MORNING SAMPLE QUESTIONS

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

(A) concavity of the curve

(B) location of inflection points on the curve

(C) number of inflection points on the curve

(D) area under the curve between certain bounds

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

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

(A) e^{5t}

(B) e^{-5t}

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

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

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

(A) $C_1 e^{-4x}$

(B) $C_1 e^{-2x}$

(C) $e^{-4x}(C_1 + C_2 x)$

(D) $e^{-2x}(C_1 + C_2 x)$

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

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

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5. Which of the following is a unit vector perpendicular to the plane determined by the vectors $\mathbf{A} = 2\mathbf{i} + 4\mathbf{j}$ 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) $\frac{1}{\sqrt{6}}(-2\mathbf{i} - \mathbf{j} - \mathbf{k})$

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

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

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

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

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

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

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

8. Three lines are defined by the three equations:

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

The three lines form a triangle with vertices at:

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

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

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

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

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

(A) –10
(B) 0
(C) 10
(D) 20

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

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

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

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

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

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

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

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

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

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

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15. Consider the equation:

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

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

(A) 1 gram-mole of As

(B) 28 grams of CO

(C) 150 grams of As

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

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

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

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

(A) 0.001 normal HCl solution

(B) 0.01 normal HCl solution

(C) 0.1 normal HCl solution

(D) 1.0 normal HCl solution

18. Consider the following equation:

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

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

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

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

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

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

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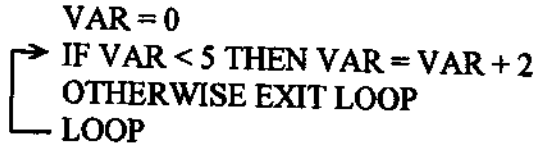
19. The flowchart for a computer program contains the following segment:



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

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

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

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

GO ON

21. Consider the following program segment:

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

This segment calculates the sum:

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

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

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

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

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

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

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

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

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

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

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

24. 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 meetings of a professional engineering society

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

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

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

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

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

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

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

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

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

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

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27. A company can manufacture a product using hand tools. Costs will be \$1,000 for tools and a \$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 anticipated annual volume of 5,000 units and neglecting interest, the breakeven point (years) is most nearly:

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

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

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

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

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

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

[redacted]	0	1	2	3	4
	–$1,100	–$400	+$1,000	+$1,000	+$1,000

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

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

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

[redacted]				
First cost	$25,000	$35,000	$20,000	$40,000
Annual costs	$ 8,000	$ 6,000	$ 9,000	$ 5,000
Salvage value	$ 2,500	$ 3,500	$ 2,000	$ 4,000

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

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

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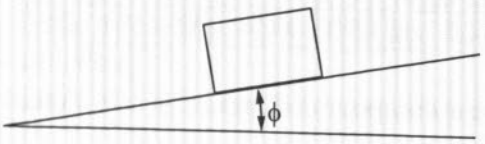
32. Referring to the figure below, the coefficient of static friction between the block and the inclined plane is 0.25. The block is in equilibrium.



As the inclined plane is raised, the block will begin to slide when:

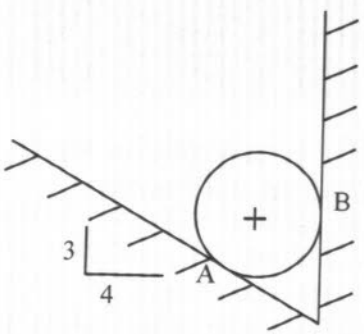
(A) $\sin \phi = 1.0$

(B) $\cos \phi = 1.0$

(C) $\cos \phi = 0.25$

(D) $\tan \phi = 0.25$

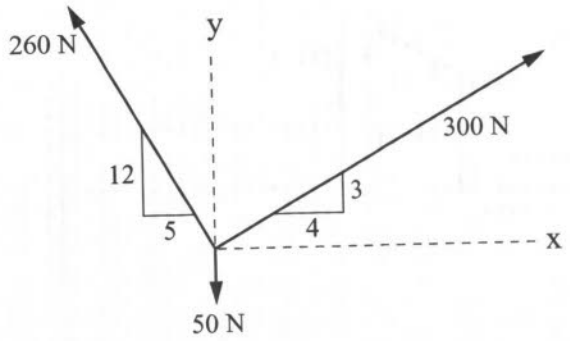
33. A cylinder weighing 120 N rests between two frictionless walls as shown in the following figure.



The wall reaction (N) at Point A is most nearly:

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

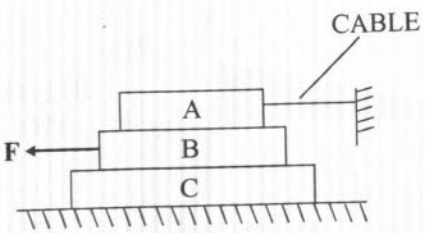
34. Three forces act as shown below.



The magnitude of the resultant of the three forces (N) is most nearly:

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

35. In the figure below, Block A weighs 50 N, Block B weighs 80 N, and Block C weighs 100 N. The coefficient of friction at all surfaces is 0.30.



