FE

SAMPLE
QUESTIONS

FUNDAMENTALS OF ENGINEERING

SAMPLE QUESTIONS

Only one thing is better than being an engineer. Being a P.E.

Clean water. Sound structures. Safe power. We are charged with preserving these and many more fundamentals that protect the health, safety, and welfare of the public. Earn your license, and join the national community of professionals committed to excellence.

YOUR BOARD SETS THE BAR

Engineering licensure in the United States is regulated by licensing boards in each state and territory. These boards set and maintain the standards that protect the public they serve. As a result, licensing requirements and procedures vary by jurisdiction, so stay in touch with your board (ncees.org/licensing-boards).

NCEES

NCEES is a national nonprofit organization made up of the U.S. engineering and surveying licensing boards in all 50 states, U.S. territories, and the District of Columbia. It develops and scores the exams used for engineering and surveying licensure in the United States. It also promotes professional mobility through its services for licensees and its member boards.

Licensure: what it takes

These are the general requirements for licensure in the United States. Check with your licensing board for details specific to your jurisdiction.

EDUCATION

Earn your 4-year bachelor of science degree.
Make sure that your engineering program is EAC/ABET accredited.

EXAMINATIONS

Pass the FE exam.
Take the FE exam right before or after you graduate. It is administered year-round at approved Pearson VUE test centers throughout the United States, the District of Columbia, and U.S. territories. Registration is always open, so plan ahead. Visit ncees.org/exams to review your state board's policies and procedures. Pass the exam, and become an E.I. (engineer intern) or E.I.T. (engineer-in-training).

Pass the PE exam.
This exam is offered in April and October, though some disciplines are offered only annually. Registration opens 3–4 months ahead and closes 4–6 weeks before the exam date. Some state licensing boards require you to gain experience before you can take the PE exam. Access your state licensing board's policies and procedures at ncees.org/exams.

EXPERIENCE

Get 4 years of engineering experience.
This means progressive, acceptable, and verifiable work in the industry. Some boards require your supervisors to be professional engineers.

Take the first step.
Take the FE.

The Fundamentals of Engineering, or FE, exam is the first exam required for licensure as a P.E. (professional engineer). You'll choose one of 7 freestanding, discipline-specific exams:

- Chemical
- Civil
- Electrical and Computer
- Environmental
- Industrial
- Mechanical
- Other Disciplines

If you're not sure which exam discipline to choose, look through *FE Sample Questions* to help you decide. Each section contains the exam specifications, or subject areas, and 10 sample questions and solutions for each discipline.

When you're ready to take your exam, go to ncees.org/FE-exam to register. Once approved, you'll schedule an appointment at an approved Pearson VUE test center near you.

Add it together. Licensure sets you apart.

Here's how.

RECOGNITION

"P.E." instantly says that you're experienced, knowledgeable, and accountable.

GROWTH

Engineering positions at all levels of industry and government increasingly require licensure.

AUTHORITY

As a P.E., you can consult in private practice. Without it, you don't have the same opportunities.

MOBILITY

Earning your P.E. license in one state allows you to more easily apply for licensure in other states—a process known as comity licensure.

MONEY

Salary studies show that as a P.E., you can expect to earn significantly more throughout your career.

FE EXAM
Q & A

WHAT'S THE FORMAT?

Each exam contains 110 multiple-choice questions and is administered via computer at approved Pearson VUE test centers. A 6-hour appointment time includes a tutorial, the exam, a break, and a survey. **You'll have 5 hours and 20 minutes to complete the actual exam.**

WHAT DOES THE EXAM COVER?

The exam is designed for recent graduates and students who are close to finishing an undergraduate engineering degree. There are 7 freestanding, discipline-specific FE exams. The full exam specifications for each discipline are included in this book and are posted online at ncees.org/FE-exam.

WHAT CAN I TAKE INTO THE EXAM ROOM?

The following items are allowed in the exam room: your ID, an NCEES-approved calculator, key to your test center locker, reusable booklet provided by Pearson VUE, eyeglasses, light sweater or jacket, and items included in the Pearson VUE Comfort Aid List. An electronic version of the *FE Reference Handbook* is incorporated into the exam.

HOW CAN I PREPARE?

Purchase an NCEES FE computer-based practice exam, which provides the most realistic exam-day simulation available (ncees.org/PracticeExams).

HOW DO I REGISTER?

Log in to your MyNCEES account, select the REGISTER button, and follow the onscreen instructions. If you need to create a MyNCEES account, go to account.ncees.org.

HOW DO I SCHEDULE MY EXAM?

Once your completed registration is approved, you'll receive an email notification that you're authorized to take the exam and are eligible to schedule your exam appointment. To schedule your exam, log in to MyNCEES, select the SCHEDULE button, and follow the onscreen instructions.

WHERE AND WHEN CAN I TAKE THE EXAM?

The FE is offered year round at approved Pearson VUE test centers.

WHERE CAN I LEARN MORE?

For more information, download the *NCEES Examinee Guide* or visit ncees.org/FE-exam.
You can also go to youtube.com/NCEESMedia to watch short instructional videos that explain what to expect on exam day.

NCEES practice exams

We do the exams. You do the math. Study with NCEES.

PURSUE EVERY ADVANTAGE

Why not study with NCEES? You'll have the advantage of using a product that is developed by the same people who create the exam that you are preparing to take. No other study materials can give you that.

KNOW WHAT TO EXPECT

NCEES practice exams are an excellent tool for helping you determine what you know—and what you don't know—before taking the exam. The computer-based practice exams

- Contain questions and solutions from past exams
- Simulate the real format, style, and level of difficulty
- Provide immediate feedback on performance in each topic area

FE COMPUTER-BASED PRACTICE EXAMS

Evaluate your readiness for the FE exam by testing your knowledge with the most realistic computer-based simulation available. Each timed practice exam consists of 50 questions and functions much the same as the actual exam. You will be given 2.5 hours to complete your exam. Solutions to the questions will show you how to approach problems, and immediate feedback about your performance in each topic area can help you focus your preparation.

Choose your discipline: $49.95 each

- Chemical
- Civil
- Electrical and Computer
- Environmental
- Industrial
- Mechanical
- Other Disciplines

SAVE **10%** WHEN PURCHASED WITH EXAM REGISTRATION.

If you purchase an FE computer-based practice
exam at the same time you register for an exam,
you'll receive a 10 percent discount on the practice exam.

FE REFERENCE HANDBOOK

Reviewing the handbook before exam day will help you become familiar with the
charts, formulas, tables, and other reference information provided. Download the
PDF and practice using it to help you navigate easily on exam day.

- Print $13.95
- Download   Free

Order at ncees.org/PracticeExams.

PROVE YOURSELF WITHOUT SAYING A WORD.

Standards matter. Character counts. Now more than ever, your P.E. can be the
competitive edge you need.

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Fundamentals of Engineering (FE)
CHEMICAL CBT Exam Specifications

Effective Beginning with the January 2014 Examinations

- The FE exam is a computer-based test (CBT). It is closed book with an electronic reference.
- Examinees have 6 hours to complete the exam, which contains 110 multiple-choice questions. The 6-hour time also includes a tutorial, a break, and a brief survey at the conclusion.
- The FE exam uses both the International System of Units (SI) and the US Customary System (USCS).

Knowledge	Number of Questions
1. Mathematics	8–12
A. Analytic geometry	
B. Roots of equations	
C. Calculus	
D. Differential equations	
2. Probability and Statistics	4–6
A. Probability distributions (e.g., discrete, continuous, normal, binomial)	
B. Expected value (weighted average) in decision making	
C. Hypothesis testing	
D. Measures of central tendencies and dispersions (e.g., mean, mode, standard deviation)	
E. Estimation for a single mean (e.g., point, confidence intervals)	
F. Regression and curve fitting	
3. Engineering Sciences	4–6
A. Applications of vector analysis (e.g., statics)	
B. Basic dynamics (e.g., friction, force, mass, acceleration, momentum)	
C. Work, energy, and power (as applied to particles or rigid bodies)	
D. Electricity and current and voltage laws (e.g., charge, energy, current, voltage, power, Kirchhoff, Ohm)	
4. Computational Tools	4–6
A. Numerical methods and concepts (e.g., convergence, tolerance)	
B. Spreadsheets for chemical engineering calculations	
C. Simulators	
5. Materials Science	4–6
A. Chemical, electrical, mechanical, and physical properties (e.g., effect of temperature, pressure, stress, strain)	
B. Material types and compatibilities (e.g., engineered materials, ferrous and nonferrous metals)	
C. Corrosion mechanisms and control	
6. Chemistry	8–12
A. Inorganic chemistry (e.g., molarity, normality, molality, acids, bases, redox reactions, valence, solubility product, pH, pK, electrochemistry, periodic table)	
B. Organic chemistry (e.g., nomenclature, structure, qualitative and quantitative analyses, balanced equations, reactions, synthesis, basic biochemistry)	

7. **Fluid Mechanics/Dynamics**   8-12
   A. Fluid properties
   B. Dimensionless numbers (e.g., Reynolds number)
   C. Mechanical energy balance (e.g., pipes, valves, fittings, pressure losses across packed beds, pipe networks)
   D. Bernoulli equation (hydrostatic pressure, velocity head)
   E. Laminar and turbulent flow
   F. Flow measurement (e.g., orifices, Venturi meters)
   G. Pumps, turbines, and compressors
   H. Compressible flow and non-Newtonian fluids

8. **Thermodynamics**   8-12
   A. Thermodynamic properties (e.g. specific volume, internal energy, enthalpy, entropy, free energy)
   B. Properties data and phase diagrams (e.g. steam tables, psychrometric charts, T-s, P-h, x-y, T-x-y)
   C. Thermodynamic laws (e.g., 1st law, 2nd law)
   D. Thermodynamic processes (e.g., isothermal, adiabatic, isentropic)
   E. Cyclic processes and efficiency (e.g., power, refrigeration, heat pump)
   F. Phase equilibrium (e.g., fugacity, activity coefficient)
   G. Chemical equilibrium
   H. Heats of reaction and mixing

9. **Material/Energy Balances**   8-12
   A. Mass balance (steady and unsteady state)
   B. Energy balance (steady and unsteady state)
   C. Recycle/bypass processes
   D. Reactive systems (e.g., combustion)

10. **Heat Transfer**   8-12
    A. Conductive heat transfer
    B. Convective heat transfer (natural and forced)
    C. Radiation heat transfer
    D. Heat transfer coefficients (e.g., overall, local, fouling)
    E. Heat transfer equipment, operation, and design (e.g., double pipe, shell and tube, fouling, number of transfer units, log-mean temperature difference, flow configuration)

11. **Mass Transfer and Separation**   8-12
    A. Molecular diffusion (e.g., steady and unsteady state, physical property estimation)
    B. Convective mass transfer (e.g., mass transfer coefficient, eddy diffusion)
    C. Separation systems (e.g., distillation, absorption, extraction, membrane processes)
    D. Equilibrium stage methods (e.g., graphical methods, McCabe-Thiele, efficiency)
    E. Continuous contact methods (e.g., number of transfer units, height equivalent to a theoretical plate, height of transfer unit, number of theoretical plates)
    F. Humidification and drying

12. Chemical Reaction Engineering 8–12
    A. Reaction rates and order
    B. Rate constant (e.g., Arrhenius function)
    C. Conversion, yield, and selectivity
    D. Type of reactions (e.g., series, parallel, forward, reverse, homogeneous, heterogeneous, catalysis, biocatalysis)
    E. Reactor types (e.g., batch, semibatch, continuous stirred tank, plug flow, gas phase, liquid phase)

13. Process Design and Economics 8–12
    A. Process flow diagrams and piping and instrumentation diagrams
    B. Equipment selection (e.g., sizing and scale-up)
    C. Cost estimation
    D. Comparison of economic alternatives (e.g., net present value, discounted cash flow, rate of return, expected value and risk)
    E. Process design and optimization (e.g., sustainability, efficiency, green engineering, inherently safer design, evaluation of specifications)

14. Process Control 5–8
    A. Dynamics (e.g., time constants and 2nd order, underdamped, and transfer functions)
    B. Control strategies (e.g., feedback, feed-forward, cascade, ratio, and PID)
    C. Control loop design and hardware (e.g., matching measured and manipulated variables, sensors, control valves, and conceptual process control)

15. Safety, Health, and Environment 5–8
    A. Hazardous properties of materials (e.g., corrosivity, flammability, toxicity, reactivity, handling and storage), including MSDS
    B. Industrial hygiene (e.g., noise, PPE, ergonomics)
    C. Process safety and hazard analysis [e.g., layer of protection analysis, hazard and operability studies (HazOps), fault-tree analysis or event tree]
    D. Overpressure and underpressure protection (e.g., relief, redundant control, intrinsically safe)
    E. Waste minimization, waste treatment, and regulation (e.g., air, water, solids, RCRA, CWA, EPA, OSHA)

16. Ethics and Professional Practice 2–3
    A. Codes of ethics (professional and technical societies)
    B. Agreements and contracts
    C. Ethical and legal considerations
    D. Professional liability
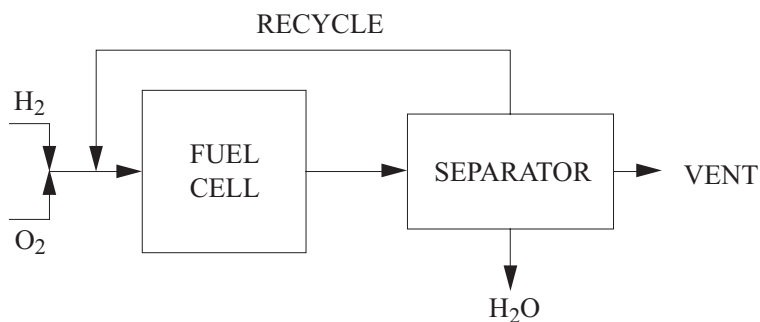   E. Public protection issues (e.g., licensing boards)

1.   The only point of inflection on the curve representing the equation $y = x^3 + x^2 - 3$ is at:

A. $x = -\dfrac{2}{3}$

B. $x = -\dfrac{1}{3}$

C. $x = 0$

D. $x = \dfrac{1}{3}$

2.   Which of the following occurs in the reaction $Cu^{+2} + Zn \rightarrow Cu + Zn^{+2}$?

A.   Only copper is oxidized.
B.   Only zinc is oxidized.
C.   Both copper and zinc are oxidized.
D.   Neither copper nor zinc is oxidized.

