

(a) $73,000

(b) $75,000

(c) $77,000

(d) $85,000

1.39 PROBLEM 39 - ENGINEERING ECONOMICS

A new machine is installed in order to increase productivity. This new machine costs $160,000 and has an ongoing operating and maintenance cost of $500 per month. The new machine will save $2,000 per month and will have a salvage value of $15,000 after 10 years. If the interest rate is 4%, then what is the annual cost of the new machine?

(a) $500

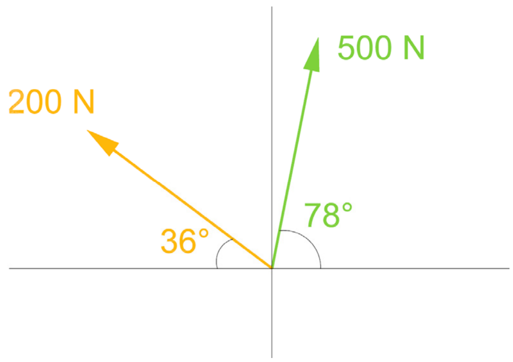
(b) $6,500

(c) $11,500

(d) $19,000

1.44 PROBLEM 44 – STATICS

Given the two force vectors shown in the vector below, find the x and y components of the combined force vector.



(a) F_x = -58 N; F_y = 607 N;

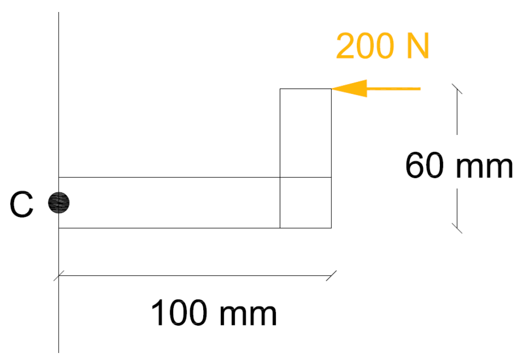
(b) F_x = -158 N; F_y = 75 N;

(c) F_x = -256 N; F_y = 444 N;

(d) F_x = -781 N; F_y = 856 N;

1.45 PROBLEM 45 – STATICS

What is the moment about point C, due to the force shown? Neglect the weight of the member.



(a) 12 N-m

(b) 18 N-m

(c) 24 N-m

(d) 32 N-m

1.58 Problem 58 – Dynamics, Kinematics and Vibrations

A force of 10 N is applied to a mass of 5 kg for 3 seconds. A force of 10 N is applied to a mass of 50 kg for 3 seconds. Which of the masses has the largest momentum?

(a) 5 kg mass

(b) 50 kg mass

(c) Momentums are equal

(d) Unable to determine

1.59 Problem 59 – Dynamics, Kinematics and Vibrations

A vibrating system is described as having a spring constant of 1,000 N/m and a mass of 50 kg. The viscous damping coefficient is 400 N-s/m. What is the damped frequency?

(a) 2 rad/s

(b) 4.5 rad/s

(c) 7.8 rad/s

(d) 10 rad/s

1.108 PROBLEM 108 – THERMODYNAMICS & HEAT TRANSFER

Which term is not applicable to calculating the convection coefficient of a forced convection fluid, regardless of the fluid viscosity and turbulence?

(a) Nusselt Number

(b) Reynold's Number

(c) Grashof Number

(d) Prandtl Number

1.109 PROBLEM 109 – THERMODYNAMICS & HEAT TRANSFER

Hot water enters a counterflow, plate and frame heat exchanger at 140 F at a rate of 50 gpm. Cold water is heated from 70F to 110F at a rate of 20 gpm. Given that the NTU is 1.4, what is the effectiveness of the heat exchanger?

(a) 0.6

(b) 0.7

(c) 0.8

(d) 0.9

2.0 Full Exam Solutions

-- START SESSION 1 --

2.1 Solution 1 – Mathematics

Convert the following value to polar form.

$$5+\sqrt{-49}$$

$$Remember\ that\ \sqrt{-1}\ is\ equal\ to\ i$$

$$5+\sqrt{-1}\sqrt{49}$$

$$5+7i$$

Now convert the complex rectangular number to polar form with your calculator.

$$5+7i \rightarrow 2nd \rightarrow complex \rightarrow polar \rightarrow 8.6\angle 54.5°$$

The correct answer is most nearly, **(a) $\mathbf{8.6\angle 55°}$.**

(a) $8.6\angle 55°$

(b) $5+7\angle 50°$

(c) $8.6\angle -55°$

(d) $5\angle -55°$

2.2 Solution 2 – Mathematics

Find the product of the following two vectors, a & b.

