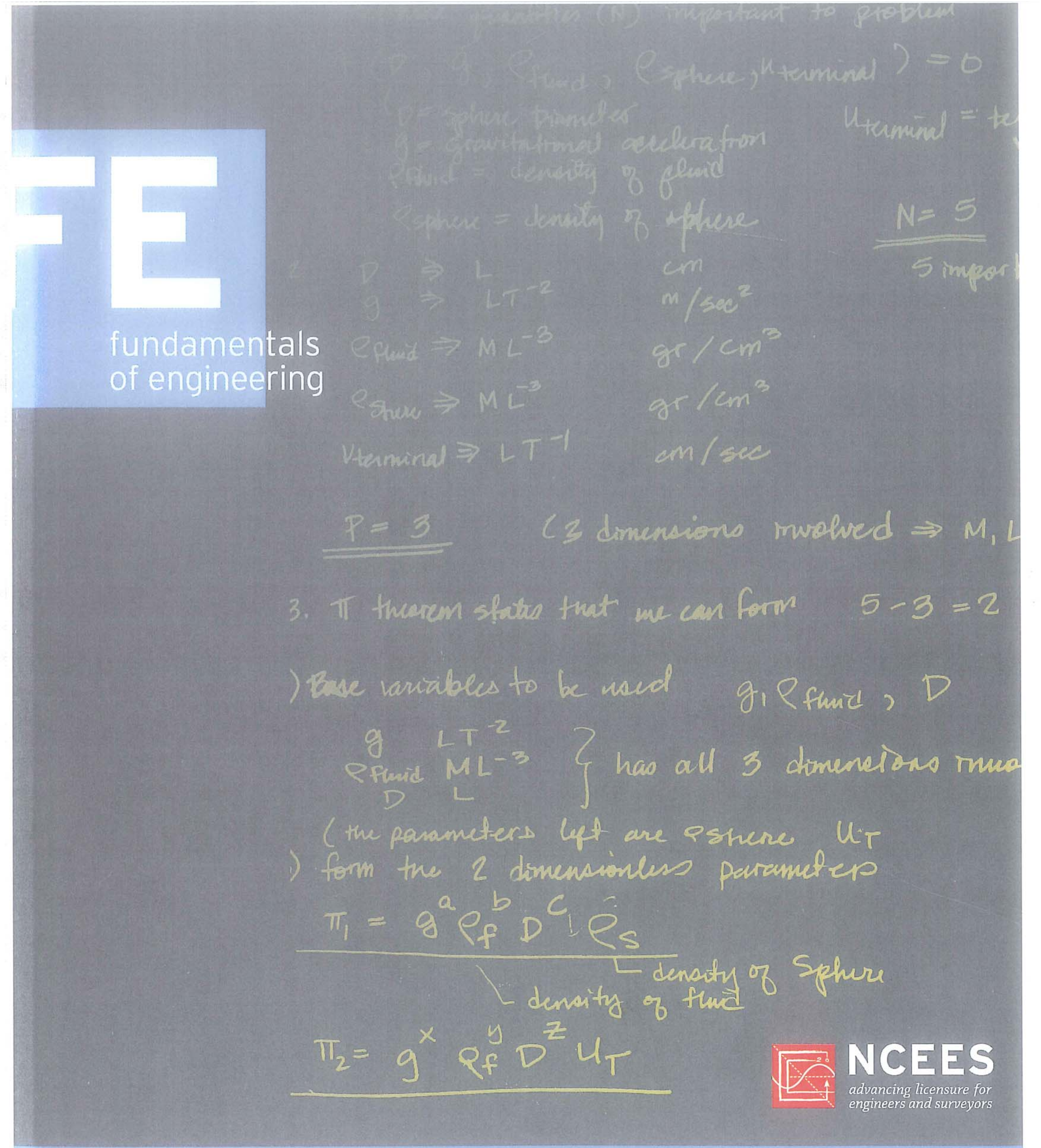
FE

fundamentals of engineering



NCEES
advancing licensure for engineers and surveyors

MECHANICAL

sample questions + solutions

fundamentals
of engineering

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NEWS AND UPDATES ON *www.ncees.org*

For news and updates about the examinations—including current exam specifications, exam policies, calculators approved for use during the examination, exam schedules, scoring, errata for this book, and other information—visit the NCEES Web site at **www.ncees.org**.

NCEES—THE EXAM DEVELOPER

- NCEES develops the examinations required of candidates for licensure as professional engineers. These examinations measure a candidate's ability to demonstrate minimum competency in the practice of engineering and are administered by each NCEES member licensing board.
- NCEES follows the guidelines established in the *Standards for Educational and Psychological Testing* published by the American Psychological Association. These procedures maximize the fairness and quality of the examinations. To ensure that procedures are followed, NCEES uses experienced testing specialists to guide the development of examinations using current testing techniques.
- NCEES relies on committees composed of professional engineers throughout the nation to prepare the examinations. These licensed engineers—who come from diverse professional backgrounds including government, industry, private consulting, and academia—supply the content expertise that is essential in developing examinations.

LICENSURE

The first step on the path to licensure as a professional engineer (P.E.) is to take and pass the Fundamentals of Engineering (FE) examination. If you are a student or a recent college graduate, you are well advised to take this step while coursework is still fresh in your mind. After passing the examination, your state board will designate you an engineer intern (E.I.).

To continue the licensure process, typically you must complete 4 years of progressive and verifiable experience that is acceptable to your licensing board. You should contact your licensing board to ensure that you are on track to meet their requirements. If you are, you will be approved to take the Principles and Practice of Engineering (PE) examination. After you pass the PE examination, you may become licensed as a professional engineer and use the distinguished P.E. designation.

Exam application procedures are available from the individual licensing boards in each state. Requirements and fees vary among the boards.

DESCRIPTION OF EXAMINATIONS

The purpose of the FE examination is to determine if the examinee has an adequate understanding of basic science, mathematics, engineering science, engineering economics, and discipline-specific subjects normally covered in coursework taken in the last 2 years of an engineering bachelor degree program. The examination identifies those applicants who have demonstrated an acceptable level of competence in these subjects.

The 8-hour FE examination is a no-choice examination in a multiple-choice format. The examination is administered in two 4-hour sessions. The morning session contains 120 questions, and the afternoon session contains 60 questions. Each question has four answer options. Numerical questions are posed

either in metric units, normally International System of Units (SI), or in U.S. Customary System (USCS) units. The exam specifications presented in this book give details of the subjects covered on the examination.

The morning session is common to all examinees, regardless of their engineering discipline. The afternoon session is administered in the following seven modules—Chemical, Civil, Electrical, Environmental, Industrial, Mechanical, and Other Disciplines. In general, if your major is a discipline other than chemical, civil, electrical, environmental, industrial, or mechanical engineering, you should choose the Other Disciplines module in the afternoon.

This book presents a sample examination, which contains half the number of questions as the actual exam. By illustrating the general content of the subject areas, the level of difficulty of the exam questions, and the format of the exam, the questions should be helpful in preparing for the examination. Solutions are presented for all the questions. The solution presented may not be the only way to solve the question. The intent is to demonstrate the typical effort required to solve each question. Exam questions, content, and subject matter do change from time to time, so be sure to check the NCEES Web site for current information.

SCORING

Both sessions of the FE examination are worth the same total number of points, and questions are weighted at one point for each morning question and two points for each afternoon question. Within each session, every question has equal weight. Points are not subtracted for incorrect responses. Therefore, it is to your advantage to answer every question. Your final score on the examination is determined by summing the number of points obtained in each session.

One of the most critical considerations in developing and administering examinations is establishing passing scores that reflect a standard of minimum competency. Before setting a minimum passing score for a new examination or for the first examination after a change in the specifications or standards, NCEES conducts studies involving a representative panel of engineers familiar with the examinee population. This panel uses procedures widely recognized and accepted for occupational licensing purposes and develops a written standard of minimum competency that clearly articulates what knowledge is required of engineering interns. Panelists then take the examination, evaluating the difficulty level of each question in the context of the minimum competency standard. Finally, NCEES reviews the panel's work and sets the passing score for the initial exam. For subsequent exams, an equating method is used to set the passing score. The passing (raw) score is never disclosed.

NCEES does not use a fixed-percentage pass rate. The key issue is whether an individual candidate meets the standard of minimal competence, *not* whether the candidate is better or worse than other candidates. To avoid the confusion that might arise from fluctuations in the passing score, exam results are reported simply as *pass* or *fail*. Some licensing jurisdictions may choose to report exam results of failing candidates as a scaled score.

The legal authority for making licensure decisions rests with the individual licensing boards and not with NCEES.

EXAM POLICIES AND PROCEDURES

A breach of an examination could lead to the licensure of people who are not competent to practice engineering. This puts the health, safety, and welfare of the public at risk. Therefore, NCEES takes measures necessary to protect the integrity of the exam process. This includes, for example, restricting cell phones, certain calculators, pencils, loose sheets of paper, and recording devices; controlling access into and out of the exam site; and monitoring activity in and around the exam room. Violating exam policies could result in such measures as dismissal from the exam, cancellation of exam results, and, in some cases, criminal action.

Be sure that you understand the policies outlined in the NCEES Candidate Agreement, and read all instructions from your board or testing service before exam day so that you know exactly what the expectations for examinees are.

NCEES Candidate Agreement

The NCEES Candidate Agreement explains the policies, procedures, and conditions examinees must agree to while taking an NCEES examination. Examinees are required to sign a statement on their answer sheet before the examination starts to affirm that they have been provided the NCEES Candidate Agreement, have read and understand the material, and agree to abide by the conditions cited. These conditions apply to all NCEES examinations. A current NCEES Candidate Agreement is available on the NCEES Web site.

Special Accommodations

If you require special accommodations in the test-taking procedure, you should contact your state licensing board office well in advance of the day of the examination so that appropriate arrangements may be determined. Only preapproved accommodations are allowed on exam day.

Exam Admission Requirements

For exam admission, examinees must present a current, signed, government-issued photographic identification (such as a valid state driver's license or passport). Student IDs are not acceptable. Examinees must report to the exam site by the designated time. Examinees will not be admitted after the proctor begins reading the exam instructions.

References

The FE examination is a closed-book examination. However, since engineers rely heavily on reference materials, you will be given a copy of the NCEES *FE Supplied-Reference Handbook* at the exam site. The *Handbook* contains formulas and data that examinees cannot reasonably be expected to memorize. The *Handbook* does not contain all the information required to answer every question on the examination. For example, basic theories, formulas, and definitions that examinees are expected to know have not been included. To familiarize yourself with the content of the *Handbook* before the examination, visit the NCEES Web site to purchase or print a copy of the *Handbook*. You will not be allowed to take your copy of the *Handbook* into the examination; you must use the copy provided to you by the proctor in the exam room.

Prohibited Items

A current list of prohibited items is included in the NCEES Candidate Agreement on the NCEES Web site. If a prohibited item is found in an examinee's possession after the exam begins, the item will be

confiscated and sent to NCEES. Having a prohibited item in your possession is grounds for dismissal and/or invalidation of your exam results.

Exam Irregularities

Fraud, deceit, dishonesty, and other irregular behavior in connection with taking any NCEES examination are strictly prohibited. Irregular behavior includes but is not limited to the following:

- Copying or allowing the copying of exam answers
- Failing to work independently
- Possessing unauthorized devices or source materials
- Surrogate testing or other dishonest conduct
- Disrupting other examinees
- Creating safety concerns
- Beginning the exam before the proctor instructs you to do so
- Failing to cease work on the examination or put down the pencil when time is called
- Possessing, reproducing, or disclosing exam questions, answers, or other information about the examination without authorization before, during, or after the exam administration
- Communicating with other examinees or with any outside source during the examination by telephone, personal computer, Internet, or any other means

Exam Results

Examinees are understandably eager to find out how they performed on the examination. To ensure that the process is fair and equitable to examinees and to maintain the validity of the exam questions, NCEES uses a rigorous scoring process for each of the NCEES multiple-choice examinations that takes approximately 12 weeks to complete.

- First, NCEES scans all answer sheets as they are received from the states. Answer sheets are flagged for review when they are missing critical information, such as the candidate ID number. The scoring process continues only when these issues are resolved.
- Next, a psychometric analysis is performed on a sample population of answer sheets from each multiple-choice examination to identify any questions with unusual statistics, which flag the question for review.
- Then, at least two subject-matter experts who are licensed engineers review the flagged items. In addition, NCEES reviews all Examinee Comment Forms, and the subject-matter experts consider comments on the forms about specific exam questions. If the reviews confirm an error in a question, credit may be given for more than one answer.
- When the analyses and reviews are completed, NCEES revises the answer keys as necessary. The passing score and the final correct answers for each examination are then used to score all the answer sheets. Scanners are calibrated before and during scoring. A percentage of the answer sheets are hand-graded and the results compared to the machine score to ensure accuracy of results.
- Finally, NCEES releases the results to the state boards or testing agencies, who in turn report the results to examinees.

EXAM SPECIFICATIONS
FOR THE MORNING SESSION

FUNDAMENTALS OF ENGINEERING (FE) EXAMINATION

Effective April 2009

- The FE examination is an 8-hour supplied-reference examination: 120 questions in the 4-hour morning session and 60 questions in the 4-hour afternoon session.
- The afternoon session is administered in the following seven modules—Chemical, Civil, Electrical, Environmental, Industrial, Mechanical, and Other Disciplines.
- Examinees work all questions in the morning session and all questions in the afternoon module they have chosen.

MORNING SESSION
(120 questions in 12 topic areas)

Topic Area	Approximate Percentage of Test Content
I. Mathematics A. Analytic geometry B. Integral calculus C. Matrix operations D. Roots of equations E. Vector analysis F. Differential equations G. Differential calculus	15%
II. Engineering Probability and Statistics A. Measures of central tendencies and dispersions (e.g., mean, mode, standard deviation) B. Probability distributions (e.g., discrete, continuous, normal, binomial) C. Conditional probabilities D. Estimation (e.g., point, confidence intervals) for a single mean E. Regression and curve fitting F. Expected value (weighted average) in decision-making G. Hypothesis testing	7%
III. Chemistry A. Nomenclature B. Oxidation and reduction C. Periodic table D. States of matter E. Acids and bases F. Equations (e.g., stoichiometry) G. Equilibrium H. Metals and nonmetals	9%

	Topic Area	Approximate Percentage of Test Content
IV.	**Computers** A. Terminology (e.g., memory types, CPU, baud rates, Internet) B. Spreadsheets (e.g., addresses, interpretation, "what if," copying formulas) C. Structured programming (e.g., assignment statements, loops and branches, function calls)	7%
V.	**Ethics and Business Practices** A. Code of ethics (professional and technical societies) B. Agreements and contracts C. Ethical versus legal D. Professional liability E. Public protection issues (e.g., licensing boards)	7%
VI.	**Engineering Economics** A. Discounted cash flow (e.g., equivalence, PW, equivalent annual FW, rate of return) B. Cost (e.g., incremental, average, sunk, estimating) C. Analyses (e.g., breakeven, benefit-cost) D. Uncertainty (e.g., expected value and risk)	8%
VII.	**Engineering Mechanics (Statics and Dynamics)** A. Statics 1. Resultants of force systems 2. Concurrent force systems 3. Equilibrium of rigid bodies 4. Frames and trusses 5. Centroid of area 6. Area moments of inertia 7. Friction B. Dynamics 1. Linear motion 2. Angular motion 3. Mass moments of inertia 4. Impulse and momentum applied to: a. particles b. rigid bodies 5. Work, energy, and power as applied to: a. particles b. rigid bodies 6. Friction	10%

	Topic Area	Approximate Percentage of Test Content
VIII.	**Strength of Materials**	7%
	A. Shear and moment diagrams	
	B. Stress types (e.g., normal, shear, bending, torsion)	
	C. Stress strain caused by:	
	1. Axial loads	
	2. Bending loads	
	3. Torsion	
	4. Shear	
	D. Deformations (e.g., axial, bending, torsion)	
	E. Combined stresses	
	F. Columns	
	G. Indeterminant analysis	
	H. Plastic versus elastic deformation	
IX.	**Material Properties**	7%
	A. Properties	
	1. Chemical	
	2. Electrical	
	3. Mechanical	
	4. Physical	
	B. Corrosion mechanisms and control	
	C. Materials	
	1. Engineered materials	
	2. Ferrous metals	
	3. Nonferrous metals	
X.	**Fluid Mechanics**	7%
	A. Flow measurement	
	B. Fluid properties	
	C. Fluid statics	
	D. Energy, impulse, and momentum equations	
	E. Pipe and other internal flow	
XI.	**Electricity and Magnetism**	9%
	A. Charge, energy, current, voltage, power	
	B. Work done in moving a charge in an electric field (relationship between voltage and work)	
	C. Force between charges	
	D. Current and voltage laws (Kirchhoff, Ohm)	
	E. Equivalent circuits (series, parallel)	
	F. Capacitance and inductance	
	G. Reactance and impedance, susceptance and admittance	
	H. AC circuits	
	I. Basic complex algebra	

	Topic Area	Approximate Percentage of Test Content
XII.	**Thermodynamics**	7%
	A. Thermodynamic laws (e.g., 1st Law, 2nd Law)	
	B. Energy, heat, and work	
	C. Availability and reversibility	
	D. Cycles	
	E. Ideal gases	
	F. Mixture of gases	
	G. Phase changes	
	H. Heat transfer	
	I. Properties of:	
	1. Enthalpy	
	2. Entropy	

MORNING

SAMPLE QUESTIONS

THE MORNING SAMPLE EXAMINATION CONTAINS 60 QUESTIONS,
HALF THE NUMBER ON THE ACTUAL EXAMINATION.

1. If the functional form of a curve is known, differentiation can be used to determine all of the following except the:

(A) concavity of the curve

(B) location of inflection points on the curve

(C) number of inflection points on the curve

(D) area under the curve between certain bounds

2. Which of the following is the general solution to the differential equation and boundary condition shown below?

$$\frac{dy}{dt}+5y=0;\ y(0)=1$$

(A) e^{5t}

(B) e^{-5t}

(C) $e^{\sqrt{-5t}}$

(D) $5e^{-5t}$

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3. If D is the differential operator, then the general solution to $(D+2)^2 y = 0$ is:

(A) $C_1 e^{-4x}$
(B) $C_1 e^{-2x}$
(C) $e^{-4x}(C_1 + C_2 x)$
(D) $e^{-2x}(C_1 + C_2 x)$

4. A particle traveled in a straight line in such a way that its distance S from a given point on that line after time t was $S = 20t^3 - t^4$. The rate of change of acceleration at time $t = 2$ is:

(A) 72
(B) 144
(C) 192
(D) 208

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5. Which of the following is a unit vector perpendicular to the plane determined by the vectors $A = 2i + 4j$ and $B = i + j - k$?

