Introduction

Part 1: How You Can Use This Book

QUICKSTART

If you never read the material at the front of your books anyway, and if you are in a hurry to begin and only want to read one paragraph, here it is:

> Most chapters in this book are independent. Start with any one and look through it. Decide if you are going to work problems in that subject. Solve as many practice problems in that subject as time allows. Use the index extensively. Don't stop studying until the exam. Start right now! Quickly! Good luck.

However, if you want to begin a thorough review, you should probably try to find out everything there is to know about the PE exam. The rest of this introduction is for you.

IF YOU ARE A PRACTICING ENGINEER

If you are a practicing engineer or an engineering major and have obtained this book as a general reference handbook, it will probably sit in your bookcase until you have a specific need.

However, if you are preparing for the PE examination in mechanical engineering, the following suggestions may help.

- Become intimately familiar with this book. This means knowing the order of the chapters, the approximate locations of important figures and tables, what appendices are available, and so on.
- Use the subject title tabs along the side of each page. The labels roughly correspond to PE exam subjects.
- Compare the Table of Contents with Table 2 to learn which subjects in this book are not covered in the PE exam. Some chapters in this book are supportive and do not cover exam topics. These chapters provide background and support for the other chapters.
- Skim through a chapter and its appendices. Familiarize yourself with the subjects before starting to solve practice problems.
- Identify and obtain a set of 10 to 30 solved practice problems for each of the exam subjects. I have written an accompanying book, *Practice Problems for the Mechanical Engineering PE Exam*, for this purpose. However, you may use problem sets from your old textbooks, college notes, or review course.
- Set a reasonable limit on the time you spend on each subject. It isn't necessary to solve an infinite number of practice problems. The number of practice problems you attempt will depend on how much time you have and how skilled you are in the subject.
- Use the solutions to your practice problems to check your work. If your answer isn't correct, figure out why.
- If you decide to work in customary U.S. (English) units, you will find equations in which the quantity g/g_c appears. For calculations at standard gravity, the numerical value of this fraction is 1.00. Therefore, it is necessary to incorporate this quantity only in calculations with a nonstandard gravity or when you are being meticulous with units.
- To minimize time spent in searching for often-used formulas and data, prepare a one-page summary of all the important formulas and information in each subject area. You can then use these summaries during the examination instead of searching in this book.
- Use the subject index extensively. Every significant term, law, theorem, and concept has been indexed in every conceivable way—backward and forward. If you don't recognize a term, look for it in the index.
- Some subjects appear in more than one chapter. Use the index liberally to learn all there is to know about a particular subject.

IF YOU ARE AN INSTRUCTOR

If you are teaching a review course for the PE examination without the benefit of recent, firsthand exam experience, you can use the material in this book as a guide to prepare your lectures. You should emphasize the subjects in each chapter and avoid subjects omitted. You can feel confident that subjects omitted from this book have rarely, if ever, appeared on the PE exam.

I have always tried to overprepare my students. Also, you will appreciate the fact that it is more efficient to cover several procedural steps in one practice problem than to ask simple "one-liners" or definition questions. Those are the reasons that my problems are often longer and harder than actual exam problems.

To do all the homework for some chapters requires approximately 15 to 20 hours of preparation per week. "Capacity assignment" is the goal in my review courses. If you assign 20 hours of homework, and a student is able to put in only 10 hours of preparation that week, that student will have worked to his or her capacity. After the PE examination, that student will honestly say that he or she could not have prepared any more than he or she did in your course.

Homework assignments in my review courses are not individually graded. Instead, students are permitted to make use of existing solutions to learn procedures and techniques to the problems in their homework set, such as those in the accompanying *Practice Problems for the Mechanical Engineering PE Exam*, which contains solutions to all practice problems. However, each student must turn in a completed set of problems for credit each week. Though I don't correct the homework problems, I address special needs or questions written on the assignments.

I have found that a 14-week format works well for a PE review course. It's a little rushed, but the course is over before everyone gets bored with my jokes. Each week, there is a three-hour meeting, which includes lecture and a short break. Table 1 outlines a course format that might work for you. If you can add more course time, your students will appreciate it. Another lecture covering HVAC or mechanical systems and materials would be wonderful. However, I don't think you can cover the full breadth of material in much less time or in many fewer weeks.

I have tried to order the subjects in a logical, progressive manner. For example, heat transfer and HVAC are dependent on thermodynamic principles, so they come after the thermodynamics chapters. Also, machine design comes after statics, engineering materials, and mechanics of materials.

Lecture coverage of some examination subjects is necessarily brief; other subjects are not covered at all. These omissions are intentional; they are not the result of scheduling omissions. Why? First, time is not on our side in a review course. Second, some subjects rarely contribute to the examination. Third, some subjects are not well received by the students. For example, I have found that very few people study modeling and systems analysis, material handling, and manufacturing methods. Unless you have two quarters in which to teach your PE review, your students' time can be better spent covering other subjects.

All the skipped chapters and any related practice problems are presented as floating assignments to be made up in the students' "free time."

I strongly believe in exposing my students to a realistic sample examination, but I no longer administer an in-class mock exam. Since the review course usually ends only a few days before the real PE examination, I hesitate to make students sit for several hours in the late evening to take a "final exam." Rather, I distribute and assign a take-home sample exam at the first meeting of the review course.

If the practice test is to be used as an indication of preparedness, caution your students not to even look at the sample exam prior to taking it. Looking at the sample examination or otherwise using it to direct their review will produce unwarranted specialization in subjects contained in the sample exam.

There are many ways to organize a PE review course, depending on your available time, budget, intended audience, facilities, and enthusiasm. However, all good

Table 1 *Typical PE Exam Review Course Format*

meeting	subject covered	chapters
1	introduction to the exam; units; mathematics	1, 3–12
2	thermodynamics	23–25
3	power cycles	27–33
4	compressible fluid flow	26
5	heat transfer	34–37
6	fluids and hydraulic machines	14–19
7	fans and ductwork	20
8	HVAC	38–42
9	combustion	22
10	engineering materials and statics	43–47
11	mechanics of materials	48–50
12	mechanical systems and machine design	51–54
13	kinematics of machinery	55–59
14	engineering economic analysis	69

course formats have the same result: The students struggle with the workload during the course, and then they breeze through the examination after the course.

Part 2: Everything You Ever Wanted to Know About the PE Exam

WHAT IS THE FORMAT OF THE PE EXAM?

The NCEES PE examination in mechanical engineering consists of two four-hour sessions separated by a one-hour lunch period. The morning "breadth" session is taken by all examinees. In the afternoon, you will be able to select from among three "depth" modules: HVAC and refrigeration, mechanical systems and materials (formerly known as "machine design"), and thermal and fluids systems. All three depth modules will be present in your examination booklet for review prior to making your selection. After you begin working in a depth module, you may leave it and begin working in another module. However, keep in mind that you won't be given any additional time.

Both the morning and afternoon sessions contain 40 questions in multiple-choice (i.e., "objective") format. As this is a "no-choice" exam, you must answer all questions in each session correctly to receive full credit. There are no optional questions.

WHAT SUBJECTS ARE ON THE PE EXAM?

NCEES has published a list of subjects on the examination. Irrespective of the published examination structure, the exact number of questions that will appear in each subject area cannot be predicted reliably. There is no guarantee that any single subject will occur in any quantity. One of the reasons for this is that some of the questions span several disciplines. You might consider a steam flow question to come from the subject of thermodynamics, while someone else might categorize it as fluid flow or compressible flow.

Table 2 lists exam subjects at the time of this printing. Any changes to the subjects will be posted on the PPI website (**www.ppi2pass.com/stateboards.html**). NCEES has noted, "The examination is developed with problems that will require a variety of approaches and methodologies including design, analysis, application, and operations. Some problems may require knowledge of engineering economics."

WHAT IS THE TYPICAL QUESTION FORMAT?

Almost all of the questions are stand-alone—that is, they are completely independent. However, NCEES allows that some sets of questions may start with a statement of a "situation" that will apply to (typically) two to five following questions.

Since the questions are multiple-choice in design, all required data should appear in the situation statement. You will not generally be required to come up with numerical data that might affect your success on the question. There will be superfluous information in the majority of questions.

