FUNDAMENTALS OF ENGINEERING (FE) EXAMINATION
MORNING SESSION SPECIFICATIONS
EFFECTIVE OCTOBER 1996

SUBJECT	% OF QUESTIONS
Chemistry	9
Computers	6
Dynamics	7
Electric Circuits	10
Engineering Economics	4
Ethics	4
Fluid Mechanics	7
Materials Science/Structure of Matter	7
Mathematics	20
Mechanics of Materials	7
Statics	10
Thermodynamics	9
Total	100

CHEMISTRY
- Acids and Bases
- Equilibrium
- Equations
- Electrochemistry
- Inorganic Chemistry
- Kinetics
- Metals and Nonmetals
- Nomenclature
- Organic Chemistry
- Oxidations and Reduction
- Periodicity
- States of Matter
- Solutions
- Stoichiometry

COMPUTERS
- Algorithm Flowchart
- Spreadsheets
- Psuedocode
- Data Transmission and Storage

DYNAMICS
- Force, Mass, and Acceleration
- Friction
- Impulse and Momentum
- Kinematics
- Vibrations
- Work and Energy

ELECTRIC CIRCUITS
- AC Circuits
- Diode Applications
- DC Circuits
- Electric and Magnetic Fields
- Capacitance and Inductance
- Ideal Transformers
- Fourier and Laplace Transforms
- Operational Amplifiers (Ideal)

ENGINEERING ECONOMICS
- Annual Cost
- Breakeven Analysis
- Benefit-Cost Analysis
- Future Worth or Value
- Present Worth
- Valuation and Depreciation

FLUID MECHANICS
- Flow Measurement
- Fluid Properties
- Fluid Statics
- Impulse and Momentum
- Pipe and Other Internal Flow
- Similitude and Dimensional Analysis

MATERIAL SCIENCE/ STRUCTURE OF MATTER
- Atomic Structure
- Crystallography
- Corrosion
- Diffusion
- Materials
- Binary Phase Diagrams
- Properties
- Processing and Testing

MATHEMATICS
- Analytic Geometry
- Differential Equations
- Differential Calculus
- Difference Equations
- Integral Calculus
- Linear Algebra
- Laplace Transforms
- Probability and Statistics
- Roots of Equations
- Vector Analysis

MECHANICS OF MATERIALS
- Beams
- Bending
- Columns
- Combined Stresses
- Shear
- Stress and Strain
- Tension and Compression
- Torsion

STATICS
- 2-Dimensional Equilibrium
- 3-Dimensional Equilibrium
- Centroid of Area
- Concurrent Force Systems
- Friction
- Moment of Inertia
- Vector Forces

THERMODYNAMICS
- 1st Law
- 2nd Law
- Availability-Reversibility
- Cycles
- Energy, Heat and Work
- Ideal Gases
- Mixture of Gases
- Phase Changes
- Properties: Enthalpy, Entropy, Free Energy
- Thermodynamic Processes

ETHICS
- Relations with Clients
- Relations with Peers
- Relations with Public

- The FE examination is an eight-hour supplied-reference examination: 120 one-point questions in the four-hour morning session and 60 two-point questions in the four-hour afternoon session.
- The morning session is common to all disciplines.
- The afternoon session is administered in the following five disciplines—Chemical, Civil, Electrical, Industrial, and Mechanical—with a general engineering section for all remaining disciplines.
- Examinees will work all questions in the morning session and all questions in the afternoon section they have chosen.

MORNING
SAMPLE QUESTIONS

NOTE: THESE QUESTIONS REPRESENT ONLY HALF THE NUMBER ON THE ACTUAL EXAMINATION.

Morning Session

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then blacken the corresponding space on the answer sheet.

1. The partial derivative $\frac{\partial y}{\partial x}$ of $y = x^2z + 3z^2x + 6(x + z)$ is

   (A) $2xz + 3z^2 + 6$
   (B) $x^2z + 6zx + 6z$
   (C) $2x + 9$
   (D) $2x + 6z + 6$

2. 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

3. Consider a function of x equal to the determinant shown below.

$$f(x)=\begin{vmatrix} x & x^2 \\ x^4 & x^3 \end{vmatrix}$$

   The first derivative $f'(x)$ of this function with respect to x is equal to

   (A) $3x^2 - 8x^4$
   (B) $4x^3 - 6x^5$
   (C) $x^4 - x^6$
   (D) $3x^4 - 5x^6$

4. The Laplace transform of a step function of magnitude a is

   (A) $\frac{1}{s+a}$

   (B) $\frac{a}{s}$

   (C) $\frac{a}{s+a}$

   (D) $\frac{a}{s^2}$

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Morning Session

5. 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 increases in

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

6. 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

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

   Which of the following is the general solution to the differential equation and boundary condition shown above?

   (A) e^{5t}
   (B) e^{-5t}
   (C) $e^{\sqrt{-5t}}$
   (D) $5\,e^{-5t}$

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

   (A) C_1e^{-4x}

   (B) C_1e^{-2x}

   (C) $e^{-4x}(C_1 + C_2x)$

   (D) $e^{-2x}(C_1 + C_2x)$

GO ON TO THE NEXT PAGE

9. 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

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

(A) $-2\mathbf{i} + \mathbf{j} - \mathbf{k}$

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

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

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

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

12. 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

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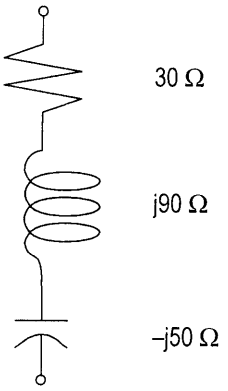
Morning Session

13. If the apparent power is 1,500 volt amperes with a power factor of 0.866 lagging, the reactive power is

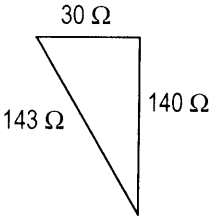
(A) 0 VAR
(B) 750 VAR
(C) 1,300 VAR
(D) 1,500 VAR

14.