(A) $-2i + j - k$

(B) $\frac{1}{\sqrt{5}}(i + 2j)$

(C) $\frac{1}{\sqrt{6}}(-2i + j - k)$

(D) $\frac{1}{\sqrt{6}}(-2i - j - k)$

6. If f' denotes the derivative of a function of $y = f(x)$, then $f'(x)$ is defined by:

(A) $\lim_{\Delta y \to 0} \frac{\Delta x}{\Delta y}$

(B) $\lim_{\Delta y \to 0} \frac{\Delta y}{\Delta x}$

(C) $\lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x}$

(D) $\lim_{\Delta y \to 0} \frac{f(x - \Delta x) + f(x)}{\Delta y}$

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7. What is the area of the region in the first quadrant that is bounded by the line $y = 1$, the curve $x = y^{3/2}$, and the y-axis?

(A) 2/5
(B) 3/5
(C) 2/3
(D) 1

8. Three lines are defined by the three equations:

$$\begin{aligned} x + y &= 0 \\ x - y &= 0 \\ 2x + y &= 1 \end{aligned}$$

The three lines form a triangle with vertices at:

(A) $(0, 0), \left(\frac{1}{3}, \frac{1}{3}\right), (1, -1)$

(B) $(0, 0), \left(\frac{2}{3}, \frac{2}{3}\right), (-1, -1)$

(C) $(1, 1), (1, -1), (2, 1)$

(D) $(1, 1), (3, -3), (-2, -1)$

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9. The value of the integral $\int_0^{\pi} 10 \sin x dx$ is:

(A) −10
(B) 0
(C) 10
(D) 20

10. You wish to estimate the mean M of a population from a sample of size n drawn from the population. For the sample, the mean is x and the standard deviation is s. The probable accuracy of the estimate improves with an increase in:

(A) M
(B) n
(C) s
(D) $M + s$

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11. A bag contains 100 balls numbered from 1 to 100. One ball is removed. What is the probability that the number on this ball is odd or greater than 80?

(A) 0.2
(B) 0.5
(C) 0.6
(D) 0.8

12. The standard deviation of the population of the three values 1, 4, and 7 is:

(A) $\sqrt{3}$
(B) $\sqrt{6}$
(C) 4
(D) 6

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13. Suppose the lengths of telephone calls form a normal distribution with a mean length of 8.0 min and a standard deviation of 2.5 min. The probability that a telephone call selected at random will last more than 15.5 min is most nearly:

(A) 0.0013
(B) 0.0026
(C) 0.2600
(D) 0.9987

14. The volume (L) of 1 mol of H_2O at 546 K and 1.00 atm pressure is most nearly:

(A) 11.2
(B) 14.9
(C) 22.4
(D) 44.8

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15. Consider the equation:

$$As_2O_3 + 3\ C \rightarrow 3\ CO + 2\ As$$

Atomic weights may be taken as 75 for arsenic, 16 for oxygen, and 12 for carbon. According to the equation above, the reaction of 1 standard gram mole of As_2O_3 with carbon will result in the formation of:

(A) 1 gram mole of As

(B) 28 grams of CO

(C) 150 grams of As

(D) a greater amount by weight of CO than of As

16. If 60 mL of NaOH solution neutralizes 40 mL of 0.50 M H_2SO_4, the concentration of the NaOH solution is most nearly:

(A) 0.80 M
(B) 0.67 M
(C) 0.45 M
(D) 0.33 M

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17. The atomic weights of sodium, oxygen, and hydrogen are 23, 16, and 1, respectively. To neutralize 4 grams of NaOH dissolved in 1 L of water requires 1 L of:

(A) 0.001 normal HCl solution

(B) 0.01 normal HCl solution

(C) 0.1 normal HCl solution

(D) 1.0 normal HCl solution

18. Consider the following equation:

$$K = \frac{[C]^2[D]^2}{[A]^4[B]}$$

The equation above is the formulation of the chemical equilibrium constant equation for which of the following reactions?

(A) $C_2 + D_2 \leftrightarrow A_4 + B$

(B) $4A + B \leftrightarrow 2C + 2D$

(C) $4C + 2D \leftrightarrow 2A + B$

(D) $A_4 + B \leftrightarrow C_2 + D_2$

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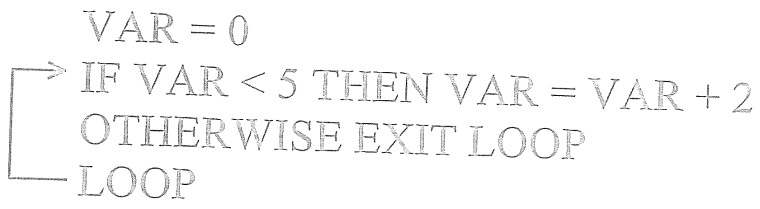
19. The flowchart for a computer program contains the following segment:



What is the value of VAR at the conclusion of this routine?

(A) 0
(B) 2
(C) 4
(D) 6

20. In a spreadsheet, the number in Cell A4 is set to 6. Then A5 is set to A4 + A4. This formula is copied into Cells A6 and A7. The number shown in Cell A7 is most nearly:

(A) 12
(B) 24
(C) 36
(D) 216

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21. Consider the following program segment:

```
INPUT Z, N
S = 1
T = 1
FOR K = 1 TO N
T = T*Z/K
S = S + T
NEXT K
```

This segment calculates the sum:

(A) $S = 1 + ZT + 2\,ZT + 3\,ZT + \ldots + N\,ZT$

(B) $S = 1 + ZT + \frac{1}{2}ZT + \frac{1}{3}ZT + \ldots + \left(\frac{1}{N}\right)ZT$

(C) $S = 1 + \frac{Z}{1} + \frac{2Z}{2} + \frac{3Z}{3} + \ldots + \left(\frac{NZ}{N}\right)$

(D) $S = 1 + \frac{Z}{1!} + \frac{Z^2}{2!} + \frac{Z^3}{3!} + \ldots + \left(\frac{Z^N}{N!}\right)$

22. In a spreadsheet, Row 1 has the numbers 2, 4, 6, 8, 10, ... , 20 in Columns A–J, and Row 2 has the numbers 1, 3, 5, 7, 9, ... , 19 in the same columns. All other cells are zero except for Cell D3, which contains the formula: D1 + D$1*D2. This formula has been copied into cells D4 and D5. The number that appears in cell D4 is most nearly:

(A) 3
(B) 64
(C) 519
(D) 4,216

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23. An engineer testifying as an expert witness in a product liability case should:

(A) answer as briefly as possible only those questions posed by the attorneys

(B) provide a complete and objective analysis within his or her area of competence

(C) provide an evaluation of the character of the defendant

(D) provide information on the professional background of the defendant

24. As a professional engineer originally licensed 30 years ago, you are asked to evaluate a newly developed computerized control system for a public transportation system. You may accept this project if:

(A) you are competent in the area of modern control systems

(B) your professional engineering license has not lapsed

(C) your original area of specialization was in transportation systems

(D) you have regularly attended meetings of a professional engineering society

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25. You and your design group are competing for a multidisciplinary concept project. Your firm is the lead group in the design professional consortium formed to compete for the project. Your consortium has been selected as the first to enter fee negotiations with the project owner. During the negotiations, the amount you have to cut from your fee to be awarded the contract will require dropping one of the consortium members whose staff has special capabilities not available from the staff of the remaining consortium members. Can your remaining consortium ethically accept the contract?

(A) No, because an engineer may not accept a contract to coordinate a project with other professional firms providing capabilities and services that must be provided by hired consultants.

(B) Yes, if your remaining consortium members hire a few new lower-cost employees to do the special work that would have been provided by the consortium member that has been dropped.

(C) No, not if the owner is left with the impression that the consortium is still fully qualified to perform all the required tasks.

(D) Yes, if in accepting an assignment to coordinate the project, a single person will sign and seal all the documents for the entire work of the consortium.

26. You are a student and have an on-site job interview with Company A. Just before you fly to the interview, you get a call from Company B asking you to come for an on-site interview at their offices in the same city. When you inform them of your interview with Company A, they suggest you stop in after that. Company A has already paid for your airfare and, at the conclusion of your interview with them, issues you reimbursement forms for the balance of your trip expenses with instructions to file for all your trip expenses. When you inform them of your added interview stop at Company B, they tell you to go ahead and charge the entire cost of the trip to Company A. You interview with Company B, and at the conclusion, they give you travel reimbursement forms with instructions to file for all your trip expenses. When you inform them of the instructions of Company A, they tell you that the only expenses requiring receipts are airfare and hotel rooms, so you should still file for all the other expenses with them even if Company A is paying for it because students always need a little spending money. What should you do?

(A) Try to divide the expenses between both firms as best you can.

(B) Do as both recruiting officers told you. It is their money and their travel policies.

(C) File for travel expenses with only one firm.

(D) Tell all your classmates to sign up to interview with these firms for the trips.

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27. A company can manufacture a product using hand tools. Tools will cost $1,000, and the manufacturing cost per unit will be $1.50. As an alternative, an automated system will cost $15,000 with a manufacturing cost per unit of $0.50. With an anticipated annual volume of 5,000 units and neglecting interest, the breakeven point (years) is most nearly:

(A) 2.8
(B) 3.6
(C) 15.0
(D) never

28. A printer costs $900. Its salvage value after 5 years is $300. Annual maintenance is $50. If the interest rate is 8%, the equivalent uniform annual cost is most nearly:

(A) $224
(B) $300
(C) $327
(D) $350

29. The need for a large-capacity water supply system is forecast to occur 4 years from now. At that time, the system required is estimated to cost $40,000. If an account earns 12% per year compounded annually, the amount that must be placed in the account at the end of each year in order to accumulate the necessary purchase price is most nearly:

(A) $8,000
(B) $8,370
(C) $9,000
(D) $10,000

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30. A project has the estimated cash flows shown below.

Year End	0	1	2	3	4
Cash Flow	–$1,100	–$400	+$1,000	+$1,000	+$1,000

Using an interest rate of 12% per year compounded annually, the annual worth of the project is most nearly:

(A) $450
(B) $361
(C) $320
(D) $226

31. You must choose between four pieces of comparable equipment based on the cash flows given below. All four pieces have a life of 8 years.

Parameter	Equipment			
	A	B	C	D
First cost	$25,000	$35,000	$20,000	$40,000
Annual costs	$8,000	$6,000	$9,000	$5,000
Salvage value	$2,500	$3,500	$2,000	$4,000

The discount rate is 12%. Ignore taxes. The most preferable top two projects and the difference between their present worth values are most nearly:

(A) A and C, $170
(B) B and D, $170
(C) A and C, $234
(D) B and D, $234

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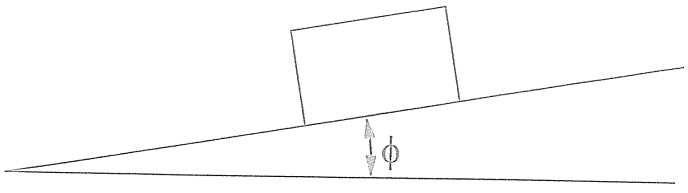
32. In the figure below, the coefficient of static friction between the block and the inclined plane is 0.25. The block is in equilibrium. As the inclined plane is raised, the block will begin to slide when:

(A) $\sin \phi = 1.0$

(B) $\cos \phi = 1.0$

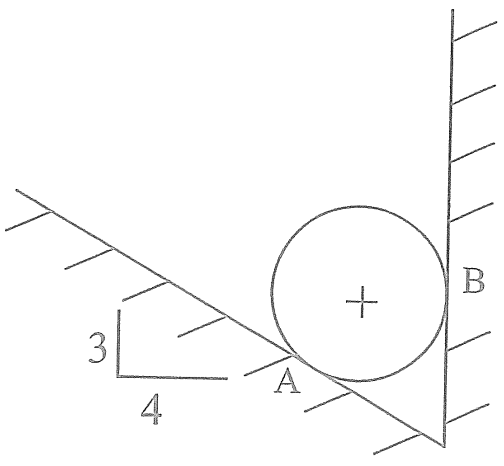
(C) $\cos \phi = 0.25$

(D) $\tan \phi = 0.25$



33. A cylinder weighing 120 N rests between two frictionless walls as shown in the figure below. The wall reaction (N) at Point A is most nearly:

(A) 96
(B) 139
(C) 150
(D) 200



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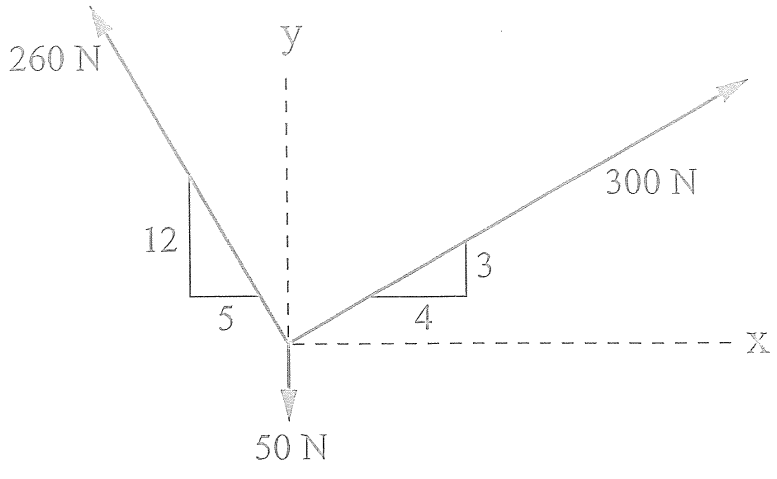
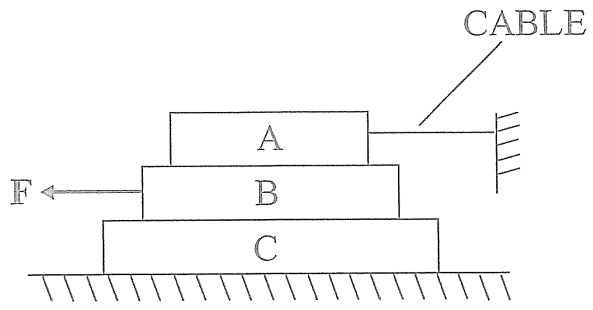
34. Three forces act as shown below. The magnitude of the resultant of the three forces (N) is most nearly:

(A) 140
(B) 191
(C) 370
(D) 396



35. In the figure below, Block A weighs 50 N, Block B weighs 80 N, and Block C weighs 100 N. The coefficient of friction at all surfaces is 0.30. The maximum force F (N) that can be applied to Block B without disturbing equilibrium is most nearly:

(A) 15
(B) 54
(C) 69
(D) 84



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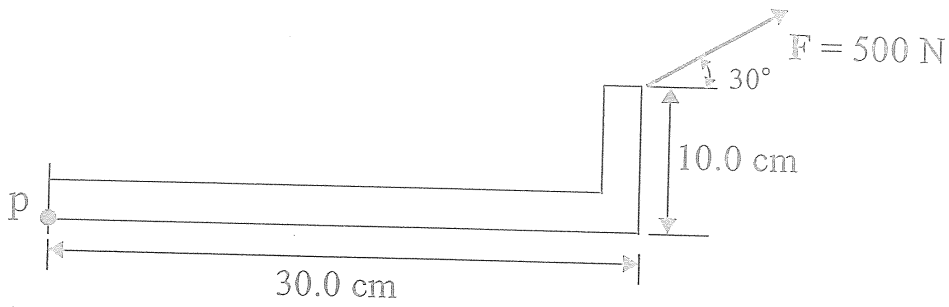
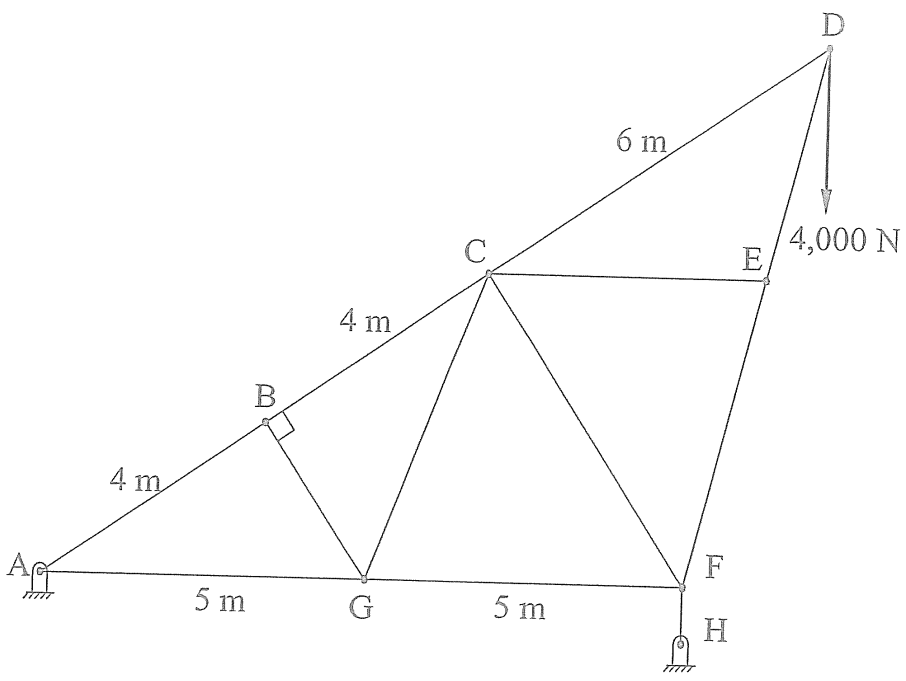
36. The moment of force F (N·m) shown below with respect to Point p is most nearly:

