Study Guide for the Professional Licensure of Mining and Mineral Processing Engineers

seventh edition

SME

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Principles and Practice of Engineering (P.E.) Examination

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Society for Mining, Metallurgy, and Exploration, Inc. (SME)
8307 Shaffer Parkway
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(303) 973-9550 / (800) 763-3132
www.smenet.org

SME advances the worldwide minerals community through information exchange and professional development. SME is the world's largest association of mining and minerals professionals.

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Preface

The *Study Guide for Professional Licensure of Mining and Mineral Processing Engineers* is primarily intended as an aid for individuals applying and preparing for a state mining and mineral processing professional engineering (PE) examination. This examination is offered each fall by many, but not all, of the 50 states, four territories, and the District of Columbia. The licensing board of each state or territory is responsible for administering the examination in that state or territory. Specific questions about dates, procedures, and locations should be directed to that particular board. Chapter 6 is a list of the licensure and registration boards.

The Mining and Mineral Processing PE examination includes 80 multiple-choice questions that meet the test specifications outlined in Chapter 10 of this study guide. The examination is 8 hours in length and is divided into two 4-hour sessions of 40 questions each. Chapter 12 presents a sample examination containing questions similar to those given on previous exams.

The Professional Engineers Exam Committee of the Society for Mining, Metallurgy, and Exploration, Inc. (SME), prepares the Mining and Mineral Processing PE examination under contract to the National Council of Examiners for Engineering and Surveying (NCEES). NCEES was established to assist the state and U.S. territory licensing boards and supplied much of the material contained in this study guide. The council's permission to use this information is gratefully acknowledged.

The Study Guide Revision Committee also thanks Frank Filas, P.E., editor of the 6th edition, which formed the basis of much of this document, and all of the SME staff and Professional Engineers Exam Committee participants who contributed to this new edition.

Study Guide Revision Committee
Rahul Bhaduri, M.S., P.E.
David E. Krebs, P.E.
Georgene Renner
William K. Smith, Ph.D., P.E.
Landy A. Stinnett, M.S., P.E.
R. Karl Zipf Jr., Ph.D., P.E.

Introduction

Engineers involved in mining, mineral processing, exploration, and closely related fields have been licensed or registered in individual states for many years. However, a national examination on the principles and practices of mining and mineral process engineering did not become available until 1979 when the Society for Mining, Metallurgy, and Exploration, Inc. (SME), with the assistance of the National Council of Examiners for Engineering and Surveying (NCEES), developed test specifications and prepared the first national examination. NCEES supplies the examination to the state boards. By administering a national examination, it is expected that individuals who qualify in one state would also qualify for licensure or registration in any other state or territory.

The examination format has changed significantly over the intervening years. Originally, the examination was given in an essay format. The candidate could choose 8 problems to work from a selection of 20 problems. These problems were then hand-graded by experts in the field. This format gradually evolved to include both essay and multiple-choice questions. At the urging of the state boards and NCEES, the test format was further changed in 2002 to the current machine-graded, 80-question, multiple-choice format. Although the test format has changed, its basic purpose—to objectively assess a candidate's engineering skills and knowledge in the mining and mineral processing field—remains the same. Beginning in 2009, the name of the examination was changed to the Mining and Mineral Processing (M/MP) exam to eliminate confusion.

In preparing the examination, SME assumes that PE licensure establishes only a minimum qualification—competence is ultimately judged by the registrant's reputation and experience. It is unreasonable to expect an examination to be the ultimate criterion of the breadth and depth of skills and knowledge required in a professional's area of practice. Accordingly, the examination is designed to demonstrate general knowledge of the mining and minerals industry and the ability to apply that general knowledge and engineering principles, with common sense, to problems of practice in the industry.

CHAPTER 1

Developing a Professional Career

A combination of education, practical work experience, and good judgment is needed to develop as a professional in the field of engineering. Good judgment includes conducting oneself in both an ethical and technically competent manner. As discussed below, each of these aspects of professional development plays an important role in one's career as an engineer.

ENGINEERING EDUCATION

Most of the practicing engineers in the United States have an undergraduate degree from an engineering program that has been accredited by ABET, Inc. (formerly the Accreditation Board for Engineering and Technology). Programs with ABET accreditation meet the required standards for curricula and faculty that give the student the opportunity to obtain a comprehensive education in an engineering discipline. Substantial equivalency to ABET accreditation has also been recognized for some engineering schools located in other countries.

Some practicing engineers do not have an undergraduate degree from an ABET-accredited program. The educational background of these individuals varies considerably. However, if you are a practicing engineer, you have most likely acquired the necessary educational background through a combination of engineering, science, and technical classes, and on-the-job engineering work experience. Most licensure boards recognize the equivalency of this type of educational background but require more years of engineering work experience before allowing you to become licensed.

With the rapid changes occurring today in most engineering and technical fields, it is increasingly important for you to continue your educational development after graduation. This may include periodically reviewing current technical literature, participating in technical societies and trade shows, and attending technical classes or short courses. Participating in civil and social activities is another form of continuing education that plays an important role in your professional development. Some licensure boards emphasize the need for continuing education by requiring licensed engineers to actively participate in various technical and educational activities as a condition of continued status as a licensed professional engineer.

WORK EXPERIENCE

If you are just out of school, you may find it difficult to immediately apply your engineering knowledge and skills to solving practical problems at a professional level. Practical work experience provides the following opportunities to help you develop your engineering abilities and professional career.

- Evaluation and counseling or mentoring on a continuing basis
- Progression toward greater responsibility
- Tasks and assignments to apply and develop knowledge and skills
- Economic compensation and advancement
- Encouragement to participate in technical society work
- Some form of organizational career ladder
- An atmosphere favorable to professional development

Employers differ considerably about what constitutes professional attitude and development. Regardless of the work environment, you must ultimately accept personal responsibility for your own professional development, both on and off the job.

ENGINEERING ETHICS

As an engineer, whether you deal directly or indirectly with the public you serve, you must be trustworthy and ethical. The National Council of Examiners for Engineering and Surveying has prepared and periodically updates the *Model Rules of Professional Conduct*. These rules, which are presented in full in Chapter 7 of this study guide, are summarized below.

Licensed professional engineers shall:

- Hold paramount the safety, health, and welfare of the public in the performance of their professional duties;
- Perform such services only in the areas of their competence;
- Issue public statements only in an objective and truthful manner;
- Act in professional matters for each employer or client as faithful agents or trustees, and avoid conflicts of interest; and
- Avoid improper solicitation of professional employment.

ENGINEERING COMPETENCE

The engineering licensure process has set some basic standards from which competency can be demonstrated. The basic standards are:

- An accredited engineering education or equivalent

- An initial examination (the Fundamentals of Engineering examination) to measure your knowledge of engineering fundamentals
- Experience and training in the engineering community, usually for a minimum of four years
- A second examination (Principles and Practice of Engineering) intended to measure, to a limited or minimum degree, your ability to solve appropriate and practical engineering problems on a professional basis
- Professional peer references testifying to performance and character

Licensure is a means to measure minimum-level competency. It does not, however, guarantee that an engineer has all the skills required to perform individual assignments. As a professional engineer, it is up to you to develop and maintain a high level of competency in the technical areas in which you routinely work.

CHAPTER 2 Why Licensure?

Because of the nature of their employment, many mining and mineral processing engineers are not required to be licensed. However, engineers engaged in private practice, and many who are employed by consulting firms, are faced with the necessity of licensure. Many others become licensed to demonstrate professional competence and to be considered for future professional positions. Some engineers are currently exempt from licensure. Under current state laws, you are exempt if you:

- Work in a corporation engaged in interstate commerce,
- Work in a manufacturing corporation, or
- Work in a public service corporation (public utility).

Licensure has become more desirable with the current national emphasis on health and safety, consumer protection, and environmental concerns. Having a professional engineer's license is one way in which you can demonstrate your credibility to the public.

HISTORY OF REGISTRATION AND LICENSURE

Medicine in Europe was the first profession to be regulated. In 1140, doctors were required to present proof of competency before being allowed to practice medicine. In the reign of Roger, King of Normandy, doctors were required to be examined and certified by their peers.

Professional registration experienced a slow start in the United States, beginning in 1883 when dentists were required to be licensed. Later, doctors, lawyers, pharmacists, architects, nurses, and accountants were among those to be regulated and licensed.

Engineering registration in the United States started in Wyoming in 1907 as a way to stop abuses in land surveys and water rights. The number of jurisdictions with registration laws reached 22 in 1925 and 47 in 1941. Today, all

50 states, four U.S. territories (Guam, Northern Mariana Islands, Puerto Rico, Virgin Islands), and the District of Columbia have licensure or registration laws.

ADVANTAGES OF LICENSURE

The states license engineers as a means to protect life, health, and property, and to promote public welfare. Only about 20% of licensed engineers have a legal need to be licensed. Even though you may be exempt from licensure in the state in which you reside, or are not legally required to become a licensed engineer, doing so:

- Demonstrates your voluntary compliance with the spirit of the licensure laws;
- Confers a recognition of competency, qualifying those who meet a minimum standard;
- Establishes your credibility when you appear at public hearings and in courts of law;
- Allows you to use the title "engineer" in any way. Some companies, governmental agencies, and states restrict the use of the engineer title to those who are licensed.
- Provides greater opportunity for professional advancement.

At some future time, you may wish to enter private practice where engineering is regulated and licensure is mandatory. Keep in mind that requirements for and statutes governing licensure do change from time to time. More stringent examination standards may be imposed; exempt status may be removed.

WHAT LICENSURE DOES NOT DO

Licensure:

- Does not stipulate excellence;
- Does not denote outstanding capabilities but merely qualifies those who meet a minimum, acceptable standard;
- Does not guarantee that an individual has all the skills required for assignments
- Is not a substitute for employment standards established by a company.

PERCEPTION OF THE PROFESSIONAL

Engineering is relatively high on the list of professions in terms of public trust. The terms "for the benefit of mankind" and "for the public welfare" are included in definitions of engineering practice. When you achieve professional engineer licensure with voluntary acceptance of rules of professional conduct, you are attesting to your belief that what you do in practice best serves the client, employer, or employees and holds paramount the safety, health, and welfare of the public. This is true whether or not licensure is legally required. Licensure also helps eliminate the indiscriminate use of engineer titles by those not truly qualified by education, training, and experience.

CHAPTER 3

Professional Engineering Licensure

All 50 states, four territories, and the District of Columbia license professional engineers as a means to protect property, life, and health, and to promote public welfare. Licensure as a professional engineer through a state board is the only legal way for an engineer to publicly practice engineering.

Approval of an applicant licensed in another state through reciprocity or comity is based on satisfaction of the minimum standards of each board to which application is made. Because each state is autonomous, state statutes and board regulations are not uniform.

STATE LICENSURE BOARDS

State licensure boards are responsible for the licensing process. The boards share similar licensing procedures, although details and specific requirements vary to some extent. A board draws on its education and experience to judge candidates. The judgment process may include the formal administration of the Fundamentals of Engineering (FE) examination (formerly the Engineer-In-Training [EIT] examination) and the Principles and Practice of Engineering examination (usually referred to as the Professional Engineering [PE] examination). Both examinations are eight hours in length (divided into two four-hour sessions). All states use examinations prepared by the National Council of Examiners for Engineering and Surveying (NCEES).

NCEES is a nonprofit corporation established by the state licensing boards to oversee the licensing process. Although the states use a uniform examination, requirements in terms of education and experience for admission to the examination vary from state to state. If you are seeking licensure, consult the appropriate board in your state for specific requirements.

The United States contains 55 independent licensure jurisdictions, each of which sets and administers its own licensing requirements and operates within the framework of its own laws. The number of people on the boards varies from state to state, but most average from five to seven members. Board appointments are generally made by the state governors, often on recommendation by professional engineering societies. Chapter 6 contains a list of the licensing boards and contact information.

NATIONAL COUNCIL OF EXAMINERS FOR ENGINEERING AND SURVEYING

NCEES, which administers the engineering examinations nationally, was founded in 1920. The organization is a confederation of state and jurisdictional boards. NCEES operates by consensus of the state boards. Each of the state boards administers its own licensing requirements and has full autonomy. However, with the assistance of NCEES, the licensure standards of the various states have become more uniform over time.

In 1965, responding to a request from member boards seeking uniformity in testing procedures, NCEES offered its first professional examination in four major disciplines: Civil, Chemical, Electrical, and Mechanical Engineering. In 1978, the Society of Mining Engineers (now the Society for Mining, Metallurgy, and Exploration, Inc. [SME]) became a participating organization of NCEES. This acceptance placed the discipline of Mining/Mineral Engineering before NCEES state member boards on a national level. The first Mining and Mineral (M/M) PE examination was offered in April 1979. Beginning with the exam in 2009, the name of the exam will be changed to Mining and Mineral Processing to better reflect the content of the exam. There are currently 17 professional engineering disciplines represented through NCEES: Agricultural, Architectural, Chemical, Civil, Control Systems, Electrical and Computer, Environmental, Fire Protection, Industrial, Mechanical, Metallurgical and Materials, Mining and Mineral Processing, Naval Architecture and Marine Engineering, Nuclear, Petroleum, Structural I, and Structural II.

All states have used NCEES-prepared exams since 1984. The questions are written and compiled by professional engineers. NCEES also provides central grading services and a recommended passing score for each examination. This recommended passing score is based on an evaluation conducted by a panel of professional engineers who take the examination themselves.

SME PROFESSIONAL ENGINEERS EXAM COMMITTEE

The SME Professional Engineers Exam Committee, which prepares the Mining and Mineral Processing PE examination, consists of a minimum of 18 members, three each from the SME divisions (Coal & Energy, Environmental, Industrial Minerals, Mineral & Metallurgical Processing, Mining & Exploration, and Underground Construction). They serve three-year terms on a staggered basis. A member of the Association of Engineering Geologists serves as liaison member of the committee, and many at-large members also assist in preparing the exam. All members are required to be licensed professional engineers. Major responsibilities of the committee are to compile, supply, and evaluate the

Mining and Mineral Processing PE examination. The committee also monitors pertinent developments affecting the registration of mining and mineral processing engineers and reports regularly to the SME Board of Directors.

REQUIREMENTS FOR PROFESSIONAL ENGINEER LICENSURE

Because professional licensure is based on education, experience, and examination, the traditional path to licensure has been graduation from an accredited engineering program followed by four years of engineering work experience. Examinations are usually administered after the education and experience requirements have been met. In some cases, however, you can qualify for admission to the examination if you did not graduate from an accredited engineering program or if you have had no formal engineering training. Generally, the state boards will require that you show evidence of additional engineering training and satisfactory experience.

Virtually the same in all states, the six general requirements for licensure are:

1. **Age**—The minimum age for eligibility to become an engineer-in-training or an intern engineer varies from 19 to 21. The minimum age for eligibility to become a licensed professional engineer is 25 in most states.
2. **High School Graduation**—The minimum requirement is that all applicants hold a high school diploma or the equivalent.
3. **College Degree**—The standard requirement is an undergraduate degree in engineering from an ABET-accredited program in engineering or the equivalent in board-approved education and engineering experience. Some states require a degree in engineering as a minimum.
4. **Experience**—Evidence of sufficient qualifying engineering experience as of the date of application (not date of examination) is required. Non-degree applicants must present longer periods of experience. Each case is evaluated individually, and the experience must be accredited by the board.
5. **Character**—Usually five references, three of which must be from registered professional engineers, attesting to the applicant's good moral character and integrity are required.
6. **Examination**—In almost all cases, applicants must sit for two written examinations. Only under unusual conditions and circumstances may boards waive a part or parts of the written examinations.

NON-U.S. ENGINEERS SEEKING LICENSURE

Licensure of engineers in the United States is the responsibility of each individual state, not the federal government. To obtain your license to practice, you must apply to the appropriate board in the state in which you plan to practice (see Chapter 6). To become licensed, you must meet the requirements of that state licensing board with respect to education and experience and by passing engineering examinations. U.S. citizenship is not required in most states.

LICENSURE WITHOUT EXAMINATION: EMINENCE—THE SPECIAL CASE

Does an engineer who graduated from a recognized engineering school (ABET accredited) and has had 20 years of practical and responsible experience in engineering need to take the examination to become a licensed professional engineer?

Some states have laws that favor properly qualified engineers with many years of eminent practice. Written examinations may be waived in such cases.

Among the qualifications as evidence of eminence are: high ethical standards, integrity in the practice of the profession, outstanding ability, and interest in the profession and community. Contact the appropriate state board with questions about eminence.

CHAPTER 4

Six Steps to Professional Engineer Licensure

The steps to becoming a licensed professional engineer (PE) are:

1. Education
2. Fundamentals of Engineering (FE) examination
3. Experience
4. Application forms
5. Accreditation
6. Principles and Practice of Engineering (PE) examination

EDUCATION

Education of any kind above high school applies toward qualifying for licensure. The time spent in educational activities, if less than a full college term, will affect the minimum period of experience that is legally acceptable. The levels of education are:

1. Graduates of engineering schools accredited by ABET, Inc.
2. Graduates of other engineering schools (not ABET accredited)
3. High school graduates with partial educational credit from an engineering or technical school
4. High school graduates with no engineering education

Lack of an engineering degree is not a bar to licensure. However, the fewer the years of formal education, the more years of experience generally required. Requirements vary from state to state; check with the state in which you intend to apply for licensure. See Chapter 6 for a complete list of licensure boards.

FUNDAMENTALS OF ENGINEERING EXAMINATION

The FE examination (previously called the Engineer-in-Training exam) is usually offered to college seniors in the spring semester. The multiple-choice examination is given in two four-hour sessions and is machine-graded by the National

Council of Examiners for Engineering and Surveying. A reference handbook (see Chapter 8) is supplied at the time of examination. A list of examination topics is given in Chapter 9.

If you are interested in taking the FE examination and have been out of school for a few years, you might wish to take one of the examination review courses offered at many major universities around the country.

EXPERIENCE

Engineering experience submitted for review must be of a quality satisfactory to the state board of examiners. Board-approved experience and calendar-year experience do not necessarily coincide. All boards insist that *approved* experience be broad in scope and of such a nature as to have developed and matured your knowledge and judgment.