Each of the questions will have four answer choices, labeled "A," "B," "C," and "D." One of the answer choices is correct (or, "most nearly correct," as described in the following section). The remaining answer choices are incorrect and may consist of one or more logical distracters.

NCEES tries hard to make sure the questions are not interrelated. Questions are independent or start with new given data. A mistake on one of the questions shouldn't cause you to get a subsequent question wrong. However, considerable time may be required to repeat previous calculations with a new set of given data.

For scenarios, the multiple related questions may not necessarily be in a logical or progressive order. It may be necessary to answer some questions out of sequence, determining answers to subsequent questions before the answers to the first few questions are needed.

WHAT DOES "MOST NEARLY" REALLY MEAN?

One of the more disquieting aspects of these questions is that the available answer choices are seldom exact. Answer choices generally have only two or three significant digits. Exam questions ask, "Which answer choice is most nearly the correct value?" or they instruct you to complete the sentence, "The value is approximately. . . " A lot of self-confidence is required to move on to the next question when you don't find an exact match for the answer you calculated, and you have had to split hairs because no available answer choice is close.

The NCEES website describes it like this:

> Many of the questions on NCEES exams require calculations to arrive at a numerical answer. Depending on the method of calculation used, it is very possible that examinees working correctly will arrive at a range of answers. The phrase "most nearly" is used to all these accommodate all these answers that have been derived correctly but which may be slightly different from the correct answer choice given on the exam. You should use good engineering judgment when selecting your choice of answer. For example, if

Table 2 *Detailed Analysis of Tested Subjects*[a,b]

MORNING SESSION
(40 multiple-choice questions)

Basic Engineering Practice (30%)

Engineering terms and symbols; economic analysis; project management; interpretation of technical drawings; electrical concepts; units and conversions

Mechanical Systems and Materials (20%)

Principles (13%): statics and dynamics; strength of materials; stress analysis; fatigue theory

Applications (7%): mechanical components; joints and fasteners; vibration/dynamic analysis; materials selection

Hydraulics and Fluids (17%)

Principles (7%): compressible and incompressible flow

Applications (10%): hydraulic and fluid equipment; piping systems and components

Energy/Power Systems (15%)

Principles (7%): thermodynamic cycles and properties; energy and mass balances; heat transfer; combustion

Applications (8%): power conversion systems; energy/power equipment; heat exchangers

HVAC/Refrigeration (18%)

Principles (10%): psychrometrics; refrigeration cycles; heat transfer

Applications (8%): HVAC/refrigeration systems and components; heating and cooling loads

AFTERNOON SESSIONS
(40 multiple-choice questions per exam)

MECHANICAL/MECHANICAL SYSTEMS AND MATERIALS DEPTH EXAM

Principles (60%)

Statics (15%): free body diagrams; friction; centroids; inertia
Kinematics (7%): linear/rotational motion; velocity; acceleration
Dynamics (10%): particle and rigid body
Material properties (10%): physical; chemical; mechanical
Strength of materials (18%): stress/strain; shear; bending; buckling; torsion

Applications (40%)

Mechanical components (10%): pressure vessels; bearings; gears; springs; belts, pulleys, and chains; clutches and brakes; power screws; shafts and keys; mechanisms; mechatronics
Joints and fasteners (10%): welding and brazing; bolts, screws, and rivets; adhesives and soldering
Vibration/dynamic analysis (10%): natural frequencies; damping; forced vibrations; vibration isolation; dynamic analysis
Materials and process (10%): materials selection; manufacturing processes; fits and tolerances; economic analysis and project management; quality control

[a] Considerable overlap, duplication, and flexibility exists in each topic.
[b] NCEES may occasionally revise exam subjects somewhat. For the most current information, visit the Exam FAQs section of PPI's website, **www.ppi2pass.com/mefaqs.html**.

(continued)

Table 2 *Detailed Analysis of Tested Subjects (continued)*

MECHANICAL/THERMAL AND FLUIDS DEPTH EXAM

Principles (45%)

Materials properties (5%): density; viscosity

Fluid mechanics (10%): compressible and incompressible fluids

Heat transfer (10%): convection; conduction; radiation

Mass balance (7%): evaporation; dehumidification; combustion

Thermodynamics (10%): thermodynamic cycles and properties; energy balances; combustion

Related principles (3%): strength of materials; fatigue theory; statics and dynamics; stress analysis; psychrometrics; welding; safety; quality control/assurance

Applications (55%)

Equipment (18%): pumps; turbines; compressors, fans and blowers; boilers and steam generators; engines and drive trains; pressure vessels; heat exchangers, condensers, and feed water heaters; cooling towers; control devices

Systems (32%): power hydraulics; pneumatic power; fluid distribution; power conversion; energy recovery; cooling and heating cycles; power cycles

Codes and standards (5%)

MECHANICAL/HVAC AND REFRIGERATION DEPTH EXAM

Principles (55%)

Thermodynamics (7%): cycles; properties; compression processes

Psychrometrics (15%): heating and cooling cycles; humidification and dehumidification; heating and cooling loads

Heat Transfer (13%)

Fluid Mechanics (7%)

Compressible Flow (3%)

Energy Balances (10%)

Applications (20%)

Equipment and components (20%): cooling towers and fluid coolers; boilers and furnaces; condensers; pumps, compressors, and fans; evaporators and chillers; cooling and heating coils; control systems components; refrigerants; refrigeration components

Systems (18%): air distribution; fluid distribution; refrigeration; energy recovery

Supportive knowledge (7%): codes and standards; air quality and ventilation; vibration control; acoustics; economic analysis; electrical concepts

the question asks you to calculate an electrical current or determine the load on a beam, you should literally select the answer option that is most nearly what you calculated, regardless of whether it is more or less than your calculated value. However, if the question asks you to select a fuse or circuit breaker to protect against a calculated current or to a beam to carry a load, you should select an answer option that will safely carry the current or load. Typically, this requires selecting a value that is closest to but larger than the current or load.

The difference is significant. Suppose you were asked to calculate "most nearly" the volumetric pure airflow required to dilute a contaminated air stream to an acceptable concentration. Suppose, also, that you calculated 823 cfm. If the answer choices were (A) 600 cfm, (B) 800 cfm, (C) 1000 cfm, and (D) 1200 cfm, you would go with answer choice (B), because it is most nearly what you calculated. If, however, you were asked to select a fan or duct with the same rated capacities, you would have to go with choice (C). Got it? If not, reread this until you understand the distinction.

HOW MUCH MATHEMATICS IS NEEDED FOR THE EXAM?

Generally, only simple algebra, trigonometry, and geometry are needed on the PE exam. You will need to use the trigonometric, logarithm, square root, and similar buttons on your calculator. There is no need to use any other method for these functions.

There are no pure mathematics (algebra, geometry, trigonometry, etc.) questions on the exam. However, you will need to apply your knowledge of these subjects to the exam questions.

Except for simple quadratic equations, you will probably not need to find the roots of higher-order equations. Occasionally, it will be convenient to use the equation-solving capability of an advanced calculator. However, other solution methods will always exist.

There is little or no use of calculus on the exam. Rarely, you may need to take a simple derivative to find a maximum or minimum of some function. Even rarer is the need to integrate to find an average.

There is essentially no need to solve differential equations. Questions involving radioactive decay, seismic vibrations, control systems, chemical reactions, and fluid mixing have appeared from time to time. However, these applications can usually be handled without having to solve differential equations.

Basic statistical analysis of observed data may be necessary. Statistical calculations are generally limited to finding means, medians, standard deviations, variances, percentiles, and confidence limits. The only population distribution you need to be familiar with is the normal curve. Probability, reliability, hypothesis testing, and statistical quality control are not explicit exam subjects.

The PE exam is concerned with numerical answers, not with proofs or derivations. You will not be asked to prove or derive formulas.

Occasionally, a calculation may require an iterative solution method. Generally, there is no need to complete more than two iterations. You will not need to program your calculator to obtain an "exact" answer. Nor will you generally need to use complex numerical methods.

HOW ABOUT ENGINEERING ECONOMICS?

For most of the early years of engineering licensing, questions on engineering economics appeared frequently on the examinations. This is no longer the case. However, in its outline of exam subjects, NCEES includes economic analyses. What this means is that engineering economics can constitute anything from nothing to several questions on the exam.