(A) 31.7 ccw
(B) 31.7 cw
(C) 43.3 cw
(D) 43.3 ccw



37. The figure below shows a simple truss. The zero-force members in the truss are:

(A) BG, CG, CF, CE
(B) BG, CE
(C) CF
(D) CG, CF



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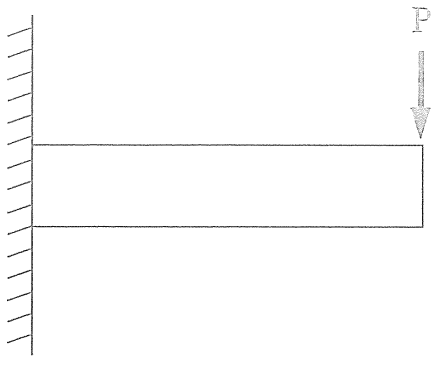
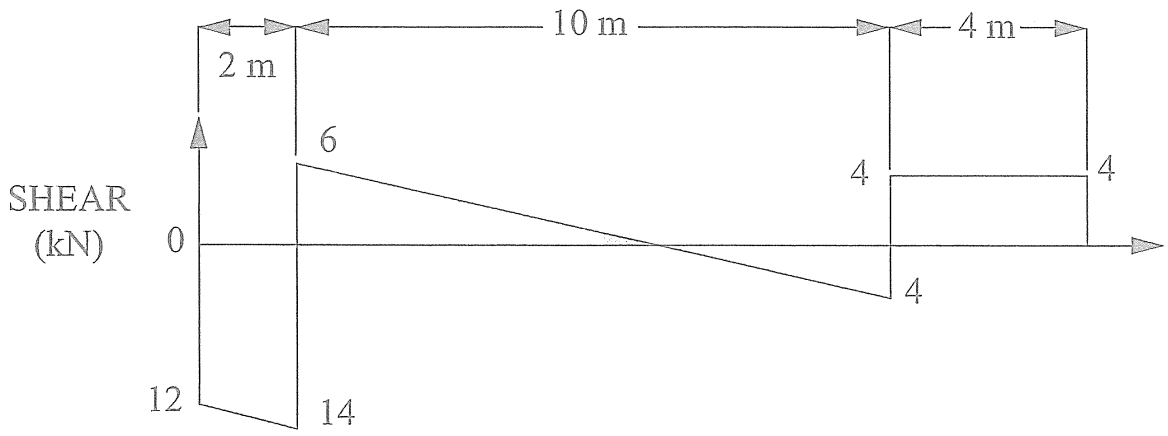
38. The beam shown below is known as a:



(A) cantilever beam
(B) statically indeterminate beam
(C) simply supported beam
(D) continuously loaded beam

39. The shear diagram for a particular beam is shown below. All lines in the diagram are straight. The bending moment at each end of the beam is zero, and there are no concentrated couples along the beam. The maximum magnitude of the bending moment (kN•m) in the beam is most nearly:

(A) 8
(B) 16
(C) 18
(D) 26



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40. The piston of a steam engine is 50 cm in diameter, and the maximum steam gage pressure is 1.4 MPa. If the design stress for the piston rod is 68 MPa, its cross-sectional area (m^2) should be most nearly:

(A) 40.4×10^{-4}
(B) 98.8×10^{-4}
(C) 228.0×10^{-4}
(D) 323.0×10^{-4}

41. A shaft of wood is to be used in a certain process. If the allowable shearing stress parallel to the grain of the wood is 840 kN/m^2, the torque (N·m) transmitted by a 200-mm-diameter shaft with the grain parallel to the neutral axis is most nearly:

(A) 500
(B) 1,200
(C) 1,320
(D) 1,500

42. The Euler formula for columns deals with:

(A) relatively short columns
(B) shear stress
(C) tensile stress
(D) elastic buckling

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43. The mechanical deformation of a material above its recrystallization temperature is commonly known as:

(A) hot working
(B) strain aging
(C) grain growth
(D) cold working

44. In general, a metal with high hardness will also have:

(A) good formability
(B) high impact strength
(C) high electrical conductivity
(D) high yield strength

45. Glass is said to be an amorphous material. This means that it:

(A) has a high melting point
(B) is a supercooled vapor
(C) has large cubic crystals
(D) has no apparent crystal structure

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46. If an aluminum crimp connector were used to connect a copper wire to a battery, what would you expect to happen?

(A) The copper wire only will corrode.

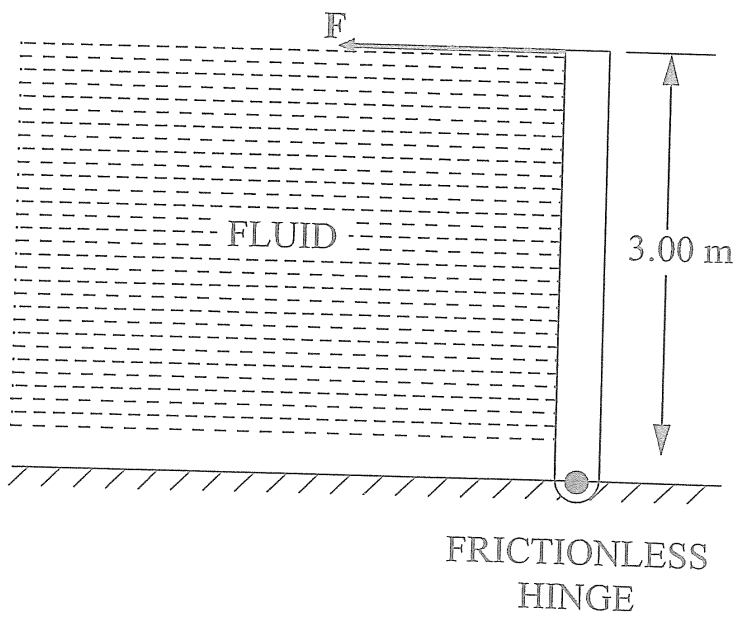
(B) The aluminum connector only will corrode.

(C) Both will corrode.

(D) Nothing

47. The rectangular homogeneous gate shown below is 3.00 m high × 1.00 m wide and has a friction-less hinge at the bottom. If the fluid on the left side of the gate has a density of 1,600 kg/m^3, the magnitude of the force F (kN) required to keep the gate closed is most nearly:

(A) 0
(B) 22
(C) 24
(D) 220



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48. Which of the following statements is true of viscosity?

(A) It is the ratio of inertial to viscous force.

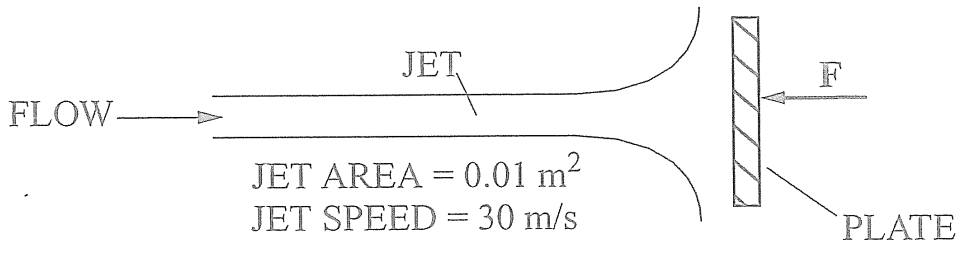
(B) It always has a large effect on the value of the friction factor.

(C) It is the ratio of the shear stress to the rate of shear deformation.

(D) It is usually low when turbulent forces predominate.

49. A horizontal jet of water (density = 1,000 kg/m^3) is deflected perpendicularly to the original jet stream by a plate as shown below. The magnitude of force F (kN) required to hold the plate in place is most nearly:

(A) 4.5
(B) 9.0
(C) 45.0
(D) 90.0



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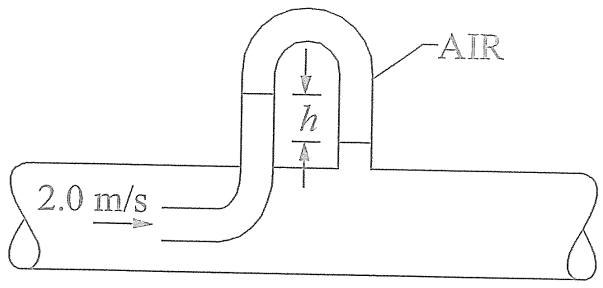
50. Which of the following statements about flow through an insulated valve is most accurate?

(A) The enthalpy rises.
(B) The upstream and downstream enthalpies are equal.
(C) Temperature increases sharply.
(D) Pressure increases sharply.

51. The pitot tube shown below is placed at a point where the velocity is 2.0 m/s. The specific gravity of the fluid is 2.0, and the upper portion of the manometer contains air. The reading h (m) on the manometer is most nearly:

(A) 20.0
(B) 10.0
(C) 0.40
(D) 0.20



52. If the complex power is 1,500 VA with a power factor of 0.866 lagging, the reactive power (VAR) is most nearly:

(A) 0
(B) 750
(C) 1,300
(D) 1,500

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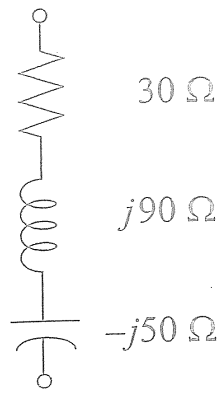
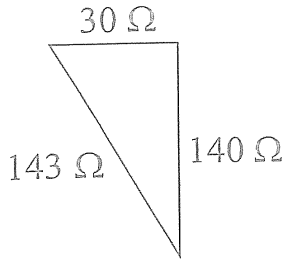
53. Series-connected circuit elements are shown in the figure below.

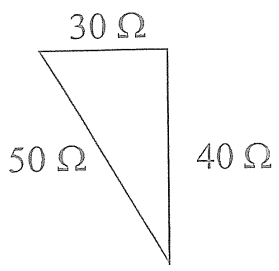


Which of the following impedance diagrams is correct according to conventional notation?

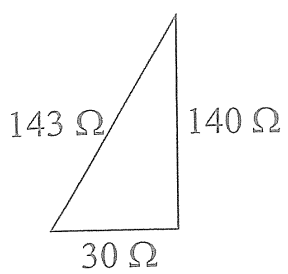
(A)



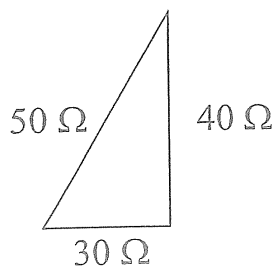
(B)



(C)



(D)



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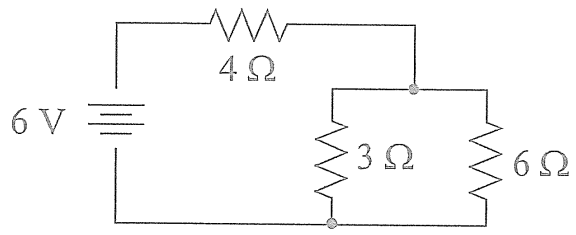
54. A 10-μF capacitor has been charged to a potential of 150 V. A resistor of 25 Ω is then connected across the capacitor through a switch. When the switch is closed for ten time constants, the total energy (joules) dissipated by the resistor is most nearly:

(A) 1.0×10^{-7}
(B) 1.1×10^{-1}
(C) 9.0×10^{1}
(D) 9.0×10^{3}

55. The connecting wires and the battery in the circuit shown below have negligible resistance. The current (amperes) through the 6-Ω resistor is most nearly:

(A) 1/3
(B) 1/2
(C) 1
(D) 3/2



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56. The term $\dfrac{(1-i)^2}{(1+i)^2}$, where $i=\sqrt{-1}$, is most nearly:

(A) -1
(B) $-1+i$
(C) 0
(D) $1+i$

57. An insulated tank contains half liquid and half vapor by volume in equilibrium. The release of a small quantity of the vapor without the addition of heat will cause:

(A) evaporation of some liquid in the tank
(B) superheating of the vapor in the tank
(C) a rise in temperature
(D) an increase in enthalpy

58. The heat transfer during an adiabatic process is:

(A) reversible
(B) irreversible
(C) dependent on temperature
(D) zero

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59. An isentropic process is one which:

(A) is adiabatic but not reversible
(B) is reversible but not adiabatic
(C) is adiabatic and reversible
(D) occurs at constant pressure and temperature

60. The universal gas constant is 8.314 kJ/(kmol·K). The gas constant [(kJ/(kg·K)] of a gas having a molecular weight of 44 is most nearly:

(A) 0.19
(B) 0.38
(C) 0.55
(D) 5.3

MORNING SOLUTIONS

Answers to the Morning Sample Questions

Detailed solutions for each question begin on the next page.

1	D	31	B
2	B	32	D
3	D	33	C
4	A	34	D
5	C	35	B
6	C	36	A
7	A	37	A
8	A	38	A
9	D	39	D
10	B	40	A
11	C	41	C
12	B	42	D
13	A	43	A
14	D	44	D
15	C	45	D
16	B	46	B
17	C	47	C
18	B	48	C
19	D	49	B
20	B	50	B
21	D	51	D
22	C	52	B
23	B	53	D
24	A	54	B
25	A	55	A
26	A	56	A
27	A	57	A
28	A	58	D
29	B	59	C
30	D	60	A

1. The area under a curve is determined by integration, not differentiation.

THE CORRECT ANSWER IS: (D)

2. The characteristic equation for a first-order linear homogeneous differential equation is:

$$r + 5 = 0$$

which has a root at $r = -5$.

Refer to Differential Equations in the Mathematics section of the *FE Supplied-Reference Handbook*. The form of the solution is then:

$y = Ce^{-\alpha t}$ where $\alpha = a$ and $a = 5$ for this problem

C is determined from the boundary condition.

$$1 = Ce^{-5(0)}$$
$$C = 1$$

Then, $y = e^{-5t}$

THE CORRECT ANSWER IS: (B)

3. Refer to Differential Equations in the Mathematics section of the *FE Supplied-Reference Handbook*. The characteristic equation for a second-order linear homogeneous differential equation is:

$$r^2 + ar + b = 0$$

In this problem, $D^2 + 4D + 4 = 0$, so:

$a = 4$ and $b = 4$

In solving the characteristic equation, it is noted that there are repeated real roots: $r_1 = r_2 = -2$

Because $a^2 = 4b$, the solution for this critically damped system is:

$$y(x) = (C_1 + C_2x)\, e^{-2x}$$

THE CORRECT ANSWER IS: (D)

4. First, the velocity is:

$$V = S' = 60t^2 - 4t^3$$

Then, the acceleration is:

$$A = S'' = 120t - 12t^2$$

Finally, the rate of change of acceleration is:

$$A' = S''' = 120 - 24t$$

When $t = 2$:

$$A' = 120 - 24(2) = 120 - 48 = 72$$

THE CORRECT ANSWER IS: (A)

5. The cross product of vectors A and B is a vector perpendicular to A and B.

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 2 & 4 & 0 \\ 1 & 1 & -1 \end{vmatrix} = \mathbf{i}(-4) - \mathbf{j}(-2-0) + \mathbf{k}(2-4) = -4\mathbf{i} + 2\mathbf{j} - 2\mathbf{k}$$

To obtain a unit vector, divide by the magnitude.

$$\text{Magnitude} = \sqrt{(-4)^2 + 2^2 + (-2)^2} = \sqrt{24} = 2\sqrt{6}$$

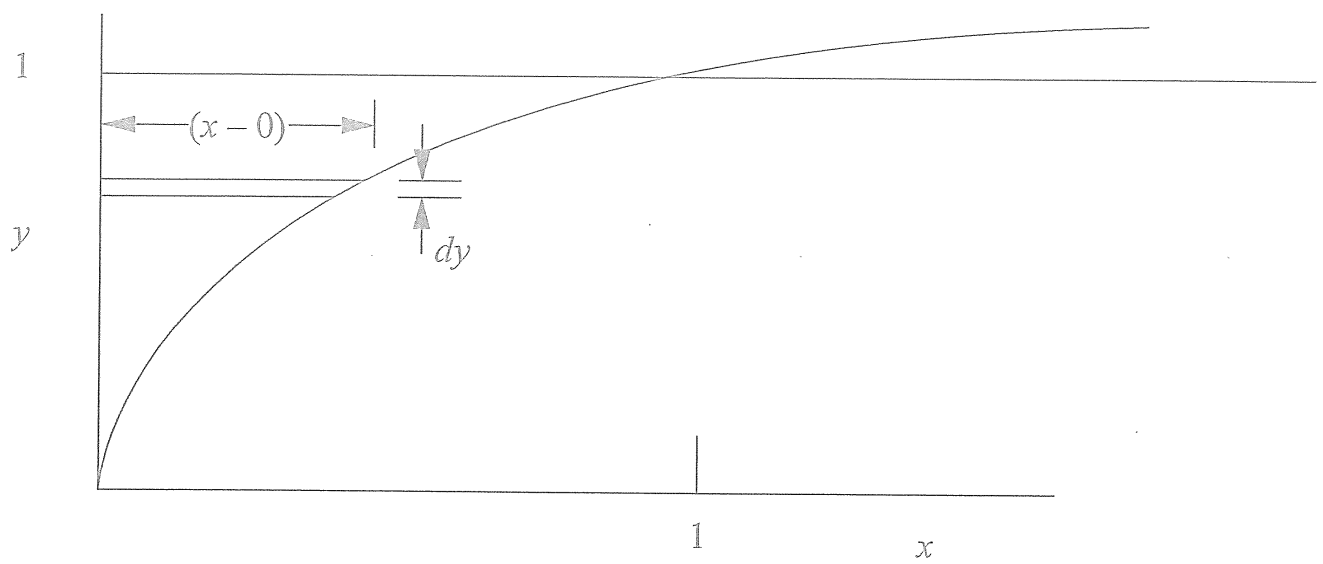
$$\frac{-4\mathbf{i} + 2\mathbf{j} - 2\mathbf{k}}{2\sqrt{6}} = \frac{-2\mathbf{i} + \mathbf{j} - \mathbf{k}}{\sqrt{6}}$$

THE CORRECT ANSWER IS: (C)

6. Refer to Differential Calculus in the Mathematics section of the *FE Supplied-Reference Handbook.*

THE CORRECT ANSWER IS: (C)

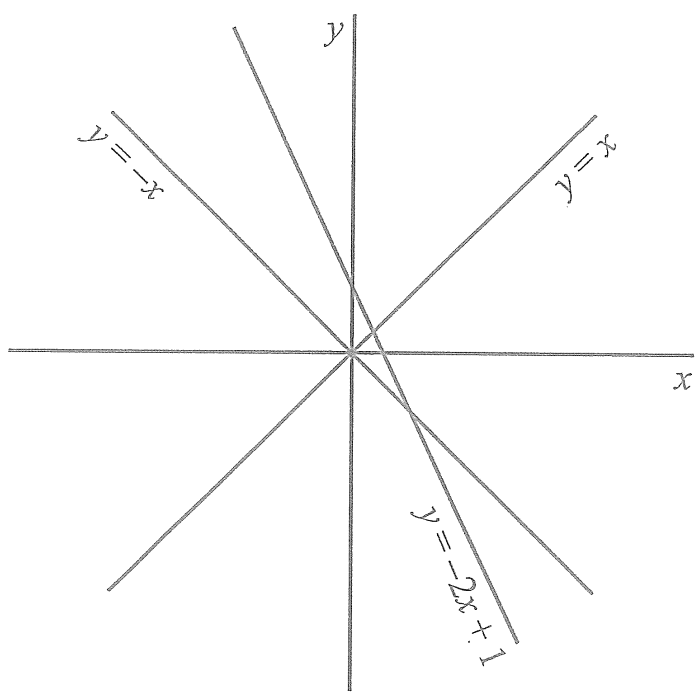
7. Define a differential strip with length $(x - 0)$ and height dy.



$$\int dA = \int_0^1 x\,dy = \int_0^1 y^{3/2}\,dy = \left.\frac{y^{5/2}}{5/2}\right|_0^1 = \frac{2}{5}$$

THE CORRECT ANSWER IS: (A)

8.