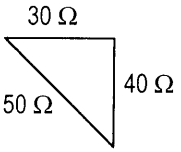


For the series-connected circuit elements shown above, which of the following impedance diagrams is correct according to conventional notation?

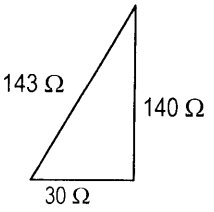
(A)



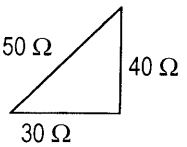
(B)



(C)



(D)



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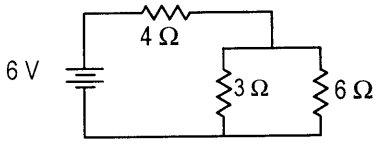
15. A 10-microfarad capacitor has been charged to a potential of 150 volts. A resistor of 25 Ω is then connected across the capacitor through a switch. When the switch is closed for 10 time constants, the total energy dissipated by the resistor is most nearly

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

16. The magnitude of the force on a particle of charge q placed in the empty space between two infinite parallel plates with a spacing d and a potential difference V is proportional to

(A) qV/d^2
(B) qV/d
(C) qV^2/d
(D) q^2V/d

17.

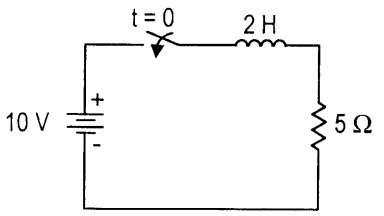


If the connecting wires and the battery in the circuit shown above have negligible resistance, the current through the 6-Ω resistor is most nearly

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

Morning Session

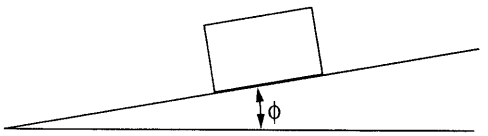
18.



The expression for the current in the 5-Ω resistor of the circuit shown above for time t greater than zero is

(A) $2e^{-2t}$ amperes
(B) $2e^{-5t}$ amperes
(C) $2(1 - e^{-2t})$ amperes
(D) $2(1 - e^{-2.5t})$ amperes

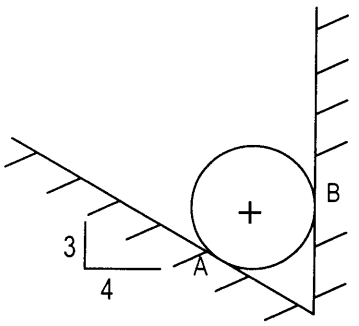
19.



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 the

(A) sine of angle $\phi = 1.0$
(B) cosine of angle $\phi = 1.0$
(C) cosine of angle $\phi = 0.25$
(D) tangent of angle $\phi = 0.25$

20.



A cylinder weighing 120 Newtons rests between two frictionless walls as shown above. The wall reaction at Point A is most nearly

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

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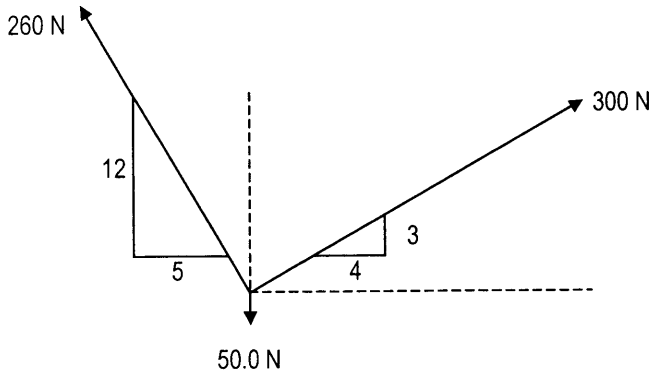
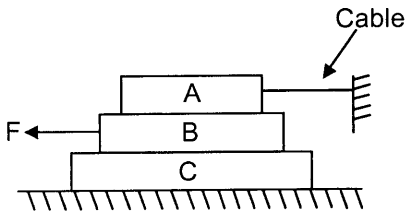
21.



The magnitude of the resultant of the three forces shown above is most nearly

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

22.

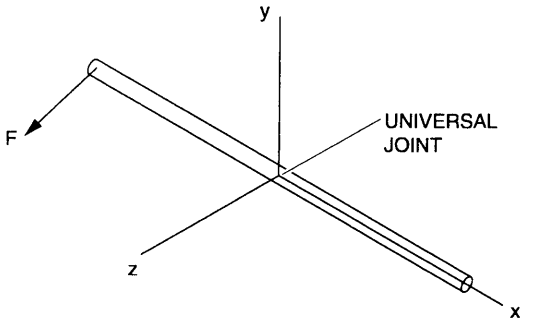


In the diagram above, Block A weighs 50 Newtons, Block B weighs 80 Newtons, and Block C weighs 100 Newtons. The coefficient of friction at all surfaces is 0.30. The maximum force **F** that can be applied to Block B without disturbing equilibrium is most nearly

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

Morning Session

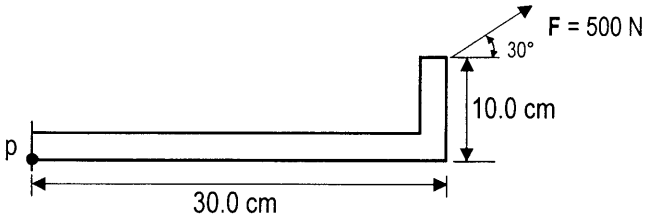
23.