While the degree of engineering economics knowledge may have decreased somewhat, the basic economic concepts (e.g., time value of money, present worth, nonannual compounding, comparison of alternatives, etc.) are still valid test subjects.

If engineering economics is incorporated into other questions, its "disguise" may be totally transparent. For example, you might need to compare the economics of buying and operating two blowers for remediation of a hydrocarbon spill—blowers whose costs must be calculated from airflow rates and heads.

WHAT ABOUT FIRE PROTECTION ENGINEERING?

At one time, fire protection was a topic on the mechanical engineering PE exam. Numerical questions dealt with sprinkler capacity, sprinkler layout, fire pumps, hydrants, standpipes, hose and nozzle flow rate, and occupancy categories. This topic disappeared when the mechanical engineering PE exam adopted the breadth-and-depth format. The fire protection chapter in this book covers basic material that might still be useful on the exam.

WHAT ABOUT NUCLEAR ENGINEERING?

At one time, nuclear engineering problems appeared regularly on the Mechanical Engineering PE exam. These problems dealt with shielding, health safety, core power development, decay, liquid metal flow and heat transfer, and core design. Such problems disappeared when the Nuclear Engineering PE exam became available. Problems involving nuclear reactor environments continue to appear, but these can always be solved with "traditional" heat transfer, thermodynamic, power cycle, and fluid machinery concepts.

WHAT ABOUT PROFESSIONALISM AND ETHICS QUESTIONS?

For many years, NCEES has discussed adding professionalism and ethics questions to the PE exam. However, these subjects are not part of the test outline, and there has yet to be a question on them in the exam.

IS THE EXAM TRICKY?

Other than providing superfluous data, the PE exam is not a "tricky exam." The exam does not overtly try to get you to fail. Examinees manage to fail on a regular basis with perfectly straightforward questions. The exam questions are difficult in their own right. NCEES does not need to provide misleading or conflicting statements. However, you will find that commonly made mistakes are represented in the available answer choices. Thus, the alternative answers (known as *distracters*) will be logical.

Questions are generally practical, dealing with common and plausible situations that you might experience on the job. You will not be asked to determine the heat transfer from the side of a spacecraft after it has landed on a Jovian moon with a methane atmosphere.

WHAT MAKES THE QUESTIONS DIFFICULT?

Some questions are difficult because the pertinent theory is not obvious. There is only one acceptable procedure, and it is heuristic (or defined by a code) such

that nothing else will be acceptable. For example, if you don't know the AGMA procedure for designing gears, no other knowledge of gear design is going to be helpful for an AGMA question.

Some questions are difficult because the data needed are hard to find. Some data just aren't available unless you happen to have brought the right reference book. Solving some HVAC problems depends on having climatological data for a specific location and performance characteristics of specific construction types.

Some questions are difficult because they defy visualization. Problems involving epicyclical gear trains can be like this. If you cannot visualize the operation of the mechanism . . . if you cannot get an intuitive feeling about what is going on, you probably cannot analyze it.

Some questions are difficult because the computational burden is high and they just take a long time. Convective heat transfer, HVAC, and pipe networks analyzed with the Hardy-Cross method fall into this category.

Some questions are difficult because the terminology is obscure, and you just don't know what the terms mean. This can happen in almost any subject.

DOES THE PE EXAM USE SI UNITS?

The PE exam in mechanical engineering uses, primarily, customary U.S. units (also known as "English units," "inch-pound units," and "British units"). Questions use the units that correspond to commonly accepted industry standards. Metric units can be used in water concentration (e.g., mg/L) and electrical (e.g., volts, amps, and watts) questions.

The exam does not differentiate between lbf and lbm (pounds-force and pounds-mass) as is done in this book.

WHY DOES NCEES REUSE SOME PROBLEMS?

NCEES reuses some of the more reliable questions from each exam. The percentage of repeat questions isn't high—no more than 25% of the exam. NCEES repeats questions in order to equate the performance of your group of examinees with the performance of an earlier group. The repeated questions are known as *equaters*.

Occasionally, a new question appears on the exam that very few of the examinees do well on. Usually, the reason for this is that the subject is too obscure or too difficult. Questions on control systems and some engineering management subjects (e.g., linear programming) fall into this category. Also, there have been cases where a low percentage of the examinees get the answer correct because the question was inadvertently stated in a poor or confusing manner. Questions that everyone gets correct are considered defectively easy.

NCEES tracks the usage and "success" of each of the exam questions. Such "rogue" questions are not repeated without modification. This is one of the reasons why historical analysis of question types shouldn't be used as the basis of your review.

IS THIS BOOK WRITTEN FOR THE BREADTH-AND-DEPTH EXAM?

This book is specifically written with the B&D formatted exam in mind.

ARE THE PROBLEMS IN THE COMPANION BOOK REPRESENTATIVE OF THE EXAM?

The problems in *Practice Problems for the Mechanical Engineering PE Exam* are targeted to cover exam subjects. However, they are generally more comprehensive and complex than actual exam problems. Many of the practice problems are marked "Time limit: one hour." Compared to the six-minute questions on the PE exam, such one-hour problems are considerably more time-consuming.

WHAT REFERENCE MATERIAL IS PERMITTED IN THE EXAM?

The PE examination is an open-book exam. Most states do not have any limits on the numbers and types of books you can use. Personal notes in a three-ring binder and other semipermanent covers can usually be used.

Some states use a "shake test" to eliminate loose papers from binders. Make sure that nothing escapes from your binders when they are inverted and shaken.

The references you bring into the examination room in the morning do not have to be the same as the references you use in the afternoon. However, you cannot share books with other examinees during the exam.

A few states do not permit collections of solved problems such as Schaum's Outline series, sample exams, and solutions manuals. A few states maintain a formal list of banned books.

Strictly speaking, loose paper and scratch pads are not permitted in the examination. Certain types of preprinted graphs (e.g., psychrometric charts) should be three-hole punched and brought in a three-ring binder. An exception to this restriction may be made for laminated and oversize charts, graphs, and tables that are commonly needed for particular types of questions.

HOW MANY BOOKS SHOULD YOU BRING?

You actually won't use many books in the examination. The trouble is, you can't know in advance which ones you will need. That's the reason why many examinees

show up with boxes and boxes of books. Without a doubt, there are things that you will need that are not in this book. But there are not so many that you need to bring your entire company's library. The examination is very fast-paced. You will not have time to use books with which you are not thoroughly familiar. The exam doesn't require you to know obscure solution methods or to use difficult-to-find data.

So, it really is unnecessary to bring a large quantity of books with you. The books that are useful are identified in Table 3, and you should be able to decide which support the areas in which you intend to work. This book and five to ten other references of your choice should be sufficient for most of the questions you answer.

MAY I PLACE TABS ON CERTAIN PAGES?

It is common to tab pages in your books in an effort to reduce the time required to locate useful sections. Inasmuch as some states consider Post-it™ notes to be "loose paper," your tabs should be of the "permanent" variety. Although you can purchase tabs with gummed attachment points, it is also possible simply to use transparent tape to attach the Post-its you have already placed in your books.

WHAT ABOUT CALCULATORS?

The exam requires use of a scientific calculator. However, it may not be obvious that you should bring a spare calculator with you to the examination. It is always unfortunate when an examinee is not able to finish because his or her calculator was dropped or stolen or stopped working for some unknown reason.

The exam has not been "optimized" for any particular brand or type of calculator. In fact, for most calculations, a $15 scientific calculator will produce results as satisfactory as those from a $200 calculator. There are definite advantages to having built-in statistical functions, graphing, unit-conversions, and equation-solving capabilities. However, these advantages are not so great as to give anyone an unfair advantage.

In most states, any calculator may be used as long as it is silent, is nonprinting, and does not have any significant word-processing functions (i.e., does not have a QWERTY keyboard). NCEES has banned communicating and text-editing calculators from the exam site. In most states, there are no restrictions on possessing or using programmable, preprogrammed, or business/financial calculators. Similarly, nomographs and specialty slide rules are permitted.

It is essential that a calculator used for the mechanical PE examination have the following functions.

- trigonometric and inverse trigonometric functions
- hyperbolic and inverse hyperbolic functions
- π
- $\sqrt{\ }$ and x^2
- both common and natural logarithms
- y^x and e^x

For maximum speed, your calculator should also have or be programmed for the following functions.