$y = -x$

$y = x$

$y = -2x + 1$

From graph one, the intersection is at (0, 0), so Options **(C)** and **(D)** are incorrect.

Also, the second intersection is at (1, –1), so the vertices are at (0, 0), $\left(\frac{1}{3}, \frac{1}{3}\right)$, (1, –1).

THE CORRECT ANSWER IS: (A)

9. $$\int_0^{\pi} 10\sin x\,dx = 10\left[-\cos x\Big|_0^{\pi}\right]$$

$$= 10\left[-\cos\pi - \left(-\cos 0\right)\right]$$

$$= 10\left[1+1\right]$$

$$= 20$$

THE CORRECT ANSWER IS: (D)

10. Accuracy increases with increasing sample size.

THE CORRECT ANSWER IS: (B)

11. The key word is **OR**. What is the probability that the number is odd **OR** greater than 80? Refer to Property 2 given under Laws of Probability in the Engineering Probability and Statistics section of the *FE Supplied-Reference Handbook*.

$P(A + B) = P(A) + P(B) - P(A,B)$

Event A is removing a ball with an odd number.

$P(A) = 50/100 = 0.5$

Event B is removing a ball with a number greater than 80.

$P(B) = 20/100 = 0.2$

Event A,B is removing a ball with an odd number that is greater than 80.

There are ten such balls.

$P(A,B) = 10/100 = 0.1$

Also $P(A,B) = P(A) \times P(B) = 0.5 \times 0.2 = 0.1$

$P(A + B) = 0.5 + 0.2 - (0.5 \times 0.2) = 0.6$

THE CORRECT ANSWER IS: (C)

12.

x	$x-\overline{x}$	$\left(x-\overline{x}\right)^2$
1	–3	9
4	0	0
7	3	9
$\sum = 12$		$\sum = 18$

$$\overline{X} = \frac{12}{3} = 4$$

$$\sigma = \sqrt{\frac{18}{3}} = \sqrt{6}$$

THE CORRECT ANSWER IS: (B)

13. $8 - 15.5 = 7.5$

$$\frac{7.5}{2.5} = 3 \text{ standard deviations}$$

From the Unit Normal Distribution table in the Engineering Probability and Statistics section of the *FE Supplied-Reference Handbook.*

For $x = 3$, $R(x) = 0.0013$

THE CORRECT ANSWER IS: (A)

14. $Pv = nRT$

$(1)(v) = (1)(0.08206)(546)$
$v = 44.8$ L

THE CORRECT ANSWER IS: (D)

15. 2 moles of As × 75 g/mole of As = 150 g of As

THE CORRECT ANSWER IS: (C)

16. $H_2SO_4 + 2\ NaOH \rightarrow Na_2SO_4 + 2\ H_2O$

0.5 M H_2SO_4 = 1.0 N H_2SO_4

1.0 M NaOH = 1.0 N NaOH

40 mL of 1.0 N H_2SO_4 = 60 mL of x N NaOH

$40 \times 1 = 60x$

$x = 40/60 = 0.67$ N = 0.67 M NaOH

THE CORRECT ANSWER IS: (B)

17. The molecular weight of NaOH is 40 g; therefore, 4 g/L of NaOH will form 1 L of 0.1 normal NaOH solution. One liter of 0.1 normal HCl solution is required to neutralize the NaOH.

THE CORRECT ANSWER IS: (C)

18. Refer to the Chemistry section of the *FE Supplied-Reference Handbook* for the equilibrium constant of a chemical reaction.

$4A + B \leftrightarrow 2C + 2D$

THE CORRECT ANSWER IS: (B)

19.

Step	VAR
1	0
2	2
3	4
4	6
EXIT LOOP	

At the conclusion of the routine, VAR = 6.

THE CORRECT ANSWER IS: (D)

20.

Row	Column A	Value of A
4	6	6
5	A4 + A4	12
6	A5 + A4	18
7	A6 + A4	24

THE CORRECT ANSWER IS: (B)

21.

Step	Variables				
	Z	N	T	K	S
1	Z	N	.	.	.
2	Z	N	1	.	1
3	Z	N	1	1	1
.	Z	N	Z	1	1
.			Z	1	1 + Z
(NEXT K)					
			$\frac{Z^2}{2}$	2	$\frac{1+Z+Z^2}{2}$
(NEXT K)					
			$\frac{Z^3}{(2)(3)}$	3	$\frac{\frac{1+Z+Z^2}{2+Z^3}}{(2)(3)}$
(NEXT K)					
			$\frac{Z^4}{(2)(3)(4)}$	4	$\frac{\frac{1+Z+Z^2}{2+Z^3}}{\frac{(2)(3)+Z^3}{(2)(3)(4)}}$

$\therefore$ The sequence is: $S = 1 + \frac{Z}{1!} + \frac{Z^2}{2!} + \frac{Z^3}{3!} + \frac{Z^4}{4!} + \ldots + \frac{Z^N}{N!}$

THE CORRECT ANSWER IS: (D)

22.

Rows	Columns				
	A	B	C	D	E
1	2	4	6	8	10
2	1	3	5	7	9
3				64	
4				519	
5					

D3: D1 + D$1 * D2 = 8 + 8(7) = 64

D4: D2 + D$1 * D3 = 7 + 8(64) = 519

THE CORRECT ANSWER IS: (C)

23. Refer to the NCEES Rules of Professional Conduct, Section A.4., in the Ethics section of the *FE Supplied-Reference Handbook.*

THE CORRECT ANSWER IS: (B)

24. Refer to the NCEES Rules of Professional Conduct, Section B.1., in the Ethics section of the *FE Supplied-Reference Handbook.*

THE CORRECT ANSWER IS: (A)

25. Refer to the NCEES Rules of Professional Conduct, Section B.3. and Section C.1., in the Ethics section of the *FE Supplied-Reference Handbook.*

THE CORRECT ANSWER IS: (A)

26. Refer to the NCEES Rules of Professional Conduct, Section B.5. and Section B.6., in the Ethics section of the *FE Supplied-Reference Handbook.*

THE CORRECT ANSWER IS: (A)

27. $1.50 (5,000) = $7,500

$0.50 (5,000) = $2,500

Annual savings = $7,500 – $2,500 = $5,000

Additional investment = $15,000 – $1,000 = $14,000

Payback = $14,000/$5,000 = 2.8 years

THE CORRECT ANSWER IS: (A)

28. Annual cost: $= \$900(A/P, 8\%, 5) + \$50 - \$300(A/F, 8\%, 5)$

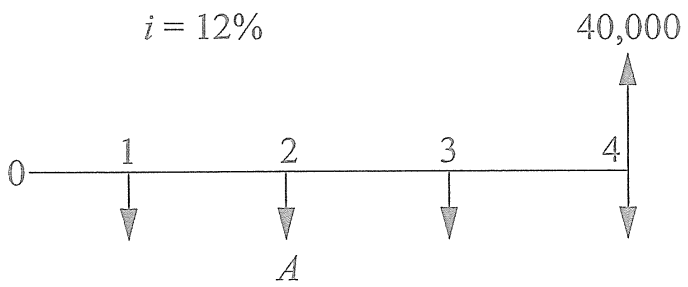
$= \$900(0.2505) + \$50 - \$300(0.1705)$

$= \$225.45 + \$50 - \$51.15$

$= \$224.30$

THE CORRECT ANSWER IS: (A)

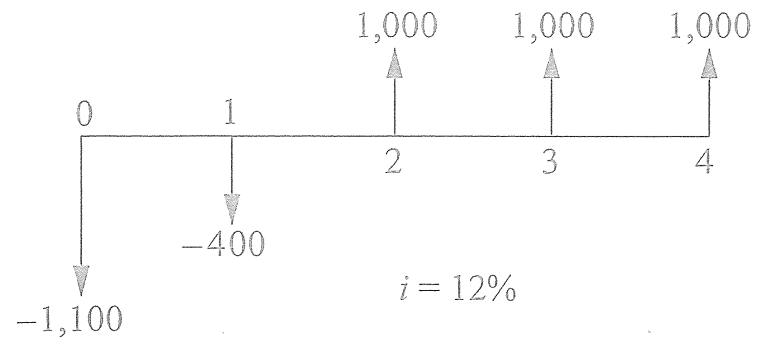
29.



$A = F\,(A/F, i, n) = 40{,}000\ (A/F, 12\%, 4) = \$8{,}369$ per year

THE CORRECT ANSWER IS: (B)

30.



$$P = -1{,}100 - 400\,(P/F, 12\%, 1) + 1{,}000\,(P/F, 12\%, 2) + 1{,}000\,(P/F, 12\%, 3) + 1{,}000\,(P/F, 12\%, 4)$$

$$= -1{,}100 - 400\,(0.8929) + 1{,}000\,(0.7972) + 1{,}000\,(0.7118) + 1{,}000\,(0.6355)$$

$$= 687.34$$

$$A = P\,(A/P, 12\%, 4) = 687.34(0.3292)$$

= $226 per year

THE CORRECT ANSWER IS: (D)

31. The easiest way to solve this problem is to look at the present worth of each alternative.

The present worth values are all given by

$$P = \text{First Cost} + \text{Annual Cost} \times (P/A, 12\%, 8) - \text{Salvage Value} \times (P/F, 12\%, 8)$$
$$= \text{First Cost} + \text{Annual Cost} \times 4.9676 - \text{Salvage Value} \times 0.4039$$

Then $P(\text{A}) = \$63{,}731$
$P(\text{B}) = \$63{,}392$
$P(\text{C}) = \$63{,}901$
$P(\text{D}) = \$63{,}222$

The cash flows are all costs, so the most preferable two projects, those with the lowest present worth costs, are B and D, and the difference between them is $170.

THE CORRECT ANSWER IS: (B)

32. Normal to the plane:

$$\Sigma F_n = 0: N - mg\cos\phi = 0 \rightarrow N = mg\cos\phi$$

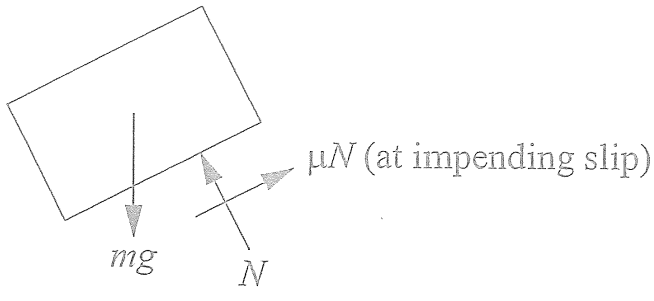
Tangent to the plane:

$$\Sigma F_t = 0: -mg\sin\phi + \mu N = 0$$

$$\therefore -mg\sin\phi + \mu mg\cos\phi = 0$$

$$\frac{\sin\phi}{\cos\phi} = \tan\phi = \mu$$

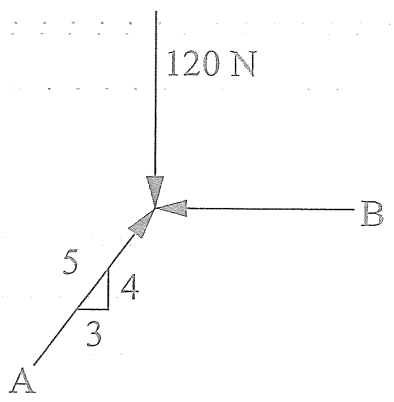
$$\tan\phi = 0.25$$



THE CORRECT ANSWER IS: (D)

33. $\Sigma F_y = 0 = -120 + \frac{4}{5}A$

$A = 150$ N



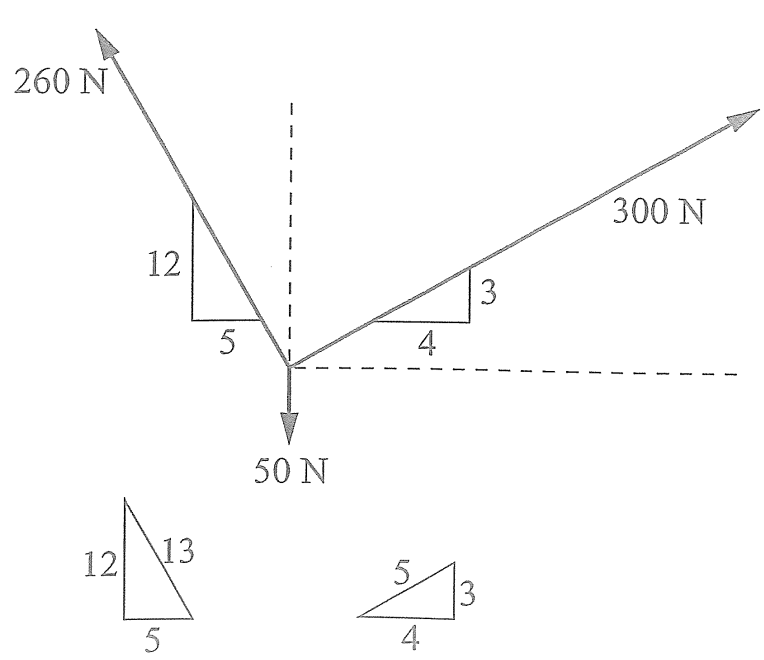
THE CORRECT ANSWER IS: (C)

34. $R_y = \Sigma F_y = \frac{12}{13}(260) + \frac{3}{5}(300) - 50 = 370$

$R_x = \Sigma F_x = -\frac{5}{13}(260) + \frac{4}{5}(300) = 140$

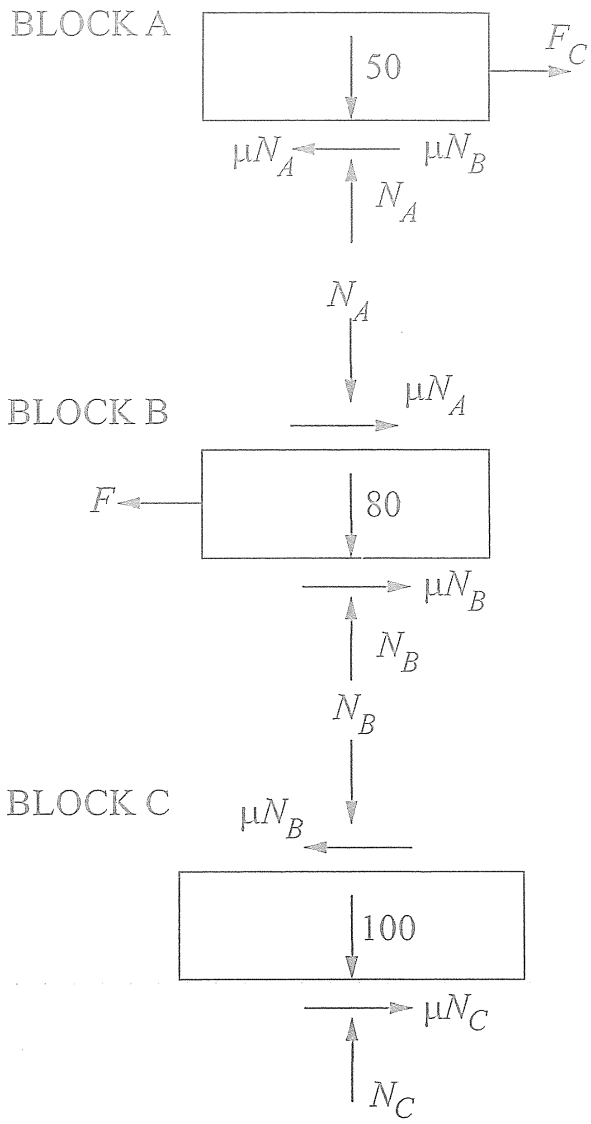
$R = \sqrt{R_x^2 + R_y^2} = \sqrt{370^2 + 140^2}$

$R = 396$ N



THE CORRECT ANSWER IS: (D)

35.

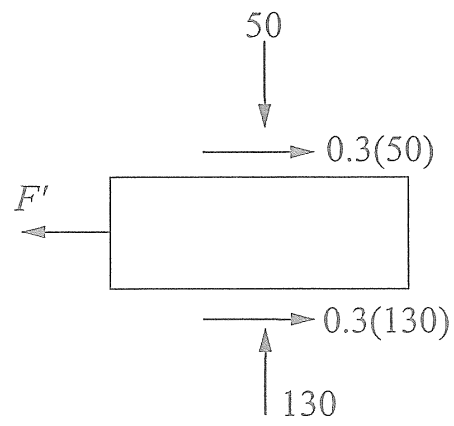


$$\Sigma F_y = 0 = -50 + N_A$$
$$N_A = 50\ N$$

$$\Sigma F_y = 0 = -50 - 80 + N_B$$
$$N_B = 130\ \text{N}$$

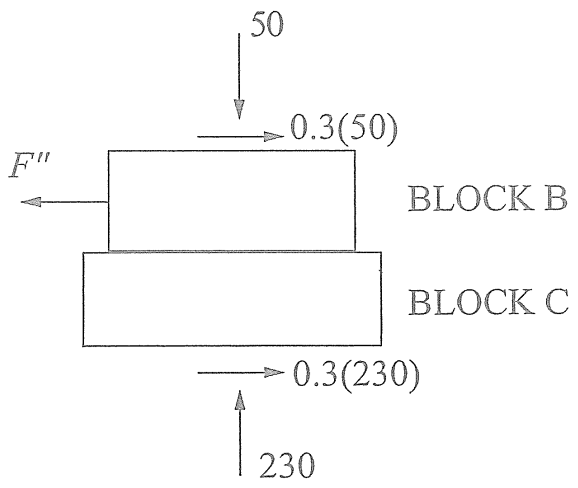
$$\Sigma F_y = 0 = -130 - 100 + N_C$$
$$N_C = 230\ \text{N}$$

Assume Blocks A and C remain stationary.



$$\Sigma F_x = 0 = -F' + 0.3(50) + 0.3(130)$$
$$F' = 54\ \text{N}$$

Assume Blocks B and C move.



$$\Sigma F_x = 0 = -F'' + 0.3(50) + 0.3(230)$$
$$F'' = 84\ \text{N}$$

$\therefore$ F = 54 N where A and C remain stationary.