3.   The pressure of 100 kg of nitrogen (N_2) at 70°C in a 100-m³ tank is most nearly:

A.   2,850 kPa
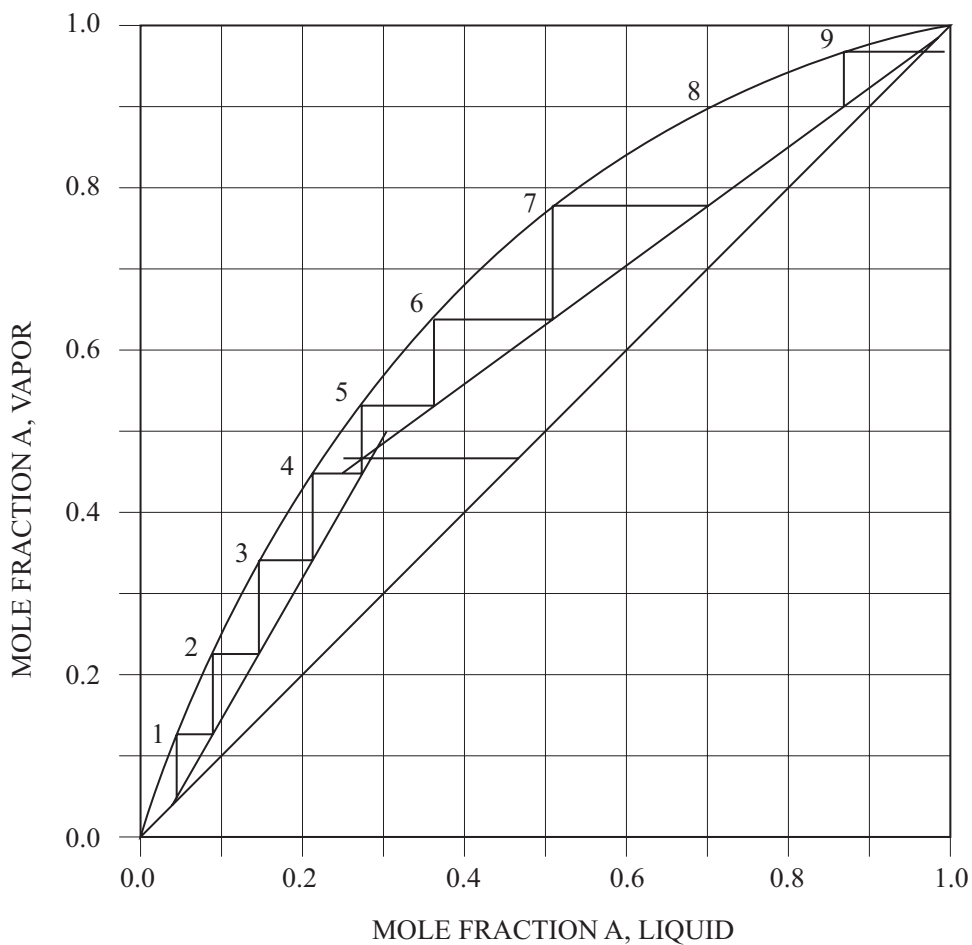B.   102 kPa
C.   20 kPa
D.   102 mPa

4. Hydrogen (H_2) and oxygen (O_2) are reacted in a fuel cell to produce energy. The product of the reaction is water, and any excess gases are vented after the fuel cell, as shown in the figure below. The hydrogen and oxygen tanks are maintained at the same temperature and pressure, and they feed at the same volumetric flow rate. The reaction goes to 60% completion in the fuel cell (hydrogen basis).

If all of the unreacted hydrogen and a portion of the unreacted oxygen are recycled, then the molar ratio of oxygen in the vent to oxygen in the fresh feed is most nearly:

A. 0.00
B. 0.50
C. 0.58
D. 0.82

5. The following figure is the solution of a binary distillation tower design using the McCabe-Thiele method. The equilibrium curve shown is for Component A. Component A is separated from B in the distillation column to produce a distillate that is 97 mole% A. The feed rate to the tower is 100 kmol/hr. The tower includes a partial reboiler and total condenser. The bottoms flow rate (kmol/hr) is most nearly:

A. 3.0

B. 42.6

C. 53.8

D. 97.0

6. Operating conditions for a plug-flow reactor for the elementary liquid-phase reaction $A + B \rightarrow R$ are as follows:

$C_{AO} = 0.10 \text{ kmol/m}^3$

$C_B = 0.10 \text{ kmol/m}^3$

$V = 0.50 \text{ m}^3$

$q = 0.20 \text{ m}^3/\text{min}$

$C_A \text{ (at exit)} = 0.40 \text{ kmol/m}^3$

The space time (min) for this reactor is most nearly:

A. 0.25
B. 0.40
C. 2.0
D. 2.5

7. If $500 is invested at an annual interest rate of 8% per year, its future worth at the end of 30 years will be most nearly:

A. $1,200
B. $1,700
C. $5,031
D. $15,000

8.   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

9.   A chemical plant has a waste stream containing 5% by weight HCl flowing at the rate of 1,000 L/min. Before it can be discharged, it must be neutralized with NaOH. A solution of NaOH at a strength of 1% by weight is available. Molecular weights are as follows:

$$NaCl \ \ = 58.4$$
$$HCl \ \ \ = 36.5$$
$$NaOH \ = 39.9$$

The specific gravity of the solutions may be assumed to be 1.0. The required flow rate (L/min) of the NaOH stream is most nearly:

    A.   8,900

    B.   5,500

    C.   4,570

    D.   220

10.   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.   you do not live in the jurisdiction where the transportation system is being installed

    C.   your original area of specialization was in transportation systems

    D.   you have regularly attended meetings of a professional engineering society

Solutions

1. $f(x) = x^3 + x^2 - 3$ Inflection point occurs when $f''(x) = 0$

   $f'(x) = 3x^2 + 2x$

   $f''(x) = 6x + 2$

   Set equal to zero

   $6x + 2 = 0$

   $x = -1/3$

   $f''(x)$ is negative below $x = -1/3$ and positive above $x = -1/3$

   Since $f''(x) = 0$ and $f''(x)$ changes signs at $x = -1/3$, the inflection point is at $x = -1/3$.

   THE CORRECT ANSWER IS: B

2. Oxidation is defined as the loss of electrons. In this case, $Cu^{+2} \rightarrow Cu$, which gains two electrons, and $Zn \rightarrow Zn^{+2}$, which loses two electrons. Therefore, only zinc is oxidized.

   THE CORRECT ANSWER IS: B

3. Use the ideal gas formula:

   $$PV = mRT$$

   $$P = \frac{mRT}{V}$$

   $$R = \frac{8,314\,J}{kmole \cdot K} \frac{kmol}{28\,kg} = 297 \frac{J}{kg \cdot K}$$

   $$P = \frac{(100\,kg)\left(297 \frac{J}{kg \cdot K}\right)(343\,K)}{100\,m^3}$$

   $$= 102,000 \frac{J}{m^3}$$

   $$= 102,000 \frac{N \cdot m}{m^3}$$

   $$= 102,000 \frac{N}{m^2}$$

   $$= 102\,kPa$$

   THE CORRECT ANSWER IS: B

Solutions

4.   Balanced equation: $H_2 + 1/2\ O_2 \rightarrow H_2O$

Feed characteristics: since $P_{H_2} = P_{O_2}$ and $\dot{V}_{H_2} = \dot{V}_{O_2}$ and $T_{H_2} = T_{O_2}$

Therefore, from ideal gas law:

$$\text{Ratio } \frac{H_2}{O_2} = \frac{P_{H_2}\ \dot{V}_{H_2} = \dot{n}_{H_2}RT_{H_2}}{P_{O_2}\ \dot{V}_2 = \dot{n}_{O_2}RT_{O_2}} = \frac{\dot{n}_{H_2}}{\dot{n}_{O_2}} = 1.0$$

Using basis of 1 mole H_2 in feed, and at maximum H_2 recycle, all the hydrogen would be consumed:

Balance equation: $H_2 + 1/2\ O_2 \rightarrow H_2O$

$$\text{Ratio } \frac{O_{2\ OUT}}{O_{2\ IN}} = \frac{0.5\ \text{mole}}{1.0\ \text{mole}} = 0.5$$

THE CORRECT ANSWER IS: B

5.   Feed = bottoms + distillate = 100 kg/hr

From diagram, mole fraction of A in the feed is 47%.

Balance on A gives

   $47 = 0.97\,D + 0.04\,B$
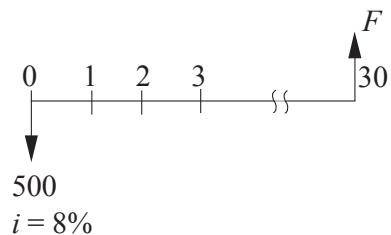
since $B = 100 - D$

then $D = \dfrac{43}{93} = 46.2$

and $B = 100 - 46.2 = 53.8$

THE CORRECT ANSWER IS: C

6. $\tau = \dfrac{V}{q} = \dfrac{0.50\,\text{m}^3}{0.20\,\text{m}^3/\text{min}} = 2.5\,\text{min}$

THE CORRECT ANSWER IS: D

Solutions

7.

500
$i = 8\%$

$F = 500(F/P, 8\%, 30)$
$= 500 \,(10.0627)$
$= \$5,031$

THE CORRECT ANSWER IS: C

8. $Pv = nRT$

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

$v = 44.8 \text{ L}$

THE CORRECT ANSWER IS: D

9. $1,000 \dfrac{\text{L}}{\text{min}} \times \dfrac{1.00 \,\text{kg}}{L} \times \dfrac{5 \,\text{kg HCl}}{100 \,\text{kg}} \times \dfrac{\text{kmol HCl}}{36.5 \,\text{kg HCl}}$

$= F \times \dfrac{1.00 \,\text{kg}}{L} \times \dfrac{1 \,\text{kg NaOH}}{100 \,\text{kg}} \times \dfrac{\text{kmol NaOH}}{39.9 \,\text{kg NaOH}}$

$F = 5,466 \text{ L/min}$

THE CORRECT ANSWER IS: B

10.   Refer to the NCEES Rules of Professional Conduct.

THE CORRECT ANSWER IS: A

Fundamentals of Engineering (FE)
CIVIL CBT Exam Specifications

Effective Beginning with the January 2014 Examinations

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Knowledge	Number of Questions
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A. Analytic geometry	
B. Calculus	
C. Roots of equations	
D. Vector analysis	
2. Probability and Statistics	4–6
A. Measures of central tendencies and dispersions (e.g., mean, mode, standard deviation)	
B. Estimation for a single mean (e.g., point, confidence intervals)	
C. Regression and curve fitting	
D. Expected value (weighted average) in decision making	
3. Computational Tools	4–6
A. Spreadsheet computations	
B. Structured programming (e.g., if-then, loops, macros)	
4. Ethics and Professional Practice	4–6
A. Codes of ethics (professional and technical societies)	
B. Professional liability	
C. Licensure	
D. Sustainability and sustainable design	
E. Professional skills (e.g., public policy, management, and business)	
F. Contracts and contract law	
5. Engineering Economics	4–6
A. Discounted cash flow (e.g., equivalence, PW, equivalent annual worth, FW, rate of return)	
B. Cost (e.g., incremental, average, sunk, estimating)	
C. Analyses (e.g., breakeven, benefit-cost, life cycle)	
D. Uncertainty (e.g., expected value and risk)	
6. Statics	7–11
A. Resultants of force systems	
B. Equivalents of force systems	
C. Equilibrium of rigid bodies	
D. Frames and trusses	
E. Centroid of area	
F. Area moments of inertia	
G. Static friction	

7. **Dynamics** 4–6
   A. Kinematics (e.g., particles and rigid bodies)
   B. Mass moments of inertia
   C. Force acceleration (e.g., particles and rigid bodies)
   D. Impulse momentum (e.g., particles and rigid bodies)
   E. Work, energy, and power (e.g., particles and rigid bodies)

8. **Mechanics of Materials** 7–11
   A. Shear and moment diagrams
   B. Stresses and strains (e.g., axial, torsion, bending, shear, thermal)
   C. Deformations (e.g., axial, torsion, bending, thermal)
   D. Combined stresses
   E. Principal stresses
   F. Mohr's circle
   G. Column analysis (e.g., buckling, boundary conditions)
   H. Composite sections
   I. Elastic and plastic deformations
   J. Stress-strain diagrams

9. **Materials** 4–6
   A. Mix design (e.g., concrete and asphalt)
   B. Test methods and specifications (e.g., steel, concrete, aggregates, asphalt, wood)
   C. Physical and mechanical properties of concrete, ferrous and nonferrous metals, masonry, wood, engineered materials (e.g., FRP, laminated lumber, wood/plastic composites), and asphalt