The maximum force **F** (N) that can be applied to Block B without disturbing equilibrium is most nearly:

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

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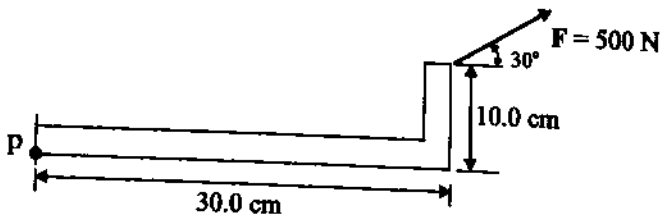
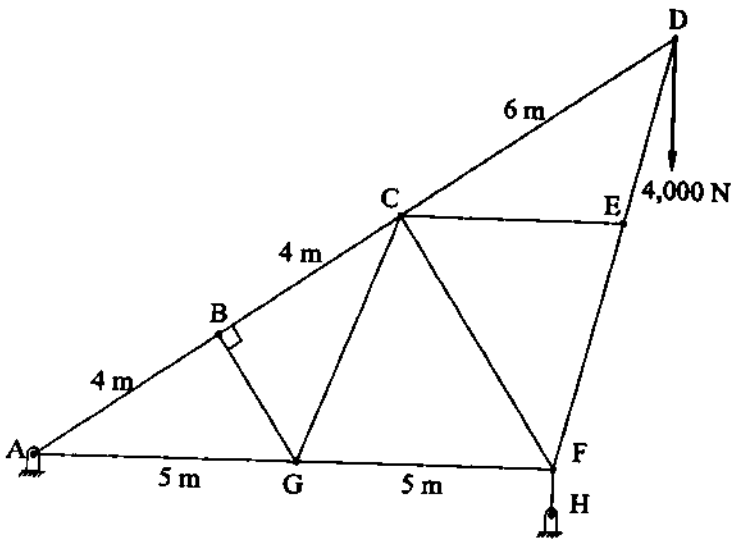
36. The moment of force **F** (N•m) shown below with respect to Point p is most nearly:



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

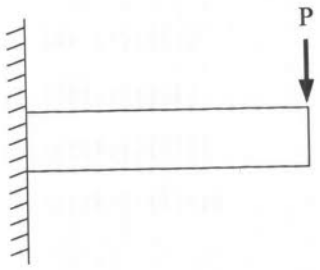
37. The figure below shows a simple truss.



The zero-force members in the truss are:

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

38. The beam shown below is known as a:



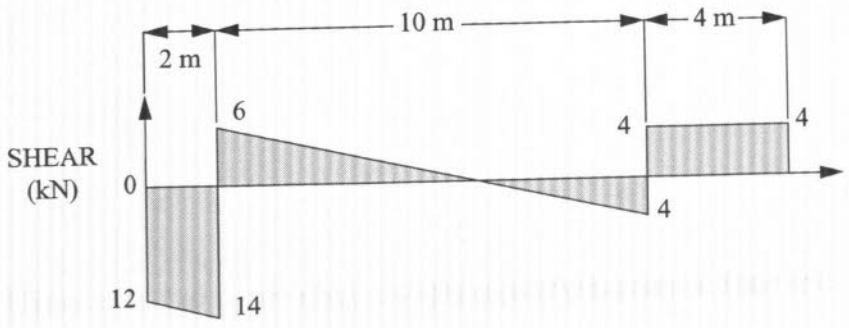
(A) cantilever beam

(B) statically indeterminate beam

(C) simply supported beam

(D) continuously loaded beam

39. The shear diagram for a particular beam is shown below. All lines in the diagram are straight. The bending moment at each end of the beam is zero, and there are no concentrated couples along the beam.



The maximum magnitude of the bending moment (kN•m) in the beam is most nearly:

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

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

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

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

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

42. The Euler formula for columns deals with:

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

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

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

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

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

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

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

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

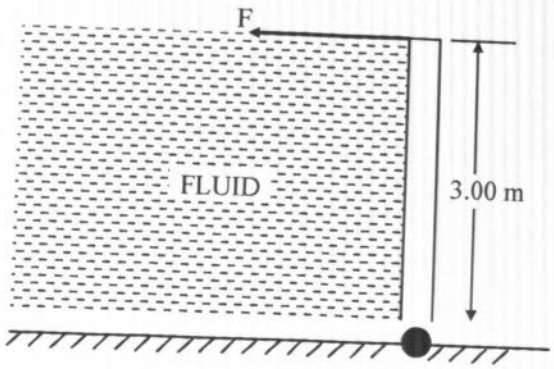
(A) The copper wire only will corrode.

(B) The aluminum connector only will corrode.

(C) Both will corrode.

(D) Nothing

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



(A) 0

(B) 22

(C) 24

(D) 220

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

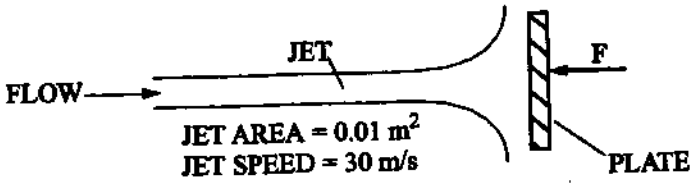
(A) It is the ratio of inertial to viscous force.

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

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

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

49. A horizontal jet of water (density = 1,000 kg/m^3) is deflected perpendicularly to the original jet stream by a plate as shown below.



The magnitude of force **F** (kN) required to hold the plate in place is most nearly:

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

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

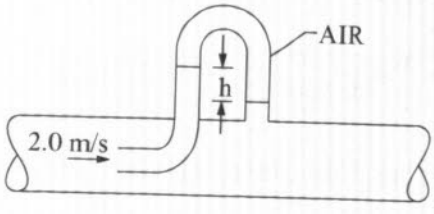
(A) The enthalpy rises.

(B) The upstream and downstream enthalpies are equal.

(C) Temperature increases sharply.

(D) Pressure increases sharply.

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

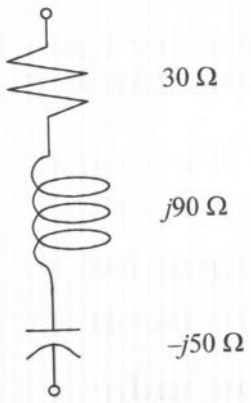


(A) 20.0
(B) 10.0
(C) 0.40
(D) 0.20

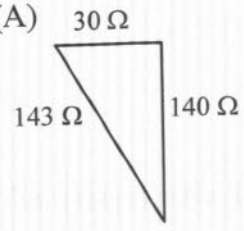
52. If the complex power is 1,500 VA with a power factor of 0.866 lagging, the reactive power (VAR) is most nearly:

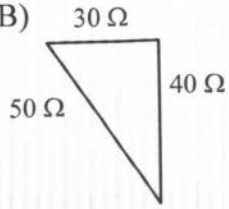
(A) 0
(B) 750
(C) 1,300
(D) 1,500

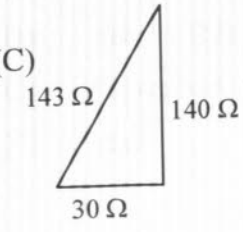
53. Series-connected circuit elements are shown in the figure below.