A uniform bar is mounted so its midpoint is anchored at the origin of a three-dimensional coordinate system. The bar can rotate in any direction about this mounting. A force **F** of $3\mathbf{i} + 4\mathbf{j} + 5\mathbf{k}$ acts on one end of the bar. The bar will remain stationary if acting on its other end there is a force of

(A) $3\mathbf{i} + 4\mathbf{j} + 5\mathbf{k}$
(B) $3\mathbf{i} + 4\mathbf{j} - 5\mathbf{k}$
(C) $3\mathbf{i} - 4\mathbf{j} - 5\mathbf{k}$
(D) $-3\mathbf{i} - 4\mathbf{j} - 5\mathbf{k}$

24.



The moment of force **F** shown above with respect to point p is most nearly

(A) 31.7 N•m ccw
(B) 31.7 N•m cw
(C) 43.3 N•m cw
(D) 43.3 N•m ccw

25. 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 the liquid in the tank
(B) superheating of the vapor in the tank
(C) a rise in temperature
(D) an increase in enthalpy

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26. The heat transfer during an adiabatic process is

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

27. 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

28. Pure water is boiling in an open pan at atmospheric pressure. Salt at a temperature equal to that of the boiling water is added. Immediately after the salt dissolves, which of the following will most likely occur?

(A) The boiling ceases.
(B) The temperature of the solution drops by 10°C.
(C) The water ionizes.
(D) The entire mass becomes solid.

29. When the pressure of an ideal gas is doubled while the absolute temperature is halved, the volume is

(A) quadrupled
(B) doubled
(C) halved
(D) quartered

30. The statement that equal volumes of all gases under the same conditions of temperature and pressure contain very nearly the same number of molecules is known as

(A) Avogadro's law
(B) Boyle's law
(C) Dalton's law
(D) Gay-Lussac's law

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Morning Session

31. 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 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

32. Ethane gas burns according to the equation

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O.$

What volume of CO_2, measured at standard temperature and pressure, is formed for each gram-mole of C_2H_6 burned?

(A) 22.4 liters
(B) 44.8 liters
(C) 88.0 liters
(D) 89.6 liters

33. The valence (oxidation state) of manganese in potassium permanganate, $KMnO_4$, is

(A) +3
(B) +4
(C) +5
(D) +7

34. The atomic weight of sodium is 23, oxygen 16, and hydrogen 1. To neutralize 4 grams of NaOH dissolved in 1 liter of water requires 1 liter 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

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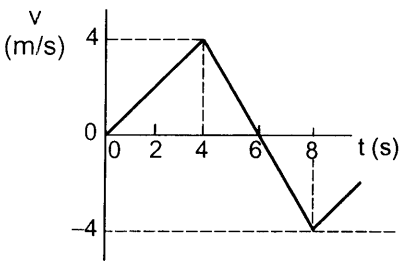
35. $K = \dfrac{[C]^2[D]^2}{[A]^4[B]}$

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) $A_4 + B \leftrightarrow C_2 + D_2$

36. A 40-gram projectile with a horizontal speed of 900 meters per second collides with and is embedded in an 80-gram block of wood that is initially at rest on a horizontal frictionless surface. The speed of the block after impact is most nearly

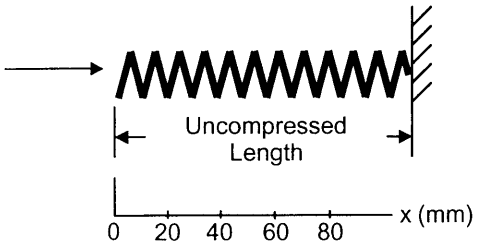
(A) 900 m/s
(B) 600 m/s
(C) 450 m/s
(D) 300 m/s

37. 

A particle moves along a straight path with a velocity v that varies with time t as shown in the graph above. The total displacement of the particle between t = 4 seconds and t = 8 seconds is most nearly

(A) 0 m
(B) 4 m
(C) 8 m
(D) 12 m

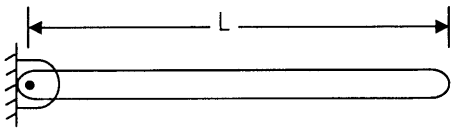
38.



The modulus of the spring shown above is 2.0 Newtons per millimeter. The work done in compressing this spring from x = 20 millimeters to x = 40 millimeters is

(A) 0.40 J
(B) 0.60 J
(C) 0.80 J
(D) 1.2 J

39.