APPLICATION FORMS

Contact the appropriate state board for the application forms. Chapter 6 is a complete list of licensure boards. Because the forms are fairly complex, take ample time to fill them out. Completely and accurately type all information requested. Some states require significant lead time to process applications. Do not wait until the last minute.

When evaluating your engineering experience, the state board members decide whether to accept or reject your application on the basis of your written form and, especially, how well you have documented the evidence. Account for all time. List all experience of an engineering nature and show progression and greater responsibility.

Be scrupulously accurate. All evidence of experience must be attested to by your references. Preferably, the person sought for a reference should be your immediate supervisor for that period of experience.

Some states require the signatures of five additional references with at least three of these being practicing registered professional engineers. These references should be personally acquainted with your professional record. Use good references. Get accurate and current addresses. It is advisable to send a letter, in advance, to each of your references. Tell them what you are doing and thank them, in advance, for quickly endorsing and returning the state board inquiry. If the references respond quickly, delays will be avoided.

A typical application form also requires a certified transcript of your college record. Be sure to include the proper fee when filing the forms.

ACCREDITATION

When a completed application is received by the state board, the board secretary collects all supporting documents and related correspondence. Upon completion of the requirements, the application file is presented to the board members for study. At its next regularly scheduled meeting, the board will make a final decision.

After a decision has been made, you will be notified if you are qualified to take the written examination. The process to this point may have taken 3 to 6 months, so it is advisable to begin the procedure at least 6 months before the next scheduled examination (late October each year for the Mining and Mineral Processing PE exam).

PRINCIPLES AND PRACTICE OF ENGINEERING (PE) EXAMINATION

Professional Engineering (PE) examinations are offered twice a year (April and October) for the larger engineering disciplines and once a year (October) for the smaller engineering disciplines, such as Mining and Mineral Processing. States are not required to offer a PE examination for each engineering discipline. Most states give the Mining and Mineral Processing PE examination in the fall of each year. Most of the PE exams have a multiple-choice format and are given in two four-hour sessions.

In most states, a successful candidate is licensed only as a professional engineer without listing of a specific engineering discipline. However, some states require registration by individual discipline. Regardless of the registration system, as a professional engineer, you are not allowed to accept professional responsibility outside of your area of competence.

CHAPTER 5

The Licensed Professional Engineer

After taking the test, you may wait two to three months for examination results before you are notified by the state board that you passed the test and are now a licensed professional engineer.

ENGINEER'S SEAL

The state board may ask the successful candidate to obtain a personal seal or stamp that meets its set of standards. Depending on the state, the seal or stamp is placed adjacent to (or on top of) your personal signature when you file plans, reports, or correspondence that you have prepared or supervised. You may not give, loan, or sell your seal to someone else for any purpose.

The professional seal serves two purposes: It identifies the professional engineer and it indicates that state authorization was obtained to engage in professional practice. When you place your seal on a document, you are assuming responsibility for the document in terms of the acceptability of the engineering work (including in regard to public health, safety, and welfare).

MULTIPLE LICENSURE

Some engineers do not restrict their practice to a single state or region. However, legal licensure in one state does not entitle you to practice engineering in another state. Because there is no such thing as national licensure, you will need to apply separately for a license in each state in which you plan to practice.

Most boards will grant licensure to a professional engineer licensed in another state through either reciprocity or comity. Reciprocity implies the existence of a formal written agreement between any two boards. Comity is an established legal practice whereby one state extends to citizens of another state the same rights and privileges it accords its own citizens. Some states may also require additional examination in laws that apply within the state, such as earthquake-stability requirements in California.

The National Council of Examiners for Engineering and Surveying (NCEES) Records Verification Program offers a service to professional engineers seeking licensure in multiple jurisdictions. This program allows you to establish a record of your education, experience, references, examination results, and licensing information, which is then verified by NCEES. Once verified, the record is available to all the licensing boards, thereby eliminating a large portion of the paperwork associated with engineering licensure in multiple jurisdictions. All jurisdictions, however, will require that you complete at least part of the standard application, and a few may require additional information to supplement the NCEES record.

CHAPTER 6

List of Licensure and Registration Boards

This chapter contains the mailing addresses of member and affiliate member licensure boards with the name of the person in charge of the office, telephone/fax numbers, and e-mail addresses (as of the publication date of this guide). A current board list may be obtained from the

National Council of Examiners for Engineering and Surveying
280 Seneca Creek Rd.
PO Box 1686
Clemson, SC 29633-1686
Telephone: (864) 654-6824 or (800) 250-3196
Fax: (864) 654-6033
www.ncees.org

ALABAMA

State Board of Licensure for Professional Engineers and Surveyors
100 N. Union St., Suite 382
Montgomery, AL 36104
Mail: PO Box 304451
Montgomery, AL 36130-4451
Regina A. Dinger, Executive Director
Telephone: (334) 242-5568, Fax: (334) 242-5105
E-mail: regina.dinger@bels.alabama.gov
Web site: www.bels.alabama.gov

ALASKA

State Board of Registration for Architects, Engineers and Land Surveyors
State Office Building, 333 Willoughby, 9th Floor
Juneau, AK 99811
Mail: PO Box 100806
Juneau, AK 99811-0806
Ginger Morton, Executive Administrator
Telephone: (907) 465-1676, Fax: (907) 465-2974
E-mail: ginger.morton@Alaska.gov
Web site: www.commerce.state.ak.us/occ/pael.cfm

ARIZONA

State Board of Technical Registration
1110 W. Washington St., Suite 240
Phoenix, AZ 85007
Ronald W. Dalrymple, Executive Director
Telephone: (602) 364-4930, Fax: (602) 364-4931
E-mail: info@btr.state.az.us
Web site: www.azbtr.gov

ARKANSAS

State Board of Registration for Professional Engineers and Land Surveyors
623 Woodlane Dr.
Little Rock, AR 72201
Mail: PO Box 3750
Little Rock, AR 72203
Stephen W. Haralson, P.E., Executive Director
Telephone: (501) 682-2824, Fax: (501) 682-2827
E-mail: stephenw.haralson@arkansas.gov
Web site: www.arkansas.gov/pels

CALIFORNIA

Board for Professional Engineers and Land Surveyors
2535 Capitol Oaks Dr., Suite 300
Sacramento, CA 95833-2944
Cindi Christenson, P.E., Executive Director
Telephone: (916) 263-2230, Fax: (916) 263-2221
E-mail: bpels_office@dca.ca.gov
Web site: www.pels.ca.gov

COLORADO

State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors
1560 Broadway, Suite 1350
Denver, CO 80202
Charles H. Adams, Program Director
Telephone: (303) 894-7788, Fax: (303) 894-7790
E-mail: charles.adams@dora.state.co.us
Web site: www.dora.state.co.us/aes

CONNECTICUT

State Board of Examiners for Professional Engineers and Land Surveyors
The State Office Building
165 Capitol Ave., Room 110
Hartford, CT 06106-1630
Barbara Syp-Maziarz, Board Administrator
Telephone: (860) 713-6145, Fax: (860) 713-7230
E-mail: barbara.syp@ct.gov
Web site: www.ct.gov/dcp

DELAWARE

Delaware Association of Professional Engineers
56 W. Main St., Suite 208, Plaza 273
Christiana, DE 19702
Margaret Abshagen, Executive Director
Telephone: (302) 368-6708, Fax: (302) 368-6710
E-mail: peggy@dape.org
Web site: www.dape.org

DISTRICT OF COLUMBIA

Board of Professional Engineering
941 N. Capitol St. NE, Suite 7200
Washington, DC 20002
Theresa Ennis, Board Representative
Telephone: (202) 442-4320, Fax: (202) 442-4528
E-mail: theresa.ennis@dc.gov
Web site: www.asisvcs.com/indhome_fs.asp?CPCAT=EN09STATEREG

FLORIDA

Board of Professional Engineers
2507 Callaway Rd., Suite 200
Tallahassee, FL 32303
Carrie Flynn, Executive Director
Telephone: (850) 521-0500, Fax: (850) 521-0521
E-mail: cflynn@fbpe.org
Web site: www.fbpe.org

GEORGIA

State Board of Registration for Professional Engineers and Land Surveyors
237 Coliseum Dr.
Macon, GA 31217-3858
Darren Mickler, Executive Director
Telephone: (478) 207-1450, Fax: (478) 207-1456
E-mail: pels@sos.state.ga.us
Web site: www.sos.state.ga.us/plb/pels/

GUAM

Guam Board of Registration for Professional Engineers, Architects and Land Surveyors
Government of Guam
East-West Business Center
718 N. Marine Dr., Suite 208
Upper Tumon, GU 96913
Amor A. Pakingan, Board Administrator
Telephone: (671) 646-3115/3138, Fax: (671) 649-9533
E-mail: amor@guam-peals.org
Web site: www.guam-peals.org

HAWAII

Board of Professional Engineers, Architects, Surveyors and Landscape Architects
335 Merchant St.
Honolulu, HI 96813
Mail: PO Box 3469
Honolulu, HI 96801
James Kobashigawa, Executive Officer
Telephone: (808) 586-2702, Fax: (808) 586-2689
E-mail: easla@dcca.hawaii.gov
Web site: www.hawaii.gov/dcca/pvl

IDAHO

Board of Professional Engineers and Professional Land Surveyors
5535 West Overland Rd.
Boise, ID 83705
David L. Curtis, P.E., Executive Director
Telephone: (208) 373-7210, Fax: (208) 373-7213
E-mail: dave.curtis@ipels.state.id.gov
Web site: www.ipels.idaho.gov

ILLINOIS

Board of Professional Engineers/Department of Financial and Professional Regulation
320 W. Washington St., 3rd Floor
Springfield, IL 62786
M. David Brime, Design Licensing Manager
Telephone: (217) 524-3211, Fax: (217) 782-7645
E-mail: david.brime@illinois.gov
Web site: www.idfpr.com

INDIANA

State Board of Registration for Professional Engineers
402 W. Washington St., Room W-072
Indianapolis, IN 46204
Angela Smith Jones, Board Director
Telephone: (317) 234-3022, Fax: (317) 233-4236
E-mail: ajones@pla.in.gov
Web site: www.pla.in.gov

IOWA

Engineering & Land Surveying Examining Board
1920 SE Hulsizer Rd.
Ankeny, IA 50021
Gleean Coates, Executive Officer
Telephone: (515) 281-7360, Fax: (515) 281-7411
E-mail: gleean.coates@iowa.gov
Web site: www.state.ia.us/government/com/prof/engineer/home.html

KANSAS

State Board of Technical Professions
Landon State Office Building
900 SW Jackson, Suite 507
Topeka, KS 66612-1257
Jean Boline, Executive Director
Telephone: (785) 296-3054, Fax: (785) 296-0167
E-mail: ksbtp2@ink.org
Web site: www.kansas.gov/ksbtp

KENTUCKY

State Board of Licensure for Professional Engineers and Land Surveyors
Kentucky Engineering Center
160 Democrat Dr.
Frankfort, KY 40601
B. David Cox, Executive Director
Telephone: (800) 573-2680 or (502) 573-2680, Fax: (502) 573-6687
E-mail: bdavid.cox@ky.gov
Web site: http://kyboels.ky.gov

LOUISIANA

Louisiana Professional Engineering and Land Surveying Board
9643 Brookline Ave., Suite 121
Baton Rouge, LA 70809-1433
Donna Sentell, Executive Secretary
Telephone: (225) 925-6291, Fax: (225) 925-6292
E-mail: donna@lapels.com
Web site: www.lapels.com

MAINE

State Board of Licensure for Professional Engineers
Augusta Airport Terminal Building, 2nd Floor
Augusta, ME 04330
Mail: 92 State House Station
Augusta, ME 04333-0092
Beatrice M. Labbe, Administrative Office Manager
Telephone: (207) 287-3236, Fax: (207) 626-2309
E-mail: pengineers@prexar.com
Web site: www.maine.gov/professionalengineers/

MARYLAND

State Board for Professional Engineers
500 N. Calvert St., Room 308
Baltimore, MD 21202-3651
Daniel Parr, Executive Director
Telephone: (410) 230-6322, Fax: (410) 333-0021
E-mail: pe@dllr.state.md.us
Web site: www.dllr.state.md.us

MASSACHUSETTS

Board of Registration of Professional Engineers and Professional Land Surveyors
Division of Professional Licensure
239 Causeway St.
Boston, MA 02114
Susan E. Coco, Board Administrator
Telephone: (617) 727-9957, Fax: (617) 727-1627
E-mail: susan.e.coco@state.ma.us
Web site: www.mass.gov/dpl/boards/en/

MICHIGAN

Michigan Department of Labor and Economic Growth, Board of Professional Engineers
2501 Woodlake Cir.
Okemos, MI 48864
Mail: PO Box 30018
Lansing, MI 48909
Gloria Keene, Licensing Administrator
Telephone: (517) 241-9253, Fax: (517) 373-2162
E-mail: gkeene@michigan.gov
Web site: www.michigan.gov/engineers

MINNESOTA

State Board of Architecture, Engineering, Land Surveying, Landscape Architecture, Geoscience, and Interior Design
The Golden Rule Building
85 E. Seventh Pl., Suite 160
St. Paul, MN 55101
Doreen Frost, Executive Director
Telephone: (651) 296-2388, Fax: (651) 297-5310
E-mail: doreen.johnson-frost@state.mn.us
Web site: www.aelslagid.state.mn.us

MISSISSIPPI

State Board of Licensure for Professional Engineers and Surveyors
The Robert E. Lee Building
239 N. Lamar, Suite 501
Jackson, MS 39205
Mail: PO Box 3
Jackson, MS 39205
Rosemary Brister, Executive Director
Telephone: (601) 359-6160, Fax: (601) 359-6159
E-mail: information@pepls.state.ms.us
Web site: www.pepls.state.ms.us

MISSOURI

Board for Architects, Professional Engineers, Land Surveyors, and Landscape Architects
3605 Missouri Blvd., Suite 380
Jefferson City, MO 65109
Mail: PO Box 184
Jefferson City, MO 65102
Judy Kempker, Executive Director
Telephone: (573) 751-0047, Fax: (573) 751-8046
E-mail: moapels@pr.mo.gov
Web site: http://pr.mo.gov/apelsla.asp

MONTANA

Board of Professional Engineers and Professional Land Surveyors
Department of Commerce
301 S. Park Ave., 4th Floor
Helena, MT 59620
Mail: PO Box 200513
Helena, MT 59620-0513
Brooke Jasmin, Executive Officer
Telephone: (406) 841-2367, Fax: (406) 841-2309
E-mail: dlibsdpels@state.mt.gov
Web site: www.engineer.mt.gov

NEBRASKA

Board of Engineers and Architects
215 Centennial Mall South, Suite 400
Lincoln, NE 68509
Mail: PO Box 95165
Lincoln, NE 68509
Melinda E. Pearson, Executive Director
Telephone: (402) 471-2021 or (402) 471-2407, Fax: (402) 471-0787
E-mail: board@ne.gov
Web site: www.ea.state.ne.us

NEVADA

State Board of Professional Engineers and Land Surveyors
1755 E. Plumb Ln., Suite 135
Reno, NV 89502
Noni Johnson, Executive Director
Telephone: (775) 688-1231, Fax: (775) 688-2991
E-mail: board@boe.state.nv.us
Web site: www.boe.state.nv.us

NEW HAMPSHIRE

Board of Professional Engineers
57 Regional Dr.
Concord, NH 03301
Louise Lavertu, Executive Director
Telephone: (603) 271-2219, Fax: (603) 271-6990
E-mail: llavertu@nhsa.state.nh.us
Web site: www.state.nh.us/jtboard/home.htm

NEW JERSEY

State Board of Professional Engineers and Land Surveyors
124 Halsey St., 3rd Floor
Newark, NJ 07102
Mail: PO Box 45015
Newark, NJ 07101
Arthur Russo, Executive Director
Telephone: (973) 504-6460, Fax: (973) 273-8020
E-mail: russoa@dca.lps.state.nj.us
Web site: www.state.nj.us/lps/ca/nonmedical/pels.htm

NEW MEXICO

Board of Licensure for Professional Engineers and Professional Surveyors
4001 Office Court Dr., Suite 903
Santa Fe, NM 87505-4962
Elena Garcia, Executive Director
Telephone: (505) 827-7561, Fax: (505) 827-7566
E-mail: elena.garcia@state.nm.us
Web site: www.sblpes.state.nm.us

NEW YORK

State Board for Engineering and Land Surveying
State Education Building
89 Washington Ave., 2nd Floor Mezzanine East Wing
Albany, NY 12234-1000
Jane Blair, Executive Secretary
Telephone: (518) 474-3817 Ext. 140, Fax: (518) 473-6282
E-mail: enginbd@mail.nysed.gov
Web site: www.op.nysed.gov

NORTH CAROLINA

Board of Examiners for Engineers and Surveyors
4601 Six Forks Rd., Suite 310
Raleigh, NC 27609
Andrew L. Ritter, Executive Director
Telephone: (919) 791-2000, Fax: (919) 791-2012
E-mail: aritter@ncbels.org
Web site: www.ncbels.org

NORTH DAKOTA

State Board of Registration for Professional Engineers and Land Surveyors
723 W. Memorial Hwy.
Bismarck, ND 58504
Mail: PO Box 1357
Bismarck, ND 58502-1357
Clifford E. Keller, Executive Secretary
Telephone: (701) 258-0786, Fax: (701) 258-7471
E-mail: cliff.ndboard@btinet.net
Web site: www.ndpelsboard.org/

NORTHERN MARIANA ISLANDS

Board of Professional Licensing
Commonwealth of Northern Mariana Islands
PO Box 502078
Saipan, Northern Mariana Islands 96950
Ms. Florence C. Sablan, Executive Director
Telephone: (011) (670) 664-4809, Fax: (011) (670) 664-4813
E-mail: nmi.bpl@gtepacifica.net