- interpolation
- finding standard deviations and variances
- extracting roots of quadratic and higher-order equations
- calculating determinants of matrices
- linear regression
- confidence limits
- calculating factors for economic analysis questions

For the mechanical engineering exam, a calculator with built-in thermodynamic properties of air, steam, and water is a significant advantage.

You may not share calculators with other examinees.

Laptop computers are generally not permitted in the examination. Their use has been considered, and some states may actually permit them. However, considering the nature of the exam questions, it is very unlikely that laptops would provide any advantage.

You may not use a walkie-talkie, cellular telephone, interactive pager, or other communications device during the exam.

Be sure to take your calculator with you whenever you leave the examination room for any length of time.

HOW IS THE EXAM GRADED AND SCORED?

The maximum number of points you can earn on the mechanical engineering PE exam is 80. The minimum number of points for passing (referred to by NCEES as the "cut score") varies from exam to exam. The cut score is determined through a rational procedure, without the benefit of knowing examinees' performance on the exam. That is, the exam is not graded on a curve. The cut score is selected based on what you are expected to know, not based on passing a certain percentage of engineers.

Each of the questions is worth one point. Grading is straightforward, since a computer grades your score sheet. Either you get the question right or you don't.

There is no deduction for incorrect answers, so guessing is encouraged. However, if you mark two or more answers, no credit is given for the question.

You will receive the results of your examination from your state board (not NCEES) by mail. Allow at least four months for notification. Your score will not be revealed to you, only whether you passed or failed. If you fail, you will also receive a diagnostic report showing whether you are strong or weak in each subject area.

HOW YOU SHOULD GUESS

NCEES produces defensible licensing exams. As a result, there is no pattern to the placement of correct responses. Therefore, it is not important whether you randomly guess all "A," "B," "C," or "D."

The proper way to guess is as an engineer. You should use your knowledge of the subject to eliminate illogical answer choices. Illogical answer choices are those that violate good engineering principles, that are outside normal operating ranges, or that require extraordinary assumptions. Of course, this requires you to have some basic understanding of the subject in the first place. Otherwise, it's back to random guessing. That's the reason why the minimum passing score is higher than 25%.

You won't get any points using the "test-taking skills" that helped you in college—the skills that helped with tests prepared by amateurs. You won't be able to eliminate any [verb] answer choices from "Which [noun] . . ." questions. You won't find questions with four answer choices, two of which are of the "more than 50" and "less than 50" variety. You won't find one answer choice among the four that has a different number of significant digits, or whose verb is written in a different tense, or that has some singular/plural discrepancy with the stem. The distracters will always match the stem, and they will be logical.

WHAT IS THE HISTORICAL PASSING RATE?

Since the mechanical engineering PE exam became a no-choice breadth-and-depth (B&D) exam with multiple-choice questions, the passing rate for first-timers has been 60–65%. The passing rate for repeat examinees is lower. The no-choice, objective, B&D format has reduced the variability in the passing rate considerably.

HOW IS THE CUT SCORE ESTABLISHED?

The PE exam is not graded on a curve. Rather, the minimum passing score (i.e., the "cut score") is determined independent of examinee performance. The raw cut score may be established before or after the exam is administered, although final adjustments may be made following the exam date.

NCEES uses a process known as the "modified Angoff" procedure to establish the cut score. This procedure starts with a group (the "cut score panel") of professional engineers selected by NCEES. Each individual in the group reviews each question and makes an estimate of its difficulty. Specifically, each individual estimates the number of minimally qualified engineers out of a hundred examinees who should know the correct answer to the question. (This is equivalent to predicting the percentage of minimally qualified engineers who will answer correctly.) This is done by each panelist for each problem.

Next, the panel assembles, and the estimates for each question are openly compared and discussed. Eventually, a consensus value is obtained for each question. When the panel has established a consensus value for every question, the values are summed and divided by 100 to establish the cut score.

Various minor adjustments can be made to account for examinee population (as characterized by the average performance on equater questions), "beta test" questions, and any flawed questions.

ARE ALL OF THE DEPTH MODULES EQUAL IN DIFFICULTY?

Nothing in the modified Angoff procedure ensures that the cut score will be the same in all of the depth modules. Thus, each depth module will have a different cut score. The easier the questions, the higher the cut score will be. Accordingly, the passing rate is different for each depth module.

CHEATING AND EXAM SUBVERSION

There aren't very many ways to cheat on an open-book test. The proctors are well trained on the few ways that do exist. It goes without saying that you should not talk to other examinees in the room, nor should you pass notes back and forth. The number of people who are released to use the restroom may be limited to prevent discussions.

NCEES regularly reuses good questions that have appeared on previous exams. Therefore, examination security is a serious issue with NCEES, which goes to great lengths to make sure nobody copies the questions. You may not keep your exam booklet, enter text of questions into your calculator, or copy questions into your own material.

The proctors are concerned about exam subversion, which generally means activity that might invalidate the examination or the examination process. The most common form of exam subversion involves trying to copy exams for future use.

Part 3: How to Prepare for and Pass the PE Exam in Mechanical Engineering

WHAT SHOULD YOU STUDY?

The exam covers many diverse subjects. Strictly speaking, you don't have to study every subject on the exam in order to pass. However, the more subjects you study, the more you'll improve your chances of passing. You should decide early in the preparation process which subjects you are going to study. This strategy you select will depend on your background. Here are the four most common strategies.

A broad approach is the key to success for examinees who have recently completed their academic studies. Their strategy is to review the fundamentals in a broad range of undergraduate subjects (which means studying all or most of the chapters in this book). The examination includes enough fundamentals questions to make this strategy worthwhile. Overall, it's the best approach.

Engineers who have little time for preparation tend to concentrate on the subject areas in which they hope to find the most questions. By studying the list of examination subjects, some have been able to focus on those subjects that will give them the highest probability of finding enough questions that they can answer. This strategy works as long as the examination "cooperates" and has enough of the types of questions they need. Too often, though, examinees who "pick and choose" subjects to review can't find enough questions to complete the exam.

Engineers who have been away from classroom work for a long time tend to concentrate on the subjects in which they have had extensive experience, in the hope that the exam will feature questions on those subjects. This method is seldom successful.

Some engineers plan on modeling their solutions from similar questions they have found in textbooks, collections of solved problems, and old exams. These engineers often spend a lot of time compiling and indexing the example and sample problem types in all of their books. This is not a legitimate preparation method, and it is almost never successful.

DO YOU NEED A CLASSROOM REVIEW COURSE?

Most first-time PE examinees take a review course of some form. Classroom, audio, video, correspondence, and internet courses are available for some or all of the exam topics. Classroom review courses are useful for a number of reasons. Courses provide several significant advantages over self-directed study, some of which may apply to you.

- A course structures and paces your review. It ensures that you keep going forward without getting bogged down in one subject.
- A course focuses you on a limited amount of material. Without a course, you might not know what subjects to study.
- A course provides you with the questions you need to solve. You won't have to spend time looking for them.
- The course "spoon-feeds" you the material. You may not need to read the book!
- The course instructor can answer your questions when you are stuck.

You probably already know if any of these advantages apply to you. A review course will be less valuable if you are thorough, self-motivated, and highly disciplined.

HOW LONG SHOULD YOU STUDY?

We've all heard stories of the person who didn't crack a book until the week before the exam and still passed it with flying colors. Yes, these people really exist. However, I'm not one of them, and you probably aren't either. In fact, after having taught thousands of engineers in my own classes, I'm convinced that these people are as rare as the ones who have taken the exam five times and still can't pass it.

A thorough review takes approximately 300 hours. Most of this time is spent solving problems. Some of it may be spent in class; some is spent at home. Some examinees spread this time over a year. Others cram it all into two months. Most classroom review courses last for three or four months. The best time to start studying will depend on how much time you can spend per week.

WHAT THE WELL-HEELED MECHANICAL ENGINEER WOULD TAKE TO THE EXAM

There are many references and resources that you should begin to assemble for review and for use in the examination. Some of the items (particularly anything in loose-sheet form) may not be permitted in the examination but will still be valuable during your studies.