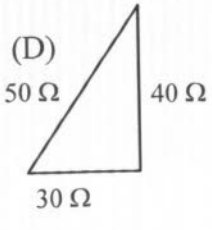


Which of the following impedance diagrams is correct according to conventional notation?

(A)


(B)


(C)


(D)


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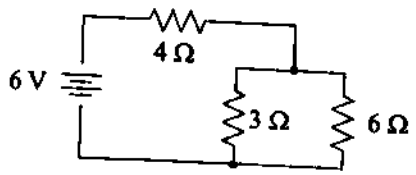
54. A 10-μF capacitor has been charged to a potential of 150 V. A resistor of 25 Ω is then connected across the capacitor through a switch. When the switch is closed for ten time constants, the total energy (joules) dissipated by the resistor is most nearly:

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

55. The connecting wires and the battery in the circuit shown below have negligible resistance.



The current (amperes) through the 6-Ω resistor is most nearly:

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

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

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

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

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

58. The heat transfer during an adiabatic process is:

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

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59. An isentropic process is one which:

(A) is adiabatic but not reversible

(B) is reversible but not adiabatic

(C) is adiabatic and reversible

(D) occurs at constant pressure and temperature

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

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

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

MORNING SOLUTIONS

ANSWERS TO THE MORNING QUESTIONS

Detailed solutions for each question begin on the next page.

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

MORNING SOLUTIONS

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

THE CORRECT ANSWER IS: (D)

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

$$r + 5 = 0$$

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

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

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

C is determined from the boundary condition.

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

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

THE CORRECT ANSWER IS: (B)

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

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

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

$$2a = 4 \text{ or } a = 2 \text{ and } b = 4$$

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

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

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

THE CORRECT ANSWER IS: (D)

4. First, the velocity is:

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

Then, the acceleration is:

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

Finally, the rate of change of acceleration is:

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

When $t = 2$:

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

THE CORRECT ANSWER IS: (A)

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

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

To obtain a unit vector, divide by the magnitude.

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

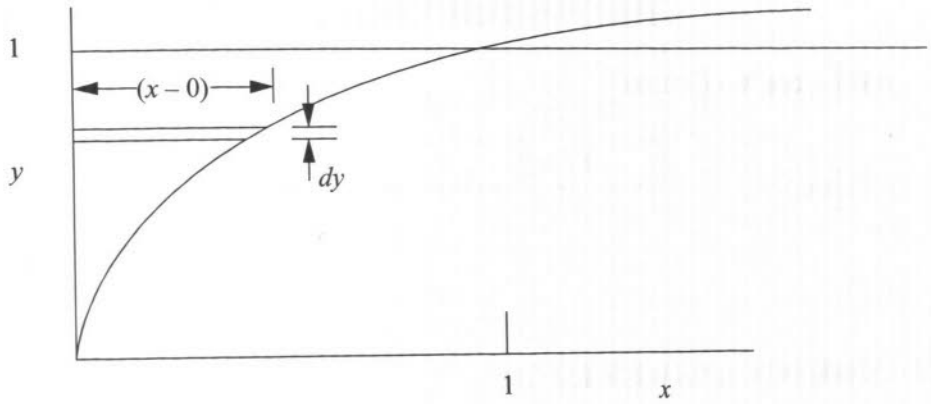
$$\frac{-4\mathbf{i} + 2\mathbf{j} - 2\mathbf{k}}{2\sqrt{6}} = \frac{-2\mathbf{i} + \mathbf{j} - \mathbf{k}}{\sqrt{6}}$$

THE CORRECT ANSWER IS: (C)

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

THE CORRECT ANSWER IS: (C)

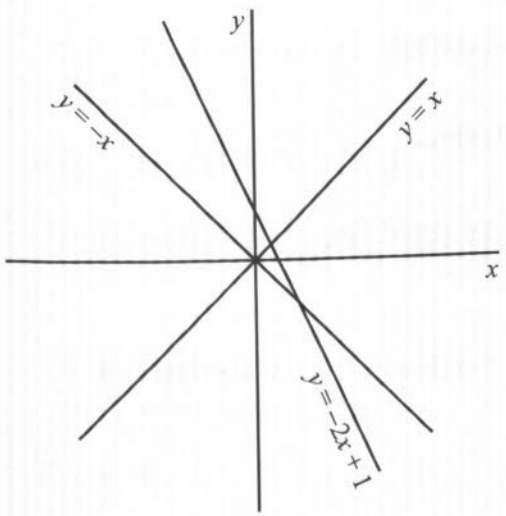
7. Define a differential strip with length $(x - 0)$ and height dy.



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

THE CORRECT ANSWER IS: (A)

8.



$y = -x$

$y = x$

$y = -2x + 1$

from graph one, intersection is at (0,0), so (C) and (D) are incorrect.

Also, second intersection is at (1,–1), so key has to be (A).

(0,0) (1/3, 1/3) and (1,–1)

THE CORRECT ANSWER IS: (A)

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

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

$= 10[1+1]$

$= 20$

THE CORRECT ANSWER IS: (D)

10. Accuracy increases with increasing sample size.

THE CORRECT ANSWER IS: (B)

11. The key word is **OR**. What is the probability that the number is odd **OR** greater than 80? Refer to Property 2 given under 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.