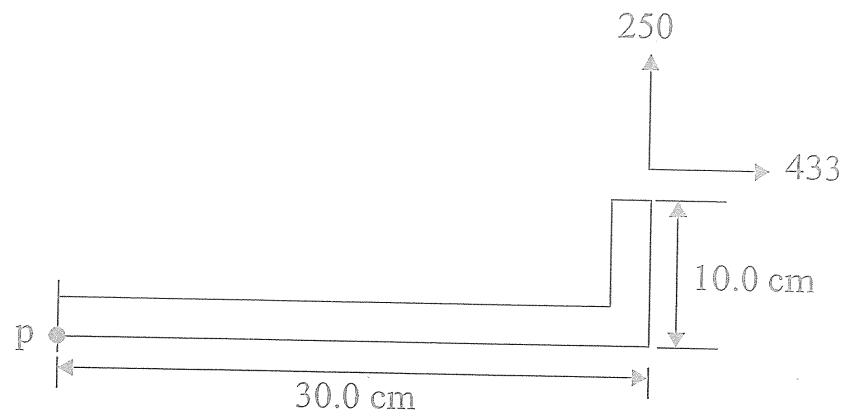
THE CORRECT ANSWER IS: (B)

36. $F_H = 500 \cos 30° = 433$

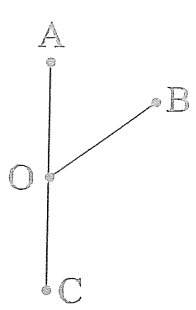
$F_V = 500 \sin 30° = 250$

$M_P = 250(0.30) - 433(0.10) = 31.7$ N·m ccw

THE CORRECT ANSWER IS: (A)



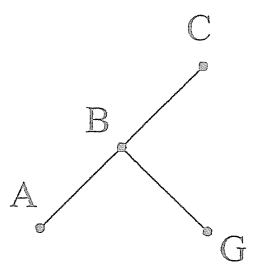
37. Zero-force members usually occur at joints where members are aligned as follows:



That is, joints where two members are along the same line (OA and OC) and the third member is at some arbitrary angle. That member (OB) is a zero-force member because the forces in OA and OC must be equal and opposite.

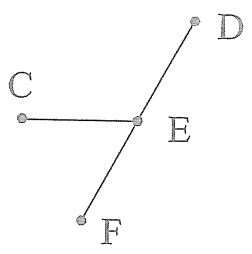
For this specific problem, we immediately examine Joints B and E:

B:



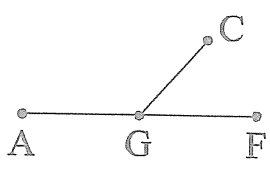
BG is a zero-force member

E:



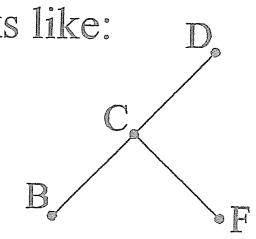
CE is a zero-force member

Now, examine Joint G. Since BG is zero-force member, the joint effectively looks like:



and, therefore, CG is another zero-force member.

Finally, examine Joint C. Since both CG and CE are zero force members, the joint effectively looks like:



and, therefore, CF is another zero-force member. Thus, BG, CE, CG, CF are the zero-force members.

THE CORRECT ANSWER IS: (A)

38. By definition of a cantilever beam, it is not statically indeterminate, it is completely supported, and it is loaded only at a specific point.

THE CORRECT ANSWER IS: (A)

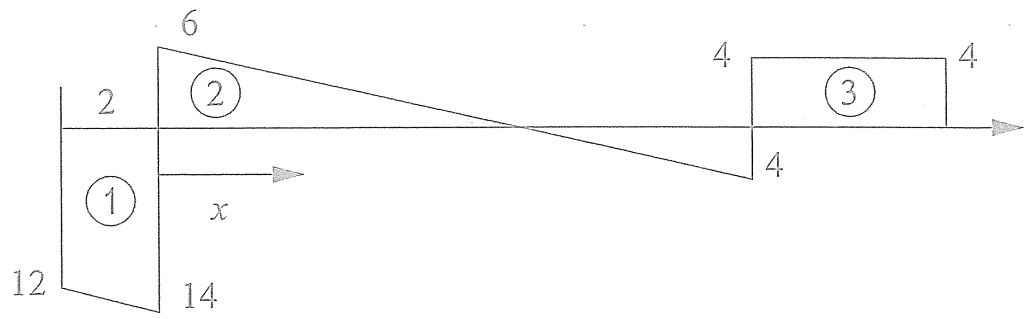
39. $$\frac{10\text{ m}}{10\text{ kN}} = \frac{x}{6\text{ kN}}$$

$x = 6$ m

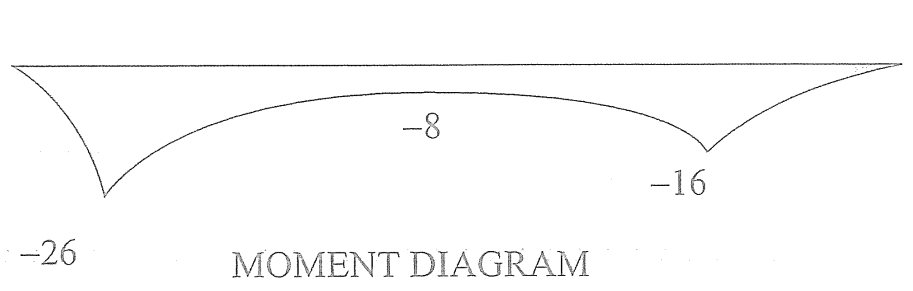
Area 1 $= 13(2) = 26$ kN·m

Area 2 $= \frac{6(6)}{2} = 18$ kN·m

Area 3 $= 4(4) = 16$ kN·m



SHEAR DIAGRAM



MOMENT DIAGRAM

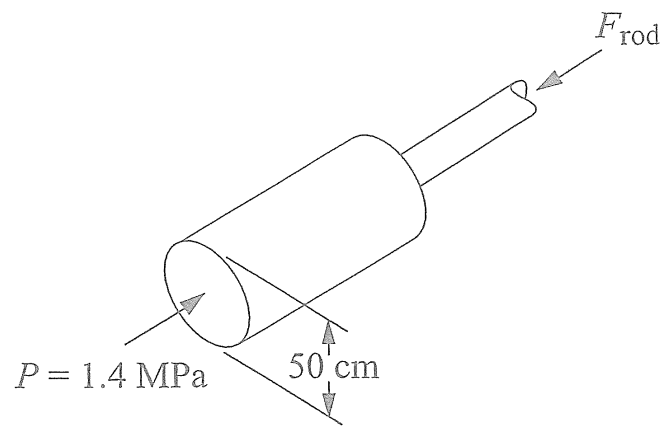
Maximum magnitude of the bending moment is 26 kN·m.

THE CORRECT ANSWER IS: (D)

40. $$\Sigma F = PA = \left(1.4 \times 10^6\right)\left(\frac{\pi(0.5)^2}{4}\right) = F_{\text{rod}}$$

$F_{\text{rod}} = 275\text{ kN} = \sigma A = 68 \times 10^6 A$

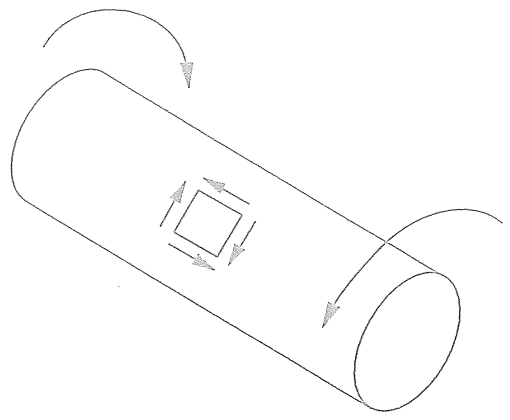
$A = 40.4 \times 10^{-4}\text{ m}^2$



THE CORRECT ANSWER IS: (A)

41.

$$\tau = \frac{Tr}{J} = \frac{T\frac{d}{2}}{\frac{\pi d^4}{32}} = \frac{16T}{\pi d^3}$$



$$T = \frac{\pi d^3 \tau}{16} = \frac{\pi(0.2)^3(840 \times 10^3)}{16}$$

$$T = 1{,}319\,\text{N}\cdot\text{m}$$

THE CORRECT ANSWER IS: (C)

42. The Euler formula is used for elastic stability of relatively long columns, subjected to concentric axial loads in compression.

THE CORRECT ANSWER IS: (D)

43. The question statement is the definition of hot working.

THE CORRECT ANSWER IS: (A)

44. By definition, a metal with high hardness has a high tensile strength and a high yield strength.

THE CORRECT ANSWER IS: (D)

45. By definition, amorphous materials do not have a crystal structure.

THE CORRECT ANSWER IS: (D)

46. Aluminum is anodic relative to copper and, therefore, will corrode to protect the copper.

THE CORRECT ANSWER IS: (B)

47. The mean pressure of the fluid acting on the gate is evaluated at the mean height, and the center of pressure is 2/3 of the height from the top; thus, the total force of the fluid is:

$$F_f = \rho g \frac{H}{2}(H) = 1,600(9.807)\frac{3}{2}(3) = 70,610 \text{ N}$$

and its point of application is 1.00 m above the hinge. A moment balance about the hinge gives:

$$F(3) - F_f(1) = 0$$

$$F = \frac{F_f}{3} = \frac{70,610}{3} = 23,537 \text{ N}$$

THE CORRECT ANSWER IS: (C)

48. Refer to the Fluid Mechanics section of the *FE Supplied-Reference Handbook.*

$$\tau_t = \mu\left(\frac{dv}{dy}\right)$$

where τ_t = shear stress and

$\frac{dv}{dy}$ = rate of shear deformation

Hence, μ is the ratio of shear stress to the rate of shear deformation.

THE CORRECT ANSWER IS: (C)

49. $Q = A_1 V_1 = (0.01 \text{ m}^2)(30 \text{ m/s})$

$= 0.3 \text{ m}^3/\text{s}$

Since the water jet is deflected perpendicularly, the force F must deflect the total horizontal momentum of the water.

$F = \rho QV = (1{,}000 \text{ kg/m}^3)\ (0.3 \text{ m}^3/\text{s})\ (30 \text{ m/s}) = 9{,}000 \text{ N} = 9.0 \text{ kN}$

THE CORRECT ANSWER IS: (B)

50. Flow through an insulated valve closely follows a throttling process. A throttling process is at constant enthalpy.

THE CORRECT ANSWER IS: (B)

51. $\dfrac{\rho v^2}{2} = gh(\rho - \rho_{air})$

$$\therefore h = \frac{\rho v^2}{2g(\rho - \rho_{air})} \approx \frac{v^2}{2g} \approx \frac{(2)^2}{(2)(9.8)} \approx 0.204 \text{ m}$$

THE CORRECT ANSWER IS: (D)

52. S = apparent power

P = real power

Q = reactive power

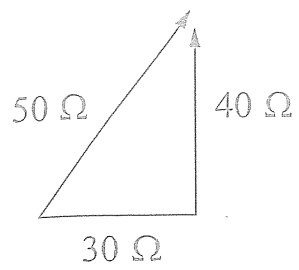
$S = P + jQ = |S| \cos\theta + j\,|S| \sin\theta$

$\cos\theta = \text{pf} = 0.866$

$Q = (1{,}500 \text{ VA}) \sin[\cos^{-1} 0.866] = 750 \text{ VAR}$

THE CORRECT ANSWER IS: (B)

53. $Z = 30 + j90 - j50 = 30 + j40\ \Omega$



THE CORRECT ANSWER IS: (D)

54. Initially, $V_C(t) = 150$ V

$$W_C(t) = \frac{1}{2}CV_C^2 = \frac{1}{2}(10 \times 10^{-6}\text{F})(150\text{ V})^2$$

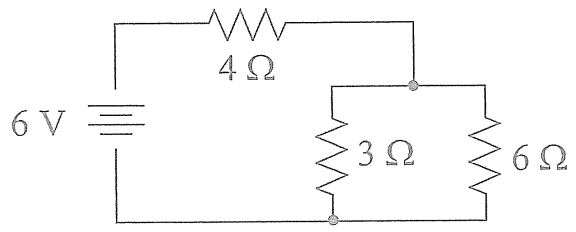
$W_C = 0.113$ J initial stored energy.

After ten time constants, all energy will be dissipated.

THE CORRECT ANSWER IS: (B)

55. $R_T = 4\,\Omega + 3\,\Omega \,||\, 6\,\Omega = 4\,\Omega + 2\,\Omega$

$$R_T = 6\,\Omega \Rightarrow I_T = \frac{6\text{ V}}{6\,\Omega} = 1\text{ A}$$



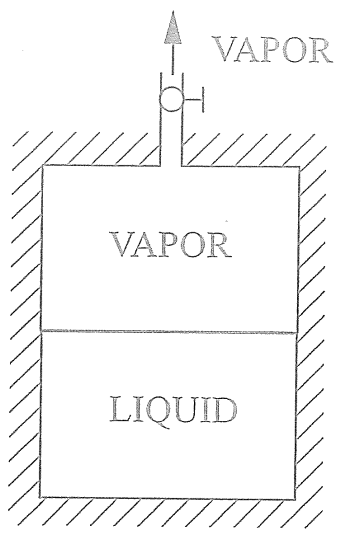
$$I_x = \frac{3}{9}(I_T) = \frac{1}{3}\text{A}$$

THE CORRECT ANSWER IS: (A)

56. $$\frac{(1-i)^2}{(1+i)^2} = \frac{1-2i+i^2}{1+2i+i^2} = \frac{1-1-2i}{1-1+2i} = \frac{-i}{i} = -1$$

THE CORRECT ANSWER IS: (A)

57. As vapor escapes, the mass within the tank is reduced. With constant volume, the specific volume within the tank must increase. This can happen only if liquid evaporates.



THE CORRECT ANSWER IS: (A)

58. By definition, an adiabatic process is a process in which no heat is transferred.

THE CORRECT ANSWER IS: (D)

59. An isentropic process is one for which the entropy remains constant. Entropy is defined by the equation:

$$ds = \left(\frac{\delta Q}{T}\right)_{\text{reversible}}$$

The entropy will be constant if $\delta Q = 0$ and the process is reversible. It is theoretically possible for a nonadiabatic, irreversible process to have a constant entropy, but this is not one of the responses. Option (D) describes a state, not a process.

THE CORRECT ANSWER IS: (C)

60. $$R = \frac{\bar{R}}{(\text{MW})} = \frac{8.314}{44} = 0.1890 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$$

THE CORRECT ANSWER IS: (A)

EXAM SPECIFICATIONS
FOR THE AFTERNOON SESSION

AFTERNOON SESSION IN MECHANICAL ENGINEERING
(60 questions in 8 topic areas)

	Topic Area	Approximate Percentage of Test Content
I.	**Mechanical Design and Analysis** A. Stress analysis (e.g., combined stresses, torsion, normal, shear) B. Failure theories (e.g., static, dynamic, buckling) C. Failure analysis (e.g., creep, fatigue, fracture, buckling) D. Deformation and stiffness E. Components (e.g., springs, pressure vessels, beams, piping, bearings, columns, power screws) F. Power transmission (e.g., belts, chains, clutches, gears, shafts, brakes, axles) G. Joining (e.g., threaded fasteners, rivets, welds, adhesives) H. Manufacturability (e.g., fits, tolerances, process capability) I. Quality and reliability J. Mechanical systems (e.g., hydraulic, pneumatic, electro-hybrid)	15%
II.	**Kinematics, Dynamics, and Vibrations** A. Kinematics of mechanisms B. Dynamics of mechanisms C. Rigid body dynamics D. Natural frequency and resonance E. Balancing of rotating and reciprocating equipment F. Forced vibrations (e.g., isolation, force transmission, support motion)	15%
III.	**Materials and Processing** A. Mechanical and thermal properties (e.g., stress/strain relationships, ductility, endurance, conductivity, thermal expansion) B. Manufacturing processes (e.g., forming, machining, bending, casting, joining, heat treating) C. Thermal processing (e.g., phase transformations, equilibria) D. Materials selection (e.g., metals, composites, ceramics, plastics, bio-materials) E. Surface conditions (e.g., corrosion, degradation, coatings, finishes) F. Testing (e.g., tensile, compression, hardness)	10%
IV.	**Measurements, Instrumentation, and Controls** A. Mathematical fundamentals (e.g., Laplace transforms, differential equations) B. System descriptions (e.g., block diagrams, ladder logic, transfer functions) C. Sensors and signal conditioning (e.g., strain, pressure, flow, force, velocity, displacement, temperature) D. Data collection and processing (e.g., sampling theory, uncertainty, digital/analog, data transmission rates) E. Dynamic responses (e.g., overshoot/time constant, poles and zeros, stability)	10%

Topic Area	Approximate Percentage of Test Content
V. Thermodynamics and Energy Conversion Processes A. Ideal and real gases B. Reversibility/irreversibility C. Thermodynamic equilibrium D. Psychrometrics E. Performance of components F. Cycles and processes (e.g., Otto, Diesel, Brayton, Rankine) G. Combustion and combustion products H. Energy storage I. Cogeneration and regeneration/reheat	15%
VI. Fluid Mechanics and Fluid Machinery A. Fluid statics B. Incompressible flow C. Fluid transport systems (e.g., pipes, ducts, series/parallel operations) D. Fluid machines: incompressible (e.g., turbines, pumps, hydraulic motors) E. Compressible flow F. Fluid machines: compressible (e.g., turbines, compressors, fans) G. Operating characteristics (e.g., fan laws, performance curves, efficiencies, work/power equations) H. Lift/drag I. Impulse/momentum	15%
VII. Heat Transfer A. Conduction B. Convection C. Radiation D. Composite walls and insulation E. Transient and periodic processes F. Heat exchangers G. Boiling and condensation heat transfer	10%
VIII. Refrigeration and HVAC A. Cycles B. Heating and cooling loads (e.g., degree day data, sensible heat, latent heat) C. Psychrometric charts D. Coefficient of performance E. Components (e.g., compressors, condensers, evaporators, expansion valve)	10%

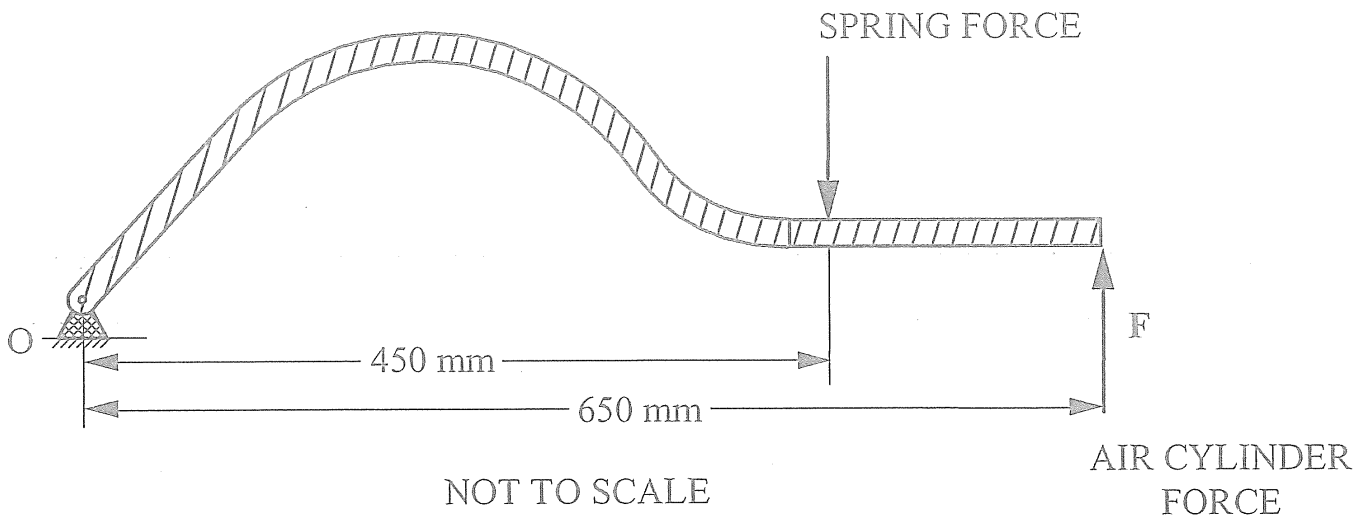
MECHANICAL
AFTERNOON SAMPLE QUESTIONS

THE AFTERNOON SAMPLE EXAMINATION CONTAINS 30 QUESTIONS,
HALF THE NUMBER ON THE ACTUAL EXAMINATION.