OHIO

State Board of Registration for Professional Engineers and Surveyors
50 West Broad St., Suite 1820
Columbus, OH 43215
John F. Greenhalge, Executive Director
Telephone: (614) 466-3651, Fax: (614) 728-3059
E-mail: john.greenhalge@pes.ohio.gov
Web site: www.ohiopeps.org

OKLAHOMA

State Board of Licensure for Professional Engineers and Land Surveyors
Oklahoma Engineering Center
201 NE 27th St., Room 120
Oklahoma City, OK 73105
Kathy Hart, Executive Director
Telephone: (405) 521-2874, Fax: (405) 523-2135
E-mail: kathy@pels.state.ok.us
Web site: www.pels.state.ok.us/

OREGON

State Board of Examiners for Engineering and Land Surveying
670 Hawthorne Ave. SE, Suite 220
Salem, OR 97301
Mari Lopez, Executive Secretary
Telephone: (503) 362-2666, Fax: (503) 362-5454
E-mail: lopezm@osbeels.org
Web site: www.osbeels.org

PENNSYLVANIA

State Registration Board for Professional Engineers, Land Surveyors, and Geologists
2601 N. Third St.
Harrisburg, PA 17110
Mail: PO Box 2649
Harrisburg, PA 17105-2649
Terie Kocher, Board Administrator
Telephone: (717) 783-7049, Fax: (717) 705-5540
E-mail: st-engineer@state.pa.us
Web site: www.dos.state.pa.us/eng

PUERTO RICO

Board of Examiners of Engineers and Land Surveyors
Secretaria Auxiliar de Juntas Examinadoras
151 Calle de la Fortaleza
San Juan, PR 00901-1545
Mail: Secretaria Auxiliar de Juntas Examinadoras
Department of State
PO Box 9023271
San Juan, PR 00902-3271
Executive Director
Telephone: (787) 722-4816, (787) 722-2122 Ext. 232 (Board), Fax: (787) 722-4818
E-mail: ingenarios@estado.gobierno.pr
Web site: www.estado.gobierno.pr/ingenieros.htm

RHODE ISLAND

Board of Registration for Professional Engineers
1 Capitol Hill, 2nd Floor
Providence, RI 02908
Lois Marshall, Administrative Assistant
Telephone: (401) 222-2565, Fax: (401) 222-5744
E-mail: loism@mail.state.ri.us
Web site: www.bdp.state.ri.us

SOUTH CAROLINA

State Board of Registration for Professional Engineers and Land Surveyors
Kingstree Building
110 Centerview Dr., Suite 201
Columbia, SC 29210
Mail: PO Box 11597
Columbia, SC 29211-1597
Jan Simpson, Board Administrator
Telephone: (803) 896-4422, Fax: (803) 896-4427
E-mail: engls@mail.llr.state.sc.us
Web site: www.llr.state.sc.us/POL/Engineers

SOUTH DAKOTA

Board of Technical Professions
2040 W. Main St., Suite 304
Rapid City, SD 57702-2447
Mark Humphreys, Executive Director
Telephone: (605) 394-2510, Fax: (605) 394-2509
E-mail: mark.humphreys@state.sd.us
Web site: www.state.sd.us/dol/boards/engineer

TENNESSEE

State Board of Architectural and Engineering Examiners
Department of Commerce and Insurance
500 James Robertson Pkwy., 3rd Floor
Nashville, TN 37243-1142
John Cothron, Executive Director
Telephone: (615) 741-3221 or (800) 256-5758, Fax: (615) 532-9410
E-mail: john.cothron@state.tn.us
Web site: www.state.tn.us/commerce/boards/ae/

TEXAS

Board of Professional Engineers
1917 Interstate Hwy. 35 South
Austin, TX 78741
Paul Cook, Acting Executive Director
Randi Warrington, Deputy Executive Director
Telephone: (512) 440-7723, Fax: (512) 440-0417
E-mail: peboard@tbpe.state.tx.us
Web site: www.tbpe.state.tx.us

UTAH

Utah Professional Engineers and Professional Land Surveyors Board
160 East 300 South, 1st Floor
Salt Lake City, UT 84111
Mail: PO Box 146741
Salt Lake City, UT 84114-6741
Dennis Meservy, Board Administrator
Telephone: (801) 530-6696, Fax: (801) 530-6511
E-mail: dmeservy@utah.gov
Web site: www.dopl.utah.gov

VERMONT

Board of Professional Engineering
Vermont Secretary of State, Office of Professional Regulation
National Life Building North, Floor 2
Montpelier, VT 05602-3402
Loris Rollins, Board Administrator
Telephone: (802) 828-1505, Fax: (802) 828-2465
E-mail: lrollins@sec.state.vt.us
Web site: www.vtprofessionals.org

VIRGIN ISLANDS

Board for Architects, Engineers, and Land Surveyors
Department of Licensing & Consumer Affairs
Golden Rock Shopping Center
Christiansted, St. Croix, Virgin Islands 00820
Lisa Davis, Administrator
Telephone: (340) 773-2226, Fax: (340) 713-8308
E-mail: boards@dlca.gov.vi
Web site: www.dlca.gov.vi/pro-aels.html

VIRGINIA

Board of Architects, Professional Engineers, Land Surveyors, Certified Interior Designers, and Landscape Architects
Department of Professional & Occupational Regulation
9960 Maryland Dr., Suite 400
Richmond, VA 23233
Mail: DPOR
PO Box 11066
Richmond, VA 23230
Mark N. Courtney, Administrator
Telephone: (804) 367-8512 (Board), (804) 367-8514 (Administrator), Fax: (804) 527-4294
E-mail: APELSCIDLA@dpor.state.va.us
Web site: www.dpor.virginia.gov

WASHINGTON

State Board of Registration for Professional Engineers and Land Surveyors
405 Black Lake Blvd. SW
Olympia, WA 98502
Mail: PO Box 9025
Olympia, WA 98507-9025
George Twiss, P.L.S., Executive Director
Telephone: (360) 664-1575, Fax: (360) 664-2551
E-mail: engineers@dol.wa.gov
Web site: www.dol.wa.gov/business/engineerslandsurveyors

WEST VIRGINIA

State Board of Registration for Professional Engineers
300 Capitol St., Suite 910
Charleston, WV 25301
Lesley L. Rosier-Tabor, P.E., Executive Director
Telephone: (304) 558-3554, Fax: (304) 558-6232
E-mail: lesley@wvpebd.org
Web site: www.wvpebd.org

WISCONSIN

Examining Board of Architects, Landscape Architects, Professional Engineers, Designers and Land Surveyors
1400 E. Washington Ave.
Madison, WI 53703
Mail: PO Box 8935
Madison, WI 53708
Tim Wellnitz, Director
Telephone: (608) 266-2112, Fax: (608) 267-3816
E-mail: dorl@drl.state.wi.us
Web site: www.drl.state.wi.us

WYOMING

State Board of Registration for Professional Engineers and Professional Land Surveyors
6920 Yellowtail Dr., Suite 100
Cheyenne, WY 82002
Christine Turk, Executive Director
Telephone: (307) 777-6155, Fax: (307) 777-3403
E-mail: wyopepls@state.wy.us
Web site: http://engineersandsurveyors.wy.gov

CHAPTER 7

NCEES Model Rules of Professional Conduct

The National Council of Examiners for Engineering and Surveying (NCEES) *Model Rules of Professional Conduct* provide guidance and direction for licensed engineers and land surveyors regarding ethical and moral conduct. NCEES recommends that state legislatures or licensing boards adopt these rules. These rules, last revised in 2007, are presented verbatim in this chapter with NCEES permission.

PREAMBLE

To comply with the purpose of the (identify jurisdiction, licensing statute), which is to safeguard life, health, and property, to promote the public welfare, and to maintain a high standard of integrity and practice—the (identify board, licensing statute) has developed the following *Rules of Professional Conduct*. These rules shall be binding on every person holding a certificate of licensure to offer or perform engineering or surveying services in this state. All persons licensed under (identify jurisdiction's licensing statute) are required to be familiar with the licensing statute and these rules. The *Rules of Professional Conduct* delineate specific obligations the licensee must meet. In addition, each licensee is charged with the responsibility of adhering to the highest standards of ethical and moral conduct in all aspects of the practice of professional engineering and surveying.

The practice of professional engineering and surveying is a privilege, as opposed to a right. All licensees shall exercise their privilege of practicing by performing services only in the areas of their competence according to current standards of technical competence.

Licensees shall recognize their responsibility to the public and shall represent themselves before the public only in an objective and truthful manner. They shall avoid conflicts of interest and faithfully serve the legitimate interests of their employers, clients, and customers within the limits defined by these rules. Their professional reputations shall be built on the merit of their services, and they shall not compete unfairly with others.

The *Rules of Professional Conduct* as promulgated herein are enforced under the powers vested by (identify jurisdiction's enforcing agency). In these rules, the word "licensee" shall mean any person holding a license or a certificate issued by (identify jurisdiction's licensing agency).

RULES OF PROFESSIONAL CONDUCT

A. Licensee's Obligation to Society
   1. Licensees, in the performance of their services for clients, employers, and customers, shall be cognizant that their first and foremost responsibility is to the public welfare.
   2. Licensees shall approve and seal only those design documents and surveys that conform to accepted engineering and surveying standards and safeguard the life, health, property, and welfare of the public.
   3. Licensees shall notify their employer or client and such other authority as may be appropriate when their professional judgment is overruled under circumstances where the life, health, property, or welfare of the public is endangered.
   4. Licensees shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony.
   5. Licensees shall express a professional opinion publicly only when it is founded upon an adequate knowledge of the facts and a competent evaluation of the subject matter.
   6. Licensees shall issue no statements, criticisms, or arguments on technical matters which are inspired or paid for by interested parties, unless they explicitly identify the interested parties on whose behalf they are speaking and reveal any interest they have in the matters.
   7. Licensees shall not permit the use of their name or firm name by, nor associate in the business ventures with, any person or firm which is engaging in fraudulent or dishonest business or professional practices.
   8. Licensees having knowledge of possible violations of any of these *Rules of Professional Conduct* shall provide the board with the information and assistance necessary to make the final determination of such violation.

B. Licensee's Obligation to Employer and Clients
   1. Licensees shall undertake assignments only when qualified by education or experience in the specific technical fields of engineering or surveying involved.
   2. Licensees shall not affix their signatures or seals to any plans or documents dealing with subject matter in which they lack competence, nor

to any such plan or document not prepared under their direct control and personal supervision.

3. Licensees may accept assignments for coordination of an entire project, provided that each design segment is signed and sealed by the licensee responsible for preparation of that design segment.
4. Licensees shall not reveal facts, data, or information obtained in a professional capacity without the prior consent of the client or employer except as authorized or required by law. Licensees shall not solicit or accept gratuities directly or indirectly, from contractors, their agents, or other parties in connection with work for employers or clients.
5. Licensees shall make full prior disclosures to their employers or clients of potential conflicts of interest or other circumstances which could influence or appear to influence their judgment or the quality of their service.
6. Licensees shall not accept compensation, financial or otherwise, from more than one party for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.
7. Licensees shall not solicit or accept a professional contract from a governmental body on which a principal or officer of their organization serves as a member. Conversely, licensees serving as members, advisors, or employees of a government body or department, who are the principals or employees of a private concern, shall not participate in decisions with respect to professional services offered or provided by said concern to the governmental body which they serve.

C. Licensee's Obligation to Other Licensees

1. Licensees shall not falsify or permit misrepresentation of their, or their associates', academic or professional qualifications. They shall not misrepresent or exaggerate their degree of responsibility in prior assignments nor the complexity of said assignments. Presentations incident to the solicitation of employment or business shall not misrepresent pertinent facts concerning employers, employees, associates, joint ventures, or past accomplishments.
2. Licensees shall not offer, give, solicit, or receive, either directly or indirectly, any commission, or gift, or other valuable consideration in order to secure work, and shall not make any political contribution with the intent to influence the award of a contract by public authority.
3. Licensees shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other licensees, nor indiscriminately criticize other licensees' work.

CHAPTER 8

NCEES Publications

The National Council of Examiners for Engineering and Surveying (NCEES) offers the publications listed below to help you prepare for and take the Fundamentals of Engineering (FE) and Professional Engineering (PE) examinations. You can order these publications from:

National Council of Examiners for Engineering and Surveying
1820 Seneca Creek Rd.
PO Box 1686
Clemson, SC 29633-1686
Telephone: (864) 654-6824 or (800) 250-3196
Fax: (864) 654-6033
www.ncees.org

FE SUPPLIED-REFERENCE HANDBOOK

The *Fundamentals of Engineering Supplied-Reference Handbook* is the only reference material allowed in the FE exam room. Review this book before the exam to become familiar with the charts, formulas, tables, and other reference information it contains. You cannot bring a personal copy of this handbook into the exam room; however, an identical handbook will be supplied with the examination.

FE TYPICAL QUESTIONS AND SOLUTIONS

Fundamentals of Engineering: Typical Questions and Solutions provides 30 example FE questions and solutions from the morning portion of the exam and 6 questions from each of the seven disciplines offered in the afternoon.

FE SAMPLE QUESTIONS AND SOLUTIONS

Each book (seven in all) gives half of a sample FE examination, including questions and solutions from the morning portion of the exam as well as questions and solutions from one of the seven disciplines offered in the afternoon. The seven disciplines are Chemical, Civil, Electrical, Environmental, Industrial, Mechanical, and Other/General Engineering.

PE SAMPLE QUESTIONS AND SOLUTIONS—CIVIL

Principles and Practice of Engineering: Sample Questions and Solutions—Civil presents half the number of questions that appear in an actual Civil PE examination plus detailed exam specifications and solutions.

PE SAMPLE QUESTIONS AND SOLUTIONS—OTHER DISCIPLINES

Each of these books contains a complete sample PE exam plus detailed exam specifications and solutions. Books are available for Chemical, Electrical, Environmental, Mechanical, and Structural Engineering.

CHAPTER 9

The Fundamentals of Engineering Examination

The National Council of Examiners for Engineering and Surveying (NCEES) supplies the references for the Fundamentals of Engineering (FE) examination. You may carry only pencils and calculators into the examination room. The reference handbook will be supplied along with the examination materials. Before leaving the examination, you must turn in your examination booklet, answer sheet, and supplied reference handbook.

The FE examination consists of morning and afternoon sessions and you must complete both sessions to receive a score. The four-hour morning session is common to all disciplines and consists of 120 one-point questions. The four-hour afternoon session is administered in the following seven modules: Chemical, Civil, Electrical, Environmental, Industrial, Mechanical, and an Other/General Engineering section for all remaining disciplines. The afternoon session consists of 60 two-point questions. You must work all the questions in the morning session and all the questions in the afternoon session.

MORNING SESSION

The morning session of the FE exam consists of 120 multiple-choice questions from the 12 subjects on the following page. Four answer choices are given from which you must select the one best answer. Scores depend on the number of questions answered correctly. No subtraction is made for incorrect answers. The percentage of questions in each subject area is also given.

Topic Area		Percentage
I.	Mathematics	15
II.	Engineering Probability and Statistics	7
III.	Chemistry	9
IV.	Computers	7
V.	Ethics and Business Practices	7
VI.	Engineering Economics	8
VII.	Engineering Mechanics (Statics and Dynamics)	10
VIII.	Strength and Materials	7
IX.	Material Properties	7
X.	Fluid Mechanics	7
XI.	Electricity and Magnetism	9
XII.	Thermodynamics	7
	Total	100

AFTERNOON SESSION

The afternoon session consists of 60 two-point, multiple-choice questions in one of the following disciplines: Chemical, Civil, Electrical, Environmental, Industrial, Mechanical, and Other/General Engineering. You must specify which afternoon session you will take when applying to take the exam. Scores depend on the number of questions you answer correctly. Points are not subtracted for incorrect answers. Specifications for each of the afternoon sessions are summarized in the following tables. Additional details regarding each session and study guide materials may be obtained from NCEES at www.ncees.org.

Chemical Engineering

Topic Area	Percentage
Chemistry	10
Material/Energy Balances	15
Chemical Engineering Thermodynamics	10
Fluid Dynamics	10
Heat Transfer	10
Mass Transfer	10
Chemical Reaction Engineering	10
Process Design and Economic Optimization	10
Computer Usage in Chemical Engineering	5
Process Control	5
Safety, Health, and Environmental	5
Total	100

Civil Engineering

Topic Area	Percentage
Surveying	11
Hydraulics and Hydrologic Systems	12
Soil Mechanics and Foundations	15
Environmental Engineering	12
Transportation	12
Structural Analysis	10
Structural Design	10
Construction Management	10
Materials	8
Total	100

Environmental Engineering

Topic Area	Percentage
Water Resources	25
Water and Wastewater Engineering	30
Air Quality Engineering	15
Solid and Hazardous Waste Engineering	15
Environmental Science and Management	15
Total	100

Industrial Engineering

Topic Area	Percentage
Engineering Economics	15
Probability and Statistics	15
Modeling and Computation	12
Industrial Management	10
Manufacturing and Production Systems	13
Facilities and Logistics	12
Human Factors, Productivity, Ergonomics, and Work Design	12
Quality	11
Total	100

Other/General Engineering

Topic Area	Percentage
Advanced Engineering Mathematics	10
Engineering Probability and Statistics	9
Biology	5
Engineering Economics	10
Application Engineering Mechanics	13
Engineering of Materials	11
Fluids	15
Electricity and Magnetism	12
Thermodynamics and Heat Transfer	15
Total	100

Electrical Engineering

Topic Area	Percentage
Circuits	16
Power	13
Electromagnetics	7
Control Systems	10
Communications	9
Signal Processing	8
Electronics	15
Digital Systems	12
Computer Systems	10
Total	100

Mechanical Engineering

Topic Area	Percentage
Mechanical Design and Analysis	15
Kinematics, Dynamics, and Vibrations	15
Materials and Processing	10
Measurements, Instrumentation, and Controls	10
Thermodynamics and Energy Conversion Processes	15
Fluid Mechanics and Fluid Machinery	15
Heat Transfer	10
Refrigeration and HVAC	10
Total	100

FUTURE EXAMINATION DATES

The FE and Mining and Mineral Processing Professional Engineer (PE) examinations are scheduled for the following dates. The PE exams are scheduled on Fridays; the FE exams are scheduled on Saturdays.