10. **Fluid Mechanics** 4–6
    A. Flow measurement
    B. Fluid properties
    C. Fluid statics
    D. Energy, impulse, and momentum equations

11. **Hydraulics and Hydrologic Systems** 8–12
    A. Basic hydrology (e.g., infiltration, rainfall, runoff, detention, flood flows, watersheds)
    B. Basic hydraulics (e.g., Manning equation, Bernoulli theorem, open-channel flow, pipe flow)
    C. Pumping systems (water and wastewater)
    D. Water distribution systems
    E. Reservoirs (e.g., dams, routing, spillways)
    F. Groundwater (e.g., flow, wells, drawdown)
    G. Storm sewer collection systems

12. **Structural Analysis**   6-9
   - A. Analysis of forces in statically determinant beams, trusses, and frames
   - B. Deflection of statically determinant beams, trusses, and frames
   - C. Structural determinacy and stability analysis of beams, trusses, and frames
   - D. Loads and load paths (e.g., dead, live, lateral, influence lines and moving loads, tributary areas)
   - E. Elementary statically indeterminate structures

13. **Structural Design**   6-9
   - A. Design of steel components (e.g., codes and design philosophies, beams, columns, beam-columns, tension members, connections)
   - B. Design of reinforced concrete components (e.g., codes and design philosophies, beams, slabs, columns, walls, footings)

14. **Geotechnical Engineering**   9-14
   - A. Geology
   - B. Index properties and soil classifications
   - C. Phase relations (air-water-solid)
   - D. Laboratory and field tests
   - E. Effective stress (buoyancy)
   - F. Stability of retaining walls (e.g., active pressure/passive pressure)
   - G. Shear strength
   - H. Bearing capacity (cohesive and noncohesive)
   - I. Foundation types (e.g., spread footings, deep foundations, wall footings, mats)
   - J. Consolidation and differential settlement
   - K. Seepage/flow nets
   - L. Slope stability (e.g., fills, embankments, cuts, dams)
   - M. Soil stabilization (e.g., chemical additives, geosynthetics)
   - N. Drainage systems
   - O. Erosion control

15. **Transportation Engineering**   8-12
   - A. Geometric design of streets and highways
   - B. Geometric design of intersections
   - C. Pavement system design (e.g., thickness, subgrade, drainage, rehabilitation)
   - D. Traffic safety
   - E. Traffic capacity
   - F. Traffic flow theory
   - G. Traffic control devices
   - H. Transportation planning (e.g., travel forecast modeling)

16. Environmental Engineering 6-9
    A.   Water quality (ground and surface)
    B.   Basic tests (e.g. water, wastewater, air)
    C.   Environmental regulations
    D.   Water supply and treatment
    E.   Wastewater collection and treatment

17. Construction 4-6
    A.   Construction documents
    B.   Procurement methods (e.g., competitive bid, qualifications-based)
    C.   Project delivery methods (e.g., design-bid-build, design build, construction management, multiple prime)
    D.   Construction operations and methods (e.g., lifting, rigging, dewatering and pumping, equipment production, productivity analysis and improvement, temporary erosion control)
    E.   Project scheduling (e.g., CPM, allocation of resources)
    F.   Project management (e.g., owner/contractor/client relations)
    G.   Construction safety
    H.   Construction estimating

18. Surveying 4-6
    A.   Angles, distances, and trigonometry
    B.   Area computations
    C.   Earthwork and volume computations
    D.   Closure
    E.   Coordinate systems (e.g., state plane, latitude/longitude)
    F.   Leveling (e.g., differential, elevations, percent grades)

1. The only point of inflection on the curve representing the equation $y = x^3 + x^2 - 3$ is at:

A. $x = -\dfrac{2}{3}$

B. $x = -\dfrac{1}{3}$

C. $x = 0$

D. $x = \dfrac{1}{3}$

2. 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. you do not live in the jurisdiction where the transportation system is being installed

C. your original area of specialization was in transportation systems

D. you have regularly attended meetings of a professional engineering society

3. If $500 is invested at an annual interest rate of 8% per year, its future worth at the end of 30 years will be most nearly:

A. $1,200

B. $1,700

C. $5,031

D. $15,000

4.   The following preliminary concrete mix has been designed assuming that the aggregates are in oven-dry condition.

Water = 305 lb/yd³
Cement = 693 lb/yd³
Coarse aggregate (SSD) = 1,674 lb/yd³
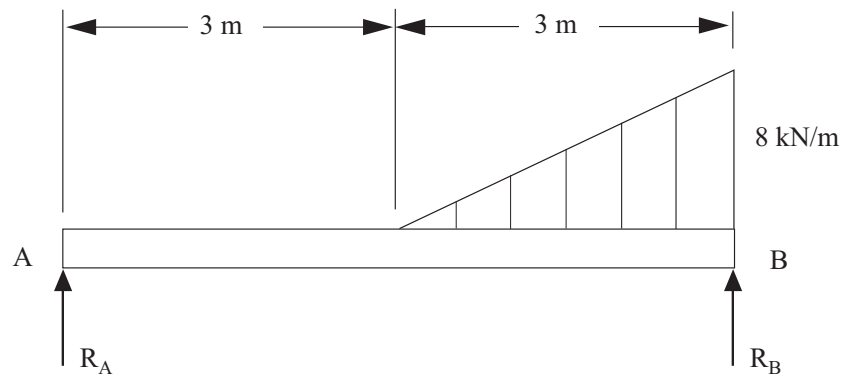Fine aggregate (SSD) = 1,100 lb/yd³

The properties of the aggregates are:

Property	Coarse Aggregate	Fine Aggregate
Absorption (moisture content at SSD)	0.5%	0.7%
Moisture content as used in mix	2.0%	6.0%

The amount of water (lb/yd³) that would be used in the final mix is most nearly:

A.   206
B.   222
C.   305
D.   388

5.   A 20-acre parcel of land has a rainfall intensity of 1.5 in./hr and a rational method runoff coefficient (C) of 0.10. The flow rate (cfs) for this site is most nearly:

A.   3.0
B.   5.0
C.   7.5
D.   9.0

6. Beam AB has a distributed load as shown and supports at A and B. If the weight of the beam is negligible, the force R_B (kN) is most nearly:

A. 24

B. 12

C. 10

D. 8

7. Which of the following is true of a normally consolidated clay?

A. It will not settle further under present loading conditions.

B. It appears to have been subjected to previous desiccation or drying.

C. It will settle an additional amount if the water table rises.

D. It appears to have been subjected to greater loading condition.

8.   A horizontal circular curve has the following data:

$I = 40°50'$
$R = 600.00$
Station of $PI = 20+00.00$

The station of the PT is most nearly:

A.   22+00.76

B.   22+04.27

C.   22+23.34

D.   22+32.34

9.   A municipal wastewater treatment plant is processing a waste flow with a 5-day BOD of 200 mg/L at 20°C. If the BOD rate constant k_1 (base e) at 20°C is 0.23 day⁻¹, the ultimate BOD (mg/L) of the raw wastewater at 20°C is most nearly:

A.   133

B.   233

C.   293

D.   420

10.   A loader has a full-bucket capacity of 3 yd³, and the average time required to place one bucketload of soil into a truck is 1 min. The loader is supported by four trucks with a volume of 15 yd³ each and a cycle time of 12 min plus the time to load the truck. The ideal productivity (yd³/hr) of this system is most nearly:

A.   180

B.   212

C.   277
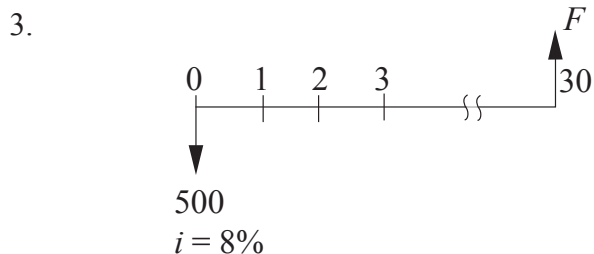
D.   300

1. $f(x) = x^3 + x^2 - 3$ Inflection point occurs when $f''(x) = 0$

   $f'(x) = 3x^2 + 2x$

   $f''(x) = 6x + 2$

   Set equal to zero

   $6x + 2 = 0$

   $x = -1/3$

   $f''(x)$ is negative below $x = -1/3$ and positive above $x = -1/3$

   Since $f''(x) = 0$ and $f''(x)$ changes signs at $x = -1/3$, the inflection point is at $x = -1/3$.

   THE CORRECT ANSWER IS: B

2. Refer to the NCEES Rules of Professional Conduct.

   THE CORRECT ANSWER IS: A

3.

   $F = 500(F/P, 8\%, 30)$
   $ = 500\,(10.0627)$
   $ = \$5,031$

   THE CORRECT ANSWER IS: C

4. The moisture content of each aggregate includes: (1) water that would be needed to bring aggregates to SSD condition (the absorbed water) and (2) the excess water that is free to add to the mix water. Since the as-used moisture content is greater than the absorption for each aggregate, each aggregate contributes the excess water to the mix, thus reducing the water that must be added to the mix. The water added to the mix is the water computed for oven-dry aggregates (305 lb/yd³) plus the excess water in each aggregate.

   Final water = $305 - [(2.0\% - 0.5\%)/100] \times 1{,}674 - [(6.0\% - 0.7\%)/100] \times 1{,}100 = 221.6$ lb/yd³

   THE CORRECT ANSWER IS: B

CIVIL

5. Use the rational formula.

$Q = CIA$
$Q = (0.10)(1.5 \text{ in./hr})(20 \text{ acres}) = 3.0 \text{ cfs}$

THE CORRECT ANSWER IS: A

6. The triangular force distribution can be replaced with a concentrated force F acting through the centroid of the triangle. The magnitude of F is numerically equal to the area of the triangle.

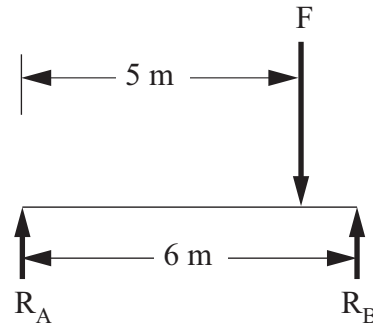$F = 1/2(3m)(8 \text{ kN/m})$

$F = 12 \text{ kN/m}$

$\Sigma M_A = 0$
$\Sigma M_A = (6m)(R_B) - (5m)(12 \text{ kN/m})$
$(6m)(R_B) - (5m)(12 \text{ kN/m}) = 0$

$6R_B = (5m)(12 \text{ kN/m})$

$6R_B = 60 \text{ kN}$

$R_B = 10 \text{ kN}$

THE CORRECT ANSWER IS: C

7. A normally consolidated clay will not settle further under present loading conditions.

THE CORRECT ANSWER IS: A

8. $T = R \tan\left(\frac{I}{2}\right) = 600 \times \tan\frac{40.8333°}{2} = 223.34$

$L = RI\frac{\pi}{180} = 600 \times 40.8333° \times \frac{\pi}{180} = 427.61$

$PC = PI - T = 20 + 00.00 - 223.34 = 17 + 76.66$

$PT = PC + L = 17 + 76.66 + 427.61 = 22 + 04.27$

THE CORRECT ANSWER IS: B

9. $BOD_5 = 200$ mg/L

    $\therefore t = 5$ days

    $k_1 = 0.23$ day^{-1}

    $BOD_t = BOD_{ult}\,(1 - e^{-k_1 t})$

    200 mg/L $= BOD_{ult}\,(1 - e^{-0.23 \times 5})$

    $BOD_{ult} = 200/(1 - e^{-1.15})$

    $BOD_{ult} = 292.7$ mg/L

    THE CORRECT ANSWER IS: C

10.   Time to load one truck $= 15$ yd^3/3 yd^3/min

                                       $= 5$ min

    Four trucks are available.

    Cycle time for one truck $= 5$ min loading plus 12 min to travel, dump, and return $= 17$ min.

    Loading time for four trucks $= 4 \times 5 = 20$ min.