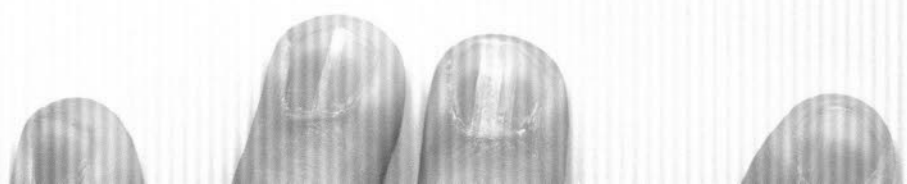
There are ten such balls.

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

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)



12.

1	–3	9
4	0	0
7	3	9
$\Sigma = 12$		$\Sigma = 18$

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

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

THE CORRECT ANSWER IS: (B)

13. $8 - 15.5 = 7.5$

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

From the Unit Normal Distribution Table in the Mathematics section of the *FE Reference Handbook*.

For X = 3, R(X) = 0.0013

THE CORRECT ANSWER IS: (A)

14. PV = nRT

1V = (1)(0.08206)(546)

solve for V = 44.8 L

THE CORRECT ANSWER IS: (D)

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

THE CORRECT ANSWER IS: (C)

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

0.5 M H_2SO_4 = 1.0 N H_2SO_4

1.0 M NaOH = 1.0 N NaOH

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

$40 \times 1 = 60x$

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

THE CORRECT ANSWER IS: (B)

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

THE CORRECT ANSWER IS: (C)

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

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

THE CORRECT ANSWER IS: (B)

19.

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

At the conclusion of the routine, VAR = 6.

THE CORRECT ANSWER IS: (D)

20.

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

THE CORRECT ANSWER IS: (B)

21.

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

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

THE CORRECT ANSWER IS: (D)

22.

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

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

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

THE CORRECT ANSWER IS: (C)

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

THE CORRECT ANSWER IS: (B)

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

THE CORRECT ANSWER IS: (A)

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

THE CORRECT ANSWER IS: (A)

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

THE CORRECT ANSWER IS: (A)

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

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

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

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

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

THE CORRECT ANSWER IS: (A)

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

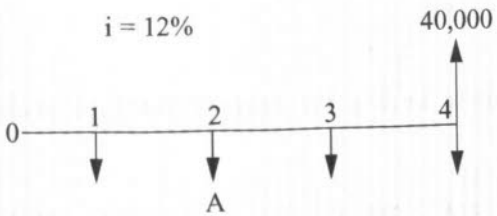
= $900(0.2505) + $50 – $300(0.1705)

= $225.45 + $50 – $51.15

= $224.30

THE CORRECT ANSWER IS: (A)

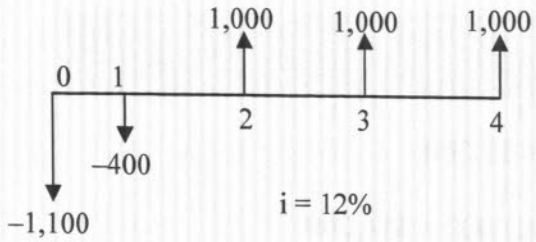
29.



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

THE CORRECT ANSWER IS: (B)

30.



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

$$+ 1{,}000\,(P/F, 12\%, 3) + 1{,}000\,(P/F, 12\%, 4)$$

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

$$= 687.34$$

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

= \$226 per year

THE CORRECT ANSWER IS: (D)

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

The present worth values are all given by

PW = First Cost + Annual Cost × (P/A, 12%, 8) – Salvage Value × (P/F, 12%, 8)
= First Cost + Annual Cost × 4.9676 – Salvage Value × 0.4039

Then PW(A) = \$63,731
PW(B) = \$63,392
PW(C) = \$63,901
PW(D) = \$63,222

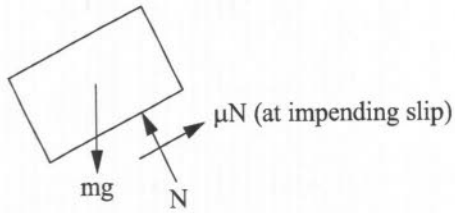
The cash flows are all costs, so the most preferable two projects, those with the lowest present worth costs, are B and D, and the difference between them is \$170.

THE CORRECT ANSWER IS: (B)

32. Normal to the plane:

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

Tangent to the plane:



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

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

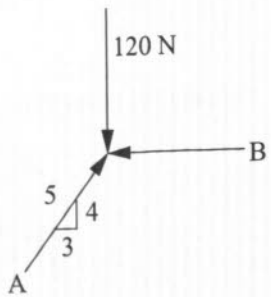
$$\frac{\sin\phi}{\cos\phi} = \tan\phi = \mu$$

$$\tan\phi = 0.25$$

THE CORRECT ANSWER IS: (D)

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

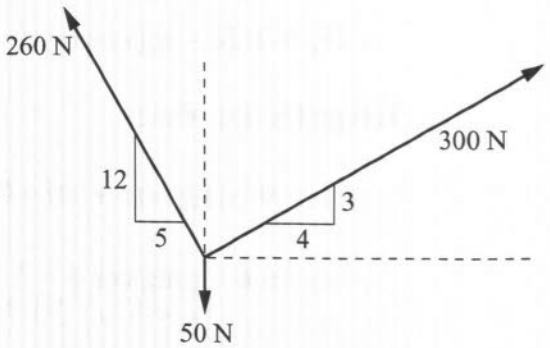
$A = 150$ N



THE CORRECT ANSWER IS: (C)