FE Examination	PE Examination (Mining and Mineral Processing)
April 25 and October 24, 2009	October 23, 2009
April 17 and October 30, 2010	October 29, 2010
April 9 and October 29, 2011	October 28, 2011
April 14 and October 27, 2012	October 26, 2012
April 13 and October 26, 2013	October 25, 2013
April 12 and October 25, 2014	October 24, 2014
April 18 and October 31, 2015	October 30, 2015
April 16 and October 29, 2016	October 28, 2016

CHAPTER 10

The Professional Engineering Examination

The Mining and Mineral Processing Professional Engineering (PE) examination is offered in the fall of each year on the dates listed in Chapter 9. The exam is open book and given in two, four-hour sessions consisting of 40 multiple-choice questions each. You must answer each question and your score is based on the number of questions you solve correctly. Budget an average of six minutes per question.

The morning and afternoon portions of the Mining and Mineral Processing PE exam each consist of 40 questions in the following order: Exploration (5 questions), Mine Planning and Operations (16 questions), Mineral Processing (12 questions), and Environment and Reclamation (7 questions). The exam also requires knowledge of general engineering skills, economics and cost management, applicable laws and regulations, and facility construction. The questions are individual, stand-alone items.

The exam is written by a cross-section of professional engineers working in the mining industry. They include representatives from mining companies, engineering consulting companies, government, product and equipment manufacturers, and academia. Accordingly, there is a wide variety of questions on the PE exam. Sample exam questions and solutions are provided in Chapter 12.

The Mining and Mineral Processing PE exam is a breadth test. The six-minute-per-question format and the broad technical field covered by the exam essentially limit the questions to mining and mineral engineering fundamentals. This format offers limited opportunity to test your depth of understanding and skill level in a certain area of expertise. The best background for the examination is a broad-based engineering education complemented by practical work experience in the mining industry. If your experience has been concentrated in a narrow area, you may find the exam difficult without additional preparation.

ALLOWED AND NECESSARY ITEMS FOR TAKING THE EXAMINATION

Examinees may use textbooks, handbooks, bound reference materials, scales, and calculators from the National Council of Examiners for Engineering and Surveying (NCEES) "approved calculator list." Examinees are cautioned to check the current calculator policy on the NCEES Web site, www.ncees.org, or with their state board. Writing tablets, unbound tables, and notes are typically not permitted in the exam room. If you wish to bring graphs, tables, and other data from personal files, the data must be printed or typed and bound, even if it is in a three-ring notebook. However, not all states allow the use of three-ring notebooks. Check these requirements with the examining state board. Mechanical pencils are furnished for your use. Consider bringing the following items:

- Watch (nonbeeping)
- Straight edge, protractor, triangles, and scales (engineering, English, metric)
- Silent, battery-operated NCEES-approved calculator and an extra battery or backup calculator
- English–metric conversion table
- Reference books
- Beverage

REFERENCE MATERIALS

The best reference materials to bring to the exam are books and manuals that are familiar to you. The short time allowed for each question does not allow you to spend a lot of time looking for formulas, conversion factors, or reference values. If there are areas of the exam in which you do not have extensive experience or appropriate reference materials, obtain and study general reference materials covering these areas and then bring those reference materials to the exam. The Society for Mining, Metallurgy, and Exploration, Inc. (SME), publishes many excellent general references. These include mining engineering, mineral processing, coal preparation, and mining reference handbooks.

A word of caution—study guides such as this book and other books of solved problems are generally not allowed in the exam room. This includes any of the Fundamentals of Engineering or Professional Engineering examination books published by NCEES or other organizations. Questions about items permitted in the exam room should be addressed to the examinee's state board. Chapter 6 provides a complete list of state licensing boards.

TEST SPECIFICATION

The following test specification is used in creating the Mining and Mineral Processing PE exam and is intended to cover the breadth of knowledge and skills required for licensure. The exam is divided into four major areas: Exploration, Mine Planning and Operations, Mineral Processing, and Environment and Reclamation. Each of these areas is further subdivided into groups of knowledge and skills with the number of questions per group specified in parenthesis. A total of 80 questions is apportioned in morning and afternoon sessions among the groups.

Examples of potential question topics are presented for each of the knowledge and skill groups. The SME Professional Engineers Exam Committee strives to assemble a balanced exam each year that provides equal weighting of the more important topic areas within each group. However, there is no guarantee that certain types of questions will or will not be on the test. The committee also recognizes that there are universal considerations common to each of the knowledge and skill groups. The universal considerations topics include general engineering skills, engineering economics and cost management, observance of laws and regulations, and facility construction. These universal considerations may be incorporated into any of the questions on the exam.

THE NATIONAL COUNCIL OF EXAMINERS FOR ENGINEERING AND SURVEYING

Principles and Practice of Engineering Examination
Mining and Mineral Processing Engineering

EFFECTIVE October 2009

	Approximate Percentage of Examination
I. EXPLORATION (10 PROBLEMS)	**12.50%**
A. Apply exploration methods and techniques	**3.75%**
1. Fundamental physical and structural geology and stratigraphy	
2. Geological surveying and mapping	
3. Laws and regulations governing hard-rock minerals, leasable minerals, and common variety minerals (e.g., 1872 Mining Law, Titles 30 and 43 CFR)	
B. Characterize site geologic and geotechnical conditions	**3.75%**
1. Hydrology/hydrogeology	
2. Sampling techniques (e.g., exploratory drilling, trenching, field samples)	
3. Analysis and interpretation (e.g., chemical and physical properties of the samples, rock mass classifications, ground stress)	
4. Modeling (e.g., geologic, digital terrain model [DTM])	
C. Estimate, characterize, and evaluate resources/reserves	**5.00%**
1. Resource/reserve classification systems	
2. Economic geology (e.g., grade distribution, cut-off grade, stripping ratios)	
3. Resource estimation techniques and interpretation (e.g., quality and quantity methodologies)	

II.	**MINE PLANNING/OPERATIONS (32 PROBLEMS)**	**40.00%**

A. Plan, design, and implement mining methods and layouts — **10.00%**

1. Surface mining methods and planning (e.g., contour strip, open pit/area, quarries, dredging)
2. Underground mining methods and planning (e.g., block caving, cut and fill, room and pillar, shrinkage stopping, underhand and over-hand stopping, longwall)
3. Deposit access (e.g., adits, slopes, shafts, haul roads)

B. Plan, design, select, and/or construct mine equipment, facilities, and systems — **16.25%**

1. Production equipment, facilities, and systems
2. Material handling and transportation equipment, facilities, and systems
3. Ventilation equipment, facilities, and systems
4. Power distribution equipment, facilities, and systems (e.g., electrical, compressed air, hydraulic)
5. Rock fragmentation equipment, facilities, and systems (e.g., cutting/boring machines, drilling, blasting and explosives)
6. Pumping, dewatering, and drainage equipment, facilities, and systems
7. Communication, monitoring, and control equipment, facilities and systems

C. Evaluate and design ground control — **8.75%**

1. Surface and underground ground control analysis and methods for coal, hard rock, and industrial minerals (e.g., slope stability, strata control, pillar design, shaft stability, geomechanics)

D. Operate and manage mines and systems — **5.00%**

1. Mine surveying and mapping
2. Resource requirements evaluation (e.g., equipment, materials, personnel, logistical support)
3. Mine maintenance systems

III.	**MINERAL PROCESSING (24 PROBLEMS)**	**30.00%**

A. Perform laboratory and pilot testing/analyses — **5.00%**

1. Lab-scale metallurgical, mineral processing, and analytical test procedures (e.g., atomic absorption, diagnostic leaching, solvent extraction, Bond work index, coal washability, physical separations)
2. Integration of mineralogical and chemical characteristics for selection of appropriate processing techniques

B. Design and evaluate process flowsheets — **11.25%**

1. Laboratory and pilot results interpretation, process flowsheet determination, and production level scale-up
2. Hydrometallurgical principles (e.g., electrochemistry, biohydrometallurgy, leaching, solvent extraction, precipitation, crystallization)
3. Pyrometallurgical principles (e.g., fluid bed roasting, smelting, calcination)
4. Comminution, classification, and beneficiation principles (e.g., crushing, grinding, flotation, gravity separation)
5. Laboratory and pilot results interpretation, process flowsheet deter-Solid/liquid separation principles (e.g., thickening, filtration)
6. Material, water, heat, and energy balances

C. Plan, design, select, and/or construct plant equipment, facilities, and systems **8.75%**
1. Site considerations and plant layout
2. Unit operations and equipment selection and sizing (e.g., tank sizing, pumping, piping, conveying)

D. Operate and manage plants and facilities **5.00%**
1. Control of plant performance to maintain product quality (e.g., operate mill or preparation plant equipment, process control systems)
2. Maintenance of mill or preparation plant systems
3. Resource requirements evaluation (e.g., reagents, materials, personnel, mill feed, logistical support)

IV. ENVIRONMENT AND RECLAMATION (14 PROBLEMS) **17.50%**

A. Characterize site, mining, and process environment **5.00%**
1. Surface water, groundwater, air characterization and contaminant transport
2. Environmental chemistry, geochemistry, geology, and ecology
3. Waste characterization
4. Characterization of site conditions using field and laboratory data

B. Plan and design to mitigate exploration, mining, and processing impacts **6.25%**
1. Waste containment systems (e.g., tailings and slurry impoundments, caps, liners, leakage recovery and detection systems)
2. Potable, process, and wastewater treatment systems
3. Mining and processing solid waste treatment systems
4. Pollution monitoring and prevention measures (e.g., sediment control, surface water discharge, dust, air filtration systems)
5. Site water balance preparation

C. Operate and manage environmental and reclamation plan **3.75%**
1. Site monitoring and analysis (e.g., subsidence, ground and surface water, vibration, noise, air)
2. Environmental planning and cost estimation
3. Reclamation planning and cost estimation

D. Close and reclaim the site **2.50%**
1. Earthwork techniques and equipment (e.g., grading, cutting, filling, ripping)
2. Post-mining land configuration and erosion control system design (e.g., riprap, ditches, silt fences, matting, sedimentation ponds)

NOTES:
1. The knowledge areas specified under A, B, C, etc., are examples of kinds of knowledge, but they are not exclusive or exhaustive categories.
2. This exam contains 80 multiple-choice questions. Examinee works all questions.
3. This exam includes universal considerations common to each of the knowledge and skill groups. The universal considerations topics include general engineering skills, engineering economics and cost management, observance of laws and regulations, and facility construction. These universal considerations may be incorporated into any of the questions on the exam.

CHAPTER 11 Preparing, Taking, and Grading the Exam

The Mining and Mineral Processing Professional Engineering (PE) exam is prepared by the Professional Engineers Exam Committee of the Society for Mining, Metallurgy, and Exploration, Inc. (SME). The committee consists of 18 professional engineers, 3 from each of the six SME divisions (Coal & Energy, Industrial Minerals, Mining & Exploration, Mineral & Metallurgical Processing, Environmental, and Underground Construction) plus many at-large members who volunteer their time to the committee. A professional engineer from the Association of Engineering Geologists also serves as a liaison to the SME committee. The SME Professional Engineers Exam Committee coordinator and SME staff help the committee to develop test content, write and review problems, conduct cut-score studies, and evaluate test results. The committee works under contract to the National Council of Examiners for Engineering and Surveying (NCEES), which reviews and grades each test and audits the committee's work.

A cut-score study is periodically conducted by the SME Professional Engineers Exam Committee and NCEES to determine the appropriate passing score for the examination. The study involves a panel of qualified professional engineers who assess the expected performance of a minimally competent candidate on the examination. The passing score on subsequent examinations is determined using a statistical method referred to as equating. The purpose of equating is to account for slight variations in the level of difficulty of each examination and to set the passing score accordingly.

PREPARING THE TEST

Members of the SME Professional Engineers Exam Committee prepare the questions for the Mining and Mineral Processing PE exam. Each member is responsible for writing questions within his or her discipline and reviewing questions within all disciplines. Each exam question requires a minimum of two reviews by committee members and a final review by the SME committee coordinator before it is included in the examination. This apportionment of questions among the various division representatives and multiple reviews is intended to produce a fair and balanced test with each section of the test having the same relative level of difficulty.

Committee members write questions in their area of expertise that typically can be solved by a minimally competent candidate in an average of four to six minutes. Some members write questions that are similar to questions you may have worked in a college class; others write questions reflective of practical operating experience. Some questions provide all the data needed to solve the problems; others require looking up factors or values in reference books. Some questions provide graphs, figures, or tables; others are limited to text only. Either English or metric units or a combination of units may be used. The questions on the test are just as varied as the committee members writing the exam. And because a portion of the committee membership changes every year, no two examinations are exactly the same.

Despite the variable approaches to writing questions, exam questions share many common characteristics. They are written concisely to address knowledge and skills listed in the test specification. Neither trickery nor using subjective material that may be interpreted in more than one way is allowed. However, subtle but important distinctions may be used to delineate the right answer. All questions are independent of other questions. The correct answer to any question is not dependent on correctly answering any other question.

Four potential answers are listed (A, B, C, or D) for each question. Numeric answers are listed in ascending or descending order. The units to be used in the answer are typically stated in the question and are not repeated in the potential answers. An exception to this occurs when some of the potential answers are in different units. There can be only one correct answer to each question. Questions that ask for the inverse response (e.g., which of the following is **NOT** an appropriate method) will emphasize the negative word using underlining, capitalization, or bold print to alert you to the negative context.

TAKING THE TEST

An important part of doing well on the test is taking the time to read carefully and understand each problem statement. Although the question may look similar to ones that you have worked in the past, it may be different in a subtle way. For example, you may work in a plant where the product is in the overflow of a gravity-separation system, but the question may concern a relatively heavy product. In this case, you would need to be careful when setting up the problem so that you determine the product to be in the underflow rather than the overflow. Note the units specified for the answer. You will get the question wrong if the problem statement calls for gallons and you solve the question in cubic feet and then forget to convert to gallons.

Take a close look at any figures, tables, or graphs provided with the questions. If a figure is to scale, you may be able to get the values you need to solve the question by scaling and/or using a protractor rather than doing a calculation.

Graphs or tables included with the question will, in many cases, be from standard reference books and may save you the time required to look up values or constants. However, in these cases, you will still need to identify and select the data that are relevant to the problem.

Finally, before trying to solve the question, take a quick look at the four potential solutions. If there is a wide range in potential answers, it may not be necessary to perform a detailed solution. On the other hand, if the potential solutions are closely bunched, it is probably not a good idea to take too many shortcuts in solving the question.

Remember that there is only one correct answer to each question. If you solve a question and your solution does not match any of the potential answers, review the problem statement to see if there is something that you missed or forgot to do. In some cases, if a figure is not provided, it may be worthwhile to make a quick sketch to clarify the problem statement in your own mind. If you are not sure of the correct answer, eliminate the choices you know are wrong and then choose the best remaining alternative.

Intelligent time management is an important part of taking the exam. Don't spend too much time agonizing over a particular question. If you can't solve it quickly, put a mark next to it and move on. You can come back to it at the end of the session if you have time. There is no partial credit given for any work that you do in trying to solve the problem, so don't waste time in being overly neat or meticulous. Because you are graded solely on the number of right answers, make sure that you have checked one answer for every question on the exam before finishing. A practice dry run using the sample exam provided in Chapter 12 may help you prepare for the exam.

GRADING THE TEST

The exams are machine-graded by NCEES and the results are statistically evaluated. Questions exhibiting a high fail rate are identified and later reviewed by the SME Professional Engineers Exam Committee. After the grades have been tabulated, they are forwarded to the individual states with a recommended passing grade. The state licensure boards send the exam results to the candidates.

The recommended passing grade is based on the results of a cut-score study. The study is conducted periodically under NCEES guidelines. It requires a group of registered professional engineers practicing in mining, mineral processing, or related fields to take the exam and recommend a passing score. The cut-score study group is diverse in composition, and members cannot have participated in preparing the exam. The group typically includes registered professional engineers from the six SME divisions and various geographical areas of the United States. The recommended passing score is determined through a consensus-building process with all group members participating. The tabulated passing score from the cut-score study is forwarded to the SME Professional Engineers Exam Committee for review and discussion before finalizing and submitting to NCEES. As previously mentioned, the passing score typically changes slightly from year to year, depending on the relative difficulty of each exam.

CHAPTER 12

Sample Professional Engineer Examination for Mining and Mineral Processing

This chapter presents a sample examination for mining and mineral processing engineers. The exam consists of 80 multiple-choice questions: 40 questions in the morning session and 40 questions in the afternoon session. The format of the sample exam is similar to the National Council of Examiners for Engineering and Surveying (NCEES) examination format. These sample questions will never be used on a future exam, but some have been used on examinations in the past. The Professional Engineers Exam Committee of the Society for Mining, Metallurgy, and Exploration, Inc., gratefully acknowledges the permission of NCEES to reproduce questions that have appeared on past examinations.

MORNING SESSION (4 HOURS)

101. The portal for an exploration decline will be at 10,500 ft N; 6,400 ft E; and an elevation of 4,260 ft. The bottom of the decline will be at 9,600 ft N; 7,000 ft E; and an elevation of 4,010 ft.