    Therefore, an empty truck is always available to load.

$$\text{Ideal production capacity} = \left(\frac{60\,\text{min/hr}}{5\,\text{min/truck}}\right)\left(15\,\frac{\text{yd}^3}{\text{truck}}\right)$$

$$= 180\,\frac{\text{yd}^3}{\text{hr}}$$

    THE CORRECT ANSWER IS: A

Fundamentals of Engineering (FE)
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Knowledge	Number of Questions
1. Mathematics	11–17

A. Algebra and trigonometry
B. Complex numbers
C. Discrete mathematics
D. Analytic geometry
E. Calculus
F. Differential equations
G. Linear algebra
H. Vector analysis

2. Probability and Statistics   4–6
A. Measures of central tendencies and dispersions (e.g., mean, mode, standard deviation)
B. Probability distributions (e.g., discrete, continuous, normal, binomial)
C. Expected value (weighted average) in decision making
D. Estimation for a single mean (e.g., point, confidence intervals, conditional probability)

3. Ethics and Professional Practice   3–5
A. Codes of ethics (professional and technical societies)
B. NCEES Model Law and Model Rules
C. Intellectual property (e.g., copyright, trade secrets, patents)

4. Engineering Economics   3–5
A. Time value of money (e.g., present value, future value, annuities)
B. Cost estimation
C. Risk identification
D. Analysis (e.g., cost-benefit, trade-off, breakeven)

5. Properties of Electrical Materials   4–6
A. Chemical (e.g., corrosion, ions, diffusion)
B. Electrical (e.g., conductivity, resistivity, permittivity, magnetic permeability)
C. Mechanical (e.g., piezoelectric, strength)
D. Thermal (e.g., conductivity, expansion)

6. Engineering Sciences   6–9
A. Work, energy, power, heat
B. Charge, energy, current, voltage, power
C. Forces (e.g., between charges, on conductors)
D. Work done in moving a charge in an electric field (relationship between voltage and work)

E.   Capacitance
F.   Inductance

7. **Circuit Analysis (DC and AC Steady State)**   10-15
    A.   KCL, KVL
    B.   Series/parallel equivalent circuits
    C.   Thevenin and Norton theorems
    D.   Node and loop analysis
    E.   Waveform analysis (e.g., RMS, average, frequency, phase, wavelength)
    F.   Phasors
    G.   Impedance

8. **Linear Systems**   5-8
    A.   Frequency/transient response
    B.   Resonance
    C.   Laplace transforms
    D.   Transfer functions
    E.   2-port theory

9. **Signal Processing**   5-8
    A.   Convolution (continuous and discrete)
    B.   Difference equations
    C.   Z-transforms
    D.   Sampling (e.g., aliasing, Nyquist theorem)
    E.   Analog filters
    F.   Digital filters

10. **Electronics**   7-11
    A.   Solid-state fundamentals (e.g., tunneling, diffusion/drift current, energy
         bands, doping bands, p-n theory)
    B.   Discrete devices (diodes, transistors, BJT, CMOS) and models and their
         performance
    C.   Bias circuits
    D.   Amplifiers (e.g., single-stage/common emitter, differential)
    E.   Operational amplifiers (ideal, non-ideal)
    F.   Instrumentation (e.g., measurements, data acquisition, transducers)
    G.   Power electronics

11. **Power**   8-12
    A.   Single phase and three phase
    B.   Transmission and distribution
    C.   Voltage regulation
    D.   Transformers
    E.   Motors and generators
    F.   Power factor (pf)

12. **Electromagnetics**   5-8
    A.   Maxwell equations
    B.   Electrostatics/magnetostatics (e.g., measurement of spatial
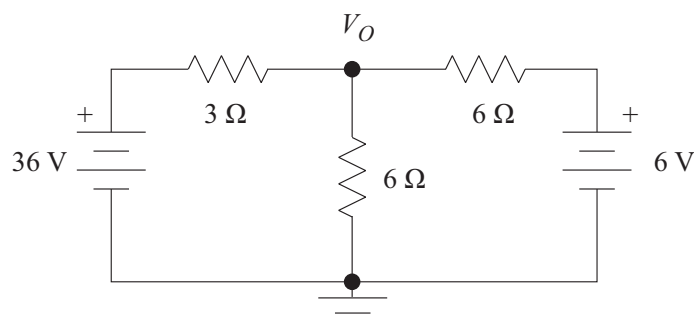   relationships, vector analysis)
    C.   Wave propagation

1. The only point of inflection on the curve representing the equation $y = x^3 + x^2 - 3$ is at:

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    B. $x = -\dfrac{1}{3}$

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3. If $500 is invested at an annual interest rate of 8% per year, its future worth at the end of 30 years will be most nearly:

    A. $1,200

    B. $1,700

    C. $5,031

    D. $15,000

4.   In the circuit shown, voltage V_O (V) is most nearly:

A.   19.5
B.   18.5
C.   16.5
D.   3.0

5.   The following electronic system is designed to process measurements from an accelerometer that produces the input voltage signal $v_1(t)$.

For a practical measurement situation, the signal v_2 is periodic and can be characterized by the Fourier series:

$$v_2(t) = 1.6 \sin (1,000t) + 0.8 \sin (2,000t) + 0.4 \sin (3,000t) + ...$$

The amplitude (volts) of the fundamental component in $v_3(t)$ is most nearly:

A.   1.6
B.   1.13
C.   0.56
D.   0.3

6. The figure below shows a circuit with an *n*-channel enhancement mode MOSFET transistor.

In the FET triode region:

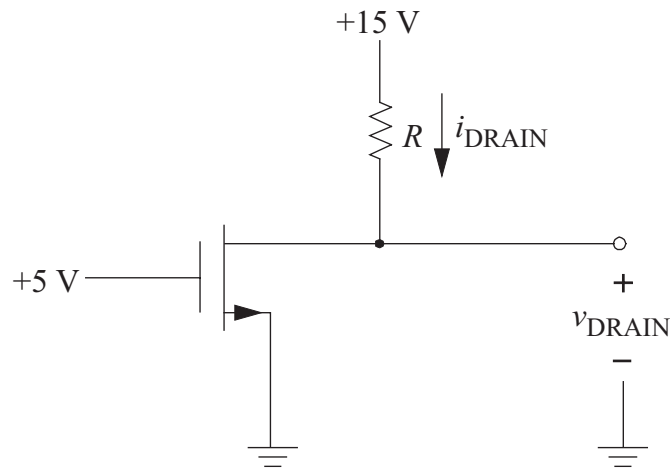$$i_{DRAIN} = K[2(v_{GS} - V_t)v_{DS} - v_{DS}^2]$$

In the FET saturation region:

$$i_{DRAIN} = K(v_{GS} - V_t)^2$$

The FET operates in saturation for $v_{DS} \geq v_{GS} - V_t$.

Assume that $K = 0.5$ mA/V² and $V_t = 1$ V.

If $v_{DRAIN} = 2$ V, the value of R (kΩ) is most nearly:

A.   1.63
B.   2.17
C.   2.50
D.   3.42

7. An industrial plant load is rated at 2.8 MVA at 0.7 pf lagging. If a capacitor bank rated at 3 MVA is added to the load, the new overall power factor of the system is most nearly:

A.   0.9 leading
B.   0.9 lagging
C.   0.6 leading
D.   0.6 lagging

8. The following Routh array has been constructed for a simple control system with a gain of K in the feedback path.

$$
\begin{array}{llll}
s^4 & 1 & 12 & 42K \\
s^3 & 7 & 10 + 14K & \\
s^2 & 74 - 14K & 42K & \\
s^1 & 196K^2 - 602K - 740 & & \\
s^0 & 42K & &
\end{array}
$$

The denominator of the **closed-loop** system transfer function is:

A. $s^3 + 7s^2 + 12s + 10$

B. $s^4 + 7s^3 + 12s^2 + 10s$

C. $s^4 + 7s^3 + 12s^2 + (10 + 14K)s + 42K$

D. not defined from the Routh array

9. Which of the following is true of the electric field intensity about an isolated point charge?

A. It varies directly as the distance to the charge.

B. It varies inversely as the distance to the charge.

C. It varies directly as the square of the distance to the charge.

D. It varies inversely as the square of the distance to the charge.

10. The binary number 1011 corresponds to the decimal number:

A. 3

B. 10

C. 11

D. 15

Solutions

1.　　$f(x) = x^3 + x^2 - 3$　　　　Inflection point occurs when $f''(x) = 0$

$f'(x) = 3x^2 + 2x$

$f''(x) = 6x + 2$

Set equal to zero

$6x + 2 = 0$

$x = -1/3$

$f''(x)$ is negative below $x = -1/3$ and positive above $x = -1/3$

Since $f''(x) = 0$ and $f''(x)$ changes signs at $x = -1/3$, the inflection point is at $x = -1/3$.

THE CORRECT ANSWER IS: B

2.　　Refer to the NCEES Rules of Professional Conduct.

THE CORRECT ANSWER IS: A

3.

$F = 500(F/P, 8\%, 30)$
  $= 500\,(10.0627)$
  $= \$5,031$

THE CORRECT ANSWER IS: C

4.　　Apply KCL to the node marked V_o:

$$\frac{1}{3}(V_o - 36) + \frac{1}{6}V_o + \frac{1}{6}(V_o - 6) = 0 \Longrightarrow V_o = 19.5\,\text{V}$$

THE CORRECT ANSWER IS: A

5. The second stage of the circuit is an inverting amplifier with a gain A_2 given by:

$$A_2 = -\frac{\mathbf{Z}_F}{10\,k\Omega} \text{ where } \mathbf{Z}_F = 10\,k\Omega \| (\frac{1}{j\omega C}) = \frac{10\,k\Omega}{1 + j\omega(10\,k\Omega \times 0.1\,\mu F \times 10^{-6})}$$

The frequency of the fundamental component is 1,000 rad/s, giving

$$\mathbf{Z}_F = \frac{10\,k\Omega}{(1+j)\Omega} = \frac{10,000}{\sqrt{2}} \angle -45° \text{ and } A_2 = 0.707 \angle -45°$$

Since the amplitude of the fundamental component of $v_2(t) = 1.6$ V, the amplitude of the fundamental component in $v_3(t) = 1.6 \times 0.707 = 1.13$ V.

THE CORRECT ANSWER IS: B

6. $v_{DS} = 2$ V

$v_{GS} - V_t = 5 - 1 = 4$ V

$v_{DS} < v_{GS} - V_t$, so the transistor operates in the triode region.

$i_{DRAIN} = 0.5\,[2(4)(2) - 4] = 6$ mA

$$R = \frac{15-2}{6} = 2.17\,k\Omega$$

THE CORRECT ANSWER IS: B

7. $P_L = 2.8\,(0.7) = 1.96$ MW

$Q_L = 2.8\,\sin[\cos^{-1} 0.7] = 2$ Mvar

$\mathbf{S}_L = P_L + jQ_L = 1.96 + j2$ MVA

$\mathbf{S} = \mathbf{S}_L + \mathbf{S}_C = (1.96 + j2) + (-j3) = 1.96 - j1 = 2.2\ \angle -27°$ MVA

pf $= \cos(-27°) = 0.89$ leading

THE CORRECT ANSWER IS: A

8.   From the given array, this is a fourth-order system. The denominator of the system is of the form:

$$a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s + a_0$$

The Routh array is formed by:

a_n	a_{n-2}	a_{n-4}	...	...	...
a_{n-1}	a_{n-3}	a_{n-5}	...	...	...
b_1	b_2	b_3	...	...	...
c_1	c_2	c_3	...	...	...

where

$$b_1 = \frac{a_{n-1}a_{n-2} - a_n a_{n-3}}{a_{n-1}} \qquad c_1 = \frac{a_{n-3}b_1 - a_{n-1}b_2}{b_1}$$

$$b_2 = \frac{a_{n-1}a_{n-4} - a_n a_{n-5}}{a_{n-1}} \qquad c_2 = \frac{a_{n-5}b_1 - a_{n-1}b_3}{b_1}$$

Substituting from the given Routh array yields the denominator polynomial:

$$s^4 + 7s^3 + 12s^2 + (10 + 14K)s + 42K$$

THE CORRECT ANSWER IS: C

9.   The formula for electric field intensity can be found in Electrostatic Fields in the Electrical and Computer Engineering section of the *FE Reference Handbook.* This formula is

$$\mathbf{E} = \frac{Q_1}{4\pi\varepsilon r^2}\mathbf{a}_{r12}$$

where r is the distance. Since r^2 is in the denominator, $\mathbf{E}$ varies inversely as the square of the distance to the charge.

THE CORRECT ANSWER IS: D

10. $1011 = (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$
       $= 8 + 0 + 2 + 1$
       $= 11$

THE CORRECT ANSWER IS: C

ELECTRICAL & COMPUTER

Fundamentals of Engineering (FE)
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Knowledge	Number of Questions
1. Mathematics	4–6
A. Analytic geometry	
B. Numerical methods	
C. Roots of equations	
D. Calculus	
E. Differential equations	
2. Probability and Statistics	3–5
A. Measures of central tendencies and dispersions (e.g., mean, mode, standard deviation)	
B. Probability distributions (e.g., discrete, continuous, normal, binomial)	
C. Estimation (point, confidence intervals) for a single mean	
D. Regression and curve fitting	
E. Expected value (weighted average) in decision making	
F. Hypothesis testing	
3. Ethics and Professional Practice	5–8
A. Codes of ethics (professional and technical societies)	
B. Agreements and contracts	
C. Ethical and legal considerations	
D. Professional liability	
E. Public protection issues (e.g., licensing boards)	
F. Regulations (e.g., water, wastewater, air, solid/hazardous waste, groundwater/soils)	
4. Engineering Economics	4–6
A. Discounted cash flow (e.g., life cycle, equivalence, PW, equivalent annual worth, FW, rate of return)	
B. Cost (e.g., incremental, average, sunk, estimating)	
C. Analyses (e.g., breakeven, benefit-cost)	
D. Uncertainty (expected value and risk)	
5. Materials Science	3–5
A. Properties (e.g., chemical, electrical, mechanical, physical)	
B. Corrosion mechanisms and controls	
C. Material selection and compatibility	

6. **Environmental Science and Chemistry** 11–17
   A. Reactions (e.g., equilibrium, acid base, oxidation-reduction, precipitation)
   B. Stoichiometry
   C. Kinetics (chemical, microbiological)
   D. Organic chemistry (e.g., nomenclature, functional group reactions)
   E. Ecology (e.g., Streeter-Phelps, fluviology, limnology, eutrophication)
   F. Multimedia equilibrium partitioning (e.g., Henry's law, octonal partitioning coefficient)

7. **Risk Assessment** 5–8
   A. Dose-response toxicity (carcinogen, noncarcinogen)
   B. Exposure routes

8. **Fluid Mechanics** 9–14
   A. Fluid statics
   B. Closed conduits (e.g., Darcy-Weisbach, Hazen-Williams, Moody)
   C. Open channel (Manning)
   D. Pumps (e.g., power, operating point, parallel and series)
   E. Flow measurement (e.g., weirs, orifices, flowmeters)
   F. Blowers (e.g., power, operating point, parallel, and series)

9. **Thermodynamics** 3–5
   A. Thermodynamic laws (e.g., 1st law, 2nd law)
   B. Energy, heat, and work
   C. Ideal gases
   D. Mixture of nonreacting gases
   E. Heat transfer