$$a = 5+6i;\ \ b=\sqrt{2}-7i;$$

There are multiple ways to solve this problem, but the easiest is to use your calculator. Make sure you put parentheses around the vectors.

$$(5+6i)(\sqrt{2}-7i) = 49-26.5i$$

$$(49-26.5i) \rightarrow 2nd \rightarrow complex \rightarrow polar \rightarrow 56\angle -28°$$

The correct answer is most nearly, **(c) $\mathbf{56\angle -28°}$.**

2.15 SOLUTION 15 - PROBABILITY & STATISTICS

A machined product must have a strength of 10 MPa. A sample of 10 products are tested out of the entire population of products. The mean of the sample is 9.8 MPa. The population standard deviation is 0.5 MPa. What is the probability that the population mean is greater than 10 MPa?

For this problem, you have your sample mean and your desired population mean. You also have your population standard deviation. This allows you to use the below equation from the Probability section of the FE Reference Handbook.

$$\mu = \bar{X} + Z_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}};$$

$$\mu = population\ mean;\ \ \bar{X} = sample\ mean;\ Z_{\frac{\alpha}{2}} = Z - factor\ from\ normal\ distribution\ table$$

$$\sigma = population\ standard\ deviation;\ n = number\ of\ samples$$

$$10 = 9.8 + Z_{\frac{\alpha}{2}} \frac{0.5}{\sqrt{10}}$$

$$Z\alpha_{/2} = 1.265;$$

Now, go to the Normal distribution table and find the resulting probability. You want to find the probability that this Z-factor is greater than 1.265, because this will make the population mean larger than 10 MPa.

$$Z\alpha_{/2} > 1.265; \quad R(1.265) = 10\%$$

The correct answer is most nearly, **(b) 10%**.

(a) 3%

(b) 10%

(c) 40%

(d) 90%

2.16 SOLUTION 16 - PROBABILITY & STATISTICS

A machined product must have a strength of 10 MPa. A sample of 10 products are tested out of the entire population of products. The mean of the sample is 9.8 MPa. The population standard deviation is unknown but the sample deviation is 0.9 MPa. What is the probability that the population mean is greater than 10 MPa? Hint: Use the t-distribution.

For this problem, you have your sample mean and your desired population mean. But you don't have your population standard deviation. This means you to use the below equation from the Probability section of the FE Reference Handbook.

$$\mu = \bar{X} + t_{\frac{\alpha}{2}} \frac{S}{\sqrt{n}};$$

$$\mu = population\ mean;\ \ \bar{X} = sample\ mean;\ Z_{\frac{\alpha}{2}} = Z - factor\ from\ normal\ distribution\ table$$

$$s = sample\ standard\ deviation;\ n = number\ of\ samples; degrees\ of\ freedom = n - 1$$

$$10 = 9.8 + t_{\frac{\alpha}{2}} \frac{0.9}{\sqrt{10}}$$

$$t\alpha_{/2} = 0.703;$$

Now, go to the t-distribution table and find the resulting probability with 9 degrees of freedom. You want to find the probability that this t-factor is greater than 0.703, because this will make the population mean larger than 10 MPa.

$$t\alpha_{/2} > 0.703;\quad \alpha(0.703, v = 9) = 25\%$$

The correct answer is most nearly, **(d) 25%**.

(a) 1%

(b) 5%

(c) 15%

(d) 25%

2.17 Solution 17 – Chemistry

Given the following the chemical reaction, determine the current equilibrium constant. The equilibrium constant during equilibrium is equal to 1 x 10^{-5}.

$$CaSO_4 \rightleftharpoons Ca^{+2} + SO_4^{-2}$$

$$Current:\ [Ca^{+2}] = 0.01M;\ \ [SO_4^{-2}] = 0.1\ M;\ \ [CaSO^4] = 0.5M$$

The equation for chemical equilibrium constant is shown in the chemistry section. Just remember that it is products over reactants.

$$K_{eq} = \frac{[0.01] * [0.1]}{0.5} = 0.002$$

The correct answer is most nearly, (c) 2 x 10^{-3}.

(a) 1 x 10^{-4}

(b) 6 x 10^{-4}

(c) 2 x 10^{-3}

$$2Ag^{+} + Cu \longrightarrow Cu^{2+} + 2Ag\ (+0.462)$$

The correct answer is most nearly, (c) 0.462 V.