The length (feet) of the decline is most nearly:

(A) 955
(B) 1,080
(C) 1,110
(D) 1,230

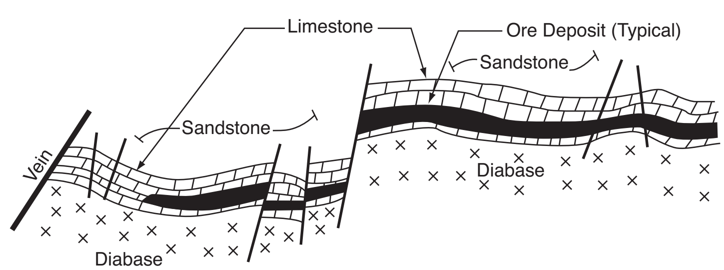
102. Three vertical drill holes (A, B, and C) are drilled sequentially on a straight line and 30-m centers. The terrain is flat and the holes intersect a prospective vein at the depths listed in the following table:

Drill Hole	Depth to Top of Vein (m)	Depth to Bottom of Vein (m)
A	30	56
B	68	98
C	106	140

The average thickness (m) of the vein is most nearly:

(A) 18.0
(B) 22.5
(C) 24.0
(D) 32.0

Figure for Question 103



Cross-Sectional View of Ore Deposit

103. The ore deposit shown in the figure appears to be controlled by:

(A) faulting and folding
(B) vein contact
(C) mineral zoning
(D) lithology

104. Approximately how many metric tonnes are contained in a mineralized deposit having uniform geometry and the following characteristics?

Strike distance	400 m
Dip distance	500 m
Dip of ore body	85° from horizontal
Top of ore body	10 m
Bottom of ore body thickness	20 m
Density	2.45 tonnes/m^3

(A) 3,000,000
(B) 4,900,000
(C) 7,400,000
(D) 9,800,000

105. You are conducting a stope sampling program in an underground lead/zinc mine. Management wants the results reported based on the equivalent lead content. Based on the following conditions, the equivalent Pb content (% Pb) is most nearly:

Sample grades:	3.8% Pb	1.2% Zn
Price:	Pb $0.36/lb	Zn $0.58/lb
Milling recovery:	Pb 96.5%	Zn 85.0%
Smelter recovery:	Pb 95.0%	Zn 85.0%

Lead smelter freight, smelting, and refinery costs $0.13/lb saleable Pb
Zinc smelter freight, smelting, and refinery costs $0.16/lb saleable Zn

(A) 5.32
(B) 5.53
(C) 5.73
(D) 5.99

106. A four-entry main in a room-and-pillar operation is mined to a uniform height of 2 m. Main entries and crosscuts are 6-m wide. Mains are on 25-m centers and crosscuts on 30-m centers and 90° angles from the mains. Assuming an ore specific gravity of 2.0, the tonnes mined per 30 m of main advance is most nearly:

(A) 1,100
(B) 2,800
(C) 4,200
(D) 12,000

107. A coal property measures 850 acres and contains a continuous 12-ft-thick seam. The coal density is 80 lb/ft^3 and the projected coal recovery rate is 80%. If the mining rate is 1.8 million tons per year, the mining life of the property (years) is most nearly:

(A) 8
(B) 10
(C) 12
(D) 14

108. A 5-ft-thick tabular deposit outcrops on flat terrain and dips at 10°. What is the approximate average stripping ratio (bank yd^3/ton) for open pit mining of this deposit given the following information?

Highwall slope angle = 60°

Maximum depth of overburden removal = 100 ft

Deposit density = 160 lb/ft^3

(A) 5
(B) 10
(C) 15
(D) 20

109. Your company has defined a copper ore body with 1,800,000 tons of oxide ore at 2% copper and plans to heap leach the ore. Given the following information, the annual cash flow ($ millions) is most nearly:

Copper recovery = 80%
Operating cost = $9/ton
Copper selling price = $1.00/lb
Mining rate = 300,000 tons of ore/year

(A) 6.9
(B) 9.3
(C) 9.6
(D) 15.0

110. Given the following data for a loader-truck haulage system at a surface mining operation, the truck cycle time (minutes) is most nearly:

Truck spot time (min) = 0.5 Truck dump time (min) = 1.0

Truck load time (min) = 2.5 Average haul distance (km) = 15

Travel Segment	Grade (%)	Distance (m)	Haul Speed (km/hr)	Return Speed (km/hr)
1	8	4,500	10	20
2	0	8,200	25	35
3	−4	2,300	20	15

(A) 55
(B) 64
(C) 90
(D) 94

111. A coal mine with two intakes and two returns has a mine resistance of 2.5 [(inches of water)/(cfm)^2]. If an additional return and an additional intake of the same cross-sectional area are added, the resistance [(inches of water)/(cfm)^2] of the six-entry system would be most nearly:

(A) 0.87
(B) 1.11
(C) 1.67
(D) 5.63

112. A mine ventilation system is being designed for 250,000 cfm of air flow, a mine resistance of 5.0 [(inches of water)/(cfm)^2], and an air density of 0.065 pcf. The theoretical minimum fan or air horsepower required for the mine is most nearly:

(A) 430
(B) 1,070
(C) 2,130
(D) 2,460

113. The following data pertain to a pumping application.

Q = flow rate = 200 gallons per minute (gpm)

TDH = total dynamic head = 600 ft

Motor efficiency = E_M = 85%

Pump efficiency = E_{P1} = 70%

The brake horsepower (hp) of the pump is most nearly:

(A) 30
(B) 36
(C) 43
(D) 51

114. Given a 35-ft-deep, 7⅞-in.-diameter hole, 10 ft of stemming, and a prill specific gravity of 0.85; the charge (lb) of free poured ammonium nitrate and fuel oil (ANFO) prill is most nearly:

(A) 285
(B) 378
(C) 448
(D) 627

115. A hoisting system has the following characteristics:

Hoisting depth = 600 m

Hoisting and return rate, instantaneous = 400 m/min

Acceleration and deceleration rate = 1 m/s^2

Fixed time (load, dump, creep) = 1 min

The required time (seconds) to load, hoist, and dump is most nearly:

(A) 107
(B) 150
(C) 157
(D) 163

116. The bench face at an open pit mine contains a joint plane dipping at 45 degrees through the face. The primary effect of water filling the joint plane would be to:

(A) reduce cohesion by making the joint surface slippery
(B) reduce internal friction by making the rock material more slippery
(C) reduce friction by decreasing the normal forces on the joint plane
(D) increase the driving force by the normal component of the added water

117. A horizontal coal seam is mined using room-and-pillar methods. All entries and crosscuts are 6-m wide. The pillars are 10-m wide by 15-m long. The overburden is 300-m thick with a specific gravity of 2.7. The average vertical stress on the pillars (kPa) is most nearly:

(A) 1,500
(B) 7,900
(C) 14,400
(D) 17,600

118. A mine has the following two types of untensioned, resin-grouted rock bolts available. Roof rock at the mine weighs 160 lb/ft^3. The price of grade 60 bolts is 1.5 times the price of grade 40 bolts. What is the most economical bolting pattern and bolt to support a rock column 6-ft thick if the maximum allowable load on the bolts is 80% of yield?

1. #6 Rebar grade 40 (i.e., ⅝-in. diameter with 40,000 psi yield strength)
2. #6 Rebar grade 60 (i.e., ⅝-in. diameter with 60,000 psi yield strength)

(A) #6 Rebar grade 40 using a 4 ft × 4 ft pattern
(B) #6 Rebar grade 60 using a 4 ft × 4 ft pattern
(C) #6 Rebar grade 40 using a 5 ft × 5 ft pattern
(D) #6 Rebar grade 60 using a 5 ft × 5 ft pattern

119. Uniaxial strength tests of 1-m cubical coal samples provide a compressive strength of 11 MPa for a proposed coal mine in a 1.8-m-thick seam with 10-m-wide pillars. If the calculated pillar load is 5,000 kPa, what is the safety factor for the pillars using the Bieniawski formula?

(A) 1.2
(B) 1.5
(C) 2.6
(D) 5.8

120. An open pit mining operation calculates the average tons of ore delivered to the mill per truck load on a monthly basis. The ore has a bank density of 160 lb/cu ft and a swell factor of 0.65. The beginning and ending surveyed mill-stockpile inventory for the current month is 43,000 and 32,000 cu yd, respectively. The mill processed 130,000 tons of ore during the month and 2,810 truck loads of ore were delivered to the mill. The average tons (t) per truck load was most nearly:

(A) 33.3
(B) 40.8
(C) 42.3
(D) 51.8

121. A surveyor has completed an open-ended leveling traverse beginning at Station 1.The survey is underground, so the stations are in the roof or back. Given the data provided in the table, the calculated elevation of Station 3 is most nearly:

Station	Backsight	Height of Instrument	Foresight	Elevation
1	6.54			500.00
2	7.19		5.32	
3	6.87		6.91	
4	5.95		7.32	

(A) 491.59
(B) 498.50
(C) 501.50
(D) 525.96

122. In a laboratory cyanide bottle-roll test, the initial charge of cyanide is 5 lb of NaCN/ton of ore. After a 24-hour leach, a titration of the solution shows a residual free cyanide (CN^{-1}) concentration of 0.16 lb/ton of solution. If the test were run at 40% solids on a weight basis, the cyanide consumption (lb NaCN/ton of ore) is most nearly:

(A) 3.82
(B) 4.55
(C) 4.70
(D) 4.84

123. An ore sample crushed to minus 6-mesh was subjected to the Bond method for determining ball-mill work indices. The following data were collected from the test. Determine the Bond Ball-Mill Work Index number (*BWi*) in kWh/st for this ore.

$$Wi\text{ ball} = \frac{44.5}{(P_1)^{0.23}(G_{bp})^{0.82}\left(\frac{10}{P^{0.5}} - \frac{10}{F^{0.5}}\right)}$$

where P_1 is the micron size at which the grindability test was conducted, G_{bp} is the grindability value for ball mills, G_{rp} is the grindability value for rod mills, $P^{0.5}$ is the 80% passing size of the product in micrometers, and $F^{0.5}$ is the 80% passing size of the feed in micrometers.

P_1 (100% passing size of product) = 74 µm

P_{80} (80% passing size of product) = 60 µm

F_{80} (80% passing size of feed) = 2,438 µm

G_{bp} (grams per revolution) = 0.76 g

(A) 19.0
(B) 21.6
(C) 23.4
(D) 25.1

124. A phosphate beneficiation plant processes flotation feed using conventional flotation techniques. Historical records indicate that the phosphate content of the tailings from the plant is the square root of the feed grade. The final concentrate grade is not sensitive to feed grade and averages 68% phosphate. The forecast feed grade for the upcoming month is 16% phosphate. The expected flotation recovery, in percent, is most nearly:

(A) 50
(B) 67
(C) 75
(D) 80

125. Waste clay from a beneficiation plant is mixed with water and discharged to a disposal impoundment in slurry form. If the clay has a specific gravity of 2.7 and the slurry is 30% solids by weight, the volume of slurry (gallons) containing 1 ton of dry clay is most nearly:

(A) 90
(B) 190
(C) 300
(D) 650

126. Your company is evaluating the feasibility of mining and processing ore averaging 6% zinc. Assuming that the zinc concentrate will contain 50% zinc, the zinc recovery to the zinc concentrate is 90%, and that the mill would treat 3,000 tons per day, the expected daily tonnage of zinc concentrate is most nearly:

(A) 162
(B) 198
(C) 324
(D) 400

127. Gold may be precipitated with zinc according to the following equation:

$$2Au(CN)_2 + Zn \rightarrow 2Au + Zn(CN)_4$$

Atomic weights are Au = 197 and Zn = 65.4. How many pounds of zinc dust are required to precipitate 100,000 troy ounces of gold if the zinc requirement is 1.7 times the stoichiometric requirement?

(A) 669
(B) 1,137
(C) 1,759
(D) 1,933

128. How much copper (grams) can be refined ($Cu^{+2} + 2e = Cu^0$) in one day at a current of 1 ampere and 87% current efficiency? The atomic weight of copper is 63.54.

(A) 24.8
(B) 28.5
(C) 32.8
(D) 56.9

129. You are designing a mine water-supply system to pump 500 gpm of clear water from an impoundment to a storage tank. You plan to use a centrifugal pump mounted 7 ft above the impoundment surface. The suction pipe is 4 in. in diameter, 10 ft long, and has a check valve and a 90° ell on the suction end. The pump discharges through a 3-in.-diameter gate valve and 3-in.-diameter pipe that runs 400 ft horizontally and 100 ft vertically to the top of the tank. The discharge line has four 3-in.-diameter 90° ells and one 3-in.-diameter 45° ell.

Friction and other factors are as follows:

4-in.-diameter pipe (feet of head loss per 100 ft of pipe) = 13.0

4-in.-diameter 90° ell (equivalent feet of pipe) = 11.0

4-in.-diameter check valve (equivalent feet of pipe) = 43.0

3-in.-diameter pipe (feet of head loss per 100 ft of pipe) = 52.5

3-in.-gate valve (equivalent feet of pipe) = 1.7

3-in.-diameter 45° ell (equivalent feet of pipe) = 3.8

3-in.-diameter 90° ell (equivalent feet of pipe) = 8.0

Centrifugal pump efficiency (percent) = 70

The total dynamic head (feet) of the pumping system is most nearly:

(A) 110
(B) 290
(C) 350
(D) 400

130. A carbon-in-leach (CIL) circuit handling 12,000 tons of ore per day is operated at 40% solids by weight. The water used in the circuit is recycled from the tailings pond and contains 30 ppm free cyanide. If the target cyanide addition to the CIL circuit is 0.8 lb cyanide (as CN^-) per ton of ore, the amount of NaCN (lb/day) that must be added is most nearly:

(A) 8,500
(B) 16,100
(C) 18,100
(D) 21,700

131. A 4.5-m-diameter × 6-m-high tank is used to condition feed for a flotation circuit. Assuming 0.5 m of freeboard, what flow rate, in liters/minute, will provide a residence time of 10 min?

(A) 875
(B) 8,750
(C) 87,500
(D) 875,000

132. The delivered cost of propane is $0.22 per pound and the delivered cost of natural gas is $10.00 per 1,000 standard cubic feet (scf). Based on the provided calorific value and assuming all other costs are equal, which fuel will provide the lowest cost per Btu?

Fuel	Chemical Formula	Calorific Value Btu/scf
Propane	C_3H_8	2,600
Natural Gas	CH_4	960

(A) propane
(B) natural gas
(C) they are approximately equal
(D) cannot be determined with available data

133. A conventional 100-ft-diameter thickener is being fed a uniformly ground ore slurry. The thickener has an increasing slime level, an increasing rake torque, and a constant underflow density. What actions should the operator take?

(A) decrease the underflow pump rate and increase flocculant addition
(B) decrease flocculant addition and increase underflow pump rate
(C) increase underflow pump rate and leave flocculant addition constant
(D) increase flocculant addition and leave underflow pump rate constant

134. Groundwater flows to the northeast at a hydraulic gradient of 0.10 m/m. If the aquifer hydraulic conductivity is 1×10^{-4} cm/s, the approximate flow rate (meters/year) is most nearly:

(A) 1
(B) 10
(C) 100
(D) 1,000

135. Your company drove an exploration decline to obtain bulk samples for metallurgical testing and waste characterization. The decline was 10 ft high by 10 ft wide and encountered the two waste rock zones listed below. Assume a specific gravity of 2.5 and an ore cut-off grade of 0.05 oz/ton for all rock types.

Rock Zone	Distance from Portal (ft)	Gold (oz/ton)	AGP	ANP
A	Portal–160	0.005	1.2	4.0
B	160–410	0.008	1.2	9.9

AGP = Acid generation potential in tons of $CaCO_3$ required to neutralize 1,000 tons of rock.
ANP = Acid neutralization potential in tons of $CaCO_3$ equivalent per 1,000 tons of rock.

The net $CaCO_3$ requirement or abundance of the waste rock is most nearly:

(A) 1.2 tons $CaCO_3$ required to neutralize 1,000 tons of waste rock
(B) 11.5 tons excess $CaCO_3$ equivalent
(C) 12.9 tons $CaCO_3$ required to neutralize 1,000 tons of waste rock
(D) 20.5 tons excess $CaCO_3$ equivalent

136. Your company drove an exploration decline to obtain bulk samples for metallurgical testing and waste characterization. The decline was 10 ft high by 10 ft wide and encountered the three mineralized zones listed below. Assume a specific gravity of 2.5 and an ore cut-off grade of 0.05 oz/ton for all rock types.

Rock Zone	Distance from Portal (ft)	Gold (oz/ton)	AGP	ANP
C	410–580	0.062	4.4	13.7
D	580–930	0.354	10.9	0.2
E	930–1,110	1.023	11.9	0.6

AGP = Acid generation potential in tons of $CaCO_3$ required to neutralize 1,000 tons of rock.
ANP = Acid neutralization potential in tons of $CaCO_3$ equivalent per 1,000 tons of rock.

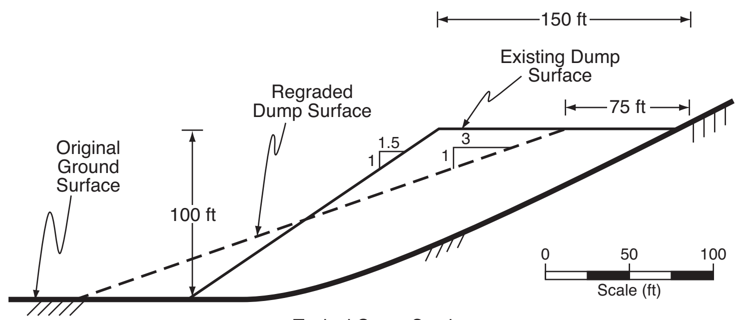
Assuming the ore will be milled at 80% minus 100 mesh, the most likely closure method for the tailings that will provide for long-term environmental protection is:

(A) surface grading to promote oxidation and runoff
(B) surface grading to promote infiltration and rinsing
(C) capping to reduce infiltration and promote aerobic conditions
(D) capping to reduce infiltration and promote anaerobic conditions

137. A 300-ft by 200-ft solution pond has a 1-ft-thick clay liner with a hydraulic conductivity of 1×10^{-6} cm/s and normally contains 15 ft of solution. Assuming that the hydraulic pressure is negligible beneath the liner, approximately how many gallons of solution seep through the liner per year?