1. A helical compression spring has a spring constant of 38.525 N/mm and a free length of 190 mm. The force (N) required to compress the spring to a length of 125 mm is most nearly:

(A) 1,500
(B) 2,500
(C) 4,800
(D) 6,500

Questions 2–3: A pivoted lever arm is in equilibrium under the force of a compression spring and an air cylinder as shown below.



2. The air cylinder has a piston diameter of 100 mm, and the compression spring exerts a force 3,333 N. The pressure (kPa) in the air cylinder required to hold the lever arm in equilibrium is most nearly:

(A) 150
(B) 270
(C) 294
(D) 305

3. If the piston diameter is reduced to 90 mm, the required release pressure will change by a factor of most nearly:

(A) 0.76
(B) 0.87
(C) 1.14
(D) 1.23

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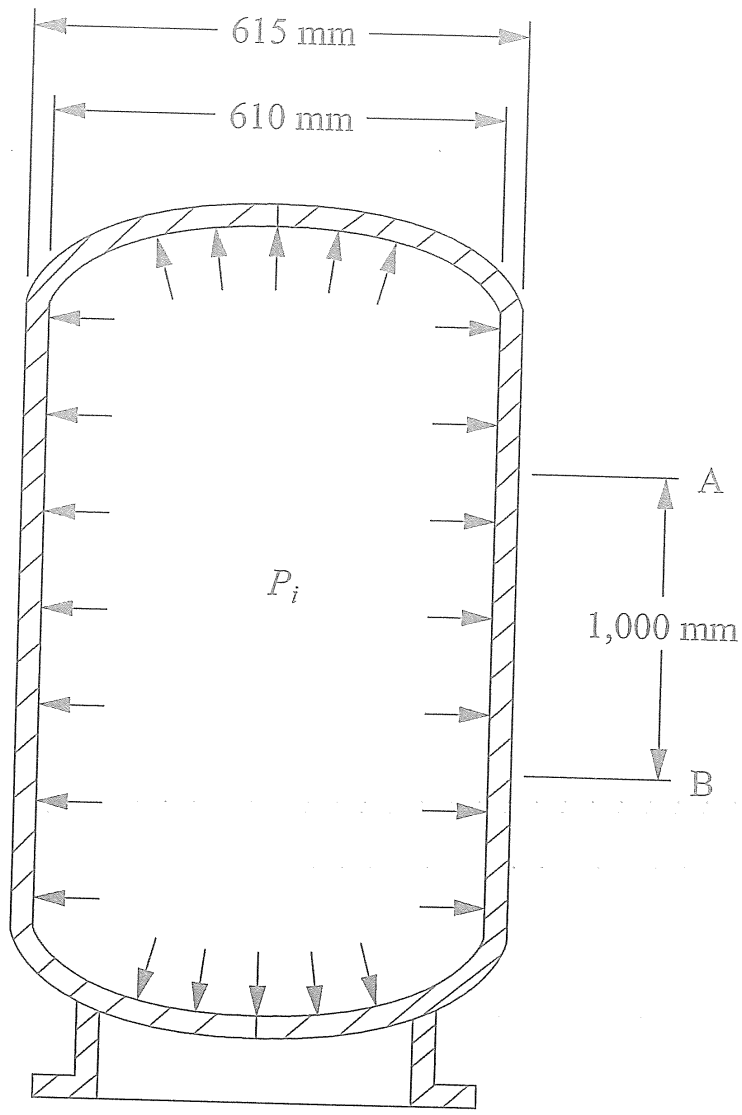
Questions 4–5: The figure below shows a pressure vessel with an internal pressure P_i. Material properties are given with the figure.

MATERIAL PROPERTIES:

$E = 210 \times 10^3$ MPa
$\nu = 0.24$
$\alpha = 10.5 \times 10^{-6}$/°C
$S_y = 400$ MPa



VERTICAL-AXIS PRESSURE VESSEL SECTION

GO ON TO THE NEXT PAGE

4. If the internal pressure in the vertical axis of the cylindrical pressure vessel shown is 600 kPa, the hoop or tangential stress (MPa) in the vessel wall between cross sections A and B is most nearly:

(A) 18.4
(B) 36.8
(C) 73.5
(D) 147

5. Assume the internal pressure is changed in the pressure vessel so that it produces the following stresses in the wall between cross sections A and B:

$\sigma_t = 46.2$ MPa
$\sigma_l = 23.1$ MPa
$\sigma_r = 0$

The increase in length (mm) of the distance between cross sections A and B is most nearly:

(A) 0.06
(B) 0.11
(C) 0.19
(D) 0.22

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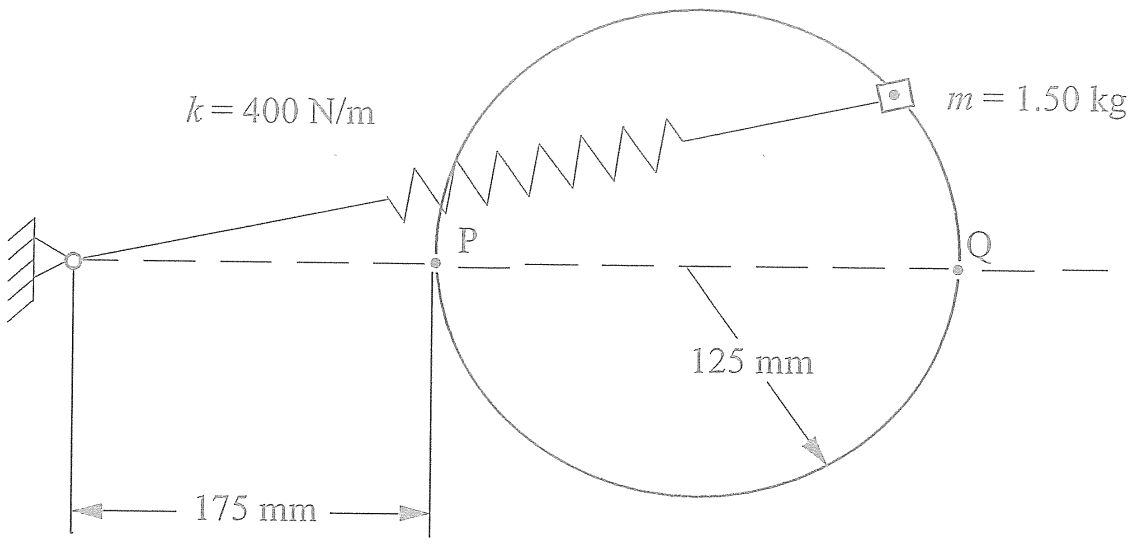
Questions 6–7: An object with a mass m of 1.50 kg moves without friction in a circular path as shown below. Attached to the object is a spring with a spring constant k of 400 N/m. The spring is undeformed when the object is at Point P, and the speed of the object at Point Q is 2.00 m/s.



NOT TO SCALE

6. The translational kinetic energy (J) of the object at Point Q is most nearly:

(A) 1.50
(B) 3.00
(C) 6.00
(D) 29.40

7. The horizontal force (N) of the spring on the object at Point Q is most nearly:

(A) 100
(B) 175
(C) 250
(D) 400

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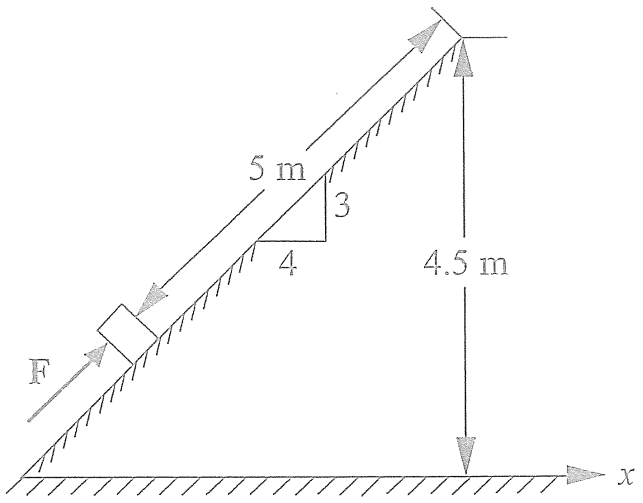
Questions 8–9: The 2-kg block shown in the figure below is accelerated from rest by force F along the smooth incline for 5 m until it clears the top of the ramp at a speed of 8 m/s.



8. The value of F (N) is most nearly:

(A) 11.8
(B) 19.6
(C) 24.6
(D) 69.4

9. The highest elevation h (m) above the x-axis the block will reach is most nearly:

(A) 1.2
(B) 3.3
(C) 5.7
(D) 7.8

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Questions 10–11: Refer to the following chart.

Constants for Diffusivity			
Solute	**Solvent**	D_o **(m²/s)**	Q **(cal/mol)**
Carbon	fcc Iron	0.2×10^{-4}	34,000
Carbon	bcc Iron	2.2×10^{-4}	29,300
Nickel	fcc Iron	0.77×10^{-4}	67,000
Copper	Aluminum	0.15×10^{-4}	30,200
Copper	Copper	0.2×10^{-4}	47,100
Carbon	hcp Titanium	5.1×10^{-4}	43,500

10. The diffusivity (m^2/s) of carbon in iron at 1,000°C is most nearly:

(A) 7.41×10^{-13}
(B) 2.91×10^{-11}
(C) 8.69×10^{-11}
(D) 2.05×10^{-9}

11. The temperature at which carbon has the same diffusivity in fcc iron as it has in hcp titanium is most nearly:

(A) 1,200°C
(B) 1,500°C
(C) 8,200°C
(D) 8,500°C

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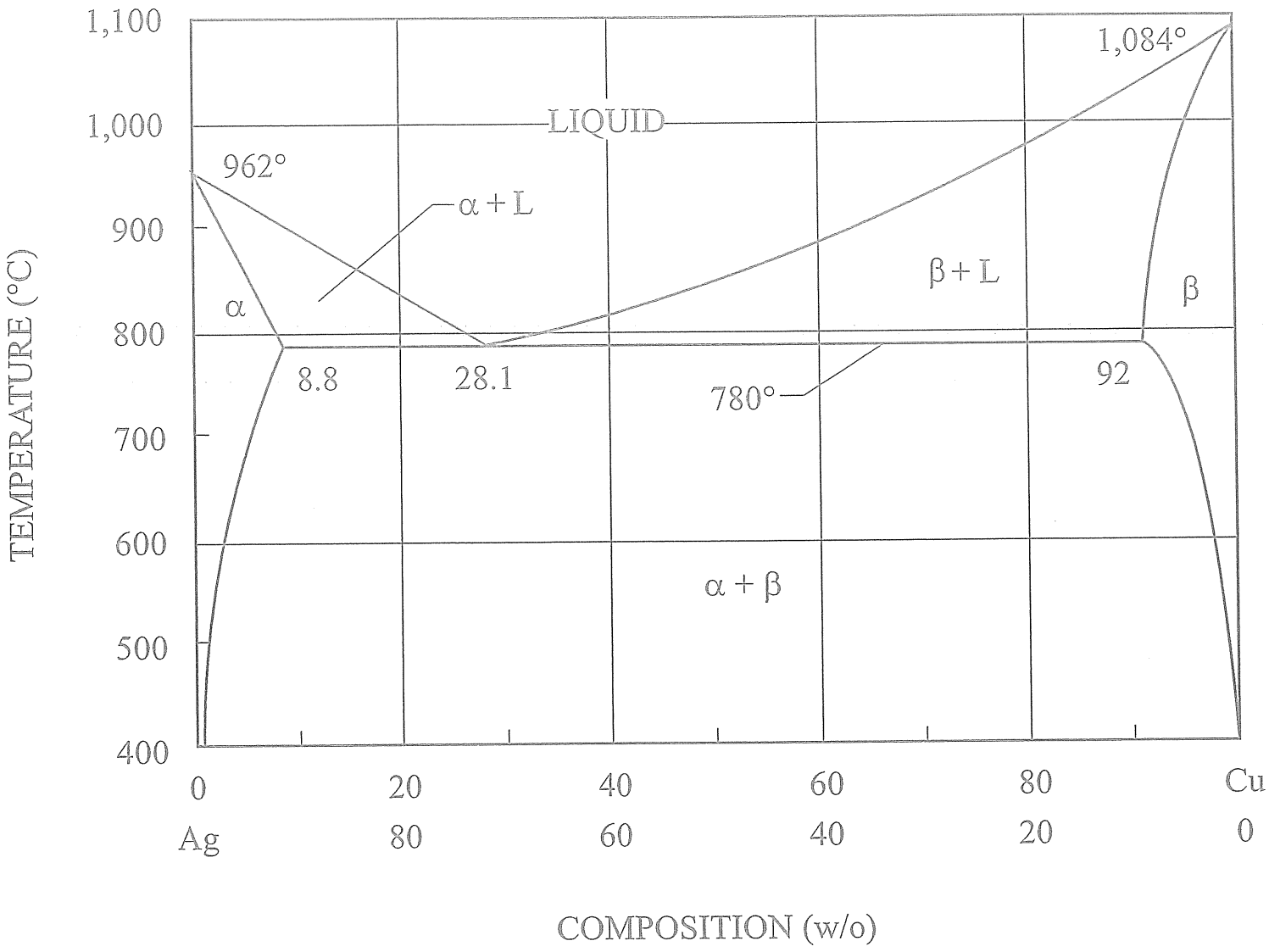
12. An alloy that is 70% copper by weight is fully melted and allowed to cool slowly. What phases are present at 850°C?

(A) Liquid only

(B) $\beta + L$

(C) $\alpha + L$

(D) $\alpha + \beta$



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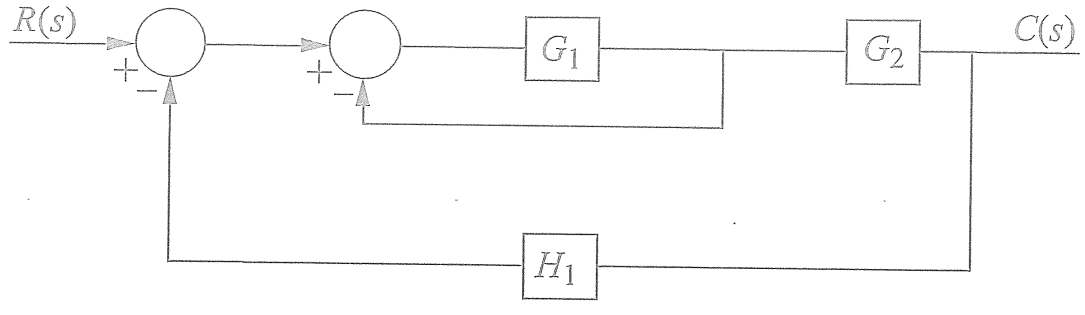
13. An automatic controls block diagram is shown below:



The single element relating the input to the output is best represented by:

(A)

(B)

(C)

(D)

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Questions 14–15: A resistance temperature detector (RTD) provides a resistance output that is related to temperature by:

$$R = R_o\,[1 + \alpha(T - T_o)],$$

where:

R = Resistance, Ω
R_o = Reference resistance, Ω
α = Coefficient, $°C^{-1}$
T = Temperature, °C
T_o = Reference temperature, °C

Consider an RTD with $R_o = 100\ \Omega$, $\alpha = 0.004\ °C^{-1}$, and $T_o = 0°C$.

14. The change in resistance (Ω) of the RTD for a 10°C change in temperature is most nearly:

(A) 0.04
(B) 0.4
(C) 4.0
(D) 100.4

15. The RTD resistance (Ω) at a temperature of 250°C would be most nearly:

(A) 1
(B) 2
(C) 100
(D) 200

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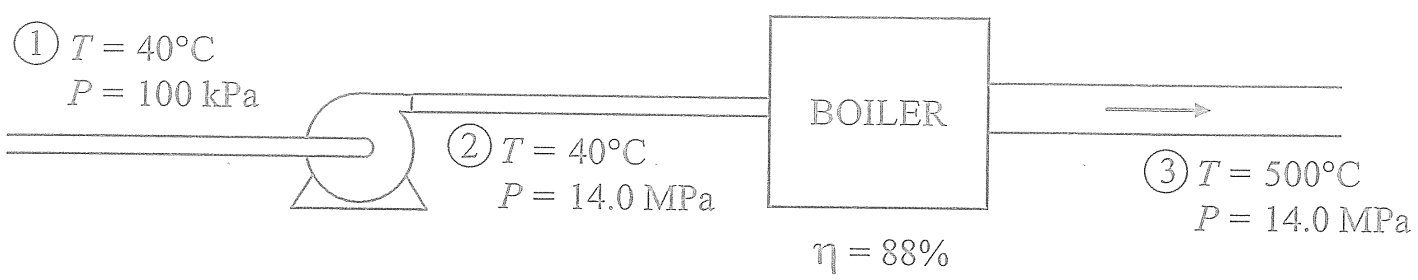
Questions 16–18: The pump shown in the figure is used to pump 50,000 kg of water per hour into a boiler. Pump suction conditions are 40°C and 100 kPa. Pump discharge conditions are 40°C and 14.0 MPa. Boiler outlet conditions are 500°C and 14.0 MPa. The boiler efficiency is 88%.