The slender homogeneous rod shown above has just been released from rest. If g is the acceleration due to gravity, the magnitude of the angular acceleration of the rod is

(A) $\frac{1L}{2g}$

(B) $\frac{6g}{L}$

(C) $\frac{3g}{2L}$

(D) $\frac{1}{3}gL$

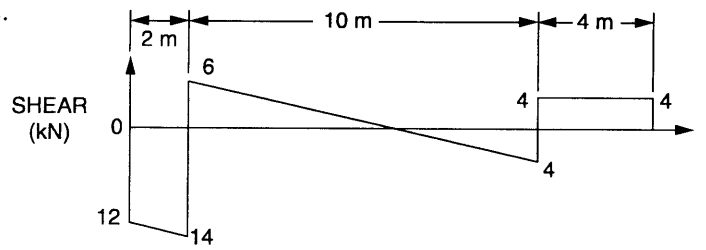
40. An object weighing 2 Newtons is traveling in a circular path of radius 5 meters at a constant speed of 10 meters per second. The acceleration of the object is most nearly

(A) 5 m/s^2
(B) 10 m/s^2
(C) 20 m/s^2
(D) 50 m/s^2

41. A particle moves along a horizontal straight line with a constant acceleration of 5.00 meters per second squared to the left. The particle starts with a velocity of 10.0 meters per second to the right. The total distance the particle moves first to the right and then to the left in the next 5.00 seconds is most nearly

(A) 17.5 m
(B) 32.5 m
(C) 50.0 m
(D) 62.5 m

42.



The shear diagram for a particular beam is shown above. 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 in the beam is

(A) 8 kN•m
(B) 16 kN•m
(C) 18 kN•m
(D) 26 kN•m

43. The piston of a steam engine is 50.0 centimeters 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 should be most nearly

(A) 40.4×10^{-4} m^2
(B) 98.8×10^{-4} m^2
(C) 228.0×10^{-4} m^2
(D) 323.0×10^{-4} m^2

Morning Session

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

    (A) 500 N•m
    (B) 1,200 N•m
    (C) 1,320 N•m
    (D) 1,500 N•m

45. The Euler formula for columns deals with

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

46. 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.

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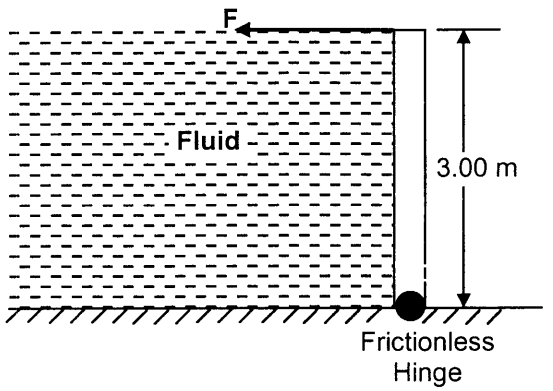
47.



The rectangular homogeneous gate shown above is 3.00 meters high and has a frictionless hinge at the bottom. If the fluid on the left side of the gate has a mass of 1,600 kilograms per cubic meter, the magnitude of the force **F** required per meter of width to keep the gate closed is most nearly

(A) 0 kN/m
(B) 22 kN/m
(C) 24 kN/m
(D) 220 kN/m

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.

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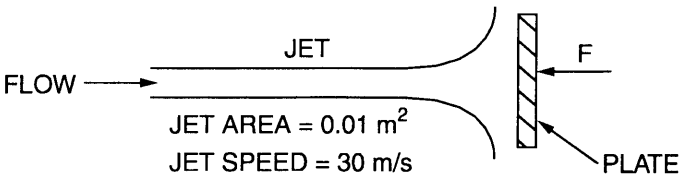
Morning Session

49.



A horizontal jet of water (density = 1,000 kilograms per cubic meter) is deflected perpendicularly to the original jet stream by a plate with an area of 0.500 square meter as shown above. The magnitude of force **F** required to hold the plate is most nearly

(A) 4.5 kN
(B) 8.8 kN
(C) 45.0 kN
(D) 88.0 kN

50. When cooled to a temperature approaching absolute zero, many materials have a sudden drop in their electrical resistivity to a value of almost zero. This phenomenon is known as

(A) the Meissner effect
(B) the Curie transition
(C) paramagnetism
(D) superconductivity

51. The mechanical deformation of a material at a temperature above its recrystallization temperature is commonly known as

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

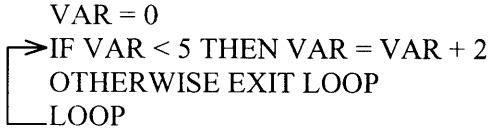
52. In general, a metal with high hardness will also have

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

53. 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

54. 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

55. In a spreadsheet, the number in cell A4 is set to 6. Then A5 is set to A4 + A4, where $ indicates the absolute cell address. 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

Morning Session

56. The program segment

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

calculates the sum

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

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

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

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

57. 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 backgrounds of the defendant

GO ON TO THE NEXT PAGE

58. A professional engineer, originally licensed 30 years ago, is asked to evaluate a newly developed computerized control system for a public transportation system. The engineer may accept this project if

    (A) he or she is competent in the area of modern control systems

    (B) his or her professional engineering license has not lapsed

    (C) his or her original area of specialization was in transportation systems

    (D) he or she has regularly attended annual meetings of their professional engineering society

59. A company can manufacture a product with off-the-shelf hand tools. Costs will be $1,000 for tools and $1.50 manufacturing cost per unit. As an alternative, an automated system will cost $15,000 with a $0.50 manufacturing cost per unit. With an annual anticipated volume of 5,000 units and neglecting interest, the break-even point is most nearly

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

60. A printer costs $900. After 5 years its salvage value 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

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY WISH TO CHECK YOUR WORK ON THIS TEST

SOLUTIONS TO THE MORNING SAMPLE QUESTIONS

CORRECT ANSWERS TO THE MORNING SAMPLE QUESTIONS

Detailed solutions for each question begin on the next page.