(A) 100,000
(B) 700,000
(C) 900,000
(D) 7,000,000

Figure for Questions 138–139



Typical Cross-Section
Mine Waste Dump

138. An existing 800-ft-long waste dump slope is to be regraded from its current 1.5 horizontal:1 vertical (1.5H/1V) slope to 3H/1V during reclamation activities. A cross-section of the dump is shown in the figure above. The required cut volume (cu yd) is most nearly:

(A) 28,000
(B) 56,000
(C) 110,000
(D) 1,500,000

139. An existing 800-ft-long waste dump slope is to be regraded from its current 1.5 horizontal:1 vertical (1.5H/1V) slope to 3H/1V during reclamation activities. A cross-section of the dump is shown in the figure above. If the topsoil has a swell factor of 0.7, how many bank cubic yards of borrow soil will be required to place 12 in. of loose soil over the regraded dump top and slope?

(A) 6,200
(B) 8,200
(C) 11,700
(D) 16,700

140. A 1-ft-thick compacted clay liner is to be installed at the base of a waste-disposal area. What moisture specification will provide the best long-term permeability characteristics for the clay liner?

(A) optimum +2%
(B) optimum –2%
(C) optimum ±4%
(D) moisture content is not important as long as the required density is achieved

AFTERNOON SESSION (4 HOURS)

501. The portal for an exploration decline will be at 10,500 ft N; 6,400 ft E; and an elevation of 4,260 ft. The bottom of the decline will be at 9,600 ft N; 7,000 ft E; and an elevation of 4,010 ft.

The bearing of the decline from the portal to the bottom is most nearly:

(A) S34°E
(B) S56°E
(C) N34°W
(D) N56°W

Figure for Question 502

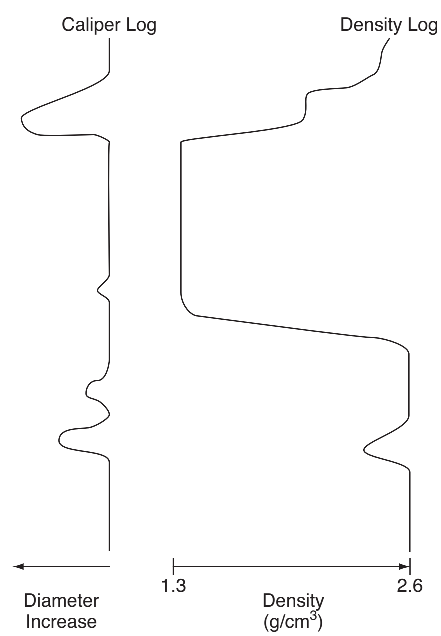


Figure adapted from *Handbook of Practical Coal Geology* by Larry Thomas, 1992. Copyright John Wiley & Sons Limited. Reproduced with permission.

502. Based on the caliper and density logs from a coal exploration program presented in the figure, mining of the coal seam is likely to result in:

(A) poor floor and roof conditions
(B) good floor and roof conditions
(C) poor floor and good roof conditions
(D) good floor and poor roof conditions

503. Coning and quartering refers to a method of:

(A) sampling
(B) reducing sample volume
(C) identifying sample bias
(D) determining sample spacing

504. What is the average grade (grams/tonne) of a gold deposit with the following grade distribution?

Grade Category	Percent of Deposit	Grams/Tonne
1	6	1 to 4
2	12	4 to 6
3	30	6 to 10
4	36	10 to 12
5	16	12 to 20

(A) 8.4
(B) 9.7
(C) 10.6
(D) 12.4

505. Channel samples have been collected in a stope from a silver vein that is surrounded by barren wall rock. The sample data are provided in the table below. If the vein is continuous and the samples were collected at equal distances along the vein, the average grade of the stope (oz/ton) is most nearly:

Channel No.	Stope Width (ft)	Vein Width (ft)	Channel Average Ag (oz/ton)
1	6	4	21
2	8	8	14
3	6	3	7
4	6	5	11

(A) 10.5
(B) 11.4
(C) 13.2
(D) 13.6

506. What is the pre-tax net present value ($ millions) of a proposed mine and process facility with the following characteristics? Use end-of-year convention for costs and cash flows. Discount to the beginning of preproduction.

Capital cost = $25 million

Construction time prior to production = 1 yr

Mine life = 10 yr

Annual cash flow = $4 million

Closure/reclamation cost = $10 million

Closure/reclamation time after production = 1 yr

Discount rate = 10%

(A) –4.2
(B) –3.6
(C) +0.1
(D) +1.6

507. Which of the following underground mining methods provides the best selective mining capability?

(A) block caving
(B) vertical crater retreat
(C) open sublevel stoping
(D) cut-and-fill stoping

508. A coal block consisting of a 20-ft-thick coal seam is being evaluated. The coal seam is relatively flat and dry but is characterized by localized rolls and frequent faulting with displacements up to 20 ft. The seam is overlain by a strong, massive sandstone. Using standard coal-mining equipment, which of the following underground mining methods is most appropriate for this coal block?

(A) room-and-pillar with pulling of pillars on retreat
(B) room-and-pillar with pulling of bottom coal on retreat
(C) room-and-pillar with pulling of top coal on retreat
(D) longwall

509. The following characteristics apply to a surface coal mine with a preparation plant.

Dragline stripping capacity (million bcy per year) = 20

Clean coal production requirement (million tons per year) = 3

Coal mine recovery factor (percent of in-place coal) = 87

Washing loss (percent of raw coal processed) = 8

The maximum average virgin strip ratio (bcy/ton) that can be sustained and still meet the coal production requirement is most nearly:

(A) 5.3
(B) 5.8
(C) 6.1
(D) 6.7

510. The following data pertain to a pumping application.

Q = flow rate = 200 gallons per minute (gpm)

TDH = Total dynamic head = 600 ft

Motor efficiency = E_M = 85%

Brake horsepower = 50 hp

Pump efficiency E_{P2} = 60%

Electrical energy cost = $.07/kWh

The pump is online 20 hours/day.

The pump is online 360 days/year.

The calculated annual energy cost ($/yr) is most nearly:

(A) 18,800
(B) 22,100
(C) 26,500
(D) 26,900

511. Given a 12¼-in.-diameter blast hole, massive volcanic tuff overburden, poured ANFO prills, prill specific gravity of 0.85, 30-ft × 36-ft pattern, 8 ft of subdrill, 21 ft of stemming, and a 50-ft shovel bench height, the powder factor (pounds of explosive per bank cubic yard) is most nearly:

(A) 0.63
(B) 0.80
(C) 1.08
(D) 1.26

512. The locomotive and cars of a rail-haulage system have a rolling frictional resistance of 20 lb/ton. If the loaded train hauls up a 3% grade, the train resistance (lb/ton) for both empty and loaded trips, respectively, is most nearly:

(A) –40 and 80
(B) –60 and 60
(C) 80 and 80
(D) 80 and –40

513. Operating factors for a dragline at a surface coal mine are given below.

Bucket size	75 cubic yards
Bucket fill factor	90%
Cycles per operating hour	55
Mechanical availability	80%
Use of availability (operating efficiency)	80%
Scheduled hours	8,000 per year
Overburden swell factor	20%

The expected annual stripping capacity (million bank cubic yards) of the dragline is most nearly:

(A) 15.8
(B) 17.6
(C) 19.0
(D) 19.8

514. Operating factors for a loader and truck operation are provided below.

Truck capacity	207 tonnes
Loader bucket size	20 m^3
Material bank density	2.55 tonnes/m^3
Swell factor	40%

The number of loader passes required to fill a truck is most nearly:

(A) 3
(B) 4
(C) 5
(D) 6

515. A maintenance shop requires a 5,000-scfm supply of compressed air at 20 psig (sea level). A used centrifugal blower has been found and the operations department has been instructed to double its speed to obtain the required supply volume. Name plate data are as follows:

Volume = 2,500 scfm   Pressure = 15 psig
Speed = 1,200 rpm   Type of drive = "V" belt
Power = 10 hp

The horsepower (hp) required to produce the required 5,000-scfm output volume is most nearly:

(A) 10
(B) 20
(C) 40
(D) 80

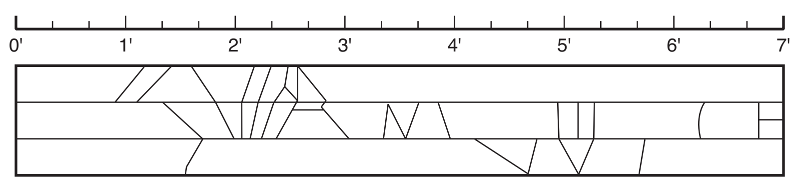
516. A maintenance shop requires a 5,000-scfm supply of compressed air at 20 psig (sea level). A used centrifugal blower has been found and the operations department has been instructed to double its speed to obtain the required supply volume. Name plate data are as follows:

Volume = 2,500 scfm   Pressure = 15 psig
Speed = 1,200 rpm   Type of drive = "V" belt
Power = 10 hp

The pressure (psig) that the modified blower produces is most nearly:

(A) 15
(B) 30
(C) 60
(D) 120

Figure for Question 517



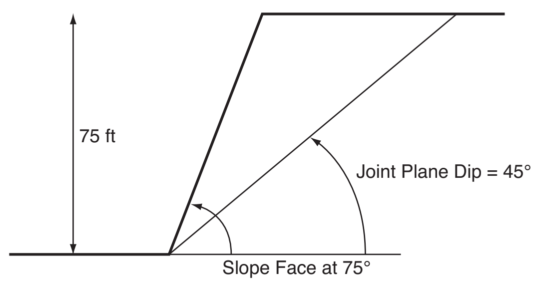
517. Given the drawing above of three 7-ft sections of rock drill core, the Rock Quality Designation (RQD) in percent is most nearly:

(A) 50
(B) 65
(C) 80
(D) 95

518. The normal and shear stress acting on a rock joint are 10 MPa and 7 MPa, respectively. The cohesion and friction angle for the rock joint are estimated as 5 MPa and 25°, respectively. Will slip occur along this rock joint?

(A) Slip will not occur because the shear stress acting on the joint (7 MPa) is less than the allowable shear stress of 9.7 MPa.
(B) Slip will occur because the shear stress acting on the joint (7 MPa) is greater than the cohesion (5 MPa).
(C) Slip will not occur because the shear stress acting on the joint (7 MPa) is less than the normal stress of 10 MPa.
(D) Slip will occur because the shear stress acting on the joint (7 MPa) is greater than the allowable shear stress of 6 MPa.

519. As shown in the figure below, the bench face at an open pit mine contains a continuous joint dipping at 45°. Cohesion and friction angle of the joint surface are estimated as 10 lb/in.^{2} and 35°, respectively.



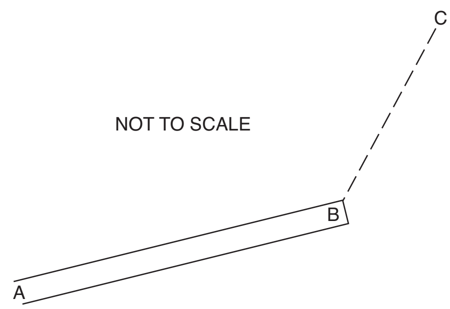
If the rock has a density of 160 lb/ft^3, the weight (lb) of a 1-ft section of the triangular block sitting on top of the joint plane is most nearly:

(A) 220,000
(B) 330,000
(C) 450,000
(D) 640,000

520. A ventilation fan operates at 80% efficiency while pulling 80 hp. The annual electrical power cost for this fan is $32,000. What is the approximate payback period (years) for installation of a new high-efficiency (88%) fan if the conversion cost is $7,000?

(A) 0.2
(B) 1.1
(C) 2.4
(D) 17.5

Figure for Question 521



521. Control points A and B are located in the back or roof of a tunnel at coordinates 1123.87 m N, 2176.56 m E and 1245.66 m N, 2468.90 m E, respectively. The alignment of the tunnel must change at point B to follow a bearing of N30°00'E. You plan to set up a total station at B, backsight on A and turn an angle right to the new bearing. What is this angle right to the nearest minute?

(A) 142°37'
(B) 143°02'
(C) 144°23'
(D) 148°37'

Figure for Question 522

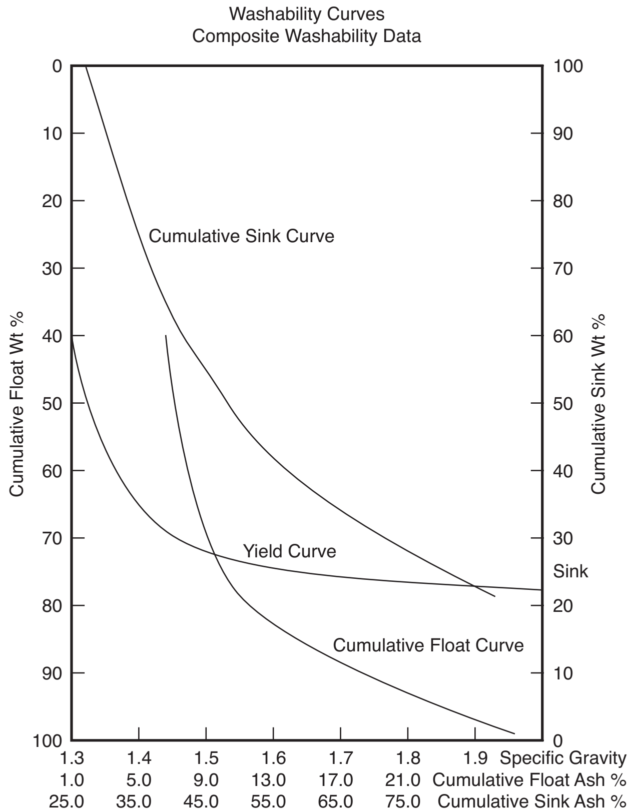


Figure adapted from *McNally Coal Preparation Manual*, 1977. Copyright McNally Manufacturing Corporation. Reproduced with permission.

522. Based on the coal-washability curves presented above, what specific gravity of separation will produce clean coal with 7% ash?

(A) 1.33
(B) 1.37
(C) 1.43
(D) 1.49

523. During a preliminary mineralogical examination of a sulfide mineral concentrate, the only source of iron was identified to be pyrite (FeS_2). If pyrite accounts for 20% of the sulfide minerals in the concentrate, the expected iron assay (%) of the concentrate would be most nearly:

(A) 9.3
(B) 10.0
(C) 12.7
(D) 13.3

526. Generally, in a heavy media cyclone operation, if the specific gravity of the media is increased, the:

(A) clean coal yield and ash percentage in the clean coal will increase
(B) clean coal yield and ash percentage in the clean coal will decrease
(C) clean coal yield will increase and ash percentage in the clean coal will decrease
(D) clean coal yield will decrease and ash percentage in the clean coal will increase

527. A dryer is to be installed at your plant for removing all of the moisture in a process stream averaging 100 dry standard tons per hour and 12% moisture by weight. The process feed has an initial temperature of 50°F and the heating parameters listed below are applicable. Heat of water vaporization = 970 Btu/lb. What is the theoretical heat (1×10^6 Btu/hr) required to heat the material to 200°F, evaporate the water, and raise the water vapor temperature to 375°F?

Material	Specific Heat Btu/(lb-°F)
Feed material	0.20
Water (liquid)	1.00
Water (gaseous)	0.48

(A) 12
(B) 35
(C) 39
(D) 54

528. Concentrate at a copper smelter consists of 90% chalcopyrite ($CuFeS_2$) and 10% nonsulfide gangue. The chemical reaction in the smelting process is: $CuFeS_2 + 5/2\ O_2 \rightarrow Cu + FeO + 2SO_2$. The molecular weights of chalcopyrite and sulfur dioxide are 183.5, and 64.1, respectively. If 120,000 tons of concentrate are smelted per year, the tons (t) of sulfur dioxide produced annually by the smelter are most nearly:

(A) 38,000
(B) 42,000
(C) 79,000
(D) 84,000

529. Thickeners are to be used in a continuous countercurrent decantation (CCD) circuit to wash a concentrate after a leach step. The feed rate is 1,500 metric tonnes of leached concentrate per day, the thickener feed pulp density after dilution is 15% solids, and the underflow slurry pulp density is 40% solids. The specific gravity of the leach liquor is 1.44.

The settling velocity of the leach residue can be assumed constant and equal to 30.5 m/day. Solution clarification is not a problem.

(Note: Weight of liquid into thickener = weight of liquid in overflow + weight of liquid in underflow)

The required thickener area (m^2) is most nearly:

(A) 122
(B) 132
(C) 142
(D) 152

530. Over a 30-day period, a 12-ft × 12-ft overflow ball mill processes 45,000 short tons of ore that is a nominal ⅜ in. The product size is 80% minus 200 mesh. If the mill uses 510,000 kWh during the 30-day period, what is the uncorrected operating Bond work index (kWh/ton) of the ground ore?

(A) 9.8
(B) 10.7
(C) 11.3
(D) 12.0

531. Which of the following materials would you expect to have the lowest Bond work index?

(A) clay
(B) gravel
(C) limestone
(D) shale

532. A test program to monitor the liner wear in a 4-ft × 10-ft wet ball mill was performed. The mill was lined with 24 liners. During the 30-day test period, the average weight loss per liner was 42 lb and the mill used 35,000 kWh. The mill's design metal liner wear is 0.01 lb/kWh. Based on the results of the test program, what should be done next?

(A) nothing, the test data indicate an acceptable wear
(B) change liner suppliers
(C) submit a composite sample of the test ore for a work index determination and check mill operating conditions
(D) submit a composite sample of the test ore for abrasion testing and check mill operating conditions

533. A plant manager wants to increase the output of a centrifugal pump by 20%. If the current drive speed is 2,000 rpm and neglecting static head, the new speed (rpm) should be most nearly:

(A) 2,400
(B) 2,880
(C) 3,200
(D) 3,460

534. Mine dewatering is expected to produce 1 million gallons per day of water with a zinc concentration of 2.5 mg/L. The water will be treated and discharged into a stream that has a flow rate of 1.4 cfs and a zinc concentration of 0.16 mg/L. The minimum percentage of zinc that will have to be removed from the mine water to maintain the downstream loading to less than 10 lb of zinc per day is most nearly:

(A) 0
(B) 60
(C) 90
(D) >100, the proposed limit cannot be met

535. Upstream and downstream sampling of a creek located near a mine site yielded the following average values for mass of solids passing and not passing a standard filter for a 500-mL sample.