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

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

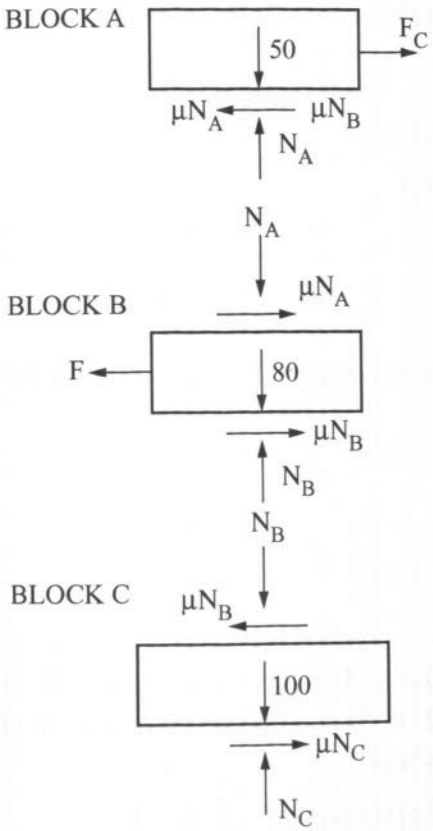


$R = \sqrt{R_x^2 + R_y^2} = \sqrt{370^2 + 140^2}$

$R = 396 \text{ N}$

THE CORRECT ANSWER IS: (D)

35.



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

$N_A = 50\ N$

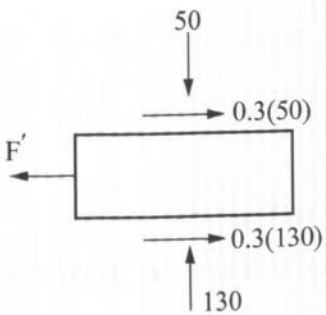
$\Sigma F_y = 0 = -50 - 80 + N_B$

$N_B = 130\ N$

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

$N_C = 230\ N$

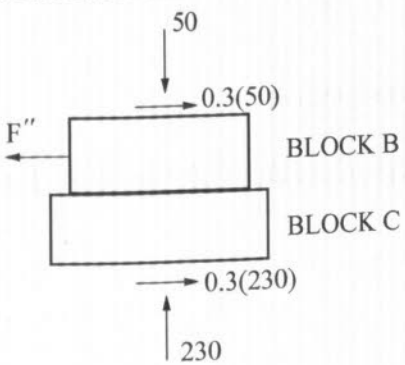
Assume Blocks A and C remain stationary.



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

$F' = 54\ N$

Assume Blocks B and C move.



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

$F'' = 84\ N$

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

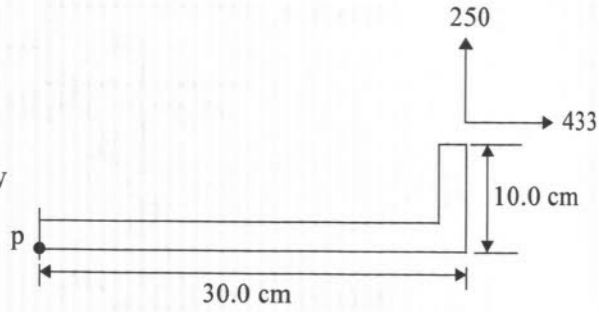
THE CORRECT ANSWER IS: (B)

36. $F_H = 500 \cos 30° = 433$

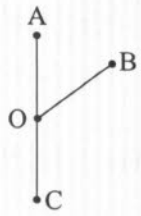
$F_V = 500 \sin 30° = 250$

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

THE CORRECT ANSWER IS: (A)



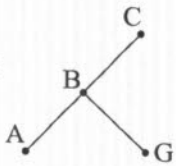
37. Zero-force members usually occur at joints where members are aligned as follows:



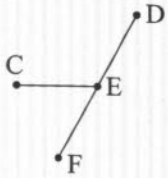
That is, joints where two members are along the same line (OA and OC) and the third member is at some arbitrary angle. That member (OB) is a zero-force member because the forces in OA and OC must be equal and opposite.

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

B:

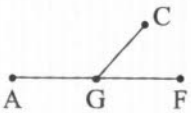


E:



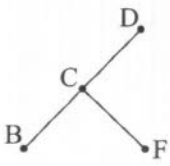
BG is zero-force member CE is zero-force member

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



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

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



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

THE CORRECT ANSWER IS: (A)

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

THE CORRECT ANSWER IS: (A)

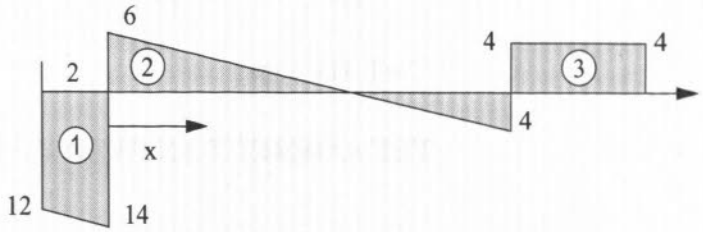
39. $\dfrac{10\text{ m}}{10\text{ kN}} = \dfrac{x}{6\text{ kN}}$

$x = 6$ m

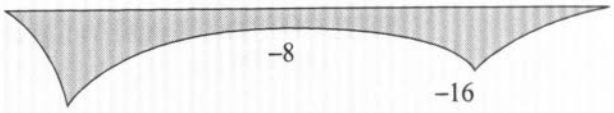
Area 1 $= 13(2)$ $= 26$ kN•m

Area 2 $= \dfrac{6(6)}{2}$ $= 18$ kN•m

Area 3 $= 4(4) = 16$ kN•m



SHEAR DIAGRAM



MOMENT DIAGRAM

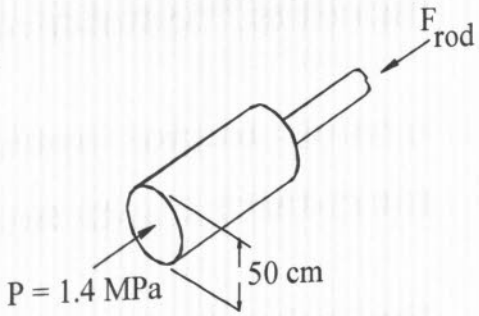
Maximum magnitude of the bending moment is 26 kN•m.