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

Morning Session Solutions

1. Differentiate y with respect to x, while considering z a parameter not a variable

$$\left(\frac{\partial y}{\partial x}\right)_z = 2xz + 3z^2 + 6$$

THE CORRECT ANSWER IS: (A)

2. The key word is OR. What is the probability that the number is odd OR greater than 80? Refer to Property 2 given under Probability and Statistics in the Mathematics section of the *FE 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)

3. Write the determinant as f(x) then differentiate f(x).

$$f(x) = \begin{vmatrix} x & x^2 \\ x^4 & x^3 \end{vmatrix} = xx^3 - x^2x^4 = x^4 - x^6$$

$f'(x) = 4x^3 - 6x^5$

THE CORRECT ANSWER IS: (B)

4. Refer to the Laplace transform table in the Mathematics section of the *FE Reference Handbook.* The transform of a unit step is $\frac{1}{s}$. A step of magnitude a will have a transform of $\frac{a}{s}$.

THE CORRECT ANSWER IS: (B)

Morning Session Solutions

5. Accuracy increases with increasing sample size.

THE CORRECT ANSWER IS: (B)

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

THE CORRECT ANSWER IS: (D)

7. The characteristic equation is

$$r + 5 = 0$$

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

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

$$y = C\, e^{-\alpha t} \text{ where } \alpha = a$$

where C is determined from the boundary condition.

$$1 = C\, e^{-5(0)} \qquad C = 1$$

The solution is

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

THE CORRECT ANSWER IS: (B)

8. Refer to the Mathematics section of the *FE Reference Handbook*. The characteristic equation is

$$r^2 + 2ar + b = r^2 + 4r + 4 = (r + 2)^2 = 0$$

$2a = 4$ or $a = 2$ and $b = 4$.

There are repeated real roots: $r_1 = r_2 = -2$

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

$$y(x) = (C_1 + C_2\, x)\, e^{-2x}$$

THE CORRECT ANSWER IS: (D)

9. 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)

10. 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.

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

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

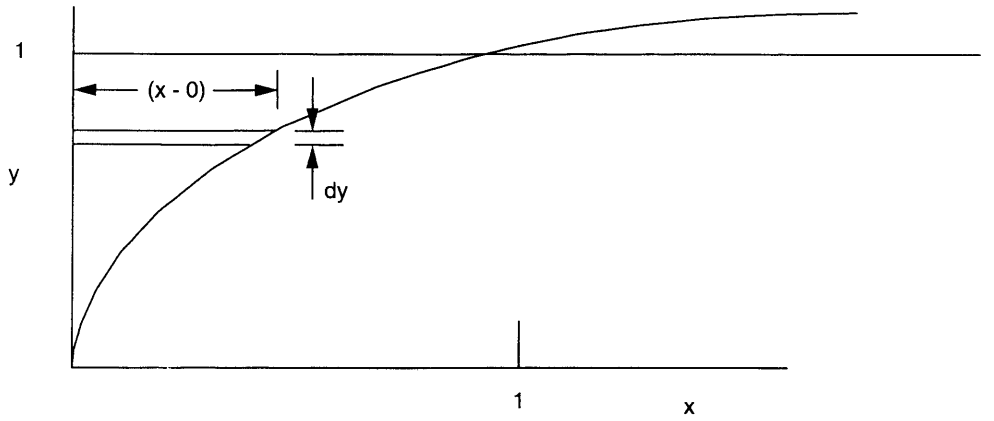
THE CORRECT ANSWER IS: (C)

11. Refer to Differential Calculus in the Mathematics section of the *FE Reference Handbook.*

THE CORRECT ANSWER IS: (C)

Morning Session Solutions

12. 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)

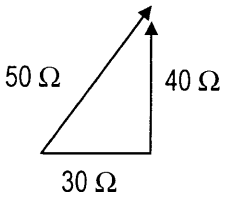
13. S = apparent power
P = real power
Q = reactive power

$S = P + jQ = |S| \cos\theta + j\,|S| \sin\theta$
$\cos\theta = pf = 0.866$

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

THE CORRECT ANSWER IS: (B)

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



THE CORRECT ANSWER IS: (D)

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

$$W_C(t) = \frac{1}{2}cV_C^2 = \frac{1}{2}(10\times10^{-6}\text{F})(150\text{ V})^2$$

$W_C = 0.113$ joules initial stored energy.
After 10 time constants, all energy will be dissipated.

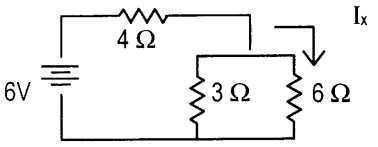
THE CORRECT ANSWER IS: (B)

16. Refer to Electrostatics in the Electric Circuit section of the *FE Reference Handbook.*

$F = qE$
and
$$E = \frac{V}{d}$$
therefore
$$F = q\left(\frac{V}{d}\right)$$

THE CORRECT ANSWER IS: (B)

17.



$$R_T = 4\Omega + 3\Omega \| 6\Omega = 4\Omega + 2\Omega$$

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

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

THE CORRECT ANSWER IS: (A)

Morning Session Solutions

18. Initially, $i = 0A = I_o$

After being closed a long time, the inductor acts like a short circuit giving

$$i = 10\frac{V}{5\,\Omega} = 2A = I_F$$

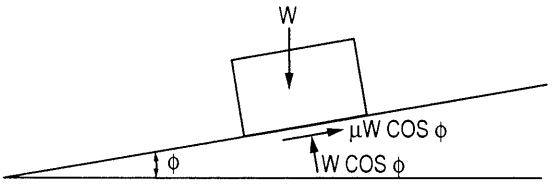
$$t = \frac{L}{R} = 2\frac{H}{5\,\Omega} = 0.4s$$

$$i_L(t) = I_F\left(1 - e\frac{-t}{\tau}\right) + I_0 \quad t > 0$$

$$i_L(t) = 2\left(1 - e\frac{-t}{0.4}\right) = 2\left(1 - e^{-2.5t}\right)$$

THE CORRECT ANSWER IS: (D)

19.