Upstream passing = 15 mg; Upstream not passing = 35 mg

Downstream passing = 40 mg; Downstream not passing = 70 mg

What was the incremental increase in concentration (mg/L) of dissolved (i.e., passing) solids between the upstream and downstream samples?

(A) 25
(B) 35
(C) 50
(D) 60

536. Reclamation of a mine site requires the installation of a permanent diversion channel to convey a peak flow of 1,500 cfs. The channel gradient is 15 ft/mile, and Manning's roughness coefficient for design is 0.05. The channel is to be a trapezoidal section with 1:1 (H:V) side slopes and a bottom width of 15 ft. Regulations require a freeboard of 10% of the depth at maximum flow plus 1 ft to account for channel degradation over time. The depth of the channel (ft) is most nearly:

(A) 11
(B) 13
(C) 15
(D) 17

537. Waste rock containing elevated levels of acid-generating sulfidic waste is mined from Zone IV of the open pit shown in the diagram. The three upper zones contained oxidized rock with little acid-generating capability. The pit is located in an area of moderate climate that receives an average of 60 in. of precipitation per year.

The open pit will ultimately be reclaimed by backfilling it with mine waste rock and covering with topsoil. Reclamation plans call for mixing the acid-generating waste with lime, placing it in 5-ft lifts, and compacting the lifts. In which of the four zones should the acid-generating waste be placed to minimize the potential for long-term groundwater contamination?

(A) Zone I
(B) Zone II
(C) Zone III
(D) Zone IV

539. Data for groundwater monitoring wells at a waste disposal site are listed below. Well locations are shown in the figure. What flow direction is indicated by the groundwater gradient in the monitored aquifer?

Well I.D.	Surface Elevation (ft)	Depth to Groundwater (ft)
S-1	325	25
S-2	340	50
S-3	400	120
S-4	442	152
S-5	434	134
S-6	385	75

(A) east
(B) west
(C) southeast
(D) northwest

540. An existing 1.5H/1V slope exhibits pronounced erosion along preferential flow paths because of surface water runoff. Which of the following alternatives provides the best means for preventing the reoccurrence of this type of erosion on a regraded slope?

(A) construction of a diversion ditch around the regraded area
(B) ripping the slope from top to bottom to promote infiltration
(C) installation of silt fences at the top and base of the slope
(D) construction of a sedimentation basin at the base of the slope

ANSWERS TO MORNING SESSION

101. (C) 1,110

$\Delta N = 10{,}500 - 9{,}600 = 900$ ft, $\Delta E = 7{,}000 - 6{,}400 = 600$ ft, ΔElev. = 250 ft

Horizontal distance = $(900^2 + 600^2)^{1/2} = 1{,}082$ ft

Decline length = $(250^2 + 1{,}082^2)^{1/2} = 1{,}110$ ft

102. (A) 18

Find the vein vertical intercept distance and the depth of the center of the vein. Then calculate the dip of the vein.

Drill Hole	Top of Vein Depth (m)	Bottom of Vein Depth (m)	Center of Vein Depth (m)	Vein Intercept (m)
A	30	56	43	26
B	68	98	83	30
C	106	140	123	34

Inspection of the center of vein depth reveals that the vein is dipping 40 m for every 30 m of horizontal distance (i.e., distance between holes). Calculate vein thickness perpendicular to the dip.

Dig angle = $\delta = \tan^{-1}(40/30) = 53°$

Average vertical vein intercept = v = (26 m + 30 m + 34 m)/3 = 30 m

Average vein thickness = t = $(v)\cos\delta = 30 \times \cos 53° = 18$ m

103. (D) lithology

The ore is located in all cases within the lower-most limestone beds, indicating a lithology-controlled deposit. There is no clear relationship between the ore and the faults/folding that are present, as some are in contact and some are not in contact. There is no vein contact with the ore. Mineral zoning may be present within the ore but is not delineated in the figure or question.

104. (C) 7,400,000

Tonnes = (400 m × 500 m) × [(10 + 20)/2] × 2.45 tonnes/m^3 = 7,350,000 tonnes

105. (B) 5.53

1% × 2,000 lb = 20 lb per %

Pb stream: 20 lb × .965 mill rec × .95 smelter rec = 18.335 lb

18.335 lb × ($0.36 pr – $0.13 frt) = $4.217 / assay %

Zn stream: 20 lb × .85 mill rec × .85 smelter rec = 14.450 lb

14.450 lb (\$0.58 pr – \$0.16 frt) = \$6.069

6.069 Zn / 4.217 Pb = 1.439 equivalent multiplier

Assay = 3.8% Pb + (1.2% Zn × 1.439) = 5.527 equiv % Pb

106. (C) 4,200

Area of four mains per 30 m of advance = 4 × (6 m × 30 m) = 720 m^2

Area of x-cuts = 3 × (19 m × 6 m) = 342 m^2

Total area per 30 m of advance = 720 m^2 + 342 m^2 = 1,062 m^2

Tons per 30 m of advance = (1,062 m^2 × 2 m × 2 tonnes/m^3) = 4,248 tonnes

107. (A) 8

Coal tonnage = [(850 acres)(43,560 ft^2/acre)(12 ft)(80 lb/ft^3)]/(2,000 lb/ton) = 17,800,000 tons

Mine life = (17.8 million tons × 0.80)/(1.8 million tons/yr) = 7.9 yr (round to 8 yr)

108. (A) 5

Divide overburden into two right triangles. Area of right triangles = ½ × base × height

Area of triangle 1 = (½) × (100 ft/tan 10°) × (100 ft) = 28,356 ft^2

Area of triangle 2 = (½) × (100 ft/tan 60°) × (100 ft) = 2,887 ft^2

Assume a 1-ft-thick cross-section:

Overburden = [1 ft × (28,356 ft^2 + 2,887 ft^2)]/(27 ft^3/bcy) = 1,157 bcy

Deposit tonnage = [(1 ft)(5 ft)(102.5 ft/sin 10°)(160 lb/ft^3)]/(2,000 lb/ton) = 236 tons

Stripping ratio = 1,157 bcy/236 tons = 5 bcy/ton

109. (A) 6.9

Cash flow = (300,000 tons × 0.02 Cu × 0.8 rec. × \$1/lb × 2,000 lb/ton) – (300,000 ton × \$9/ton) = \$6.9 million

110. (D) 94

Convert distance from meters to kilometers. Time = distance/speed

Segment 1 (out) = (60 min/hr × 4.5 km)/(10 km/hr) = 27.00 min

Segment 1 (return) = (60 min/hr × 4.5 km)/(20 km/hr) = 13.50 min

Segment 2 (out) = (60 min/hr × 8.2 km)/(25 km/hr) = 19.68 min

Segment 2 (return) = (60 min/hr × 8.2 km)/(35 km/hr) = 14.06 min

Segment 3 (out) = (60 min/hr × 2.3 km)/(20 km/hr) = 6.90 min

Segment 3 (return) = (60 min/hr × 2.3 km)/(15 km/hr) = 9.2 min

Total travel time = 90.34 min

Total cycle time = travel + spot + dump + load = 90.34 + 0.5 + 1.0 + 2.5 = 94.34 min (round to 94 min)

111. (B) 1.11

$R_2 = R_1/(n_2/n_1)^2 = (2.5)/(3/2)^2 = 1.11$ in. of water/(cfm)^2

where:

R_1 = initial resistance

R_2 = new resistance

n_1 = initial number of entries

n_2 = new number of entries

112. (B) 1,070

$H = RQ^2(d/0.075) = (5)(2.5)^2(0.065/0.075) = 27.1$ in.

where:

H = pressure head (inches of water)

R = mine resistance [(inches of water)/(cfm)^2]

Q = air flow (100,000 cfm)

d = air density (pcf)

Air horsepower = (H)(q)/6,350 = (27.1)(250,000)/6,350 = 1,067 hp

where:

H = pressure head (inches of water)

q = air flow (cfm)

6,350 = conversion factor (inches of water)(cfm)/(hp)

113. (C) 43

Brake horsepower = (200 × 600)/(3,960 × 0.7) = 43.29

114. (C) 448

Loaded length (L) = 35 ft – 10 ft = 25 ft

Hole area (A) = $\pi d^2/4 = (3.14)(0.656\ ft)^2/4 = 0.338\ ft^2$

Charge = L × A × S.G. × 62.4 lb/ft^3 = (25 ft)(0.338 ft^2)(0.85)(62.4 lb/ft^3) = 448 lb

115. (C) 157

The equation for calculating the hoist cycle time is:

Cycle time = (v/a) + (h/v) + (v/d) – (v/2)(1/a + 1/d) + tf

where:

v = hoist velocity = 400 m/min = 6.67 m/s

a = acceleration = 1 m/s^2

d = deceleration or retardation = 1 m/s^2

h = hoisting distance = 600 m

tf = fixed time (dumping, loading, creep) = 1 min = 60 s

In this case, a = d and the formula reduces to: cycle time = 2(v/a) + h/v – (v/a) + tf = v/a + h/v + tf = (6.67 m/s)/(1 m/s^2) + (600 m/6.67 m/s) + 60 s = 156.6 s

116. (C) reduce friction by decreasing the normal forces on the joint plane

The principal effect of water filling voids in a slope is to reduce the normal forces on potential sliding surfaces, thus reducing the frictional resistance by $\Delta F_n \tan\phi$.

117. (D) 17,600

In situ vertical stress = 2.7(1,000 kg/m^3)(300 m)(9.81 m/s^2) = 7,946 kN/m^2

Pillar area = 10 m × 15 m = 150 m^2

Total area = (10 m + 6 m)(15 m + 6 m) = 336 m^2

Extraction ratio = (area mined)/(total area) = (total area – pillar area)/(total area) = (336 – 150)/336 = 0.55

Average stress on pillar = 7,946 kN/m^2/(1 – 0.55) = 17,600 kN/m^2 = 17,600 kPa

118. (B) #6 Rebar grade 60 using a 4 ft × 4 ft pattern

Allowable loads:

#6 Rebar grade 40 = $(\pi/4)(6/8)^2 \times 40{,}000$ psi × 0.8 = 14,137 lb

#6 Rebar grade 60 = $(\pi/4)(6/8)^2 \times 60{,}000$ psi × 0.8 = 21,206 lb

Rock loads per bolt:

Load (5 × 5 pattern) = (5 ft)(5 ft)(6 ft)(160 lb/ft^3) = 24,000 lb

Load (4 × 4 pattern) = (4 ft)(4 ft)(6 ft)(160 lb/ft^3) = 15,360 lb

By inspection, the only option where the allowable load exceeds the rock load is #6 Rebar grade 60 on a 4 ft × 4 ft pattern.

119. (D) 5.8

Bieniawski formula: $\sigma_p = \sigma_1[0.64 + 0.36(w/h)]$

where:

σ_p = pillar strength

σ_1 = test strength = 11 MPa = 11,000 kPa

h = pillar height = 1.8 m

w = pillar width = 10 m

(Reference: Bieniawski, Z.T. 1992. *SME Mining Engineering Handbook*, 2nd ed. Edited by H.L. Hartman, Littleton, CO: SME. p. 925.)

Pillar strength = (11,000 kPa)[0.64 + (0.36)(10/1.8)] = 29,040 kPa = 29.04 MPa

Factor of safety = pillar strength/pillar load = 29.04 MPa/5.00 MPa = 5.81

120. (B) 40.8

Change in stockpile tonnage =

[(32,000 cy – 43,000 cy) × 27 cf/cy × 160 lb/cf × 0.65]/2,000 lb/ton =

–15,444 tons

Average load = (130,000 tons – 15,444 tons)/2,810 truck loads
= 40.77 tons/load

121. (B) 498.50

Subtract backsights and add foresights.

Station	Backsight	Height of Instrument	Foresight	Elevation
1	6.54			500.00
2	7.19	493.46	5.32	498.78
3	6.87	491.59	6.91	498.50
4	5.95	491.63	7.32	498.95

122. (B) 4.55

Basis: 1 ton of ore

NaCN (initial) = 5 lb

Final solution: (0.16 lb CN^{-1}/1 ton soln)(49 NaCN/26 CN^{-1}) = 0.30 lb NaCN/1 ton soln

NaCN (final) = (1 ton ore)(0.3 lb NaCN/1 ton soln)(60%/40%) = 0.45 lb NaCN

Cyanide consumption = 5 – 0.45 = 4.55 lb NaCN consumed/ton ore

123. (A) 19.0

According to the article titled "Crushing and Grinding Calculation" by Fred C. Bond published in 1961 by Allis-Chalmers and the *SME Mineral Processing Handbook* (page 30.68), the formula for determining the Bond Ball Mill Work Index when following the standard Bond procedure is:

W_i ball = $44.5 / [(P_1)^{0.23} \times (G_{bp})^{0.82} \times (10/P_{80}{}^{0.5} - 10/F_{80}{}^{0.5})]$

Solving, W_i ball = $44.5 / [(74)^{0.23} \times (0.76)^{0.82} \times (10/(60)^{0.5} - 10/(2{,}438)^{0.5})]$ = 19.0 kWh/st

124. (D) 80

Tailings grade = $(\text{feed grade})^{0.5} = (16\%)^{0.5} = 4\%$

Recovery = recovered concentrate/processed feed

= [c × (f – t)]/[f × (c – t)] × 100 = [68 × (16 – 4)]/[16 × (68 – 4)] × 100

= 79.7%

where:

c = concentrate grade = 68%

f = feed grade = 16%

t = tailings grade = 4%

125. (D) 650

Slurry volume/ton of slurry = [(0.3 ton clay × 2,000 lb/ton)/(62.4 lb/ft^3 × 2.7)] + [(0.7 ton × 2,000 lb/ton)/(62.4 lb/ft^3)] = 3.56 ft^3 + 22.4 ft^3 = 26 ft^3/ton

Slurry volume per clay ton = [(26 ft^3/ton of slurry)/(0.3 ton clay/ton of slurry)] × 7.48 gal/ft^3 = 648 gal

126. (C) 324

Tons of zinc concentrate per day = (3,000 ton/day)(.06)(0.9)/(0.5) = 324 tpd

127. (D) 1,933

From the equation, 1 mole of zinc is needed to precipitate 2 moles of gold. The excess zinc requirement is 1.7 times stoichiometric; therefore, multiply by 1.7.

Atomic weights from standard references: Au = 197 and Zn = 65.4

Zn (lb) = 1.7 × [(1 mole Zn)(65.4 gm Zn)/(2 mole Au)(197 gm Au)] × (31.1 gm/troy oz) × (1 lb/454 gm) × (100,000 oz Au) = 1,933 lb

128. (A) 24.8

Faraday's law = one faraday of electricity will reduce and oxidize one gram-equivalent or mole of electrons

1 faraday = 6.023 × 10^{23} electrons = 96,487 coulombs

1 coulomb = 1 amp × 1 s

(1 ampere day)(24 hr/day)(60 min/hr)(60 s/min) = 86,400 amp s

(86,400 amp s)(coulomb/amp s)(mole electrons/96,487 coulomb)
(mole Cu/2 moles electrons)(63.54 grams/mole Cu) = 28.45 g Cu

At 87% current efficiency, 28.45 × 0.87 = 24.8 g Cu

129. (D) 400

Suction head

7 ft (lift) + [10 ft (pipe) + 43 ft (chk. valve) + 11 ft (ell)] × (13 ft/100 ft) = 15.32 ft

Discharge head

100 ft (lift) + [500 ft (pipe) + 32 ft (4-90 ells) + 1.7 ft (gate) + 3.8 ft (45 ell)] × (52.5 ft/100 ft) = 382.19 ft

Total dynamic head = 15.32 + 382.19 = 397.51 ft

130. (B) 16,100

Total CN needed per day = (0.8 lb CN/ton ore)(12,000 ton ore/day) = 9,600 lb CN/day

Cyanide from recycled water = (30 lb CN/1,000,000 lb soln) (12,000 ton ore/day)(60 ton soln/40 ton ore)(2,000 lb/ton soln) = 1,080 lb CN/day

Net CN added per day = 9,600 – 1,080 = 8,520 lb CN/day

Convert to NaCN using proportional molecular weights:

(8,520 lb CN/day)(49 NaCN/26 CN) = 16,100 lb NaCN/day

131. (B) 8,750

Useable tank volume = $(\pi d^2/4)$ (height) = $[(3.14)(4.5^2)/4] \times (6 - 0.5)$ = 87.5 m^3

Flow rate = (87.5 m^3) × (1,000 L/m^3)/(10 min) = 8,750 L/min

132. (C) they are approximately equal

Calculate cost of propane in scf:

Molecular weight of propane = (3 × 12) + (8 × 1) = 44/mol

Volume of 1 lb of propane at scf = (359 scf/mol)/(44/mol) = 8.16 scf

Cost of propane = ($0.22/lb)(1 lb/8.16 scf) = $0.027/scf

Compare costs:

Propane ($/Btu) = ($0.027/scf)(1 scf/2,600 Btu)(1,000) = $0.010/1,000 Btu

Natural gas ($/Btu) = ($10/1,000 scf)(1 scf/960 Btu)(1,000) = $0.010/1,000 Btu

133. (C) increase underflow pump rate and leave flocculant addition constant

A thickener with increasing slime level, increasing torque, and constant density indicates the input tonnage is not being withdrawn fast enough. The proper action is to increase the underflow pumping rate while holding the flocculant addition constant.

134. (B) 10

Flow rate = $(1 \times 10^{-4}$ cm/s)(1 m/100 cm)(0.10 m/m)(31,536,000 s/yr)/(0.3) = 10 m/yr

135. (D) 20.5 tons excess $CaCO_3$ equivalent

The A & B rock are waste because their gold content is less than 0.05 oz/ton.