THE CORRECT ANSWER IS: (D)

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

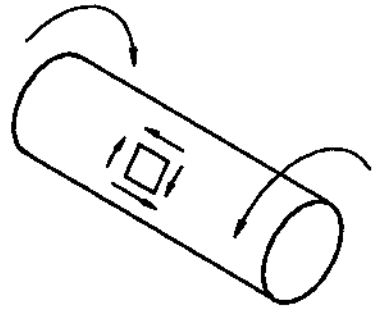
$F_{rod} = 275\text{ kN} = \sigma A = 68 \times 10^{6} A$

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



THE CORRECT ANSWER IS: (A)

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



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

$$T = 1{,}319 \text{ N•m}$$

THE CORRECT ANSWER IS: (C)

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

THE CORRECT ANSWER IS: (D)

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

THE CORRECT ANSWER IS: (A)

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

THE CORRECT ANSWER IS: (D)

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

THE CORRECT ANSWER IS: (D)

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

THE CORRECT ANSWER IS: (B)

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

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

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

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

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

THE CORRECT ANSWER IS: (C)

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

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

where τ_t = shear stress and

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

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

THE CORRECT ANSWER IS: (C)

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

$= 0.3\,m^3/s$

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

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

THE CORRECT ANSWER IS: (B)

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

THE CORRECT ANSWER IS: (B)

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

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

THE CORRECT ANSWER IS: (D)

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

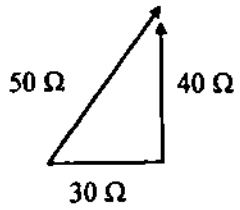
$S = P + jQ = |S|\cos\theta + j\,|S|\sin\theta$

$\cos\theta = pf = 0.866$

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

THE CORRECT ANSWER IS: (B)

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



THE CORRECT ANSWER IS: (D)

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

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

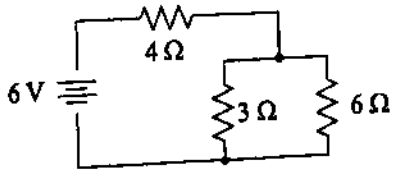
$W_C = 0.113$ J initial stored energy.

After ten time constants, all energy will be dissipated.

THE CORRECT ANSWER IS: (B)

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

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



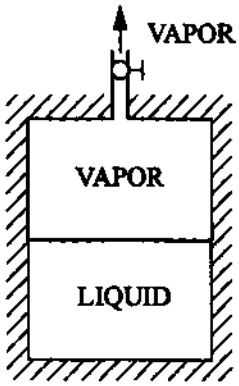
$$I_x = \frac{3}{9}(I_T) = \frac{1}{3}\text{A}$$

THE CORRECT ANSWER IS: (A)

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

THE CORRECT ANSWER IS: (A)

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



THE CORRECT ANSWER IS: (A)

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

THE CORRECT ANSWER IS: (D)

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

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

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

THE CORRECT ANSWER IS: (C)

60. $$R = \frac{Ru}{M} = \frac{8.314}{44} = 0.1890 \frac{kJ}{kg \cdot K}$$

THE CORRECT ANSWER IS: (A)

CIVIL
AFTERNOON SAMPLE QUESTIONS

NOTE: THESE QUESTIONS REPRESENT HALF THE NUMBER OF QUESTIONS THAT APPEAR ON THE ACTUAL EXAMINATION.

CIVIL SAMPLE QUESTIONS

1. A slope distance and zenith angle of 123.456 m and 102°54'00", respectively, are measured using a total station. The horizontal distance (m) is most nearly:

(A) 123.335

(B) 123.298

(C) 120.511

(D) 120.340

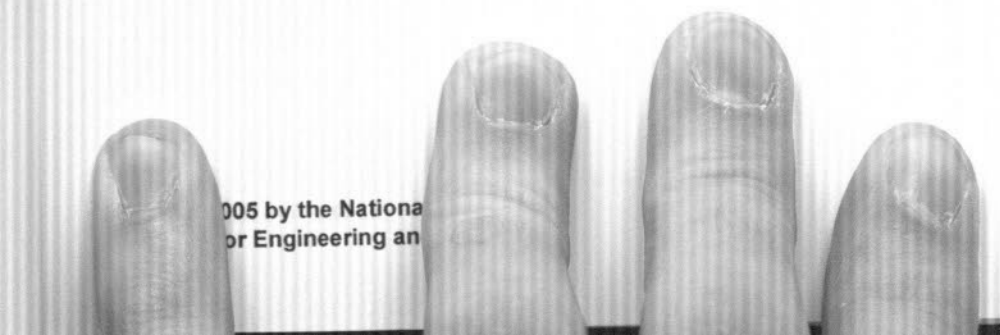
2. The arc definition of the Degree of Curve (D) is defined as the:

(A) central angle subtended by 100 ft of arc

(B) central angle subtended by 50 ft of chord

(C) central angle subtended by 50 ft of arc

(D) total arc length of the curve in stations divided by the total central angle in degrees