It is unlikely that you could pass the PE exam without accumulating other books and resources. There certainly isn't much margin for error if you show up with only one book. True, references aren't needed to answer some fluids, hydrology, and combustion questions.

However, there are many depth questions that require knowledge, data, and experience that are presented and described only in books dedicated to a single subject. You would have to be truly lucky to go in "bare," find the right mix of questions, and pass.

Few examinees are able to accumulate all of the references needed to support the exam's entire body of knowledge. The accumulation process is too expensive and time-consuming, and the sources are too diverse. Like purchasing an insurance policy, what you end up with will be more a function of your budget than of your needs. In some cases, one book will satisfy several needs. For example, ASHRAE's *Handbook of Fundamentals* contains of lot of useful HVAC and thermodynamic data.

The list in Table 3 was compiled over approximately 50 administrations of the mechanical engineering PE exam. The books and other items listed are regularly cited by examinees as being particularly useful to them. I've categorized them into the depth options as best I can.

ADDITIONAL REVIEW MATERIAL

In addition to this book and its accompanying *Practice Problems for the Mechanical Engineering PE Exam*, Professional Publications, Inc., can provide you with the following references and study aids.

- *ASME Mollier diagram*
- *Consolidated Gas Dynamics Tables*
- *Engineering Unit Conversions*
- *101 Solved Mechanical Engineering Problems*

DON'T FORGET THE DOWNLOADS

Many of the tables and appendices in this book are representative abridgments with just enough data to (a) do the practice problems in the companion book and (b) give you a false sense of security. You can download additional data and explanations by visiting **www.ppi2pass.com/resources.html**, where links to additional sources are provided.

WHAT YOU WON'T NEED

Generally, people bring too many things to the examination. One general rule is that you shouldn't bring books that you have not looked at during your review. If you didn't need a book while doing the practice problems in this book, you won't need it during the exam.

There are some other things that you won't need.

- Books on basic and introductory subjects: You won't need books that cover trigonometry, geometry, or calculus.
- Books that cover background engineering subjects that appear on the exam, such as fluids, thermodynamics, and chemistry: The exam is more concerned with the applications of these bodies of knowledge than with the bodies of knowledge themselves.
- Books on non-exam subjects: Such subjects as materials science, statics, dynamics, mechanics of materials, drafting, history, the English language, geography, and philosophy are not part of the exam.
- Books on mathematical analysis, or extensive mathematics tabulations
- Extensive collections of properties: You will not be expected to know the properties characteristics of obscure or exotic alloys, chemical compounds, or biological organisms. Most characteristics affecting performance are provided as part of the question statement.
- National building, plumbing, or safety codes
- Local, county, or state-specific codes
- Obscure books and materials: Books that are in a different language, doctoral theses, and papers presented at technical societies won't be needed during the exam
- Old textbooks or obsolete, rare, and ancient books: NCEES exam committees are aware of which textbooks are in use. Material that is available only in out-of-print publications and old editions won't be used.
- Handbooks in other disciplines: You probably won't need a civil, electrical, or industrial engineering handbook.
- The *Handbook of Chemistry and Physics*
- Computer science books: You won't need to bring books covering computer logic, programming, algorithms, program design, or subroutines for BASIC, FORTRAN, C, Pascal, HTML, Java, Active-X, or any other language.
- Crafts- and trades-oriented books: The exam does not expect to you to have detailed knowledge of trades or manufacturing operations (e.g., carpentry, plumbing, electrical wiring, roofing, sheet-rocking, foundry, metal turning, sheet-metal forming, or designing jigs and fixtures).
- Manufacturer's literature and catalogs: No part of the exam requires you to be familiar with products that are proprietary to any manufacturer.

Table 3 *What the Well-Heeled Mechanical Engineer Would Take to the Exam*

		P.M. test		
	A.M. test	thermal and fluids systems	HVAC and refrigeration	mechanical systems and materials
psychrometric charts[a]	X	X	X	
ruler[b]	X	X	X	X
steam tables[c]	X	X	X	
Mollier diagrams[d]	X	X	X	
air tables[e]	X	X		
compressible flow tables[f]	X			
Marks' Handbook[g]	X	X	X	X
Machinery's Handbook[h]	X			X
TEMA Standards[i]	X			
detailed heat transfer book[j]	X	X		
detailed HVAC book[k]	X	X	X	
extensive refrigerant data[l]	X	X	X	
machine design book[m]	X			X
Formulas for Stress and Strain[n]	X			X
detailed fluids data book[o]	X	X	X	
NFPA Standards[p]	X	X		
management science book[q]	X	X		
scientific dictionary[r]	X	X	X	X
English dictionary[s]	X	X	X	X
book of unit conversions	X	X	X	X

[a] psychrometric charts: at least 10 for normal temperature and pressure, and several each for low-pressure, low-temperature, and high-temperature problems. (Available directly from ASHRAE.)
[b] ruler: long, flexible, clear plastic ruler marked in tenths of an inch or in centimeters and millimeters.
[c] steam tables: detailed tables in both English and SI units (e.g., the old *Steam Tables* by Keenan and Keyes or *ASME Steam Tables*).
[d] Mollier diagrams: large diagrams in both English and SI units (as contained in the old *Steam Tables* by Keenan and Keyes or in the *ASME Steam Tables*; alternatively, the stand-alone *ASME Mollier Diagram* from PPI).
[e] air tables: detailed tables in both English and SI units (e.g., the old *Gas Tables* by Keenan and Kaye); alternatively, ROM card for your calculator with such functions built-in.
[f] compressible flow tables: isentropic flow and normal shock factors for various ratios of specific heats (as contained in *Gas Tables* by Keenan and Kaye; alternatively, *Consolidated Gas Dynamics Tables* from PPI.
[g] *Marks' Standard Handbook for Mechanical Engineers*: any reasonably current edition.
[h] *Machinery's Handbook*: any reasonably current edition with AGMA gear data.
[i] Standards of the Tubular Exchanger Manufacturers' Association ("TEMA Standards"): specifically for the heat exchanger correction factors.
[j] heat transfer book: with the following charts, figures, or tables: charts for solving transient heat flow problems (simple solids other than spheres); radiation arrangement factors (F_a); and correction factors (F_c) for multiple-pass heat exchangers (counterflow, crossflow, etc.), same as contained in TEMA Standards.
[k] HVAC book: such as ASHRAE's *Handbook of Fundamentals*, with the following charts, figures, or tables of data: outside design conditions versus geographic location (including winter design temperature; winter degree days; summer design temperature; summer degree days; average temperature swing; wind velocity; k or U values for various wall constructions; infiltration coefficients; heat loss coefficient for the slab-edge method; equivalent temperature differences and related CLTD support tables; cooling load factors (various)).
[l] refrigerant data: A collection of thermodynamic property data for common refrigerants, notably R134a, R-11, R-12, R-22, and ammonia. Data should be available in customary U.S. units in the form of saturation tables (by temperature and pressure both), T-s, and p-h charts. (ASHRAE's *Handbook of Fundamentals* contains a complete collection.)
[m] machine design book: such as *Mechanical Engineering Design* by Shigley and Mischke. Since basic machine design changes slowly, it is not necessary to have the latest edition. Machine design books will cover the topic that NCEES has renamed "mechanical systems and materials."

(continued)

Table 3 *What the Well-Heeled Mechanical Engineer Would Take to the Exam (continued)*

table notes

[n] *Formulas for Stress and Strain* by Roark and Young. This is good for obscure configurations requiring stress or vibration analysis. Any reasonably current edition.
[o] fluids data book: such as Crane's *Flow of Fluids Through Valves, Fittings, and Pipe (Manual 410)*, Ingersoll-Rand's *Cameron Hydraulic Data*, or Colt Industries' *Hydraulic Handbook*.
[p] NFPA Standards: Uniform Fire Code (NFPA-1, which incorporates the publication published separately as NFPA-230 (*Fire Protection of Storage*); National Fire Protection Association Standards NFPA-13 (*Installation of Sprinkler Systems*), NFPA-14 (*Installation of Standpipe and Hose Systems*), NFPA-20 (*Centrifugal Fire Pumps*) and NFPA-291 (*Recommended Practice for Fire Flow Testing and Marking of Hydrants*), or suitable substitutes such as *Fire and Explosion Protection Systems* from PPI.
[q] management science book: such as *Schaum's Quantitative Business Analysis*. Quantitative business analysis, industrial engineering, or operations research textbook covering linear programming, models for assembly line balancing, plant location, plant layout, queuing theory, Markov chains, and simple simulations.
[r] scientific or engineering dictionary: any available.
[s] standard English dictionary: any available.