10. **Water Resources** 10–15
    A. Demand calculations
    B. Population estimations
    C. Runoff calculations (e.g., land use, land cover, time of concentration, duration, intensity, frequency)
    D. Reservoir sizing
    E. Routing (e.g., channel, reservoir)
    F. Water quality and modeling (e.g., erosion, channel stability, stormwater quality management)

11. **Water and Wastewater** 14–21
    A. Water and wastewater characteristics
    B. Mass and energy balances
    C. Conventional water treatment processes (e.g., clarification, disinfection, filtration, flocculation, softening, rapid mix)
    D. Conventional wastewater treatment processes (e.g., activated sludge, decentralized wastewater systems, fixed-film system, disinfection, flow equalization, headworks, lagoons)
    E. Alternative treatment process (e.g., conservation and reuse, membranes, nutrient removal, ion exchange, activated carbon, air stripping)
    F. Sludge treatment and handling (e.g., land application, sludge digestion, sludge dewatering)

ENVIRONMENTAL

12. **Air Quality**   10–15
    A. Chemical principles (e.g., ideal gas, mole fractions, stoichiometry, Henry's law)
    B. Mass balances
    C. Emissions (factors, rates)
    D. Atmospheric sciences (e.g., stability classes, dispersion modeling, lapse rates)
    E. Gas handling and treatment technologies (e.g., hoods, ducts, coolers, biofiltration, scrubbers, adsorbers, incineration)
    F. Particle handling and treatment technologies (e.g., baghouses, cyclones, electrostatic precipitators, settling velocity)

13. **Solid and Hazardous Waste**   10–15
    A. Composting
    B. Mass balances
    C. Compatibility
    D. Landfilling (e.g., siting, design, leachate, material and energy recovery)
    E. Site characterization and remediation
    F. Hazardous waste treatment (e.g., physical, chemical, thermal)
    G. Radioactive waste treatment and disposal

14. **Groundwater and Soils**   9–14
    A. Basic hydrogeology (e.g., aquifers, permeability, water table, hydraulic conductivity, saturation, soil characteristics)
    B. Drawdown (e.g., Jacob, Theis, Thiem)
    C. Groundwater flow (e.g., Darcy's law, specific capacity, velocity, gradient)
    D. Soil and groundwater remediation

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C. $5,031
D. $15,000

4.   A gas mixture at 25°C and 1 atm contains 100 mg/L of H_2S. The partial pressure (atm) exerted by the H_2S is most nearly:

A.   0.0029

B.   0.0056

C.   0.072

D.   0.14

5.   Which of the following is associated with the corrosion of sanitary sewers?

A. H_2S

B.   BOD

C.   Fats, oils, grease (FOG)

D. NH_3

6.   A pump is used to deliver water from a lake to an elevated storage tank. The pipe network consists of 1,800 ft (equivalent length) of 8-in. pipe (Hazen-Williams roughness coefficient = 120). Ignore minor losses. The pump discharge rate is 600 gpm. The friction loss (ft) is most nearly:

A.   15

B.   33

C.   106

D.   135

7.   A community has experienced the following exponential growth in population and
      water consumption.

Year	Population	Water Consumption (MGD)
1990	45,000	6.30
2000	61,000	9.45

If the rate of expected population growth remains equal to the observed growth rate in
the 1990s, but the per capita water consumption rate stabilizes at 160 gpd, the projected
water demand (MGD) in 2010 is most nearly:

A.   12.3
B.   12.6
C.   13.2
D.   14.2

8.   For coal-fired steam electric power plants, control of SO_x emissions is most commonly
      achieved by:

A.   lime scrubbing
B.   catalytic conversion
C.   electrostatic precipitation
D.   carbon adsorption

9.   A community generates 50,000 lb/day of solid waste that is disposed of in a sanitary
      landfill. The mass ratio of refuse to cover is 3 to 1. The in-place density of the fill
      (refuse plus cover) is 1,000 lb/yd³. The necessary volume (yd³) of fill (refuse plus cover)
      for a 10-year operation period is most nearly:

A.   730,000
B.   243,000
C.   183,000
D.   61,000

10. Two monitoring wells were constructed in an unconfined aquifer. The wells are separated by a distance of 250 ft. The water surface elevations in the up-gradient and down-gradient wells were 101.00 ft and 100.85 ft, respectively. The aquifer hydraulic conductivity is 5 ft/day. The fluid velocity (ft/day) in the aquifer is most nearly:

   A.　0.0006

   B.　0.003

   C.　0.75

   D.　5

Solutions

1. $f(x) = x^3 + x^2 - 3$ Inflection point occurs when $f''(x) = 0$

$f'(x) = 3x^2 + 2x$

$f''(x) = 6x + 2$

Set equal to zero

$6x + 2 = 0$

$x = -1/3$

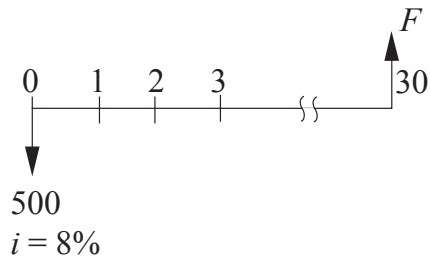$f''(x)$ is negative below $x = -1/3$ and positive above $x = -1/3$

Since $f''(x) = 0$ and $f''(x)$ changes signs at $x = -1/3$, the inflection point is at $x = -1/3$.

THE CORRECT ANSWER IS: B

2.   Refer to the NCEES Rules of Professional Conduct.

THE CORRECT ANSWER IS: A

3.

$F = 500(F/P, 8\%, 30)$

   $= 500 (10.0627)$

   $= \$5,031$

THE CORRECT ANSWER IS: C

Solutions

4.   MW H_2S = 34 g/mol

$$\text{Moles } H_2S = \left(\frac{100 \text{ mg}}{34\text{g/mol}}\right)\left(\frac{1 \text{ g}}{1,000 \text{ mg}}\right) = 0.0029 \text{ mol } H_2S$$

Using $PV = nRT$, the volume of H_2S =

$$V = \frac{nRT}{P} = \frac{(0.0029 \text{ mol})(0.08206 \frac{L°\text{atm}}{\text{mol}°K})(298 \text{ K})}{1 \text{ atm}} = 0.072 \text{ L}$$

$$\text{Partial pressure} = \frac{\text{volume of gas}}{\text{volume of air}}$$

$$\frac{0.072 \text{ L}}{1 \text{ L}} = 0.072$$

THE CORRECT ANSWER IS: C

5. H_2S is the primary product produced under conditions that can cause corrosion.

THE CORRECT ANSWER IS: A

6. $V = k_1 CR^{0.63} S^{0.54} = k_1 CR^{0.63} (h_f/L)^{0.54}$

$$\therefore h_f = L\left[\frac{V}{k_1 CR^{0.63}}\right]^{1.85}$$

$k_1 = 1.318$

$L = 1,800$ ft

$$V = \frac{Q}{A} = \frac{600 \text{ gal/min}}{(7.48 \text{ gal/ft}^3)(60 \text{ sec/min})(\pi (8/12 \text{ ft})^2/4)} = 3.830 \text{ ft/sec}$$

$C = 120$

$R = D/4 = (8/12 \text{ ft})/4 = 0.1667$ ft

$$h_f = 1,800\left[\frac{3.830}{(1.318)(120)(0.1667)^{0.63}}\right]^{1.85} = 14.9 \text{ ft}$$

THE CORRECT ANSWER IS: A

7. Annual population growth:

$$= \left(\frac{61,000}{45,000}\right)^{1/10} = 1.0309 \ (3.09\%)$$

Projected population in 2010 = $(61,000)(1.0309)^{10} = 82,689$

Flow = $(82,689)(160 \ \text{gpd})(10^{-6} \ \text{Mgal/gal}) = 13.2 \ \text{MGD}$

THE CORRECT ANSWER IS: C

8. SO_x is removed by liquid scrubbing at a high pH. Lime may be added to raise the pH.

THE CORRECT ANSWER IS: A

9. Determine mass of cover.

$$\text{Cover} = (50,000 \ \text{lb refuse})(\frac{1 \ \text{lb cover}}{3 \ \text{lb refuse}}) = 16,667 \ \text{lb}$$

Total mass fill (10-year life)

Fill = $(50,000 \ \text{lb/day refuse} + 16,667 \ \text{lb/day cover})(365 \ \text{days/yr})(10 \ \text{yr}) = 2.433 \times 10^8 \ \text{lb}$

$$\text{Volume} = \frac{2.433 \times 10^8 \ \text{lb}}{1,000 \ \text{lb/yd}^3} = 243,000 \ \text{yd}^3$$

THE CORRECT ANSWER IS: B

10. Darcy's Equation

$Q = (KA)(dh/dx)$

$V = Q/A = K \ \Delta h/\Delta x$

$K = 5 \ \text{ft/day}$

$\Delta h = 101.00 \ \text{ft} - 100.85 \ \text{ft} = 0.15 \ \text{ft}$

$\Delta x = 250 \ \text{ft}$

$$V = (5 \ \text{ft/day})\frac{(0.15 \ \text{ft})}{(250 \ \text{ft})} = 0.003 \ \text{ft/day}$$

THE CORRECT ANSWER IS: B

Fundamentals of Engineering (FE)
INDUSTRIAL CBT Exam Specifications

Effective Beginning with the January 2014 Examinations

- The FE exam is a computer-based test (CBT). It is closed book with an electronic reference.
- Examinees have 6 hours to complete the exam, which contains 110 multiple-choice questions. The 6-hour time also includes a tutorial, a break, and a brief survey at the conclusion.
- The FE exam uses both the International System of Units (SI) and the US Customary System (USCS).

Knowledge	Number of Questions
1. Mathematics	6–9

1. **Mathematics** 6–9
   A. Analytic geometry
   B. Calculus
   C. Matrix operations
   D. Vector analysis
   E. Linear algebra

2. **Engineering Sciences** 5–8
   A. Work, energy, power
   B. Material properties and selection
   C. Charge, energy, current, voltage, and power

3. **Ethics and Professional Practice** 5–8
   A. Codes of ethics and licensure
   B. Agreements and contracts
   C. Professional, ethical, and legal responsibility
   D. Public protection and regulatory issues

4. **Engineering Economics** 10–15
   A. Discounted cash flows (PW, EAC, FW, IRR, amortization)
   B. Types and breakdown of costs (e.g., fixed, variable, direct and indirect labor)
   C. Cost analyses (e.g., benefit-cost, breakeven, minimum cost, overhead)
   D. Accounting (financial statements and overhead cost allocation)
   E. Cost estimation
   F. Depreciation and taxes
   G. Capital budgeting

5. **Probability and Statistics** 10–15
   A. Combinatorics (e.g., combinations, permutations)
   B. Probability distributions (e.g., normal, binomial, empirical)
   C. Conditional probabilities
   D. Sampling distributions, sample sizes, and statistics (e.g., central tendency, dispersion)
   E. Estimation (e.g., point, confidence intervals)
   F. Hypothesis testing
   G. Regression (linear, multiple)
   H. System reliability (e.g., single components, parallel and series systems)
   I. Design of experiments (e.g., ANOVA, factorial designs)

6. **Modeling and Computations**   8–12
    A. Algorithm and logic development (e.g., flow charts, pseudocode)
    B. Databases (e.g., types, information content, relational)
    C. Decision theory (e.g., uncertainty, risk, utility, decision trees)
    D. Optimization modeling (e.g., decision variables, objective functions, and constraints)
    E. Linear programming (e.g., formulation, primal, dual, graphical solutions)
    F. Mathematical programming (e.g., network, integer, dynamic, transportation, assignment)
    G. Stochastic models (e.g., queuing, Markov, reliability)
    H. Simulation

7. **Industrial Management**   8–12
    A. Principles (e.g., planning, organizing, motivational theory)
    B. Tools of management (e.g., MBO, reengineering, organizational structure)
    C. Project management (e.g., scheduling, PERT, CPM)
    D. Productivity measures

8. **Manufacturing, Production, and Service Systems**   8–12
    A. Manufacturing processes
    B. Manufacturing systems (e.g., cellular, group technology, flexible)
    C. Process design (e.g., resources, equipment selection, line balancing)
    D. Inventory analysis (e.g., EOQ, safety stock)
    E. Forecasting
    F. Scheduling (e.g., sequencing, cycle time, material control)
    G. Aggregate planning
    H. Production planning (e.g., JIT, MRP, ERP)
    I. Lean enterprises
    J. Automation concepts (e.g., robotics, CIM)
    K. Sustainable manufacturing (e.g., energy efficiency, waste reduction)
    L. Value engineering

9. **Facilities and Logistics**   8–12
    A. Flow measurements and analysis (e.g., from/to charts, flow planning)
    B. Layouts (e.g., types, distance metrics, planning, evaluation)
    C. Location analysis (e.g., single- and multiple-facility location, warehouses)
    D. Process capacity analysis (e.g., number of machines and people, trade-offs)
    E. Material handling capacity analysis
    F. Supply chain management and design

10. **Human Factors, Ergonomics, and Safety**   8–12
    A. Hazard identification and risk assessment
    B. Environmental stress assessment (e.g., noise, vibrations, heat)
    C. Industrial hygiene
    D. Design for usability (e.g., tasks, tools, displays, controls, user interfaces)
    E. Anthropometry
    F. Biomechanics
    G. Cumulative trauma disorders (e.g., low back injuries, carpal tunnel syndrome)
    H. Systems safety
    I. Cognitive engineering (e.g., information processing, situation awareness, human error, mental models)