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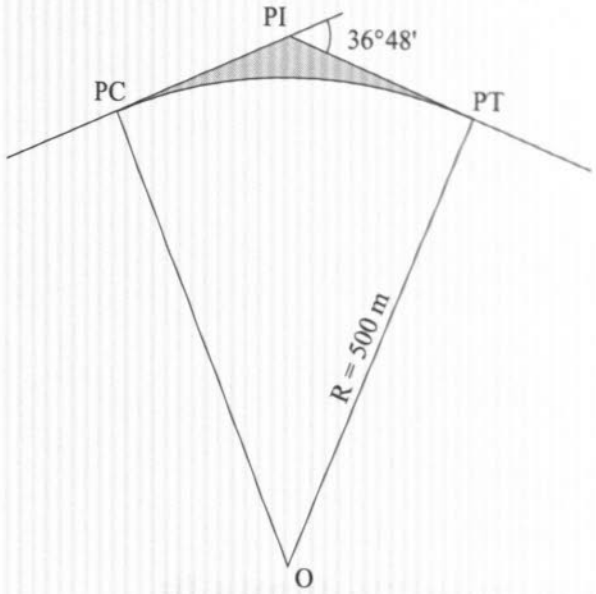
3. The area inside of the quadrilateral PC, PI, PT, and O below equals 83,164 m^2. The shaded area (m^2) between the circular curve and the tangents is most nearly:



(A) 2,879
(B) 3,577
(C) 5,407
(D) 8,286

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4. The cross-sectional areas to be excavated (cut) at certain sections of a road project are as follows:

Station	Area (ft^2)
3+00	247
4+00	269
4+35	322
5+00	395
5+65	418
6+00	293
7+00	168

Using the prismoidal method, the earth to be excavated (yd^3) between Sections 4+35 and 5+65 is most nearly:

(A) 1,460
(B) 1,840
(C) 1,860
(D) 1,900

5. A 12-in.-diameter concrete sanitary sewer (n = 0.013, constant with depth) flows half full and is constructed on a grade of 0.5%. The flow velocity (ft/sec) in this sewer is most nearly:

(A) 1.6
(B) 2.0
(C) 3.2
(D) 32.4

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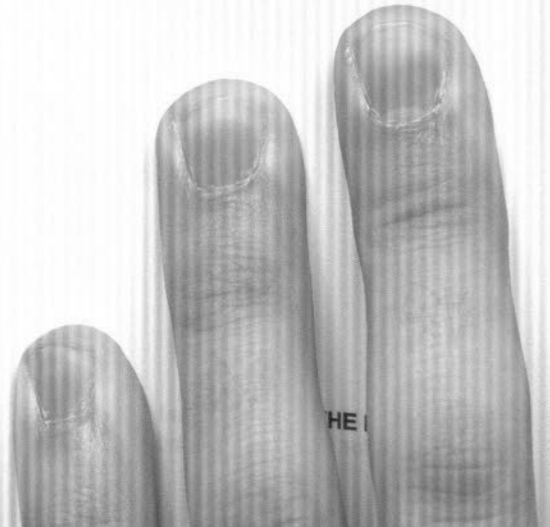
6. Two tanks are connected by a 500-ft length of 1-in.-I.D. PVC pipe. The appropriate value for the Hazen-Williams coefficient C is 150. Water at 60°F is flowing through the pipe at a velocity of 10 ft/sec. The tanks are open to the atmosphere. Entrance, exit, and minor losses are negligible. The difference in water surface elevation (ft) between the two tanks is most nearly:

(A) 81
(B) 167
(C) 182
(D) 447

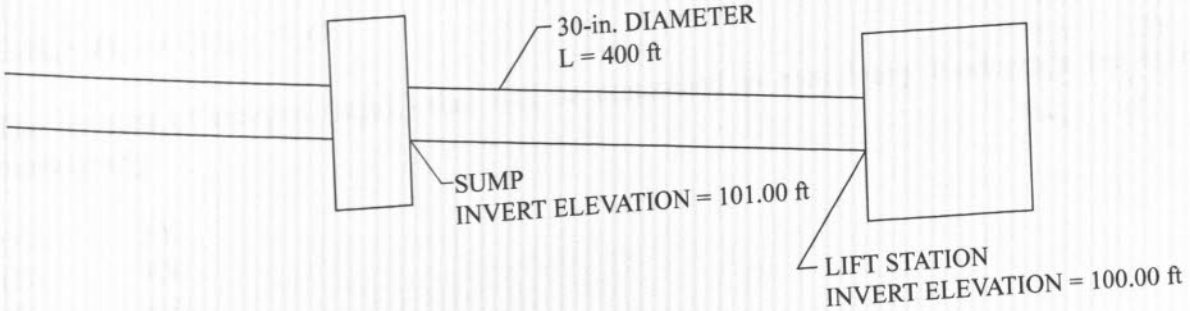
7. Waste activated sludge can be described as a Newtonian fluid with a kinematic viscosity of 20×10^{-5} ft^2/sec. At the same temperature, the kinematic viscosity ν of water is 10^{-5} ft^2/sec. The relative roughness of the piping system is 0.001.

The pressure drop for flow of water at a Reynolds number of 10^7 in this piping system was determined to be 1.0 psi. If waste activated sludge flows at the same velocity through the piping system, the pressure drop (psi) is most nearly:

(A) 1.0
(B) 2.0
(C) 3.0
(D) 4.0



8. A sanitary sewer delivers flow from a sump to a lift station as shown in the figure below. The sewer length is 400 ft, and the diameter is 30 in. The sewer is made of concrete (Manning's roughness coefficient, $n = 0.013$, and is constant with depth).