Tangent to the plane:

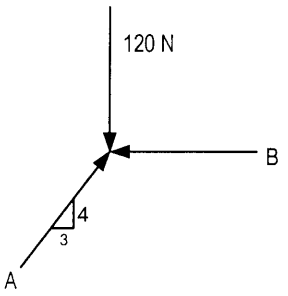
$$\Sigma F_t = 0 = -W\sin\phi + \mu W\cos\phi$$

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

$$\tan\phi = 0.25$$

THE CORRECT ANSWER IS: (D)

20.

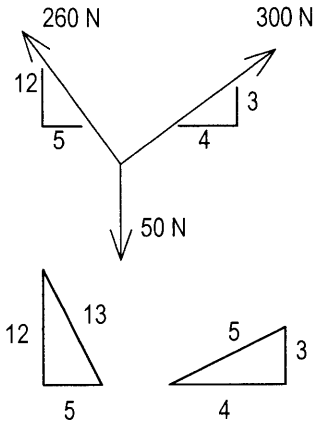


$$\Sigma F_y = 0 = -120 + \frac{4}{5}A$$

$$A = 150\ N$$

THE CORRECT ANSWER IS: (C)

21.



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

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

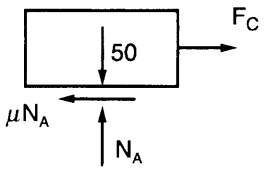
$$R = \sqrt{R_x^2 + R_y{}^2} = \sqrt{370^2 + 140^2}$$

$$= 396 \text{ N}$$

THE CORRECT ANSWER IS: (D)

Morning Session Solutions

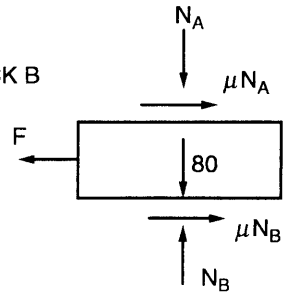
22. BLOCK A



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

$$N_A = 50\ N$$

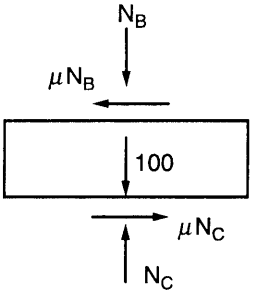
BLOCK B



$$\Sigma F_y = 0 = -50 - 80 + N_B$$

$$N_B = 130\ N$$

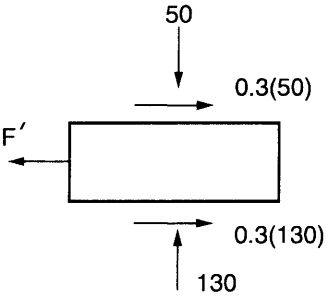
BLOCK C



$$\Sigma F_y = 0 = -130 - 100 + N_c$$

$$N_c = 230\ N$$

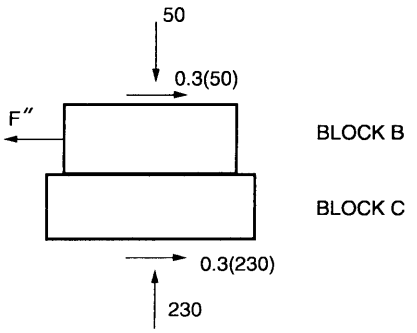
Assume Blocks A and C remain stationary.



$$\Sigma F_x = 0 = -F' + 0.3(50) + 0.3(130)$$

$$F'' = 54\ N$$

Assume Blocks B and C move.



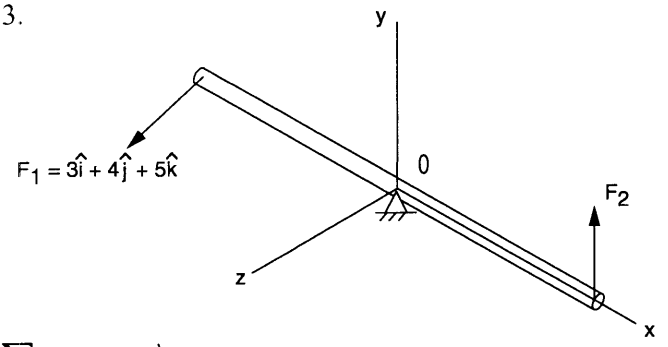
$$\Sigma F_x = 0 = -F'' + 0.3(50) + 0.3(230)$$

$$F'' = 84\ N$$

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

THE CORRECT ANSWER IS: (B)

23.



$$\sum \mathbf{M}_A = 0 \Rightarrow \mathbf{r}_1 \times \mathbf{F}_1 + \mathbf{r}_2 \times \mathbf{F}_2 = 0$$

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -L & 0 & 0 \\ 3 & 4 & 5 \end{vmatrix} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ L & 0 & 0 \\ F_{2x} & F_{2y} & F_{2z} \end{vmatrix}$$

Where L = length of bar

$i(0) - j(-5L) + k(-4L) + i(0) - j(F_{2z}L) + k(F_{2y}L) = 0$

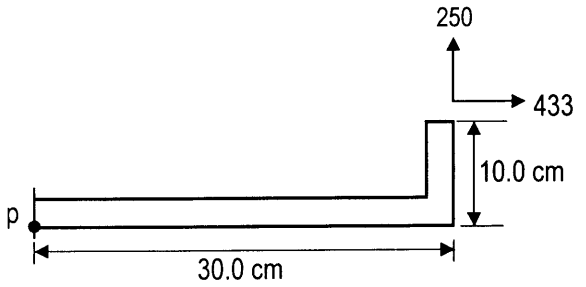
$\therefore \quad -5L + F_{2z}L = 0$
$F_{2z} = 5$

$-4L + F_{2y}L = 0$
$F_{2y} = 4$

Axial forces will be resisted by the universal joint.