P (MPa)	*T* (°C)	Condition	*h* (kJ/kg)
14.0	40	Compressed liquid	167.6
14.0	336.75	Saturated liquid	1,571.1
14.0	336.75	Saturated vapor	2,637.6
14.0	500	Superheated vapor	3,322

16. If the pump efficiency is 80%, the pump power requirement (kW) is most nearly:

(A) 150
(B) 190
(C) 240
(D) 300

17. The total heat transfer (MW) to the working fluid that occurs in the boiler is most nearly:

(A) 10
(B) 15
(C) 29
(D) 44

18. If the coal used to fire the boiler has a heating value of 28,000 kJ/kg, the rate at which coal is burned in the boiler (kg/s) is most nearly:

(A) 1.39
(B) 1.58
(C) 1.78
(D) 2.03

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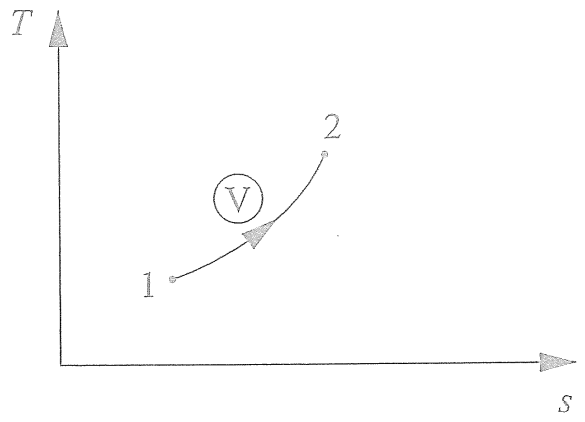
Questions 19–20: Air is to be considered as an ideal gas with the following properties:

$C_p = 1.0$ kJ/(kg·K)
$C_v = 0.718$ kJ/(kg·K)
$k = 1.4$
$R = 0.287$ kJ/(kg·K)



One kilogram of air at 172 kPa and 100°C is heated reversibly at constant volume until the pressure is 344 kPa.

19. The specific volume of the air (kJ/kg) at State 1 is most nearly:

(A) 0.17
(B) 0.62
(C) 0.93
(D) 1.28

20. The change in entropy [kJ/(kg·K)] between States 1 and 2 ($s_2 - s_1$) is most nearly:

(A) –0.498
(B) 0
(C) 0.498
(D) 0.693

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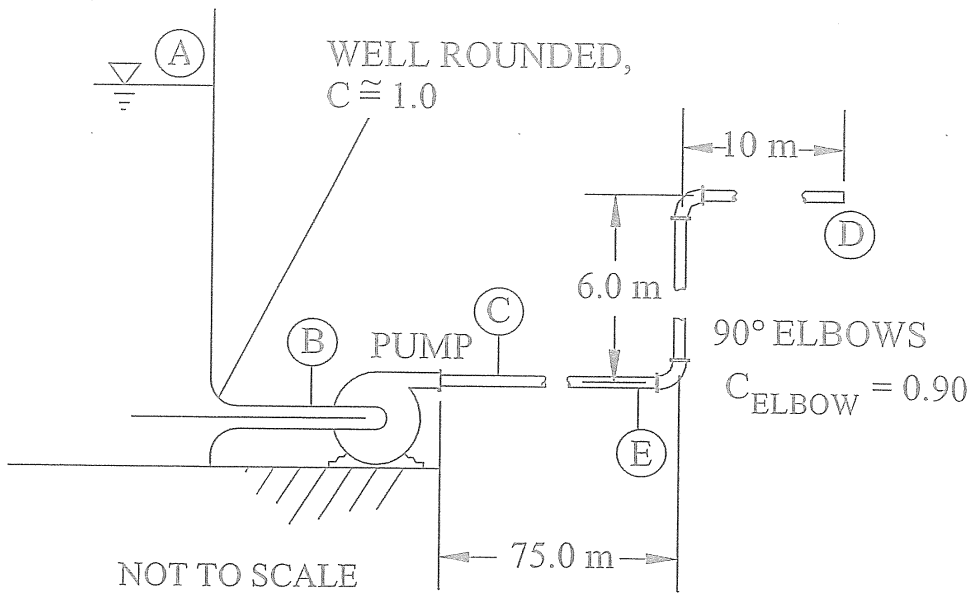
Questions 21–23: In the figure below, the pipe is steel with an internal diameter of 100 mm. Water is pumped through the system; its velocity at Point C is 2.5 m/s. The pressure at Point A is atmospheric, the gage pressure at Point B is 125 kPa, and the gage pressure at Point C is 175 kPa. The discharge at Point D is to the atmosphere.

Viscosity, μ	1.0×10^{-3} N·s/m^2
Kinematic viscosity, ν	1.0×10^{-6} m^2/s
Density, ρ	1,000 kg/m^3



21. The pumping rate (m^3/min) is most nearly:

(A) 1.02
(B) 1.18
(C) 1.50
(D) 4.71

22. The pressure drop (Pa) across each elbow is most nearly:

(A) 1,100
(B) 2,800
(C) 3,100
(D) 5,600

23. Ideally, the work that must be supplied to the pump (J/kg) is most nearly:

(A) 50
(B) 125
(C) 175
(D) 50,000

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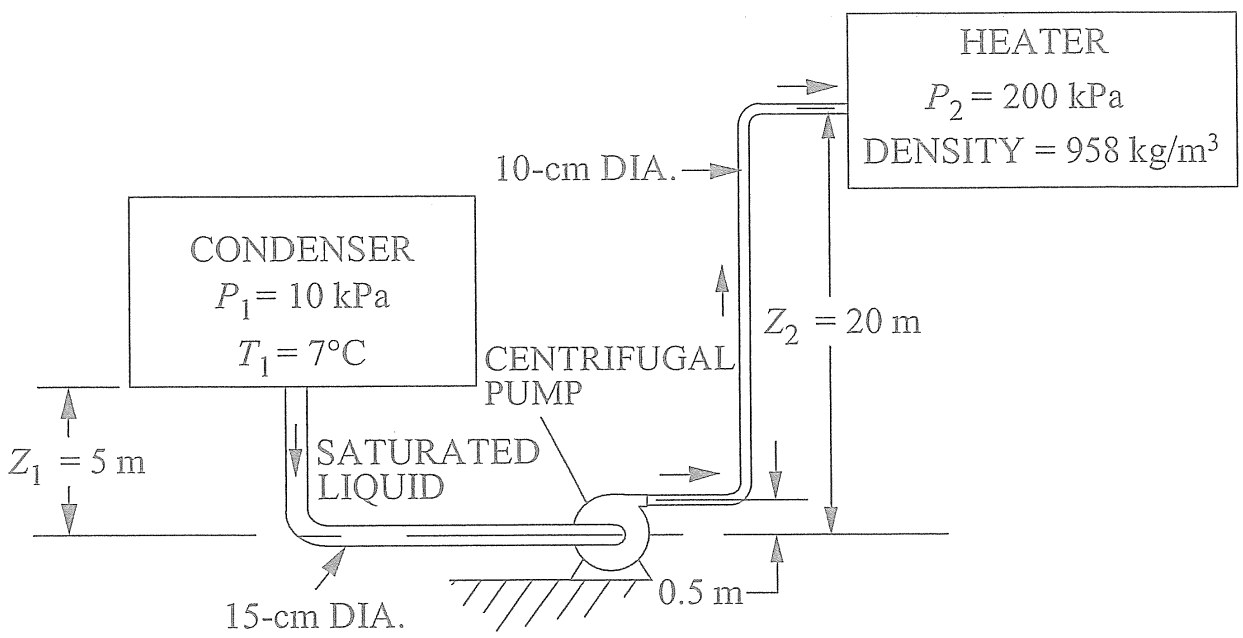
24. The centrifugal pump shown in the figure is to deliver 40 kg/s of water from a condenser maintained at 10 kPa to a deaerating heater maintained at 200 kPa.

Preliminary design data are as follows:

Elevation head on suction, referred to pump centerline	5.0 m
Friction head loss in suction line	0.60 m
Diameter of suction line	15 cm
Diameter of pump discharge line	10 cm
Elevation head on discharge into heater, referred to pump centerline	20 m
Friction head loss in discharge line, including valves	25 m
Elevation head at pump discharge, referred to pump centerline	0.5 m

The total head (m) at the discharge of the pump is most nearly:

(A) 1.3
(B) 21
(C) 46
(D) 66



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Questions 25–27 relate to a heat exchanger that was designed to heat liquid water from 150°C to 190°C inside tubes using steam condensing at 230°C on the outer surface of the tubes. The following data apply:

Data for compressed liquid water at 170°C:	
Specific heat	4.372 J/(kg•K)
Density	898 kg/m^3
Dynamic viscosity	1.59×10^{-4} N•s/m^2
Thermal conductivity	0.681 W/(m•K)
Prandtl number	1.02
Tube material, copper	k = 380 W/(m•K)
Tube I.D.	2.5 cm
Tube O.D.	3.8 cm
h_i	6,000 W/(m^2•K)
h_o	12,000 W/(m^2•K)
Outside fouling resistance	9×10^{-5} m^2•K/W
Inside fouling resistance	7×10^{-4} m^2•K/W

25. For a constant flow rate, the effect of fouling of the heat transfer surfaces is to:

(A) increase the temperature rise of the water

(B) decrease the temperature rise of the water

(C) increase heat exchanger effectiveness

(D) make no change in heat exchanger effectiveness

26. The Reynolds number for the water flowing at 1.5 m/s inside 3-m-long tubes with an I.D. of 2.5 cm is most nearly:

(A) 53,000
(B) 106,000
(C) 212,000
(D) 424,000

27. The overall coefficient of heat transfer [W/(m^2•K)] based upon inside surface area is most nearly:

(A) 1,000
(B) 1,100
(C) 4,250
(D) 4,500

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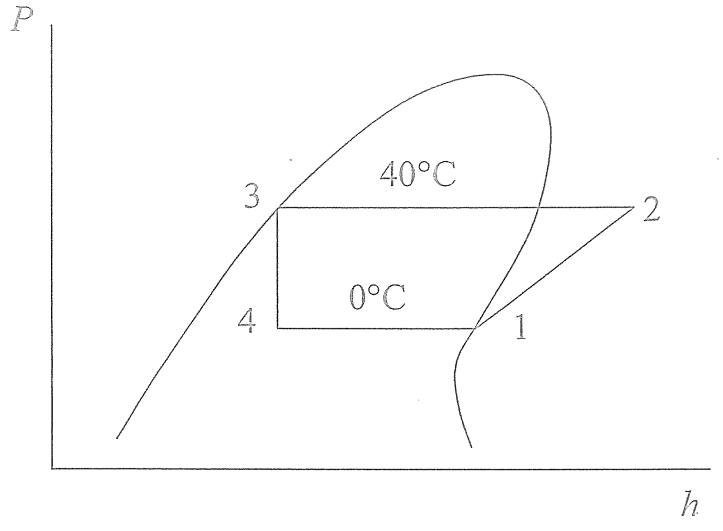
Questions 28–30: A vapor-compression refrigeration cycle using HFC-134a as the refrigerant has the pressure-enthalpy diagram shown below. The evaporator temperature is 0°C, and the condenser temperature is 40°C.



28. Assume the compression process is reversible and adiabatic. If the vapor entering the compressor is saturated, the work done on the compressor (kJ/kg) is most nearly:

(A) 15
(B) 25
(C) 35
(D) 42

29. The cooling produced by the evaporator (kJ/kg) is most nearly:

(A) 28
(B) 143
(C) 169
(D) 210

30. The process 3–4 is:

(A) constant entropy
(B) constant enthalpy
(C) reversible
(D) both constant entropy and enthalpy

MECHANICAL

AFTERNOON SOLUTIONS

ANSWERS TO THE MECHANICAL AFTERNOON SAMPLE QUESTIONS

Detailed solutions for each question begin on the next page.

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

1. The force required to displace a spring an amount δ from its free length is $F = k\delta$, where k is the spring constant or rate. In this case:

δ = free length – compressed length
= 190 mm – 125 mm
= 65 mm

The force required to deflect the spring this amount is:

$$F = k\delta = (38.525 \text{ N/mm})(65 \text{ mm}) = 2{,}504 \text{ N}$$

THE CORRECT ANSWER IS: (B)

2. The lever arm will be in equilibrium under the forces applied by the spring and the piston. Drawing a free body diagram we have,

Summing moments about the pivot pin at O:

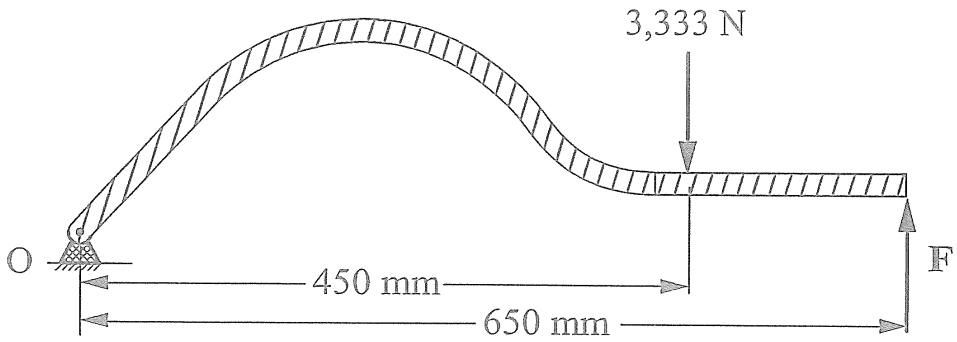
$$\Sigma M_o = (650 \text{ mm})\, F_{\text{piston}} - (450 \text{ mm})\, F_{\text{spring}} = 0$$

Solving for F_{piston}:

$$F_{\text{piston}} = \frac{450 \text{ mm}}{650 \text{ mm}} F_{\text{spring}}$$

$$= \frac{450 \text{ mm}}{650 \text{ mm}} 3{,}333 \text{ N}$$

$$= 2{,}307.5 \text{ N}$$



NOT TO SCALE

The pressure on the piston will be the force divided by the piston area:

$$p = \frac{F_{\text{piston}}}{A_{\text{piston}}} = \frac{F_{\text{piston}}}{\frac{\pi d^2_{\text{piston}}}{4}} = \frac{4\, F_{\text{piston}}}{\pi d^2_{\text{piston}}}$$

$$= \frac{(4)(2{,}307.5 \text{ N})}{\pi (100 \text{ mm})^2}$$

$$= 0.294 \text{ MPa} = 294 \text{ kPa}$$

THE CORRECT ANSWER IS: (C)

3. The pressure in the system is force/area. Since the force is the same in both cases, the ratio of pressures is inversely proportional to the diameter squared. Let p_1 be the pressure for a 100-mm diameter and p_2 be the pressure for a 90-mm diameter. Then:

$$p_1 = \frac{F_{\text{piston}}}{\pi \frac{d_1^{\,2}}{4}} \quad \text{and} \quad p_2 = \frac{F_{\text{piston}}}{\pi \frac{d_2^{\,2}}{4}}$$

$$\frac{p_2}{p_1} = \frac{d_1^{\,2}}{d_2^{\,2}} = \left(\frac{100\text{ mm}}{90\text{ mm}}\right)^2 = 1.23$$

THE CORRECT ANSWER IS: (D)

4. The formula for the hoop stress is:

$$\sigma_t = \frac{P_i \times r_m}{t} = \frac{P_i\left(\frac{D_o + D_i}{4}\right)}{\left(\frac{D_o - D_i}{2}\right)} = 0.6\text{ MPa} \times \frac{306.25\text{ mm}}{2.5\text{ mm}} = 73.5\text{ MPa}$$

THE CORRECT ANSWER IS (C)

5. The formula for the total longitudinal strain without a temperature rise is:

$$\varepsilon_{\text{axial}} = \frac{1}{E}\left(\sigma_l - \nu\left(\sigma_t + \sigma_r\right)\right) = \frac{1}{210 \times 10^3}\left(23.1\text{ MPa} - 0.24\left(46.2\text{ MPa} + 0\right)\right) = 5.72 \times 10^{-6}$$

This must be converted to displacement using the following formula:

$$\varepsilon_{\text{axial}} = \frac{\delta l}{l}, \text{ where } l \text{ is the length of the section under consideration}$$

$$\delta l = \varepsilon_{\text{axial}} \times l$$

$$= 5.72 \times 10^{-6} \times 1{,}000\text{ mm}$$

$$= 0.0572\text{ mm}$$

THE CORRECT ANSWER IS (A)

6. The kinetic energy T, when the object is at Q, is:

$$T = 1/2\ mv^2 = 1/2\ (1.5\ \text{kg})\ (2\ \text{m/s})^2 = 3\ \text{J}$$

THE CORRECT ANSWER IS: (B)

7. The horizontal force in the spring when the object is at Q is $F = k\delta$ where k is the spring constant and δ is the spring deflection. In this case:

$$\delta = \text{length at Q} - \text{length at P} = 175\ \text{mm} + 2(125\ \text{mm}) - 175\ \text{mm} = 250\ \text{mm}$$

$$F = k\delta = (400\ \text{N/m})\ (0.25\ \text{m}) = 100\ \text{N}$$

THE CORRECT ANSWER IS: (A)

8. $T_1 + U_1 + W_{1\to2} = T_2 + U_2$

$$0 + 0 + Fs = 1/2\ mv^2 + mgh$$

$$5F = 1/2\ (2)\ (8)^2 + (2)\ (9.81)\ (3)$$

$$F = 24.6\ \text{N}$$

THE CORRECT ANSWER IS: (C)

9. $V_y^2 = V_{yo}^2 + 2as$

$$V_y^2 = 0 = \left(8\left(\frac{3}{5}\right)\right)^2 - 2(9.81)(h - 4.5)$$

$$h = 5.7\ \text{m}$$

THE CORRECT ANSWER IS: (C)