- Government publications: With the exceptions of the OSHA, EPA, and other documents referred to throughout this book, no government publications are required in the PE exam.

- Your state's laws: The PE exam is a national exam. Nothing unique to your state will appear on it.

- Local, state, or national building codes

SHOULD YOU LOOK FOR OLD EXAMS?

The traditional approach to preparing for standardized tests includes working sample tests. However, NCEES does not release old tests or questions after they are used. Therefore, there are no official questions or tests available from legitimate sources. NCEES has published a booklet of sample questions and solutions to illustrate the format of the exam. However, these questions have been assembled from various previous exams, and the publication is not a true "old exam."

WHAT SHOULD YOU MEMORIZE?

You get lucky here, because it isn't necessary to actually memorize anything. The exam is open-book, so you can look up any procedure, formula, or piece of information that you need. You can speed up your problem-solving response time significantly if you don't have to look up the conversion from ft-lbf/sec to horsepower, the definition of the sine of an angle, and the chemical formula for carbon dioxide, but you don't even have to memorize these kinds of things. As you solve practice problems, you will automatically memorize the things that you come across more than a few times.

DO YOU NEED A REVIEW SCHEDULE?

It is important that you develop and adhere to a review outline and schedule. Once you have decided which subjects you are going to study, you can allocate the available time to those subjects in a manner that makes sense to you. If you are not taking a classroom review course (where the order of preparation is determined by the lectures), you should make an outline of subjects for self-study to use for scheduling your preparation. A fill-in-the-dates schedule is provided in Table 4 at the end of this Introduction.

A SIMPLE PLANNING SUGGESTION

Designate some location (a drawer, a corner, a cardboard box, or even a paper shopping bag left on the floor) as your "exam catch-all." Use your catch-all during the months before the exam when you have revelations about things you should bring with you. For example, you might realize that the plastic ruler marked off in tenths of an inch that is normally kept in the kitchen junk drawer can help you with psychrometric chart problems. Or, you might decide that a certain book is particularly valuable. Or, that it would be nice to have dental floss after lunch. Or, that large rubber bands are useful for holding books open.

It isn't actually necessary to put these treasured items in the catch-all during your preparation. You can, of course, if it's convenient. But if these items will have other functions during the time before the exam, at least write yourself a note and put the note into the catch-all. When you go to pack your exam kit a few days before the exam, you can transfer some items immediately, and the notes will be your reminders for the other items that are back in the kitchen drawer.

HOW YOU CAN MAKE YOUR REVIEW REALISTIC

In the exam, you must be able to quickly recall solution procedures, formulas, and important data. You must remain sharp for eight hours or more. When you played a sport back in school, your coach tried to put you in game-related situations. Preparing for the PE exam isn't much different from preparing for a big game. Some part of your preparation should be realistic and representative of the examination environment.

There are several things that you can do to make your review more representative. For example, if you gather most of your review resources (i.e., books) in advance and try to use them exclusively during your review, you will become more familiar with them. (Of course, you can add to or change your references if you find inadequacies.)

Learning to use your time wisely is one of the most important lessons you can learn during your review. You will undoubtedly encounter questions that end up taking much longer than you expected. In some instances, you will cause your own delays by spending too much time looking through books for things you need (or, just by looking for the books themselves!). Other times, the questions will just entail too much work. Learn to recognize these situations so that you can make an intelligent decision about skipping such questions in the exam.

WHAT TO DO A FEW DAYS BEFORE THE EXAM

There are a few things you should do a week or so before the examination. You should arrange for childcare and transportation. Since the examination does not always start or end at the designated time, make sure that your childcare and transportation arrangements are flexible.

Check PPI's website for last-minute updates and errata to any PPI books you might have and are bringing to the exam.

If you haven't already done so, read the advice from examinees posted on the Exam FAQs section of PPI's website.

If you haven't been following along on the Engineering Exam Forum on PPI's website, use the search function to locate discussions on this bulletin board.

If it's convenient, visit the exam location in order to find the building, parking areas, examination room, and restrooms. If it's not convenient, you may find driving directions and/or site maps on the web.

Take the battery cover off your calculator and check to make sure you are bringing the correct size replacement batteries. Some calculators require a different kind of battery for their "permanent" memories. Put the cover back on and secure it with a piece of masking tape. Write your name on the tape to identify your calculator.

If your spare calculator is not the same as your primary calculator, spend a few minutes familiarizing yourself with how it works. In particular, you should verify that your spare calculator is functional.

PREPARE YOUR CAR

- Gather snow chains, shovel, tow rope or chain, and tarp to lie on while installing.
- Check tire pressures.
- Check your spare tire.
- Check for tire installation tools.
- Verify that you have the vehicle manual.
- Check fluid levels (oil, gas, water, brake fluid, transmission fluid, window-washing solution).
- Fill up with gas.
- Check battery and charge if necessary.
- Know something about your fuse system (where they are, how to replace them, etc.).
- Assemble all required maps.
- Fix anything that might slow you down (missing wiper blades, etc.).
- Check your tail lights.
- Affix the recently arrived DMV license sticker.
- Fix anything that might get you pulled over on the way to the exam (burned-out taillight or headlight, broken lenses, bald tires, missing license plate, noisy muffler).
- Treat the inside windows with anti-fog solution.
- Put a roll of paper towels in the back seat.
- Gather change for any bridge tolls or toll roads.
- Put $20 in your glove box.
- Check for current registration and proof of insurance.
- Locate a spare key.
- Find your AAA or other roadside-assistance cards and phone numbers.
- Plan out alternate routes.

PREPARE YOUR EXAM KITS

Second in importance to your scholastic preparation is the preparation of your two examination kits. The first kit consists of a bag, box (plastic milk crates hold up better than cardboard in the rain), or wheeled travel suitcase containing items to be brought with you into the examination room.

[ ] letter admitting you to the examination

[ ] photographic identification (e.g., driver's license)

[ ] this book

[ ] other textbooks and reference books

[ ] English dictionary

[ ] scientific/engineering dictionary

[ ] review course notes in a three-ring binder

[ ] cardboard boxes or plastic milk crates to use as a bookcase

[ ] primary calculator

[ ] spare calculator

[ ] instruction booklets for your calculators

[ ] extra calculator batteries

[ ] erasers

[ ] straightedge and rulers

[ ] compass

[ ] protractor

[ ] scissors

[ ] stapler

[ ] transparent tape

[ ] psychrometric charts (punched in a three-ring binder)

[ ] magnifying glass

[ ] small (jeweler's) screwdriver for fixing your glasses or for removing batteries from your calculator

[ ] unobtrusive (quiet) snacks or candies, already unwrapped

[ ] two small plastic bottles of water

[ ] travel pack of tissue (keep in your pocket)

[ ] handkerchief

[ ] headache remedy

[ ] personal medication

[ ] $3.00 in miscellaneous change

[ ] light, comfortable sweater

[ ] loose shoes or slippers

[ ] cushion for your chair

[ ] earplugs

[ ] wristwatch with alarm

[ ] several large trash bags ("raincoats" for your boxes of books)

[ ] wire coat hanger (to hang up your jacket or to get back into your car in an emergency)

[ ] extra set of car keys on a string around your neck

The second kit consists of the following items and should be left in a separate bag or box in your car in case they are needed.

[ ] copy of your application

[ ] proof of delivery

[ ] light lunch

[ ] beverage in thermos or cans

[ ] sunglasses

[ ] extra pair of prescription glasses

[ ] raincoat, boots, gloves, hat, and umbrella

[ ] street map of the examination area

[ ] note to the parking patrol for your windshield

[ ] battery-powered desk lamp

[ ] your cellular phone

The following items cannot be used during the examination and should be left at home.

[ ] pencils (NCEES distributes pencils at the exam.)