11. **Work Design** 8–12
   A. Methods analysis (e.g., charting, workstation design, motion economy)
   B. Time study (e.g., time standards, allowances)
   C. Predetermined time standard systems (e.g., MOST, MTM)
   D. Work sampling
   E. Learning curves

12. **Quality** 8–12
   A. Six sigma
   B. Management and planning tools (e.g., fishbone, Pareto, QFD, TQM)
   C. Control charts
   D. Process capability and specifications
   E. Sampling plans
   F. Design of experiments for quality improvement
   G. Reliability engineering

13. **Systems Engineering** 8–12
   A. Requirements analysis
   B. System design
   C. Human systems integration
   D. Functional analysis and allocation
   E. Configuration management
   F. Risk management
   G. Verification and assurance
   H. System life-cycle engineering

1.   The only point of inflection on the curve representing the equation $y = x^3 + x^2 - 3$ is at:

A. $x = -\dfrac{2}{3}$

B. $x = -\dfrac{1}{3}$

C. $x = 0$
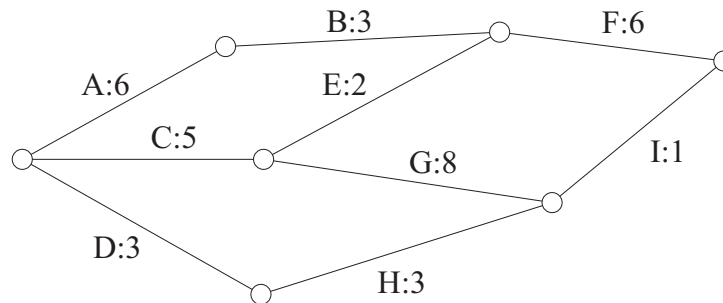
D. $x = \dfrac{1}{3}$

2.   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.   you do not live in the jurisdiction where the transportation system is being installed

C.   your original area of specialization was in transportation systems

D.   you have regularly attended meetings of a professional engineering society

3.   If $500 is invested at an annual interest rate of 8% per year, its future worth at the end of 30 years will be most nearly:

A. $1,200

B. $1,700

C. $5,031

D. $15,000

INDUSTRIAL

4. 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:
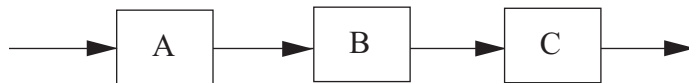
    A.   0.0013

    B.   0.0026

    C.   0.2600

    D.   0.9987

5. The project network below shows activity durations in weeks. There is a likelihood that Activity D cannot start until the end of Week 3. In this context, the earliest that the project can be completed is the end of Week:

    A.   15

    B.   17

    C.   18

    D.   43

6. The following process creates 10,000 good units per year.

The scrap rate of Process C is 20%. Process B has a scrap rate of 10%. To ensure that the raw material input to the system at Process A is limited to 18,519 or less, the maximum allowable scrap rate for Process A is most nearly:

    A.   10%

    B.   20%

    C.   25%

    D.   75%

7. A warehouse services thirty 53-ft trailers per 8-hr shift using forklifts. The typical 53-ft trailer holds 26 pallets. The warehouse receives in the first half of the shift and ships in the second half of the shift. The work standard for forklift operations is listed below:

Load/unload pallet from trailer	45 sec
Move from dock to warehouse or warehouse to dock	120 sec
Load/unload pallet from rack	30 sec
Move within warehouse	60 sec

The number of forklifts needed to process all the pallets is most nearly:

A. 7

B. 9

C. 10

D. 11

8. Polychlorinated-biphenyls (PCBs) and 2, 3, 7, 8-TCDD (dioxin) are both considered lethal in sufficient concentration. The ratio of the rates of the median lethal single dose of PCB and the median lethal single dose of dioxin that is expected to kill 50% of a group of test animals is most nearly:

A. 1.5×10^7

B. 1.5×10^4

C. 1.0×10^{-3}

D. 6.7×10^{-8}

9.	An industrial engineer conducted a time study of an assembly operation with the times given below.

Observation	Time	Observation	Time
1	3.10	6	3.15
2	3.05	7	3.12
3	3.10	8	3.08
4	3.08	9	3.05
5	3.12	10	3.10

The engineer gave a performance rating of 115. The allowance factor is 10% of job time. The standard time for this operation is most nearly:

A.	2.96

B.	3.20

C.	3.56

D.	3.92

10.	Which of the following is true for process capability?

A.	C_{pk} normally is greater than C_p.

B.	If the process is not centered, then C_{pk} equals C_p.

C.	C_p measures potential performance if the process is centered.

D.	C_{pk} is normally negative.
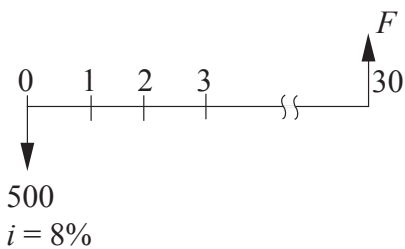
Solutions

1. $f(x) = x^3 + x^2 - 3$ Inflection point occurs when $f''(x) = 0$

       $f'(x) = 3x^2 + 2x$

       $f''(x) = 6x + 2$

       Set equal to zero

       $6x + 2 = 0$

       $x = -1/3$

       $f''(x)$ is negative below $x = -1/3$ and positive above $x = -1/3$

       Since $f''(x) = 0$ and $f''(x)$ changes signs at $x = -1/3$, the inflection point is at $x = -1/3$.

       THE CORRECT ANSWER IS: B

2.   Refer to the NCEES Rules of Professional Conduct.

       THE CORRECT ANSWER IS: A

3.

       $F = 500(F/P, 8\%, 30)$

          $= 500 \,(10.0627)$

          $= \$5{,}031$

       THE CORRECT ANSWER IS: C
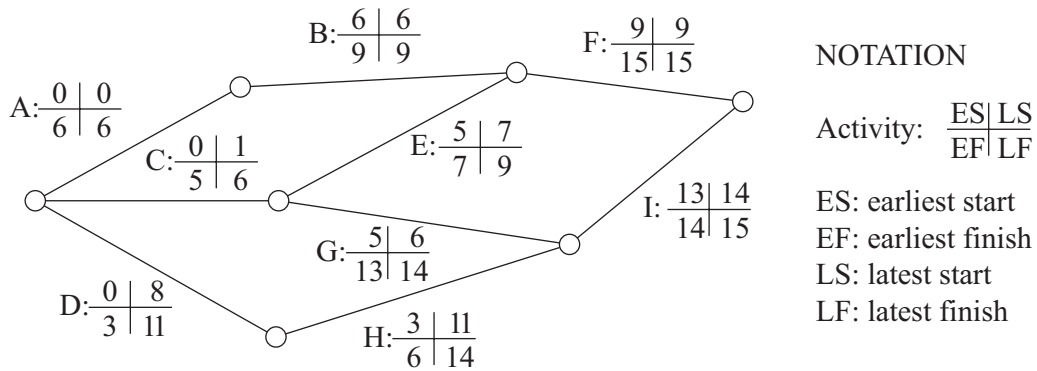

4. $8 - 15.5 = 7.5$

       $\dfrac{7.5}{2.5} = 3$ standard deviations

       From the Unit Normal Distribution table, for $x = 3$, $R(x) = 0.0013$

       THE CORRECT ANSWER IS: A

5. The diagram with early start, late start, early finish, and late finish times is as follows:

The critical path is A–B–F. Activity D has slack of 8 weeks, so starting Activity D at the end of Week 3 will not affect the completion date. Therefore, A–B–F will still be the critical path with a time of 15 weeks.

THE CORRECT ANSWER IS: A

6. Input to Process C = 10,000/0.8 = 12,500 units

Scrap rate of Process B = 10%

So, input to Process B = 12,500/0.9 = 13,889 units

So, $\dfrac{13,889}{(1-x)} \leq 18,519$

$$\dfrac{(1-x)}{13,889} \geq \dfrac{1}{18,519}$$

$$(1-x) \geq 0.75$$

$$-x \geq -0.25$$

$$x \leq 0.25$$

THE CORRECT ANSWER IS: C

7. Time to process 1 pallet = 45 + 120 + 60 + 30 + 120 = 375 sec, or 6.25 min

Pallets processed/shift = 30 × 26 = 780

Pallet processing time = $\dfrac{780 \times 6.25}{60}$ = 81.25 hr

$\dfrac{81.25 \text{ hr}}{8 \text{ hr/forklift}} = 10.15$

THE CORRECT ANSWER IS: C

8. LD_{50} PCB = 15,000

    LD_{50} dioxin = 0.001

    $Ratio = \dfrac{15,000}{0.001} = 1.5 \times 10^7$

    THE CORRECT ANSWER IS: A

9. Observed time = $\Sigma t/n$ = 30.95/10 = 3.095
    Normal time = $OT \times PR$ = 3.095 × 1.15 = 3.559
    Standard time = $NT + AF$ = 3.559 × 1.1 = 3.915

    THE CORRECT ANSWER IS: D

10. C_p indicates how well the process can perform if it is "centered" in the specification band.

    THE CORRECT ANSWER IS: C

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Knowledge	Number of Questions

1. Mathematics 6-9
   A. Analytic geometry
   B. Calculus
   C. Linear algebra
   D. Vector analysis
   E. Differential equations
   F. Numerical methods

2. Probability and Statistics 4-6
   A. Probability distributions
   B. Regression and curve fitting

3. Computational Tools 3-5
   A. Spreadsheets
   B. Flow charts

4. Ethics and Professional Practice 3-5
   A. Codes of ethics
   B. Agreements and contracts
   C. Ethical and legal considerations
   D. Professional liability
   E. Public health, safety, and welfare

5. Engineering Economics 3-5
   A. Time value of money
   B. Cost, including incremental, average, sunk, and estimating
   C. Economic analyses
   D. Depreciation

6. Electricity and Magnetism 3-5
   A. Charge, current, voltage, power, and energy
   B. Current and voltage laws (Kirchhoff, Ohm)
   C. Equivalent circuits (series, parallel)
   D. AC circuits
   E. Motors and generators

7. Statics 8-12
   A. Resultants of force systems
   B. Concurrent force systems
   C. Equilibrium of rigid bodies
   D. Frames and trusses

    E.   Centroids
    F.   Moments of inertia
    G.   Static friction

8. Dynamics, Kinematics, and Vibrations   9–14
    A.   Kinematics of particles
    B.   Kinetic friction
    C.   Newton's second law for particles
    D.   Work-energy of particles
    E.   Impulse-momentum of particles
    F.   Kinematics of rigid bodies
    G.   Kinematics of mechanisms
    H.   Newton's second law for rigid bodies
    I.   Work-energy of rigid bodies
    J.   Impulse-momentum of rigid bodies
    K.   Free and forced vibrations

9. Mechanics of Materials   8–12
    A.   Shear and moment diagrams
    B.   Stress types (axial, bending, torsion, shear)
    C.   Stress transformations
    D.   Mohr's circle
    E.   Stress and strain caused by axial loads
    F.   Stress and strain caused by bending loads
    G.   Stress and strain caused by torsion
    H.   Stress and strain caused by shear
    I.   Combined loading
    J.   Deformations
    K.   Columns

10. Material Properties and Processing   8–12
    A.   Properties, including chemical, electrical, mechanical, physical, and thermal
    B.   Stress-strain diagrams
    C.   Engineered materials
    D.   Ferrous metals
    E.   Nonferrous metals
    F.   Manufacturing processes
    G.   Phase diagrams
    H.   Phase transformation, equilibrium, and heat treating
    I.   Materials selection
    J.   Surface conditions
    K.   Corrosion mechanisms and control
    L.   Thermal failure
    M.   Ductile or brittle behavior
    N.   Fatigue
    O.   Crack propagation

11. Fluid Mechanics   9–14
    A.   Fluid properties
    B.   Fluid statics
    C.   Energy, impulse, and momentum
    D.   Internal flow

E.   External flow
F.   Incompressible flow
G.   Compressible flow
H.   Power and efficiency
I.   Performance curves
J.   Scaling laws for fans, pumps, and compressors
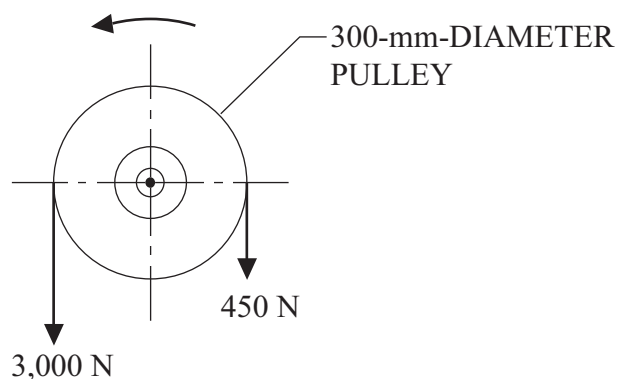
12.   **Thermodynamics**   13-20
A.   Properties of ideal gases and pure substances
B.   Energy transfers
C.   Laws of thermodynamics
D.   Processes
E.   Performance of components
F.   Power cycles, thermal efficiency, and enhancements
G.   Refrigeration and heat pump cycles and coefficients of performance
H.   Nonreacting mixtures of gases
I.   Psychrometrics
J.   Heating, ventilating, and air-conditioning (HVAC) processes
K.   Combustion and combustion products

13.   **Heat Transfer**   9-14
A.   Conduction
B.   Convection
C.   Radiation
D.   Thermal resistance
E.   Transient processes
F.   Heat exchangers
G.   Boiling and condensation

14.   **Measurements, Instrumentation, and Controls**   5-8
A.   Sensors
B.   Block diagrams
C.   System response
D.   Measurement uncertainty