(a) 1.13 V

(b) 0.799 V

(c) 0.462 V

(d) 0.009 V

2.22 SOLUTION 22 – INSTRUMENTATION & CONTROLS

A Wheatstone bridge is used to measure the change in resistance in a thermistor. The resistors all have a resistance equal to 20 ohms when the output voltage is 0 V and the input voltage is 24 V. If the variable resistor has a change of +5 ohms, then what will be the change in voltage?

$$Initial \rightarrow R_1 = R_2 = R_3 = R_4 = 20\ ohms$$

$$V_{Output} = \frac{\Delta R_4}{4R} V_{source} = \frac{5}{4(20)} 24\ V = 1.5\ V$$

The correct answer is most nearly, (b) 1.5 V.

(a) 1.0 V

(b) 1.5 V

(c) 3.0 V

(d) 6.0 V

2.23 SOLUTION 23 – INSTRUMENTATION & CONTROLS

A strain gauge has a gauge factor of 3.1. The unstrained resistance is equal to 95 ohms. There is a change in resistance of 0.08 ohms. What is the measured strain?

$$Gauge\ Factor = GF = \frac{\Delta R/R}{\Delta L/L}$$

$$GF = 3.1 = \frac{.08/95}{\varepsilon}$$

$$\varepsilon = 2.7\ x\ 10^{-4}$$

The correct answer is most nearly, (a) 2.7 x 10^{-4}.

(a) 2.7 x 10^{-4}

(b) 9.7 x 10^{-4}

(c) 4.1 x 10^{-3}

(d) 6.5 x 10^{-2}

2.24 Solution 24 – Instrumentation & Controls

A resistance temperature detector has a metal with a coefficient of $0.00210\ ^{\Omega}/_{\Omega\ °C}$. The initial conditions are 250 ohms and 20 °C. There is a change in resistance of 3 ohms. What is the final temperature?

$$R_T = R_O[1 + \alpha(T - T_O)]$$

$$253 = 250[1 + (0.00210)(T - 20\ C)]$$

$$T = 25.7\ °C$$

The correct answer is most nearly, (a) 25.7 °C.

(a) 25.7 °C

(b) 29.1 °C

(c) 36.3 °C

(d) 41.9 °C

2.25 Solution 25 – Instrumentation & Controls

A current waveform has a frequency of 60 Hz. What is the minimum sampling frequency?

According to Nyquist's sampling theorem in the Instrumentation, Measurement & Control section in the FE Handbook, the sampling frequency must be double the signal frequency.

$$n_{sampling} = 60Hz\ x\ 2 = 120\ Hz$$

The frequency is equal to the inverse of the period.

$$T = \frac{1}{120} s = 0.00833\ seconds$$

A sample must be completed in each sampling period.

The correct answer is most nearly, (a) 1 sample every 0.00833 seconds.

(a) 1 sample every 0.00833 seconds.

(d) -$620

2.38 Solution 38 - Engineering Economics

Background: A 200 HP pump operates for 1500 hours in the year. The motor is 90% efficient and the power factor is 0.88. Energy cost is $0.23 per kilowatt-hour and monthly demand cost is $8.90/KVA.

Problem: How much does it cost to operate the pump in one year?

(1) Find the KW draw from the motor:

Convert pump brake horsepower to motor horsepower.

$$P_{motor[HP]} = \frac{P_{pump[BHP]}}{\varepsilon_{motor}}$$

$$P_{motor[HP]} = \frac{200\ HP}{0.90} = 222\ HP$$

Convert to KW from HP

$$222\ HP * \frac{0.7457\ KW}{HP} = 165.6\ KW$$

(2) Find the yearly kilowatt-hours(kwh) consumed.

$$166\ KW * 1{,}500 \frac{hrs}{year} = 248{,}318\ kwh$$

Find the yearly energy cost ($)

$$248{,}318\ kwh * \frac{\$0.23}{kwh} = \$57{,}113$$

(3) Find the yearly demand cost ($)

$$(166\ KW) * \frac{1\ KVA}{0.88\ KW} * \frac{\$8.90}{KVA - month} * \frac{12\ month}{year} = \$20{,}097$$

(4) Find the total electricity cost ($)

$$\text{Total Electricity Cost} = \text{Energy Cost} + \text{Demand Cost}$$

$$\$57{,}113 + \$20{,}097 = \$77{,}210$$

The correct answer is most nearly. **(C), $77,000**

2.39 Solution 39 - Engineering Economics

A new machine is installed in order to increase productivity. This new machine costs $160,000 and has an ongoing operating and maintenance cost of $500 per month. The new machine will save $2,000 per month and will have a salvage value of $15,000 after 10 years. If the interest rate is 4%, then what is the annual cost of the new machine?

This problem involves finding the total annual cost. First, convert all your terms to an annual value.