[ ] fountain pens

[ ] radio or tape/CD player

[ ] battery charger

[ ] extension cords

[ ] scratch paper

[ ] note pads

PREPARE FOR THE WORST

All of the occurrences listed in this section happen to examinees on a regular basis. Granted, you cannot prepare for every eventuality. But, even though each of these occurrences taken individually is a low-probability event, taken together, they are worth considering in advance.

- Imagine getting a flat tire, getting stuck in traffic, a mechanical breakdown, or running out of gas on the way to the exam.
- Imagine rain and snow as you are carrying your cardboard boxes of books into the exam room. Would plastic trash bags be helpful?
- Imagine arriving late. Can you get into the exam without having to make two trips from your car?
- Imagine having to park two blocks from the exam site. How are you going to get everything to the exam room? Can you actually carry everything that far? Could you use a furniture dolly, a supermarket-type basket, or perhaps a helpmate?
- Imagine a Star Trek convention, square-dancing contest, construction, or auction in the next room.
- Imagine a site without any heat, with poor lighting, or with sunlight streaming directly into your eyes.
- Imagine a hard folding chair and a table with one short leg.
- Imagine a site next to an airport with frequent take-offs, or next to a construction site with a pile driver, or next to the NHRA's Drag Racing Championship.
- Imagine a seat where someone nearby chews gum with an open mouth; taps his pencil or drums her fingers; or wheezes, coughs, and sneezes for eight hours.
- Imagine the distraction of someone crying, or of proctors evicting yelling and screaming examinees (who have been found cheating), or of the tragedy of another examinee's serious medical emergency.
- Imagine a delay of an hour while they find someone to unlock the building, turn on the heat, or wait for the head proctor to bring instructions.
- Imagine a power outage occurring sometime during the exam.
- Imagine a proctor who (a) tells you that one of your favorite books can't be used in the exam, (b) accuses you of cheating, or (c) calls "time up" without giving you any warning.
- Imagine not being able to get your lunch out of your car or find a restaurant.
- Imagine getting sick or nervous in the exam.
- Imagine someone stealing your calculator during lunch.

WHAT TO DO THE DAY BEFORE THE EXAM

Take the day before the examination off from work to relax. Do not cram the last night. A good night's sleep is the best way to start the examination. If you live a considerable distance from the examination site, consider getting a hotel room in which to spend the night.

Practice setting up your examination work environment. Carry your boxes to the kitchen table. Arrange your "bookcases" and supplies. Decide what stays on the floor in boxes and what gets an "honored position" on the tabletop.

Use your checklist to make sure you have everything. Make sure your exam kits are packed and ready to go.

Calculate your wake-up time and set the alarms on two bedroom clocks. Select and lay out your clothing items. Select and lay out your breakfast items.

If it's going to be hot on exam day, put your (plastic) bottles of water in your freezer.

Make sure you have gas in your car and money in your wallet.

WHAT TO DO THE DAY OF THE EXAM

Turn off the quarterly and hourly alerts on your wristwatch. Leave your pager at home. If you must bring it, change it to silent mode.

Bring or buy a morning newspaper.

You should arrive at least 30 minutes before the examination starts. This will allow time for finding a convenient parking place, bringing your materials to the examination room, making room and seating changes, and calming down. Be prepared, though, to find that the examination room is not open or ready at the designated time.

Once you have arranged the materials around you on your table, take out your morning newspaper and look cool. (Only nervous people work crossword puzzles.)

WHAT TO DO DURING THE EXAM

All of the procedures typically associated with timed, proctored, computer-graded assessment tests will be in effect when you take the PE examination.

The proctors will distribute the examination booklets and answer sheets if they are not already on your tables. However, you should not open the booklets until instructed to do so. You may read the information on the front and back covers, and you should write your name in the appropriate blank spaces.

Listen carefully to everything the proctors say. Do not ask your proctors any engineering questions. Even if they are knowledgeable in engineering, they will not be permitted to answer your questions.

Answers to questions are recorded on an answer sheet contained in the test booklet. The proctors will guide you through the process of putting your name and other biographical information on this sheet when the time comes, which will take approximately 15 minutes. You will be given the full four hours to answer questions. Time to initialize the answer sheet is not part of your four hours.

The common suggestions to "use number-two pencils, completely fill the bubbles, and erase completely" apply here. Each examinee will be provided with a mechanical pencil with HB lead at the exam site. Use of ballpoint pens and felt-tip markers is prohibited for several reasons.

If you finish the exam early, and there is still more than 30 minutes remaining, you will be permitted to leave the room. If you finish less than 30 minutes before the end of the exam, you may be required to remain until the end. This is done to be considerate of the people who are still working.

When you leave, you must return your exam booklet. You may not keep the exam booklet for later review.

If there are any questions that you think were flawed, in error, or unsolvable, ask a proctor for a "reporting form" on which you can submit your comments. Follow your proctor's advice in preparing this document.

WHAT ABOUT EATING AND DRINKING DURING THE EXAM?

The official rule is probably the same in every state: no eating or drinking in the exam. That makes sense, for a number of reasons. Some exam sites don't want (or don't permit) stains and messes. Others don't want crumbs to attract ants and rodents. Your table partners don't want spills or smells. Nobody wants the distractions. Your proctors can't give you a new exam booklet when the first one is ruined with coffee.

How this rule is administered varies from site to site and from proctor to proctor. Some proctors enforce the letter of law, threatening to evict you from the exam room when they see you chewing gum. Others may permit you to have bottled water, as long as you store the bottles on the floor where any spills will not harm what's on the table. No one is going to let you crack peanuts while you work on the exam, but I can't see anyone complaining about a hard candy melting away in your mouth. You'll just have to find out when you get there.

HOW TO SOLVE MULTIPLE-CHOICE PROBLEMS

When you begin each session of the exam, observe the following suggestions.

- Use only pencil.
- Do not spend an inordinate amount of time on any single question. If you have not answered a question in a reasonable amount of time, make a note of it and move on.
- Set your wristwatch alarm for five minutes before the end of each four-hour session, and use that remaining time to guess at all of the remaining questions. Odds are that you will be successful with about 25% of your guesses, and these points will more than make up for the few points that you might earn by working during the last five minutes.
- Make mental notes about any questions for which you cannot find a correct response, that appear to have two correct responses, or that you believe have some technical flaw. Errors in the exam are rare, but they do occur. Such errors are usually discovered during the scoring process and discounted from the examination, so it is not necessary to tell your proctor, but be sure to mark the one best answer before moving on.
- Make sure all of your responses on the answer sheet are dark and completely fill the bubbles.

SOLVE PROBLEMS CAREFULLY

Many points are lost to carelessness. Keep the following items in mind when you are solving the end-of-chapter problems. Hopefully, these suggestions will be automatic in the exam.

[ ] Did you recheck all your mathematical equations?

[ ] Do the units cancel out in your calculations?

[ ] Did you convert between radius and diameter?

[ ] Did you convert between feet and inches?

[ ] Did you convert from gage to absolute pressures?

[ ] Did you convert between kPa and Pa?

[ ] Did you use the universal gas constant that corresponds to the set of units used in the calculation?

[ ] Did you recheck all data obtained from other sources, tables, and figures? (In finding the friction factor, did you enter the Moody diagram at the correct Reynolds number?)

SHOULD YOU TALK TO OTHER EXAMINEES AFTER THE EXAM?

The jury is out on this question. People react quite differently to the examination experience. Some people are energized. Most are exhausted. Some people need to unwind by talking with other examinees, describing every detail of their experience, and dissecting every examination question. Other people need lots of quiet space, and prefer to just get into a hot tub to soak and sulk. Most engineers, apparently, are in this latter category.

Since everyone who took the exam has seen it, you will not be violating your "oath of silence" if you talk about the details with other examinees. It's difficult not to ask how someone else approached a problem that had you completely stumped. However, keep in mind that it is very disquieting to think you answered a question correctly, only to have someone tell you where you went wrong.

AFTER THE EXAM

Yes, there is something to do after the exam. Most people come home, throw their exam "kits" into the corner, and collapse. A week later, when they can bear to think about the experience again, they start integrating their exam kits back into their normal lives. The calculators go back into the desk, the books go back on the shelves, the $3.00 in change goes back into the piggy bank, and all of the miscellaneous stuff you brought with you to the exam gets put back wherever it came from.

Here's what I suggest you do as soon as you get home, before you collapse.