10. The diffusivity of carbon in iron at 1,000°C is found as follows:

At 1,000°C, iron is fcc, so D_o and Q are for fcc iron. The diffusion equation is found in the Materials Science/Structure of Matter section in the *FE Supplied-Reference Handbook.*

$$D = D_o e^{-Q/RT}$$

$$D = \left(0.2 \times 10^{-4}\right) e^{\frac{-34{,}000}{(1{,}273)(1.987)}} = 2.907 \times 10^{-11}$$

THE CORRECT ANSWER IS: (B)

11. At what temperature does carbon have the same diffusivity in fcc iron as in hcp titanium? The diffusion equation is found in the Materials Science/Structure of Matter section in the *FE Supplied-Reference Handbook.*

$$D = D_o e^{-Q/RT}$$

Since D is the same for fcc iron and hcp titanium

$$\left(D_o e^{-Q/RT}\right)_{\text{titanium}} = \left(D_o e^{-Q/RT}\right)_{\text{iron}}$$

$$(5.1 \times 10^{-4})\, e^{\frac{-43{,}500}{1.987 \times T}} = (0.2 \times 10^{-4})\, e^{\frac{-34{,}000}{1.987 \times T}}$$

$$e^{\frac{-21{,}892}{T}} = 0.0392 e^{\frac{-17{,}111}{T}}$$

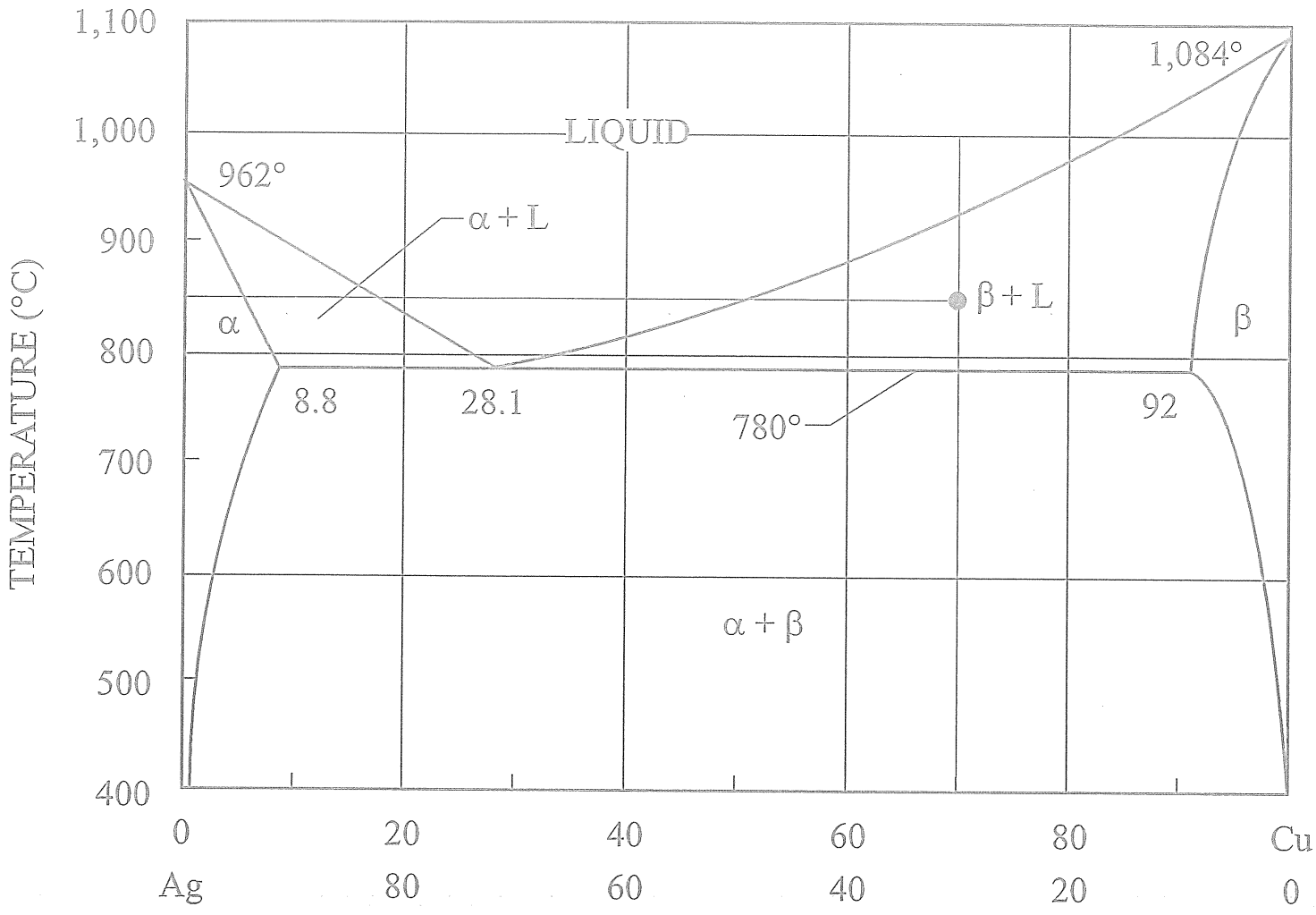
$$\frac{-21{,}892}{T} = \ln 0.0392 - \left(\frac{-17{,}111}{T}\right)$$

$$\frac{-4{,}781}{T} = -3.239$$

$$T = \frac{4{,}781}{3.239} = 1{,}476\text{K} = 1{,}203°\text{C}$$

THE CORRECT ANSWER IS: (A)

12.

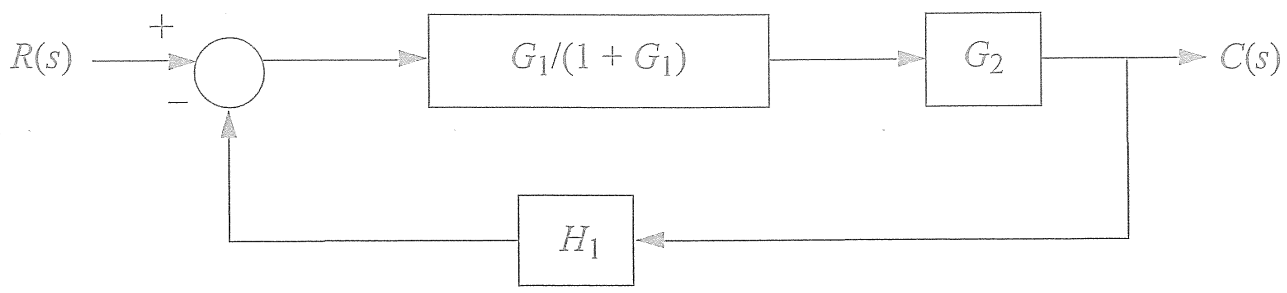


At 850°C, β + L phases are present.

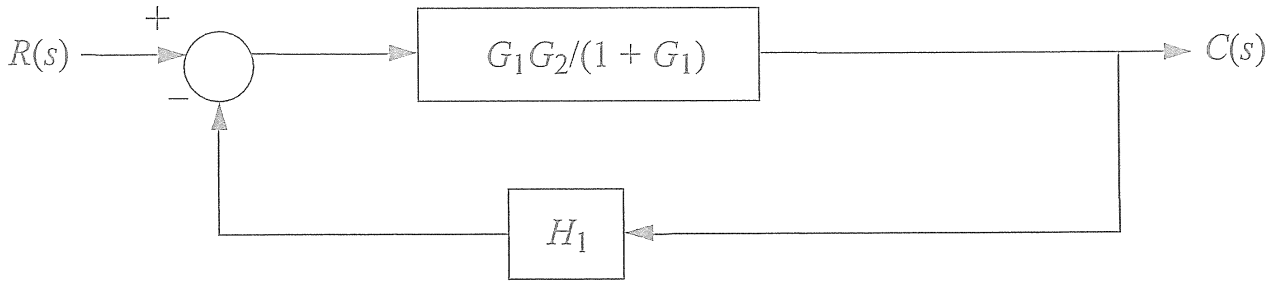
THE CORRECT ANSWER IS: (B)

13. The solution requires a step-by-step reduction of the system loops.

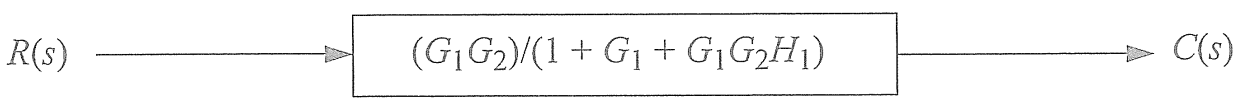
First, reduce the inner loop.



Next, combine the forward blocks.



Finally, reduce the "outer" loop.



THE CORRECT ANSWER IS: (D)

14. $R = R_o\,[1 + \alpha(T - T_o)]$

$$\Delta R = \frac{dR}{dT}\Delta T$$

$$= R_o \alpha \Delta T$$

$$= (100\ \Omega)\ (0.004\ ^\circ C^{-1})\ (10\ ^\circ C)$$

$$= 4.0\ \Omega$$

THE CORRECT ANSWER IS: (C)

15. $R = R_o\,[1 + \alpha(T - T_o)]$

$$= 100\,[1 + 0.004\ (250 - 0)]$$

$$= 200\ \Omega$$

THE CORRECT ANSWER IS: (D)

16. $v_1 = 0.001\ \text{m}^3/\text{kg}$

The pump power is:

$$\dot{W}_p = \frac{\dot{m} v_1 (P_2 - P_1)}{\eta_p}$$

$$= \frac{\left(\frac{50{,}000\ \text{kg}}{3{,}600\ \text{s}}\right)\left(0.001\ \text{m}^3/\text{kg}\right)\left[\left(14{,}000 - 100\right)\text{kN/m}^2\right]}{0.8}$$

$$= 241.3\ \text{kW}$$

THE CORRECT ANSWER IS: (C)

17. An energy balance on the boiler gives:

$$\dot{Q} = \dot{m}(h_3 - h_2) = \left(\frac{50{,}000\ \text{kg}}{3{,}600\ \text{s}}\right)\left[\left(3{,}322 - 167.6\right)\text{kJ/kg}\right] = 43{,}811\ \text{kW} = 44\ \text{MW}$$

THE CORRECT ANSWER IS: (D)

18. The mass rate of coal times its heating value divided by the boiler efficiency yields the heat added to the water in the boiler.

$$\dot{m}_f = \frac{\dot{m}(h_3 - h_2)}{(HV)\eta_b} = \frac{\left(\frac{50{,}000\ \text{kg}}{3{,}600\ \text{s}}\right)\left[\left(3{,}322 - 167.6\right)\text{kJ/kg}\right]}{(28{,}000\ \text{kJ/kg})(0.88)} = 1.778\ \text{kg/s}$$

THE CORRECT ANSWER IS: (C)

19. The specific volume is found using the ideal gas equation of state.

$$pv = RT$$

$$v = \left(\frac{RT}{p}\right) = \frac{\left[0.287\ \text{kJ/(kg·K)}\right][273+100]\ \text{K}}{172\ \text{kPa}}$$

$$v = 0.622\ \text{m}^3/\text{kg}$$

Unit check

$$\frac{\dfrac{\text{kJ}}{\text{kg·K}} \times \text{K}}{\dfrac{\text{kN}}{\text{m}^2}} = \frac{\text{kN·m·K·m}^3}{\text{kg·K·kN}} = \frac{\text{m}^3}{\text{kg}}$$

THE CORRECT ANSWER IS: (B)

20. The change in entropy is found from the equations in the Thermodynamics section of the *FE Supplied-Reference Handbook*:

$$\Delta s = c_p \ln (T_2/T_1) - R \ln (P_2/P_1)$$

For a constant volume process, $\dfrac{P_1}{T_1} = \dfrac{P_2}{T_2}$

therefore, $P_2/P_1 = T_2/T_1$

$$\Delta s = c_p \ln (P_2/P_1) - R \ln (P_2/P_1)$$

$$= (c_p - R) \ln (P_2/P_1) = c_v \ln (P_2/P_1) = 0.718 \ln 2$$

$$= 0.498\ \text{kJ/(kg.K)}$$

THE CORRECT ANSWER IS: (C)

21. The cross-sectional area of the pipe is:

$$A_c = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.10)^2 = 0.007854\ \text{m}^2$$

The flow rate is:

$$Q = A_c\, V_c = 0.007854\ (2.5)(60) = 1.178\ \text{m}^3/\text{min}$$

THE CORRECT ANSWER IS: (B)

22. $$\Delta P_{\text{elbow}} = \frac{\rho V^2}{2} C = \frac{1{,}000(2.5)^2}{2}(0.9) = 2{,}812.5 \text{ Pa}$$

THE CORRECT ANSWER IS: (B)

23. $$w_{\text{ideal}} = \frac{\Delta P}{\rho} = \frac{P_c - P_B}{\rho} = \frac{175 - 125}{1{,}000} = 0.050 \text{ kJ/kg} = 50 \text{ J/kg}$$

THE CORRECT ANSWER IS: (A)

24. The cross-sectional area of the discharge pipe is:

$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.10)^2 = 0.007854 \text{ m}^2$$

The velocity of flow in the discharge pipe is:

$$V = \frac{\dot{m}}{\rho A} = \frac{40}{1{,}000(0.007854)} = 5.093 \text{ m/s}$$

The head at the discharge into the heater is:

$$H_h = \frac{P}{\rho g} + \frac{V^2}{2g} + Z_2 = \frac{200{,}000}{1{,}000(9.807)} + \frac{(5.093)^2}{2(9.807)} + 20 = 41.7 \text{ m}$$

The head at the pump discharge is:

$$H_d = 41.7 - 0.5 + 25 = 66.2 \text{ m}$$

THE CORRECT ANSWER IS: (D)

25. The effect of fouling on the heat-transfer surfaces is to reduce the heat-transfer rate by increasing the surface resistance. The results on the water being heated would be to reduce the outlet temperature of the water.

THE CORRECT ANSWER IS: (B)

26. The Reynolds number is found in the Fluid Mechanics section of the *FE Supplied-Reference Handbook.*

$$\mathrm{Re} = \frac{VD\rho}{\mu}$$

$$V = 1.5\ \mathrm{m/s}$$

$$D = 2.5\ \mathrm{cm} = 2.5\times10^{-2}\ \mathrm{m}$$

$$\upsilon = 1.59\times10^{-4}\ \frac{\mathrm{N\cdot s}}{\mathrm{m}^2}$$

$$\rho = 898\ \mathrm{kg/m}^3$$

$$\mathrm{Re} = \frac{\left(1.5\ \mathrm{m/s}\right)\left(2.5\times10^{-2}\ \mathrm{m}\right)\left(898\ \mathrm{kg/m}^3\right)}{1.59\times10^{-4}\ \mathrm{N\cdot s/m}^2}$$

$$= 211{,}792\ \frac{\left(\mathrm{m/s}\right)\left(\mathrm{m}\right)\left(\mathrm{kg}\right)}{\left(\mathrm{N\cdot s/m}^2\right)\left(\mathrm{m}^3\right)} \qquad 1\ \mathrm{N} = 1\ \mathrm{kg\cdot m/s}^2$$

$$\text{Verify units } \frac{\left(\mathrm{m/s}\right)\left(\mathrm{m}\right)\left(\mathrm{kg}\right)}{\left(\frac{\mathrm{kg\cdot m\cdot s}}{\mathrm{s}^2\cdot\mathrm{m}^2}\right)\left(\mathrm{m}^3\right)} \qquad \left(\text{dimensionless}\right)$$

THE CORRECT ANSWER IS: (C)

27. The overall heat-transfer coefficient based on inside surface area is found from the shell-and-tube heat exchanger equation in the Heat Transfer section of the *FE Supplied-Reference Handbook*.

$$\frac{1}{UA} = \frac{1}{h_i A_i} + \frac{R_{f(i)}}{A_i} + \frac{\ln\left(\frac{D_o}{D_i}\right)}{2\pi kL} + \frac{R_{f(o)}}{A_o} + \frac{1}{h_o A_o}$$

$$If\ A = A_i$$

$$\frac{1}{U} = \frac{1}{h_i} + R_{f(i)} + \frac{A_i \ln\left(\frac{D_o}{D_i}\right)}{2\pi kL} + \frac{A_i}{A_o} R_{f(o)} + \frac{A_i}{h_o A_o}$$

$$h_i = 6,000$$

$$R_{f(i)} = 7 \times 10^{-4}$$

$$k = 380$$

$$\frac{A_i \ln\left(\frac{D_o}{D_i}\right)}{2\pi kL} = \frac{(\pi D_i L)\ln\left(\frac{D_o}{D_i}\right)}{2\pi kL} = \frac{D_i \ln\left(\frac{D_o}{D_i}\right)}{2k}$$

$$R_{f(o)} = 9 \times 10^{-5}$$

$$h_o = 12,000$$

$$\frac{A_i}{A_o} = \frac{\pi D_i L}{\pi D_o L} = \frac{D_i}{D_o} = \frac{2.5 \times 10^{-2}}{3.8 \times 10^{-2}}$$

$$\frac{1}{U} = \frac{1}{6,000} + 7 \times 10^{-4} + \frac{(2.5 \times 10^{-2}) \ln \frac{(3.8 \times 10^{-2})}{(2.5 \times 10^{-2})}}{2(380)} + \frac{2.5}{3.8}\left(9 \times 10^{-5}\right) + \frac{2.5}{(3.8)(12,000)}$$

$$\frac{1}{U} = 1.667 \times 10^{-4} + 7 \times 10^{-4} + 0.138 \times 10^{-4} + 0.592 \times 10^{-4} + 0.548 \times 10^{-4}$$

$$\frac{1}{U} = 9.945 \times 10^{-4}$$

$$U = 1,005.5\ \text{W/(m}^2 \cdot \text{K)}$$

THE CORRECT ANSWER IS: (A)

Solutions 28–30: From the P-h Diagram for Refrigerant HFC-134a given in the Thermodynamics section of the *FE Supplied-Reference Handbook*:

$$h_1 = 400 \text{ kJ/kg}$$
$$h_2 = 425 \text{ kJ/kg}$$
$$h_3 = h_4 = 257 \text{ kJ/kg}$$

28. $\dot{W}_C / \dot{m} = (h_2 - h_1) = (425 - 400) = 25 \text{ kJ/kg}$

THE CORRECT ANSWER IS: (B)

29. Evaporator cooling, $\dfrac{\dot{Q}_{\text{evap}}}{\dot{m}} = (h_1 - h_4) = (400 - 257) = 143 \text{ kJ/kg}$

THE CORRECT ANSWER IS: (B)

30. The process from 3 to 4 is a throttling process, which involves both a drop in pressure and temperature. It is an irreversible process, generally considered constant enthalpy.

THE CORRECT ANSWER IS: (B)

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