Tons of Waste Rock

A = [(160 ft)(10 ft)(10 ft)(2.5)(62.4 lb/ft^3)]/(2,000 lb/ton) = 1,248 tons

B = [(250 ft)(10 ft)(10 ft)(2.5)(62.4 lb/ft^3)]/(2,000 lb/ton) = 1,950 tons

Net Acid Neutralization Potential (NANP)

NANP of A = 4.0 – 1.2 = 2.8 tons $CaCO_3$/1,000 tons of rock

NANP of B = 9.9 – 1.2 = 8.7 tons $CaCO_3$/1,000 tons of rock

Net $CaCO_3$ Abundance

(1,248 tons)(2.8 tons $CaCO_3$/1,000 tons) + (1,950 tons)(8.7 tons $CaCO_3$/1,000 tons) = 20.5 tons excess $CaCO_3$

136. (D) capping to reduce infiltration and promote anaerobic conditions

Rock types C, D, and E constitute the ore because they have cut-off grades above 0.05 oz/ton. Review of the table shows that this material as a whole is a net acid producer (i.e., AGP > ANP). Acid-generating reactions require air, water, and reactive sulfides. To minimize the potential for acid production, contact with air should be minimized (answers A and C are incorrect) and contact with water should be minimized (answer B is incorrect). Answer D provides for reduced contact with both air and water.

137. (D) 7,000,000

$(1 \times 10^{-6}$ cm/s)(31,536,000 s/yr)(0.0328 ft/cm) = 1.03 ft/yr

Seepage = (15 ft/ft × 1.03 ft/yr)(300 ft × 200 ft)(7.48 gal/ft^3) = 6,933,960 gal

138. (B) 56,000

The easiest method to solve for the cross-sectional area is to scale the cut triangle and calculate its area using the formula: area = ½bh = ½(24 ft)(160 ft) = 1,920 ft^2.

A more precise answer can be determined by noting that the top of the dump portion of the triangle is 75 ft in length and the height of the triangle is 50 ft from where it intersects the regraded surface to the top of the dump. This yields: area = ½bh = (½)(75)(50) = 1,875 ft^2.

Cut volume = area × length = 1,875 ft^2 × 800 ft × (1 cu yd/27 cu ft) = 55,600 cu yd

139. (B) 8,200

Width of dump top = 75 ft; slope length (from scaling) = 320 ft

{or slope length from equation = $(300^2 + 100^2)^{0.5}$ = 316 ft}

Total volume of loose topsoil = (320 ft + 75 ft)(800 ft)(1 ft)(1 cy/27 cf) = 11,700 lcy

Volume of bank cubic yards = (11,700 lcy)(0.7 bcy/lcy) = 8,200 bcy

140. (A) optimum +2%

The minimum hydraulic conductivity for clay soils usually occurs when the soil is between 1% and 7% wet of optimum water content (Reference: Daniel and Koerner. 1993. *Quality Assurance and Quality Control for Waste Containment Facilities*. Washington, DC: Environmental Protection Agency). Clay liners are also typically compacted wet of optimum to guard against desiccation and cracking that may occur prior to covering. This is especially true in arid and semiarid areas. Accordingly, optimum +2% is the correct answer. The other values listed could result in putting the liner down too dry with subsequent higher permeabilities and potential cracking.

ANSWERS TO AFTERNOON SESSION

501. (A) S34°E

Δ = 10,500 – 9,600 = 900 ft to the south, Δ = 7,000 – 6,400 = 600 ft to the east

Bearing of decline from portal to bottom = $\tan^{-1}$ 600/900 = 33.69°

By inspection, bearing is southeast; therefore, the bearing = S34°E

502. (D) good floor and poor roof conditions

The logs show the coal seam (density = 1.3 g/cm^3) sitting on a relatively dense rock (density = 2.6 g/cm^3) with no evidence of an increase in borehole diameter that would indicate friability. However, the rock above the coal is less dense and, based on the relatively large increase in borehole diameter, is interpreted to be relatively friable/soft (Source: Thomas, L. 1992. *Handbook of Practical Coal Geology*. Chichester; New York: Wiley.)

503. (B) reducing sample volume

Coning and quartering is a method for reducing the sample volume by crushing and mixing the material, placing it in a conical pile, flattening the pile, dividing it into quarters, and alternately accepting and rejecting quarters. The process is repeated until the sample is reduced to the required volume.

504. (B) 9.7

Multiply average grade for each category by the percent of the deposit.

Average grade =

$0.06 \times 2.5 = 0.15$

$0.12 \times 5.0 = 0.60$

$0.30 \times 8.0 = 2.40$

$0.36 \times 11.0 = 3.96$

$0.16 \times 16.0 = \underline{2.56}$

9.67 grams/tonne

505. (A) 10.5

Average grade of stope = [Σ(vein width × Ag grade)]/Σ(stope width)

$= [(4 \times 21) + (8 \times 14) + (3 \times 7) + (5 \times 11)]/ (6 + 8 + 6 + 6) = 10.5$ oz/ton

(Adapted from Peters, W.C. 1978. *Exploration and Mining Geology*. New York: Wiley.)

506. (B) –3.6

$P/F_{i,n} = P/F_{10,1} = 0.9091$

$P/A_{i,n} = P/A_{10,10} = 6.1446$

$P/F_{i,n} = P/F_{10,12} = 0.3186$

Reference: Stermole, F.J., and J.M. Stermole. 1996. *Economic Evaluation and Investment Decision Methods*, 9th ed. Golden, CO: Investment Evaluations Corp. p. 634.

$NPV = -(0.9091)(\$25 \times 10^6) + (0.9091)(6.1446)(\$4 \times 10^6) - (0.3186)(\$10 \times 10^6) = -\$3.57 \times 10^6$

507. (D) cut-and-fill stoping

Block caving, vertical crater retreat, and open sublevel stoping provide relatively poor selective mining capability as the ore is broken and delivered to a draw point with little opportunity for selectively cutting out the subgrade material. Cut-and-fill mining provides an opportunity for being selective because up to 50% of the material may be left or taken depending on grade. The limited open volume of cut-and-fill stopes and the wall support provided by the backfill also allow a miner to follow irregular ore bodies precisely.

508. (B) room-and-pillar with pulling of bottom coal on retreat

The massive roof precludes the ability to safely pull pillars on retreat. Longwall is also inappropriate, given the high frequency of faulting that would require frequent moves and reinstallation of the longwall system. Room-and-pillar with pulling top coal on retreat makes no sense, as continuous miners can't typically reach that high and you would be cutting out the roof bolts installed during advancing operations. Room-and-pillar with pulling of bottom coal on retreat allows for installing roof support (i.e., roof bolts) during advance and maximizing recovery on retreat while still leaving pillars to support the massive roof rock.

509. (A) 5.3

Virgin coal required = (3,000,000 tons)/[(1 – 0.08) × 0.87] = 3,748,126 tons

Virgin strip ratio = 20,000,000 bcy/3,748,126 tons = 5.3 bcy/ton

510. (B) 22,100

Annual cost = (50 hp/0.85)(0.746 kW/hp)($.07/kWh)(20 hr/day) (360 d/yr) = $22,116.71

511. (B) 0.80

Bank volume fragmented per hole = burden × spacing × bench height = (30 ft)(36 ft)(50 ft)/(27 bcy/ft^3) = 2,000 bcy

Loaded length (L) of hole = bench height + subdrill – stemming = 50 ft + 8 ft – 21 ft = 37 ft

Hole area (A) = $\pi d^2/4$ = (3.14)(1.02 ft)^2/4 = 0.818 ft^2

Charge = L × A × S.G. × 62.4 lb/ft^3 = (37 ft)(0.818 ft^2)(0.85)(62.4 lb/ft^3) = 1,600 lb

Powder factor = charge/bank volume = 1,600 lb/2,000 bcy = 0.80 lb/bcy

512. (A) –40 and 80

Train resistance = rolling resistance (RR) + (grade × 20 lb/ton)

Empty down grade = 20 lb/ton + (–3)(20 lb/ton) = –40 lb/ton

Loaded up grade = 20 lb/ton + (3)(20 lb/ton) = 80 lb/ton

513. (A) 15.8

Annual production = (8,000 hr/yr × 0.80 availability × 0.80 efficiency × 75 cubic yard bucket × 0.90 bucket fill factor × 55 buckets/hr)/(1.2 cubic yard/1.0 bank cubic yard) = 15,800,000 bank cubic yards

520. (C) 2.4

Current shaft hp = 80 × 0.8 = 64 hp

Power draw using new fan = 64 hp/0.88 = 72.7 hp

Horsepower difference = 80 – 72.7 = 7.3 hp

Electrical savings per year = (7.3/80) × $32,000 = $2,920

Payback period = investment/annual savings = $7,000/($2,920/yr) = 2.4 yr

521. (A) 142°37'

The angle from A to C will include the angle from A to a line trending due east and west through Point B + 90° + 30°.

Distances from A to B:

1,245.66 – 1,123.87 = 121.79 m north

2,468.90 – 2,176.56 = 292.34 m east

arctan (121.79/292.34) = 22.62° = 22°37' from A to line trending due east and west

total angle = 22°37' + 90°00' + 30°00' = 142°37'

522. (A) 1.33

Draw a line vertically from the 7.0% cumulative float ash to the cumulative float curve. This line intersects the curve at approximately 50% cumulative float. Draw a line horizontally from this point to the yield curve. The point of intersection corresponds to a specific gravity of approximately 1.33.

523. (A) 9.3

Pyrite's (FeS_2) gram molecular weight = 55.85 + 2(32.06) = 119.97

Percent of iron in pyrite = 55.85/119.97 = 0.466 or 46.6%

Iron in concentrate = (20%)(0.466) = 9.3%

524. (B) 680

First calculate the percent solids of the media. Magnetite specific gravity = SGM = 4.6. Media specific gravity = SG = 1.55.

% solids = [SGM × (SG – 1)]/[SG × (SGM – 1)] × 100%

= [4.6 × (1.55 – 1)]/[1.55 × (4.6 – 1)] × 100% = 45.34%

Media flow rate = 500 tph × 3 = 1,500 tph

Magnetite mass flow rate = 1,500 tph × 0.4534 = 680 tph

525. (B) 2,900

Mass flow rate of media = 500 tph × 3 = 1,500 tph

Volume flow rate of media = (1,500 tph) × (CF/SG) = 1,500 × (4/1.55) = 3,871 gpm

where:

SG = specific gravity of media = 1.55

CF = conversion factor = [(2,000 lb/ton)(7.5 gal/ft^3)]/[(62.4 lb/ft^3)(60 min/hr)] = 4 gpm/tph

Overflow media flow rate = 3,871 gpm × 0.75 = 2,903 gpm

526. (A) clean coal yield and ash percentage in the clean coal will increase

As the media specific gravity increases, the percentage of both coal and ash that will float increases, resulting in greater clean coal yield and higher ash percentage in the clean coal.

527. (C) 39

Total water evaporated = wet tons – dry tons = (100 tph)/(1 – 0.12) – 100 tph = 13.6 tph

1. Heat feed material from 50°F to 200°F:

Heat 1 = (100 ton/hr)(2,000 lb/ton)(200°F – 50°F)(0.2 Btu/lb-°F) = 6.00 × 10^6 Btu/hr

2. Heat water to 212°F:

Heat 2 = (13.6 ton/hr)(2,000 lb/ton)(212°F – 50°F)(1.0 Btu/lb-°F) = 4.41 × 10^6 Btu/hr

3. Heat of vaporization:

Heat 3 = (13.6 ton/hr)(2,000 lb/ton)(970 Btu/lb) = 26.38 × 10^6 Btu/hr

4. Heat vapor to 375°F:

Heat 4 = (13.6 ton/hr)(2,000 lb/ton)(375°F – 212°F)(0.48 Btu/lb-°F) = 2.13 × 10^6 Btu/hr

Heat required = Heat 1 + Heat 2 + Heat 3 + Heat 4 = 38.92 × 10^6 Btu/hr

528. (C) 76,000

Tons of chalcopyrite in concentrate = 120,000 tons × 0.9 = 108,000 tons

(108,000 tons)([2 × 64.1]/183.5) = 75,500 tons of SO_2 produced annually

529. (C) 142

Weight of liquid into thickener = weight of liquid in overflow + weight of liquid in underflow

The velocity of the liquid reporting to the overflow must be the same as the velocity of the solids moving down. From the *SME Mineral Processing Handbook* (Section 2):

$W(1/F - 1) = AV\rho_L + W(1/u - 1)$

where:

W = weight of solid, mt/day = 1,500

F = feed slurry pulp density/100, % solids = 0.15

A = thickener area, m^2 = ?

V = velocity, m/day = 30.5

ρ_L = specific gravity of liquid = 1.44

u = underflow slurry pulp density/100, % solid = 0.40

Solving for A: $A = [W(1/F - 1/u)]/V\rho_L = 142.3\ m^2$

530. (B)10.7

⅜ in. = (0.375 in.)(25,400 µm/in.) = 9,525 µm

No. 200 screen = 74 µm (from standard reference)

Work = W = 510,000 kWh/45,000 tons = 11.34 kWh/ton

Rearrange Bond's work index to calculate the operating work index from the data given.

$Wi = (11.34\ \text{kWh/ton})/[(100/74)^{0.5} - (100/9{,}525)^{0.5}] =$

10.7 kWh/ton

531. (A) clay

Clay is, by far, the softest of the materials listed. Typical Bond work indices (kWh/ton) are 6.3 for clay, 16.1 for gravel, 13.0 for limestone, and 15.9 for shale.

532. (D) submit a composite sample of the test ore for abrasion testing and check mill operating conditions

Test wear rate = (42 lb/liner × 24 liners)/(35,000 kWh) = 0.029 lb/kWh

The test wear rate is significantly higher than the 0.01 lb/kWh design. Accordingly, the first thing to do is submit a composite of the ore tested during the 30-day period for abrasion testing to determine if the current ore being milled is significantly more abrasive than the composite on which design data were obtained. You should also check the mill's operating conditions such as mill speed, ball size, mill power meter, etc., to determine if something operational is contributing to the higher wear rate.

533. (A) 2,400

Neglecting static head: $Q_{new}/Q_{old} = rpm_{new}/rpm_{old}$

rpm_{new} = 1.2(2,000 rpm) = 2,400 rpm

534. (B) 60

Upstream loading = (1.4 ft^3/s)(0.16 mg/L)(86,400 s/day) (2.2046 × 10^{-6} lb/mg)(3.785 L/gal)(7.48 gal/ft^3) = 1.21 lb/day

Maximum mine loading = (maximum downstream loading – upstream loading) = 10 lb/day – 1.21 lb/day = 8.79 lb/day

Loading of untreated mine water = (1 × 10^6 gal/day)(2.5 mg/L) (2.2046 × 10^{-6} lb/mg)(3.785 L/gal) = 20.86 lb

Minimum percent removal = 100% × [(20.86 – 8.79)/20.86] = 57.9%

535. (C) 50

Incremental increase in dissolved solids =

(Downstream passing – upstream passing)/(sample volume) = (40 mg –15 mg)/(0.5 L) = 50 mg/L

536. (B) 13

Reference: *Mining Engineer Handbook,* Hartman, 1992, pg. 1163.

$V = 1.486/n*R^{2/3} *S^{1/2}$ and $Q = AV$

$R = A/P_w$

$A = 15d + d^2$

$P_w = 15 + 2*2^{1/2} *d$

$V = 1.584\ R^{2/3}$

There are two unknowns, V and d, so the solution is by trial and error.

d = 10 feet

A = 250 sf, P_w = 43.284, R = 5.776

V = 5.099 ft/sec; Q = 1,274.8 cfs — low

d = 11 feet

A = 286 sf, P_w = 46.113, R = 6.202

V = 5.347 ft/sec; Q = 1,529.27 cfs — slightly high

d = 10.9 feet

A = 282.31 sf, P_w = 45.829, R = 6.160

V = 5.323 ft/sec; Q = 1,502.68 cfs — close enough

d_{total} = 10.9 ft × 1.1 + 1.0 = 13.0 ft

537. (D) Zone IV

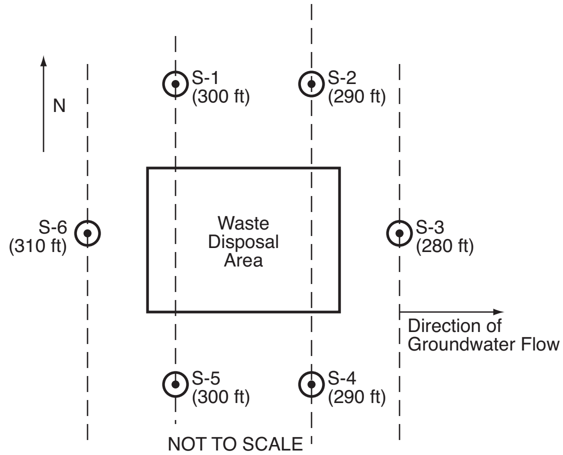
Generation of acid requires acid generating material; water, and air. Only Zone IV removes the air component by placing the material below the water table, where contact with air is limited to the minor amount of oxygen in the water. The other three zones are in an oxidized environment, as evidenced by the waste rock removed during mining operations.

538. (D) $175,000

Power consumed = $(0.7\ m^2)(90\ m/s)(7{,}845\ N/m^2)(kW\text{-}s/10^3N\text{-}m)/0.85$ = 581 kW

Power cost = (581 kW)(6,000 hr)($0.05/kWh) = $174,300

Figure for Answer 539



539. (A) east

Subtract depths to groundwater from surface elevations to find groundwater elevations. Plot groundwater elevations on map and draw contours through points of equal elevation. As shown in the figure, groundwater flows perpendicular to the contours from the high elevation toward the low elevation.

Well I.D.	Surface Elevation (ft)	Depth to Groundwater (ft)	Groundwater Elevation (ft)
S-1	325	25	300
S-2	340	50	290
S-3	400	120	280
S-4	442	152	290
S-5	434	134	300
S-6	385	75	310

540. (A) construction of a diversion ditch around the regraded area

Construction of a diversion ditch around the regraded area would effectively limit the water runoff that is eroding the slope. The other answers are incorrect because (1) ripping up and down the slope would channel water and accelerate erosion, (2) a silt fence at the top would not stop water run-on, and (3) a silt fence or sedimentation pond at the base of the slope would collect eroded soil but would not prevent it from occurring.