[ ] Thank your spouse and children for helping you during your preparation.

[ ] Take any paperwork you received on exam day out of your pocket, purse, or wallet. Put this inside your *Mechanical Engineering Reference Manual*.

[ ] Reflect on any statements regarding exam secrecy to which you signed your agreement in the exam.

[ ] Visit the PPI website and complete the after-exam survey to help PPI improve the quality of its service and products.

[ ] If you participated in a PPI Passing Zone, log on one last time to thank the instructors. (Passing Zones remain posted for a week after the exam.)

[ ] Call your employer and tell him/her that you need to take a mental health day off on Monday.

A few days later, when you can face the world again, do the following.

[ ] Make notes about anything you would do differently if you had to take the exam over again.

[ ] Consolidate all of your application paperwork, correspondence to/from your state, and any paperwork that you received on exam day.

[ ] If you took a live review course, call the instructor (or write a note) to say "Thanks."

[ ] Visit the Engineering Exam Forum part of PPI's website and see what other people are saying about the exam you took.

[ ] Return any books you borrowed.

[ ] Write thank-you notes to all of the people who wrote letters of recommendation or reference for you.

[ ] Find and read the chapter in this book that covers ethics. There were no ethics questions on your PE exam, but it doesn't make any difference. Ethical behavior is expected of a PE in any case. Spend a few minutes reflecting on how your performance (obligations, attitude, presentation, behavior, appearance, etc.) might be about to change once you are licensed. Consider how you are going to be a role model for others around you.

[ ] Put all of your review books, binders, and notes someplace where they will be out of sight.

FINALLY

By the time you've "undone" all of your preparations, you might have thought of a few things that could help future examinees. If you have any sage comments about how to prepare, any suggestions about what to do in or bring to the exam, any comments on how to improve this book, or any funny anecdotes about your experience, I hope you will share these with me through our website at **www.ppi2pass.com/errata**. By this time, you'll be the "expert," and I'll be your biggest fan.

AND THEN THERE'S THE WAIT . . .

Waiting for the exam results is its own form of mental torture.

Yes, I know the exam is 100% multiple-choice, and grading should be almost instantaneous. But, you are going to wait, nevertheless. There are many reasons for the delay.

Although the actual machine grading "only takes seconds," consider the following facts: (a) NCEES prepares multiple exams for each administration, in case one becomes unusable (i.e., is inappropriately released) before the exam date. (b) Since the actual version of the exam used is not known until after it is finally given, the cut-score determination occurs after the exam date. (c) Various adjustment factors based on examinee performance cannot be applied until after all answer sheets have been graded and the statistics evaluated.

I wouldn't be surprised to hear that NCEES receives dozens, if not hundreds, of claims from well-meaning examinees who were 100% certain that the exams they took were fatally flawed to some degree: that there wasn't a correct answer for such-and-such problem, that there were two answers for such-and-such problem, or even, perhaps, that such-and-such problem was missing from their exam booklet altogether. Each of these claims must be considered as a potential adjustment to the cut-score.

Then, the exams must actually be graded. Since grading nearly 100,000 exams (counting all the FE and PE exams) requires specialized equipment, software, and training not normally possessed by the average employee, as well as time to do the work (also not normally possessed by the average employee), grading is invariably outsourced.

Outsourced grading cannot begin until all of the states have returned their score sheets to NCEES and NCEES has sorted, separated, organized, and consolidated the score sheets into whatever "secret sauce sequence" is best.

During grading, some of the score sheets "pop out" with any number of a variety of abnormalities that demand manual scoring.

After the individual exams are scored, the results are analyzed in a variety of ways. Some of the analysis looks at passing rates by such delineators as degree, major, university, site, and state. Part of the analysis looks for similarities between physically adjacent examinees (to look for cheating). Part of the analysis looks for exam sites that have statistically abnormal group performance. And, some of the analysis looks for exam problems that have a disproportionate fraction of successful or unsuccessful examinees. Anyway, you get the idea: It's not merely putting your exam sheet in an electronic reader. All of these steps have to be completed for 100% of the examinees before any results can go out.

Once NCEES has graded your test and notified your state, when you hear about it depends on when the work gets done by your state. Some states have to approve the results at a board meeting; others prepare the certificates before sending out notifications. Some states are more computerized than others. Some states have 50 examinees, while others have 10,000. Some states are shut down by blizzards and hurricanes; others are administratively challenged—understaffed, inadequately trained, or over budget.

There is no pattern to the public release of results. None. The exam results are not released to all states simultaneously. (The states with the fewest examinees often receive their results soonest.) They are not released by discipline. They are not released alphabetically by state or examinee name. The people who failed are not notified first (or last). Your coworker might receive his or her notification today, and you might be waiting another three weeks for yours.

Some states post the names of the successful examinees on their official state websites before the results go out. Others update their websites after the results go out. Some states don't list much of anything on their websites.

Remember too that the size or thickness of the envelope that you receive from your state does not mean anything. Some states send a big congratulations package and certificate. Others send a big package with a new application to repeat the exam. Some states send a postcard. Some send a one-page letter. Some states simply send you an invoice for your license fees. (Ahh, what a welcome bill!) You just have to open it to find out.

Check the Engineering Exam Forum on the PPI website regularly to find out which states have released their results. You will find many other anxious examinees there. And any number of humorous conspiracy theories and rumors.

While you are waiting, I hope you will become a "Forum" regular. Log on often and help other examinees by sharing your knowledge, experiences, and wisdom. And, if you hear any good jokes at work, I hope you will share them as well.

AND WHEN YOU PASS . . .

- [ ] Celebrate.
- [ ] Notify the people who wrote letters of recommendation or reference for you.
- [ ] Read "FAQs about What Happens After You Pass the Exam" on PPI's website.
- [ ] Ask your employer for a raise.
- [ ] Tell the folks at PPI (who have been rootin' for you all along) the good news.

Table 4 *Schedule for Self-Study*

chapter number	subject	date to start	date to finish
1	Systems of Units		
2	Drawing		
3	Algebra		
4	Linear Algebra		
5	Vectors		
6	Trigonometry		
7	Analytic Geometry		
8	Differential Calculus		
9	Integral Calculus		
10	Differential Equations		
11	Probability and Statistics		
12	Numerical Systems		
13	Numerical Analysis		
14	Fluid Properties		
15	Fluid Statics		
16	Fluid Flow Parameters		
17	Fluid Dynamics		
18	Hydraulic Machines		
19	Fluid Power		
20	Fans and Ductwork		
21	Inorganic Chemistry		
22	Fuels and Combustion		
23	Energy, Work, and Power		
24	Thermodynamic Properties		
25	Changes in Thermodynamic Properties		
26	Compressible Fluid Dynamics		
27	Vapor Power Equipment		
28	Vapor Power Cycles		
29	Combustion Power Cycles		
30	Nuclear Power Cycles		
31	Advanced and Alternative Systems		
32	Gas Compression Cycles		
33	Refrigeration Cycles		
34	Fundamental Heat Transfer		
35	Natural Convection		
36	Forced Convection		
37	Radiation and Combined Heat Transfer		
38	Psychrometrics		
39	Ventilation		
40	Heating Load		
41	Cooling Load		
42	Air Conditioning Systems and Controls		
43	Determinate Statics		
44	Indeterminate Statics		
45	Engineering Materials		

(continued)

Table 4 *Schedule for Self-Study (continued)*

chapter number	subject	date to start	date to finish
46	Material Properties and Testing		
47	Thermal Treatment of Metals		
48	Properties of Areas		
49	Strength of Materials		
50	Failure Theories		
51	Basic Machine Design		
52	Advanced Machine Design		
53	Pressure Vessels		
54	Properties of Solid Bodies		
55	Kinematics		
56	Kinetics		
57	Mechanisms and Power Transmission		
58	Vibrating Systems		
59	Modeling of Engineering Systems		
60	Analysis of Engineering Systems		
61	Management Science		
62	Instrumentation and Measurements		
63	Manufacturing Processes		
64	Materials Handling and Processing		
65	Fire Protection Systems		
66	Environmental Engineering		
67	Electricity and Electrical Equipment		
68	Illumination and Sound		
69	Engineering Economic Analysis		
70	Engineering Law		
71	Engineering Ethics		
72	Engineering Registration in the United States		