15.   **Mechanical Design and Analysis**   9-14
A.   Stress analysis of machine elements
B.   Failure theories and analysis
C.   Deformation and stiffness
D.   Springs
E.   Pressure vessels
F.   Beams
G.   Piping
H.   Bearings
I.   Power screws
J.   Power transmission
K.   Joining methods
L.   Manufacturability
M.   Quality and reliability
N.   Hydraulic components
O.   Pneumatic components
P.   Electromechanical components

1.   The only point of inflection on the curve representing the equation $y = x^3 + x^2 - 3$ is at:

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A. $1,200
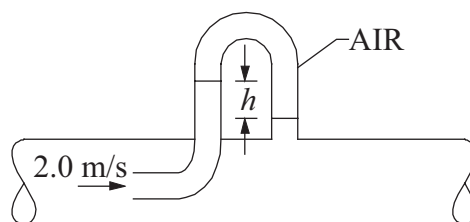
B. $1,700

C. $5,031

D. $15,000

4. A pulley is driven by a belt as shown in the figure below. Neglecting centrifugal effects, the minimum coefficient of friction that will prevent slipping between the belt and the pulley is most nearly:

300-mm-DIAMETER PULLEY

450 N

3,000 N

A.   0.60
B.   0.56
C.   0.31
D.   0.20

5. A 2-kg block slides along a rough horizontal surface and slows to 10 m/s after traveling 20 m. If the kinetic coefficient of friction between the block and surface is 0.2, the initial speed (m/s) of the block was most nearly:

A.   10.0
B.   10.4
C.   13.4
D.   20.0

6. 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

7. 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

8. Conditioned air enters a room at 13°C and 70% relative humidity. The dew-point temperature of the air is most nearly:

A. 5°C

B. 8°C

C. 10°C

D. 13°C

9. A heat exchanger is 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. 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

10. 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:
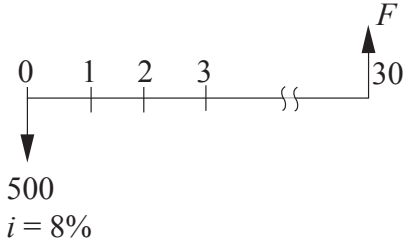
A. 1,500

B. 2,500

C. 4,800

D. 6,500

1. $f(x) = x^3 + x^2 - 3$ Inflection point occurs when $f''(x) = 0$

    $f'(x) = 3x^2 + 2x$

    $f''(x) = 6x + 2$

    Set equal to zero

    $6x + 2 = 0$

    $x = -1/3$

    $f''(x)$ is negative below $x = -1/3$ and positive above $x = -1/3$

    Since $f''(x) = 0$ and $f''(x)$ changes signs at $x = -1/3$, the inflection point is at $x = -1/3$.

THE CORRECT ANSWER IS: B

2. Refer to the NCEES Rules of Professional Conduct.

THE CORRECT ANSWER IS: A

3.

$F = 500(F/P, 8\%, 30)$

    $= 500 (10.0627)$

    $= \$5,031$

THE CORRECT ANSWER IS: C

4. $F_1 = F_2 \, e^{\mu\theta}$

   $3{,}000 = 450e^{\mu\pi}$

   Set μ equal to μ_s, the static coefficient; and $\theta = \pi$, the angle of the wrap.

   $\therefore \mu_s\pi = \ln \dfrac{3{,}000}{450}, \mu = \dfrac{1}{\pi} \ln \dfrac{3{,}000}{450}$
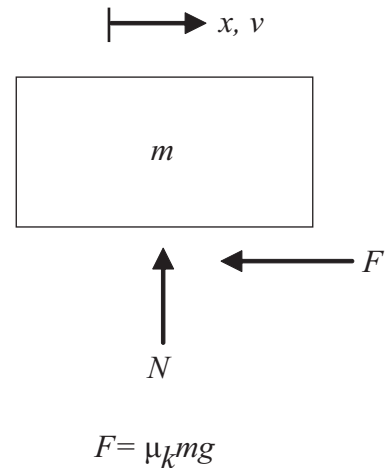
   $\mu_s = 0.60$

   THE CORRECT ANSWER IS: A

5. $T_2 + U_2 = T_1 + U_1 + W_{1 \to 2}, \quad W_{1 \to 2} = -Fx$

   $\dfrac{1}{2} mv_2^2 = \dfrac{1}{2} mv_1^2 - \mu_k mgx$

   Cancel m to obtain $\to \dfrac{1}{2}(10)^2 = \dfrac{1}{2} v_1^2 - 0.2(9.81)(20)$

   $v_1 = 13.4$ m/s

   THE CORRECT ANSWER IS: C

   x, v →

   m

   N

   F

   $F = \mu_k mg$

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

   THE CORRECT ANSWER IS: D
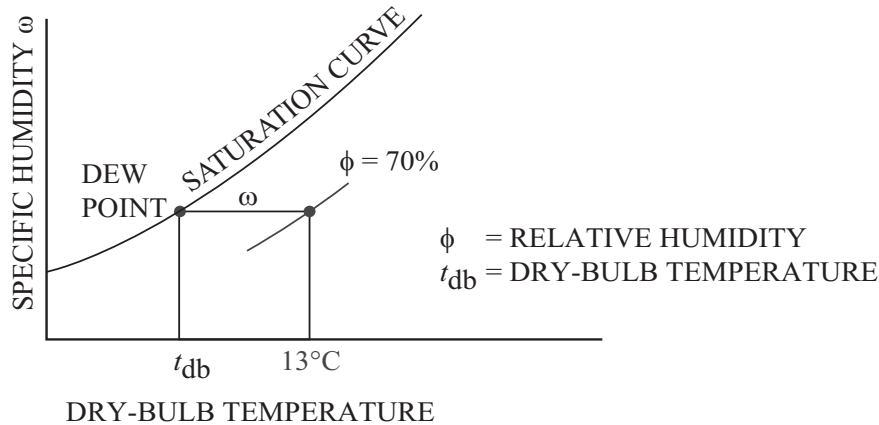
7. $\dfrac{\rho v^2}{2} = gh\,(\rho - \rho_{air})$

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

   THE CORRECT ANSWER IS: D

MECHANICAL

8.   Refer to the appropriate psychrometric chart.

DRY-BULB TEMPERATURE

At the given state, t_{db} = 13°C, ϕ = 70%, ω = 6.5 g/kg da, da = dry air.
Follow the ω = 6.5 line to the left until the saturation curve is reached.
This point is the dew point. Read down to find the dew-point temperature of 7.6°C.

THE CORRECT ANSWER IS: B

9.   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

10.   The force required to displace a spring an amount δ from its free length is F = kδ,
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 = kδ = (38.525 N/mm)(65 mm) = 2,504 N

THE CORRECT ANSWER IS: B

MECHANICAL

Fundamentals of Engineering (FE)
OTHER DISCIPLINES CBT Exam Specifications

Effective Beginning with the January 2014 Examinations

- The FE exam is a computer-based test (CBT). It is closed book with an electronic reference.
- Examinees have 6 hours to complete the exam, which contains 110 multiple-choice questions. The 6-hour time also includes a tutorial, a break, and a brief survey at the conclusion.
- The FE exam uses both the International System of Units (SI) and the US Customary System (USCS).

Knowledge	Number of Questions
1. Mathematics and Advanced Engineering Mathematics	12–18
A. Analytic geometry and trigonometry	
B. Calculus	
C. Differential equations (e.g., homogeneous, nonhomogeneous, Laplace transforms)	
D. Numerical methods (e.g., algebraic equations, roots of equations, approximations, precision limits)	
E. Linear algebra (e.g., matrix operations)	
2. Probability and Statistics	6–9
A. Measures of central tendencies and dispersions (e.g., mean, mode, variance, standard deviation)	
B. Probability distributions (e.g., discrete, continuous, normal, binomial)	
C. Estimation (e.g., point, confidence intervals)	
D. Expected value (weighted average) in decision making	
E. Sample distributions and sizes	
F. Goodness of fit (e.g., correlation coefficient, least squares)	
3. Chemistry	7–11
A. Periodic table (e.g., nomenclature, metals and nonmetals, atomic structure of matter)	
B. Oxidation and reduction	
C. Acids and bases	
D. Equations (e.g., stoichiometry, equilibrium)	
E. Gas laws (e.g., Boyle's and Charles' Laws, molar volume)	
4. Instrumentation and Data Acquisition	4–6
A. Sensors (e.g., temperature, pressure, motion, pH, chemical constituents)	
B. Data acquisition (e.g., logging, sampling rate, sampling range, filtering, amplification, signal interface)	
C. Data processing (e.g., flow charts, loops, branches)	
5. Ethics and Professional Practice	3–5
A. Codes of ethics	
B. NCEES Model Law	
C. Public protection issues (e.g., licensing boards)	

6. **Safety, Health, and Environment**   4-6
   A. Industrial hygiene (e.g., carcinogens, toxicology, MSDS, lower
      exposure limits)
   B. Basic safety equipment (e.g., pressure relief valves, emergency
      shut-offs, fire prevention and control, personal protective equipment)
   C. Gas detection and monitoring (e.g., O_2, CO, CO_2, CH_4, H_2S, Radon)
   D. Electrical safety

7. **Engineering Economics**   7-11
   A. Time value of money (e.g., present worth, annual worth, future worth,
      rate of return)
   B. Cost (e.g., incremental, average, sunk, estimating)
   C. Economic analyses (e.g., breakeven, benefit-cost, optimal economic life)
   D. Uncertainty (e.g., expected value and risk)
   E. Project selection (e.g., comparison of unequal life projects,
      lease/buy/make, depreciation, discounted cash flow)

8. **Statics**   8-12
   A. Resultants of force systems and vector analysis
   B. Concurrent force systems
   C. Force couple systems
   D. Equilibrium of rigid bodies
   E. Frames and trusses
   F. Area properties (e.g., centroids, moments of inertia, radius of gyration)
   G. Static friction

9. **Dynamics**   7-11
   A. Kinematics
   B. Linear motion (e.g., force, mass, acceleration)
   C. Angular motion (e.g., torque, inertia, acceleration)
   D. Mass moment of inertia
   E. Impulse and momentum (linear and angular)
   F. Work, energy, and power
   G. Dynamic friction
   H. Vibrations

10. **Strength of Materials**   8-12
    A. Stress types (e.g., normal, shear, bending, torsion)
    B. Combined stresses
    C. Stress and strain caused by axial loads, bending loads, torsion, or shear
    D. Shear and moment diagrams
    E. Analysis of beams, trusses, frames, and columns
    F. Deflection and deformations (e.g., axial, bending, torsion)
    G. Elastic and plastic deformation
    H. Failure theory and analysis (e.g., static/dynamic, creep, fatigue,
       fracture, buckling)

11. **Materials Science**   6-9
    A. Physical, mechanical, chemical, and electrical properties of ferrous metals
    B. Physical, mechanical, chemical, and electrical properties of nonferrous metals
    C. Physical, mechanical, chemical, and electrical properties of engineered
       materials (e.g., polymers, concrete, composites)
    D. Corrosion mechanisms and control

12. **Fluid Mechanics and Dynamics of Liquids**   8-12
    A. Fluid properties (e.g., Newtonian, non-Newtonian)
    B. Dimensionless numbers (e.g., Reynolds number, Froude number)
    C. Laminar and turbulent flow
    D. Fluid statics
    E. Energy, impulse, and momentum equations (e.g., Bernoulli equation)
    F. Pipe flow and friction losses (e.g., pipes, valves, fittings, Darcy-Weisbach equation, Hazen-Williams equation)
    G. Open-channel flow (e.g., Manning equation, drag)
    H. Fluid transport systems (e.g., series and parallel operations)
    I. Flow measurement
    J. Turbomachinery (e.g., pumps, turbines)

13. **Fluid Mechanics and Dynamics of Gases**   4-6
    A. Fluid properties (e.g., ideal and non-ideal gases)
    B. Dimensionless numbers (e.g., Reynolds number, Mach number)
    C. Laminar and turbulent flow
    D. Fluid statics
    E. Energy, impulse, and momentum equations
    F. Duct and pipe flow and friction losses
    G. Fluid transport systems (e.g., series and parallel operations)
    H. Flow measurement
    I. Turbomachinery (e.g., fans, compressors, turbines)

14. **Electricity, Power, and Magnetism**   7-11
    A. Electrical fundamentals (e.g., charge, current, voltage, resistance, power, energy)
    B. Current and voltage laws (Kirchhoff, Ohm)
    C. DC circuits
    D. Equivalent circuits (series, parallel, Norton's theorem, Thevenin's theorem)
    E. Capacitance and inductance
    F. AC circuits (e.g., real and imaginary components, complex numbers, power factor, reactance and impedance)
    G. Measuring devices (e.g., voltmeter, ammeter, wattmeter)

15. **Heat, Mass, and Energy Transfer**   9-14
    A. Energy, heat, and work
    B. Thermodynamic laws (e.g., 1st law, 2nd law)
    C. Thermodynamic equilibrium
    D. Thermodynamic properties (e.g., entropy, enthalpy, heat capacity)
    E. Thermodynamic processes (e.g., isothermal, adiabatic, reversible, irreversible)
    F. Mixtures of nonreactive gases
    G. Heat transfer (e.g., conduction, convection, and radiation)
    H. Mass and energy balances
    I. Property and phase diagrams (e.g., T-s, P-h)
    J. Phase equilibrium and phase change
    K. Combustion and combustion products (e.g., CO, CO_2, NOX, ash, particulates)
    L. Psychrometrics (e.g., relative humidity, wet-bulb)