THE CORRECT ANSWER IS: (A)

24.



$F_H = 500 \cos 30°$

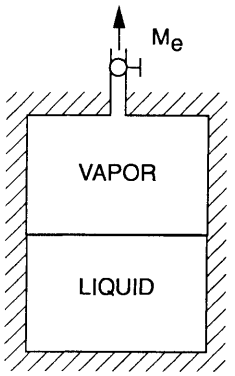
$F_V = 500 \sin 30°$

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

THE CORRECT ANSWER IS: (A)

Morning Session Solutions

25.



As m_e 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)

26. An adiabatic process, by definition, is a process in which no heat is transferred.

THE CORRECT ANSWER IS: (D)

27. 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. Response D describes a state, not a process.

THE CORRECT ANSWER IS: (C)

28. Refer to the Chemistry section of the *FE Reference Handbook*. The salt will raise the boiling point of the solution.

THE CORRECT ANSWER IS: (A)

29. Refer to Properties of Single-Component Systems in the Thermodynamics section of the *FE Reference Handbook*.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{Solving for V2:} \quad V_1 = \frac{2V_2}{1/2}$$

$$V_2 = \frac{1}{4}V_1$$

THE CORRECT ANSWER IS: (D)

30. Refer to the Chemistry section of the *FE Reference Handbook* for Avogadro's Number and molar volume of an ideal gas.

THE CORRECT ANSWER IS: (A)

31. 2 moles of As × 75 grams/moles of As = 150 grams of As

THE CORRECT ANSWER IS: (C)

32. Refer to the Chemistry section of the *FE Reference Handbook* for the molar volume of an ideal gas.

2 moles of CO_2 × 22.4 liters/mole = 44.8 liters of CO_2.

THE CORRECT ANSWER IS: (B)

33. The valence of K is +1 and the valence of O_4 is –8; therefore, Mn has a valence of +7.

THE CORRECT ANSWER IS: (D)

34. The molecular weight of NaOH is 40 grams; therefore, 4 grams per liter of NaOH will form 1 liter 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)

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

$4A + B = 2C + 2D$

THE CORRECT ANSWER IS: (B)

Morning Session Solutions

36. $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

But $v_{1f} = v_{2f} = v_f$

$v_{2i} = 0$

$\therefore m_1 v_{1i} = (m_1 + m_2) v_f$

$$v_f = \frac{m_1}{m_1 + m_2} v_{1i}$$

$$= \frac{40}{40 + 80}(900)$$

$$= 300 \text{ m/s}$$

THE CORRECT ANSWER IS: (D)

37. $s = \int V dt = \frac{4(2)}{2} - \frac{4(2)}{2} = 0$

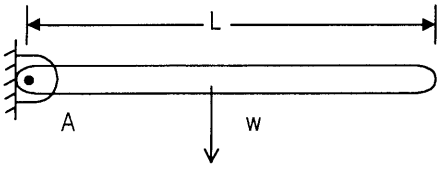
THE CORRECT ANSWER IS: (A)

38. $W = PE_2 - PE_1 = \frac{kx_2^2}{2} - \frac{kx_1^2}{2}$

$$= \frac{2(40)^2}{2} - \frac{2(20)^2}{2} = 1{,}200 \text{ N} \cdot \text{mm} = 1.2 \text{ N} \cdot \text{m} = 1.2 \text{ J}$$

THE CORRECT ANSWER IS: (D)

39.



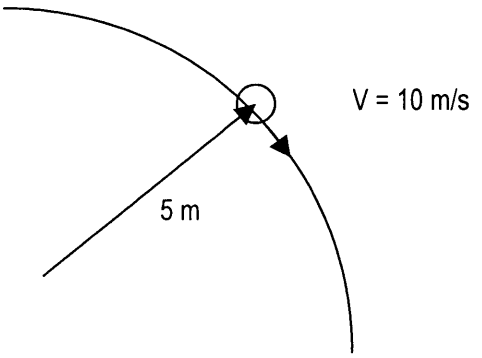
$$\sum M_A = I_A \alpha$$

$$W\frac{L}{2} = \frac{ML^2}{3}\alpha = \frac{WL^2}{3g}\alpha$$

$$\alpha = \frac{WL}{2}\left(\frac{3g}{WL^2}\right) = \frac{3g}{2L}$$

THE CORRECT ANSWER IS: (C)

40.



$$a = a_n = \frac{V^2}{r}$$

$$= \frac{10^2}{5} = 20\ m/s^2$$

THE CORRECT ANSWER IS: (C)