Initial Cost [Negative value = money lost at the beginning of the lifetime]

$$First\ navigate\ to\ your\ engineering\ economics\ tables, 4\%$$

$$Convert\ Present\ value\ (P) to\ Annual\ value\ (A)$$

$$A = P * (\frac{A}{P}, 4\%, 10)$$

$$A = -\$160{,}000 * 0.12329$$

$$A_{initial} = -\$19{,}726$$

Salvage Value [Positive value = money gained at the end of the lifetime]

$$Convert\ Future\ value\ (F) to\ Annual\ value\ (A)$$

$$A = F * (\frac{A}{F}, 4\%, 10)$$

$$A = \$15{,}000 * 0.08329$$

$$A_{salvage} = \$1249$$

Operating & Maintenance Cost [Negative value = Money lost]

$$A_{O\&M} = \frac{-\$500}{month} * 12\ months = -\$6{,}000\ per\ year$$

Savings [Positive value = Money gained]

$$A_{savings} = \frac{\$2{,}000}{month} * 12\ months = \$24{,}000\ per\ year$$

Finally, sum up all annual values.

$$A_{total} = A_{initial} + A_{salvage} + A_{O\&M} + A_{savings}$$

$$A_{total} = -\$19{,}726 + \$1249 + -\$6{,}000 + \$24{,}000$$

$$A_{total} = -\$500$$

$$Q = 55\frac{m^3}{min} * \frac{1\ min}{60s} * \frac{kg}{0.837\ m^3} * (60.74 - 42.10)\frac{kJ}{kg} = 20.41\frac{kJ}{s}20.4\ kW$$

The correct answer is most nearly, (a) 20.4 kW

(a) 20.4 KW

(b) 25.5 KW

(c) 34.9 KW

(d) 1200 KW

2.107 SOLUTION 107 – THERMODYNAMICS & HEAT TRANSFER

1 kW of heat is added to 45 kg of air for 1 hour. Air is initially at a temperature of 30 °C. What is the final temperature after 1 hour?

The heat added is 1 kW, which is equal to 1000 J/s.

$$Q = 1\frac{kJ}{s} * (1\ hours) * \left(3600\frac{s}{hr}\right) = 45\ kG * \left(0.718\frac{kJ}{kg - C}\right) * (X - 30)$$

$$X = 141\ °C$$

The correct answer is most nearly, (d) 141 C.

(a) 75 °C

(b) 92 °C

(c) 101 °C

(d) 141 °C

2.108 SOLUTION 108 – THERMODYNAMICS & HEAT TRANSFER

Which term is not applicable to calculating the convection coefficient of a forced convection fluid, regardless of the fluid viscosity and turbulence?

(a) Nusselt Number

(b) Reynold's Number

(c) Grashof Number

(d) Prandtl Number

The correct answer is most nearly, (c) Grashof Number.

The Grashof number is the ratio of buoyancy forces to viscous forces and is used to calculate the convection coefficient for heat transfer from natural convection. Natural convection is where the fluid is moving due to temperature differences, like the temperature difference between a surface and the ambient air. Forced convection is due to the forced movement of the fluid, like water flowing in a pipe. The Nusselt Number, Reynold's Number, and Prandtl Number are all used to calculate forced convection coefficients. Prandtl and Nusselt numbers are also used in natural convection calculations.

2.109 SOLUTION 109 – THERMODYNAMICS & HEAT TRANSFER

Hot water enters a counterflow, plate and frame heat exchanger at 140 F at a rate of 50 gpm. Cold water is heated from 70F to 110F at a rate of 20 gpm. Given that the NTU is 1.4, what is the effectiveness of the heat exchanger?

(a) 0.6

(b) 0.7

(c) 0.8

(d) 0.9

The NTU method is used when the LMTD cannot be calculated.

Find the capacity rate ratio. Realize that the units will cancel out, so the mass flow rate can be left in gpm.

$$c_r = \frac{C_{min}}{C_{max}} = \frac{(\dot{m}c_p)_{min}}{(\dot{m}c_p)_{max}} = \frac{20gpm * 1\ Btu/lbmF}{50\ gpm * 1\ Btu/lbmF} = 0.4$$

For a counterflow heat exchanger, using the NTU method, the effectiveness is calculated as follows.

$$\varepsilon = \frac{1 - \exp[-NTU(1 - c_r)]}{1 - c_r \exp[-NTU(1 - c_r)]}\ for\ c_r < 1$$

$$\varepsilon = \frac{1 - \exp[-1.4 * (1 - 0.4)]}{1 - 0.4 * \exp[-1.4 * (1 - 0.4)]} = 0.69$$

The answer is most nearly **(b) 0.7**