1. The only point of inflection on the curve representing the equation $y = x^3 + x^2 - 3$ is at:

A. $x = -\dfrac{2}{3}$

B. $x = -\dfrac{1}{3}$

C. $x = 0$

D. $x = \dfrac{1}{3}$

2. 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. $M + s$

3. The following segment of pseudocode describes a segment of a computer program:

```
Set A = 17
Set K = 2
While K ≤ 4
    A = A/K
    K = K + 1
End While
Print A
```

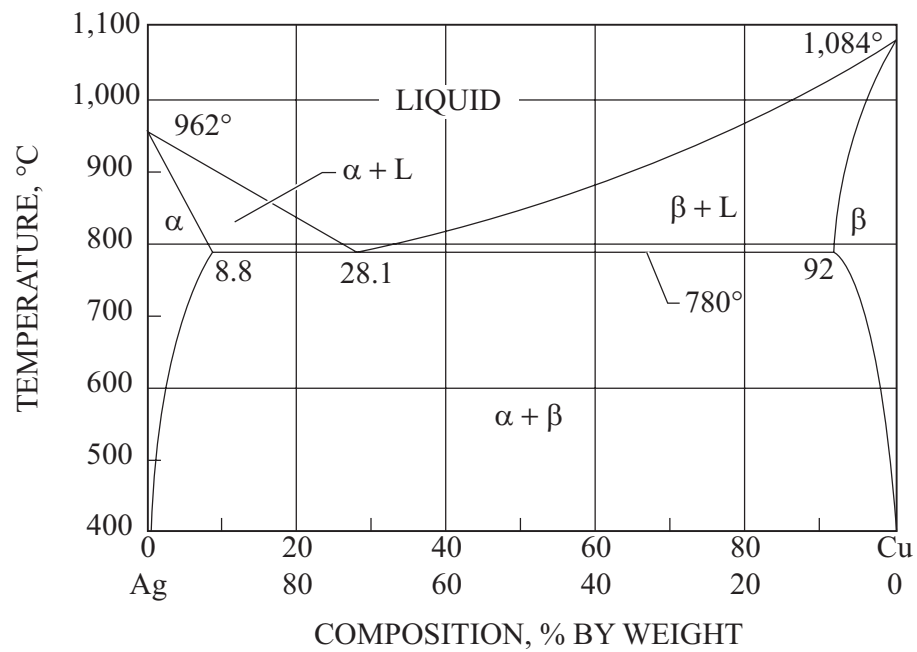The value of A that is printed is most nearly:
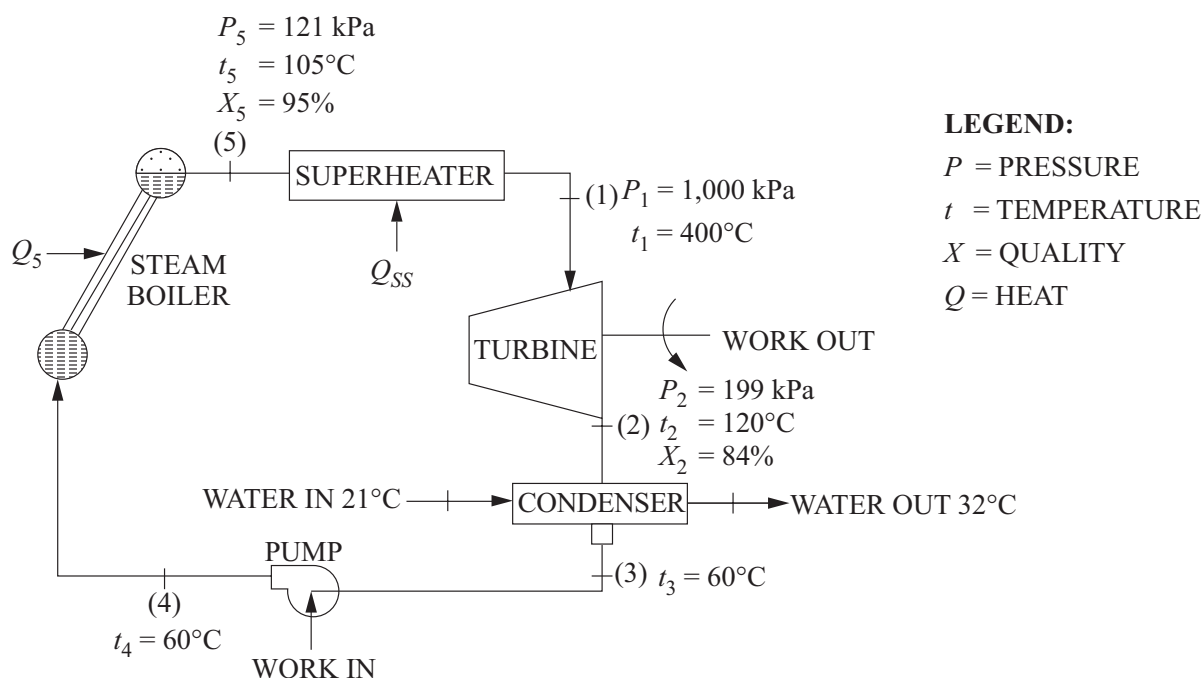
A. 0.71
B. 2.83
C. 4.25
D. 408

4.   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.   you do not live in the jurisdiction where the transportation system is being installed

C.   your original area of specialization was in transportation systems

D.   you have regularly attended meetings of a professional engineering society

5.   Portable electric tools are frequently used where operators may encounter water or other conductive materials. The safety device required by *The National Electrical Code* to protect against accidental electrocution in wet/damp environments is known as a:

A.   ground rod

B.   properly sized circuit breaker

C.   ground fault interrupter (GFI)

D.   two-conductor power cord

6.   If $500 is invested at an annual interest rate of 8% per year, its future worth at the end of 30 years will be most nearly:

A. $1,200

B. $1,700

C. $5,031

D. $15,000

7.   The pressure gage in an air cylinder reads 1,680 kPa. The cylinder is constructed of a 12-mm rolled-steel plate with an internal diameter of 700 mm. The tangential stress (MPa) inside the tank is most nearly:

A.   25

B.   50

C.   77

D.   100

8.   A silver/copper binary phase diagram is shown below. An alloy that is 70% copper by weight is fully melted and allowed to cool slowly. The temperature at which solidification begins is most nearly:

A.   962°C

B.   920°C

C.   800°C

D.   780°C

9. 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

10. A Rankine cycle with water as the working medium operates with the conditions shown in the figure.

$P_5 = 121$ kPa
$t_5 = 105°C$
$X_5 = 95\%$

(5)

SUPERHEATER

$(1) P_1 = 1,000$ kPa
$t_1 = 400°C$

$Q_5 \longrightarrow$ STEAM BOILER

Q_{SS}

LEGEND:
P = PRESSURE
t = TEMPERATURE
X = QUALITY
Q = HEAT

TURBINE — WORK OUT

$P_2 = 199$ kPa
(2) $t_2 = 120°C$
$X_2 = 84\%$

WATER IN 21°C — CONDENSER — WATER OUT 32°C

PUMP

(3) $t_3 = 60°C$

(4)
$t_4 = 60°C$

WORK IN

Disregarding pressure losses throughout the cycle and assuming a steady flow with adiabatic expansion in the turbine, the specific shaft work deliverable by the turbine (kJ/kg) is most nearly:

A. 560

B. 910

C. 1,410

D. 2,760

1. $f(x) = x^3 + x^2 - 3$ Inflection point occurs when $f''(x) = 0$

    $f'(x) = 3x^2 + 2x$

    $f''(x) = 6x + 2$

    Set equal to zero

    $6x + 2 = 0$

    $x = -1/3$

    $f''(x)$ is negative below $x = -1/3$ and positive above $x = -1/3$

    Since $f''(x) = 0$ and $f''(x)$ changes signs at $x = -1/3$, the inflection point is at $x = -1/3$.

    THE CORRECT ANSWER IS: B

2. Accuracy increases with increasing sample size.

    THE CORRECT ANSWER IS: B

3. K = 2 gives A = 17/2 = 8.5

    K = 3 gives A = 8.5/3 = 2.83

    K = 4 gives A = 2.83/4 = 0.71

    THE CORRECT ANSWER IS: A
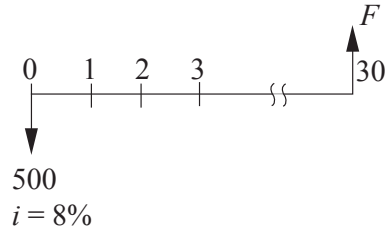

4. Refer to the NCEES Rules of Professional Conduct.

    THE CORRECT ANSWER IS: A

5. Ground fault interrupters are required for exterior residential power outlets.

    THE CORRECT ANSWER IS: C

6.

0 1 2 3   30

500
$i = 8\%$

$F = 500(F/P, 8\%, 30)$
$= 500\,(10.0627)$
$= \$5,031$

THE CORRECT ANSWER IS: C

7.   The cylinder can be considered thin-walled if $t \le \dfrac{1}{10}\, r_i$.
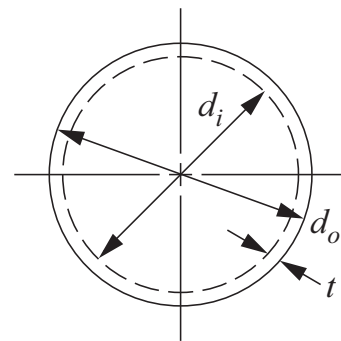In this case

$d_i = 700$ mm

$t = 12$ mm

$d_o = d_i + 2t = 700 + 2\,(12) = 724$ mm

$r_i = \dfrac{d_i}{2} = 350$ mm

$r_o = \dfrac{d_o}{2} = 362$ mm
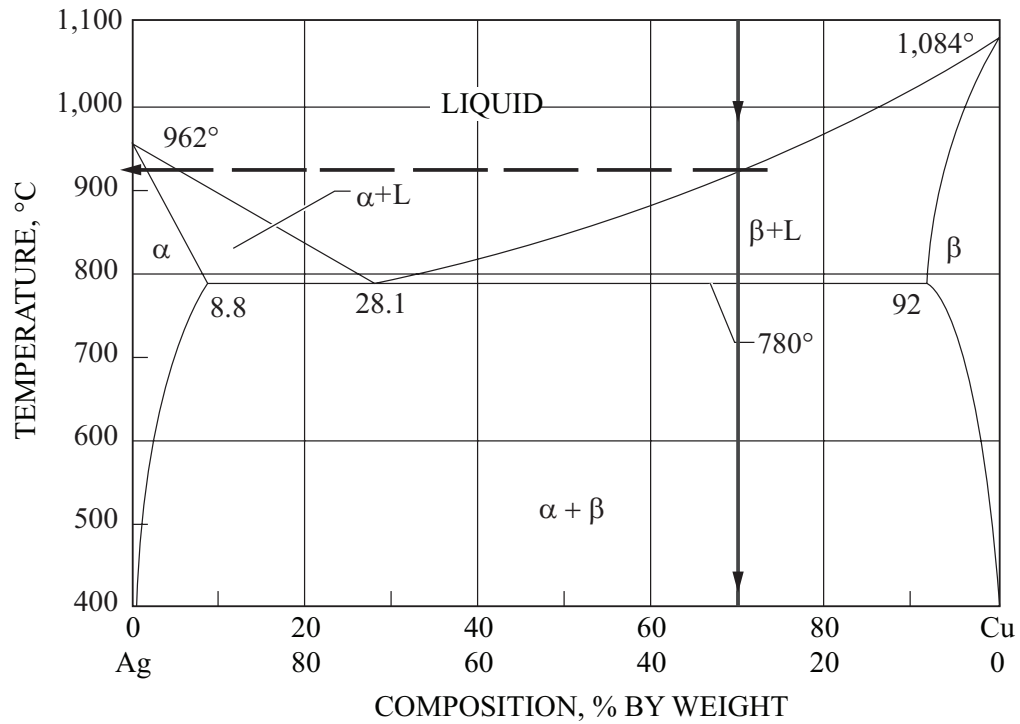
where r $= \dfrac{r_i + r_o}{2} = \dfrac{350 + 362}{2} = 356$ mm

$\sigma_t = \dfrac{P_i r}{t} = \dfrac{(1.680\ \text{MPa})(356\ \text{mm})}{12\ \text{mm}} = 49.8$ MPa

THE CORRECT ANSWER IS: B
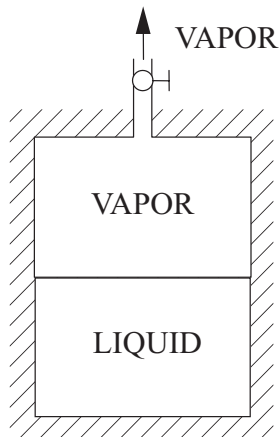
8. The solidification path of an Ag-70 w/o Cu alloy is shown as the vertical line. The temperature at which solidification begins is shown as the horizontal dashed line and is 920°C.

THE CORRECT ANSWER IS: B

9. 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

10.   The equation for work done by the turbine is

$$W_{turbine} = h_1 - h_2$$

where h_1 is enthalpy of superheated steam at 1 MPa and 400°C, and h_2 is enthalpy of 84% quality saturated steam at 199 kPa and 120°C. Enthalpy values in steam tables.

h_1 = 3,263.9 kJ/kg

h_2 $= (1 - X_2)(h_c) + (X_2)(h_r) = (0.16)(503.71 \text{ kJ/kg}) + (0.84)(2{,}706.3 \text{ kJ/kg})$
          $= 2{,}353.9 \text{ kJ/kg}$

$W_{turbine} = (3{,}263.9 - 2{,}353.9) \text{ kJ/kg} = 910 \text{ kJ/kg}$

THE CORRECT ANSWER IS: B