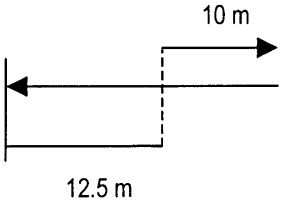
41. $a_x = -5\ m/s^2, V_{ox} = 10\ m/s$

$v_x = -5t + 10, V_x = 0 @ t = 2$

$x = -2.5t^2 + 10t$

For t = 0 to t = 2 s

$x = 10\ m$



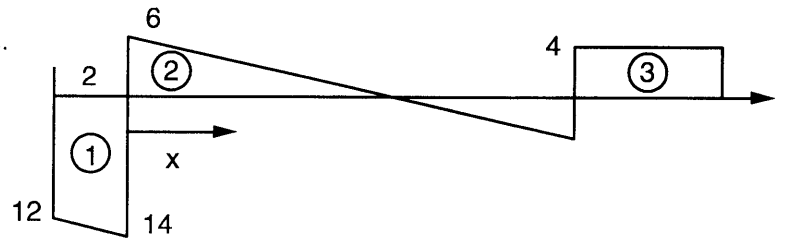
For t = 2 to t = 5 s
x = – 12.5 m at t = 5

$S_{TOTAL} = 10 + 22.5 = 32.5\ m$

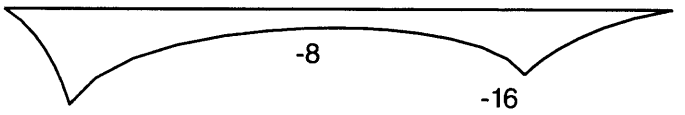
THE CORRECT ANSWER IS: (B)

Morning Session Solutions

42.



SHEAR DIAGRAM



MOMENT DIAGRAM

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

$x = 6$ m

Area 1 = 13(2)
=26 kN•m

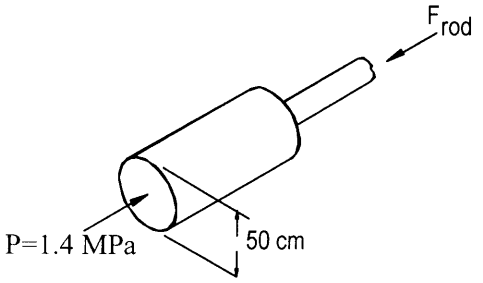
$$\text{rea } 2 = \frac{6(6)}{2} = 18\text{ kN} \bullet \text{m}$$

Area 3 = 4(4) = 16 kN • m

Maximum magnitude of moment is 26 kN • m

THE CORRECT ANSWER IS: (D)

43.



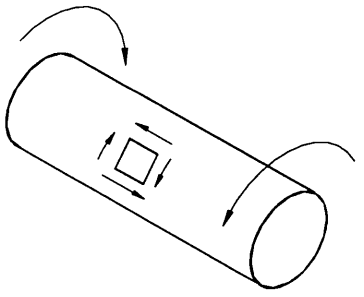
$$\Sigma F = PA = \left(1.4\times10^{6}\right)\left(\frac{\pi(0.5)^2}{4}\right) = F_{rod}$$

$$F_{rod} = 275\text{ kN} = \sigma A = 68\times10^{6}A$$

$$A = 40.4\times10^{-4}\text{m}^2$$

THE CORRECT ANSWER IS: (A)

44.



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

$$T = \frac{\pi d^3\tau}{16} = \frac{\pi(0.2)^3(840\times10^3)}{16}$$

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

THE CORRECT ANSWER IS: (C)

45. The Euler Formula is used for stability of relatively long columns, subjected to axial loads, in compression.

THE CORRECT ANSWER IS: (D)

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

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 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 rate of shear deformation.

THE CORRECT ANSWER IS: (C)

Morning Session Solutions

49. $Q = A_1V_1 = (0.01\text{m}^2)(30\text{m/s})$

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

$$V_2 = \frac{Q}{A_2} = \frac{0.3\,\text{m}^3/\text{s}}{0.5\,\text{m}^2} = 0.6\,\text{m/s}$$

$$F = Q_2\rho_2V_2 - Q_1\rho_1V_1$$

$$F = (0.3\,\text{m}^3/\text{s})(1{,}000\,\text{kg/m}^3)(0.6\,\text{m/s}) - (0.3\,\text{m}^3/\text{s})(1{,}000\,\text{kg/m}^2)(30\,\text{m/s})$$

$$F = 180 - 9{,}000 = -8{,}820\frac{\text{kg}\bullet\text{m}}{\text{s}^2}$$

$= -8{,}820\,\text{N}$

THE CORRECT ANSWER IS: (B)

50. The question statement is the definition of superconductivity.

THE CORRECT ANSWER IS: (D)

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

THE CORRECT ANSWER IS: (A)

52. A metal with high hardness has a high tensile strength and a high yield strength, by definition.

THE CORRECT ANSWER IS: (D)

53. Amorphous materials do not have a crystal structure, by definition.

THE CORRECT ANSWER IS: (D)

54.

Step	VAR
1	0
2	2
3	4
4	6

EXIT LOOP

At the conclusion of the routine, the value of VAR = 6.

THE CORRECT ANSWER IS: (D)

55.

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)

56. Step-by-Step Storage Information

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	$\frac{\frac{\frac{1+Z+Z^2}{2+Z^3}}{(2)(3)+Z^3}}{(2)(3)(4)}$

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

THE CORRECT ANSWER IS: (D)

Morning Session Solutions

57. Refer to the NCEES *Model Rules of Professional Conduct*, Section I.d. and Section III. C, in the Ethics section of the *FE Reference Handbook.*

THE CORRECT ANSWER IS: (B)

58. Refer to the NCEES *Model Rules of Professional Conduct*, Section II.a, in the Ethics section of the *FE Reference Handbook.*

THE CORRECT ANSWER IS: (A)

59. $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)

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

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

$= 225.45 + 50 - 51.15$

$= 224$

THE CORRECT ANSWER IS: (A)