For full pipe flow with water surface elevations in the upstream sewer sump and lift station wet well of 105.00 and 103.50 ft, respectively, the discharge (cfs) is most nearly:

(A) 46.1
(B) 25.1
(C) 13.8
(D) 5.1

9. An embankment having a volume of 320,000 yd^3 is to be constructed from local borrow. The dry unit weight and moisture content of the borrow material were determined to be 106 pcf and 18.2%, respectively. The embankment material has a total unit weight of 122 pcf and a moisture content of 16.7%. The volume of borrow (yd^3) needed to construct the embankment is most nearly:

(A) 274,100
(B) 315,500
(C) 324,500
(D) 373,600

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10. A sample of field sand was tested in a triaxial device. At a confining pressure of 80 psi, the field sand failed at an applied external pressure of 400 psi. The angle of internal friction of the sand is most nearly:

(A) 53°
(B) 42°
(C) 34°
(D) 24°

11. A 12-ft-high retaining wall has backfill of granular soil with an internal angle of friction of 30° and a unit weight of 125 pcf. The Rankine passive earth pressure (lb/ft^2) possible on the wall is most nearly:

(A) 2,250
(B) 3,000
(C) 9,000
(D) 27,000

12. A normally consolidated 10-ft clay layer is surcharged, which causes a decrease in thickness. The coefficient of consolidation is 0.16 ft^2 per day and the time factor is 1.2 for U = 50%. The clay layer is confined between two layers of dense sand. The time (days) required for 50% consolidation is most nearly:

(A) 5
(B) 38
(C) 188
(D) 750

13. You are designing an aerobic system to biodegrade benzene (C_6H_6). The biodegradation follows the chemical reaction below (note that you must balance this equation). The benzene concentration is 500 mg/L. (C =12, H = 1, O = 16)

$C_6H_6 + O_2 \rightarrow CO_2 + H_2O$

The amount of oxygen (mg/L) that will be consumed to completely biodegrade the benzene is most nearly:

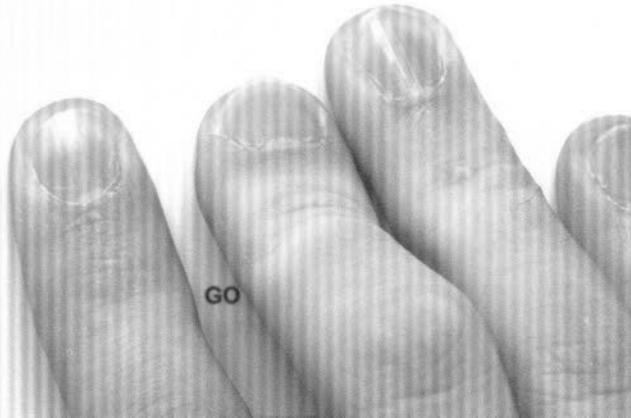
(A) 200
(B) 500
(C) 800
(D) 1,600

14. Three wastewater flows combine in a sewer, each having flows and BOD concentrations as follows.

Source	Flow (L/day)	BOD (mg/L)
1	4.0×10^6	200
2	0.8×10^6	300
3	0.2×10^6	500

If infiltration (having zero BOD) is 10% of total flow, the resulting BOD (mg/L) is most nearly:

(A) 76
(B) 207
(C) 228
(D) 333



Questions 15–16: A municipal activated sludge wastewater treatment plant with primary clarification and anaerobic digestion has the following influent characteristics:

Flow	5 MGD
BOD_5	200 mg/L @ 20°C
Suspended solids	220 mg/L

The facility is normally operated, and the following data apply:

Waste sludge flow rate	0.1 MGD
Mixed liquor suspended solids	2,500 mg/L
Return sludge concentration	6,000 mg/L
Waste activated sludge concentration	6,000 mg/L
Aeration basin hydraulic residence time	10 hr
Primary clarifier overflow rate	900 gal/day/ft^2
Effluent BOD_5	10 mg/L

15. If the plant BOD_5 removal efficiency is 95% and the primary clarifier removes 35% of the influent BOD, the amount of BOD_5 removed (lb/day) in the biological reaction is most nearly:

(A) 2,919
(B) 5,004
(C) 6,592
(D) 7,923

16. The aeration basin volume (gal) is most nearly:

(A) 1,260,000
(B) 1,870,000
(C) 2,080,000
(D) 50,000,000

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17. Which of the following is a prominent operating characteristic of cloverleaf interchanges?

(A) There are no unusual signing challenges.

(B) Traffic exits before additional traffic enters.

(C) There are low speeds on the loop ramps.

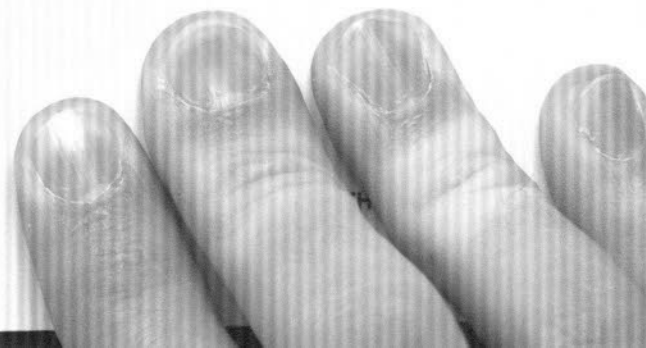
(D) There is no weaving traffic between exiting and entering traffic.

18. A person is driving a car on a road that has a gravel surface. A deer suddenly leaps into the road. The road is on a 10% downgrade, and the car is traveling at 50 mph when the deer appears. The driver's reaction time is 1.5 sec, and the coefficient of friction on the gravel surface is 0.65.

The coefficient of friction, $f = \dfrac{\text{deceleration rate, } a}{32.2 \text{ ft/sec}^2}$

The total distance (ft) required to stop is most nearly:

(A) 153
(B) 222
(C) 242
(D) 262



19. A freeway lane has a volume of 1,400 vehicles/hr and an average vehicle speed of 45 mph. The time spacing (sec) between vehicles (center to center) is most nearly:

(A) 2.6
(B) 5.2
(C) 15
(D) 31

20. A street underpass has a sag vertical curve. The following data apply:

Length of vertical curve	6.00 stations
Entering profile grade, g_1	–1.5%
Exiting profile grade, g_2	+2.5%
PVI station	32+00
PVI elevation	250.00

A drainage inlet must be designed to carry away the stormwater flow at the low point of the vertical curve. The station of the center of the inlet is most nearly:

(A) 29+75
(B) 31+25
(C) 32+75
(D) 34+25

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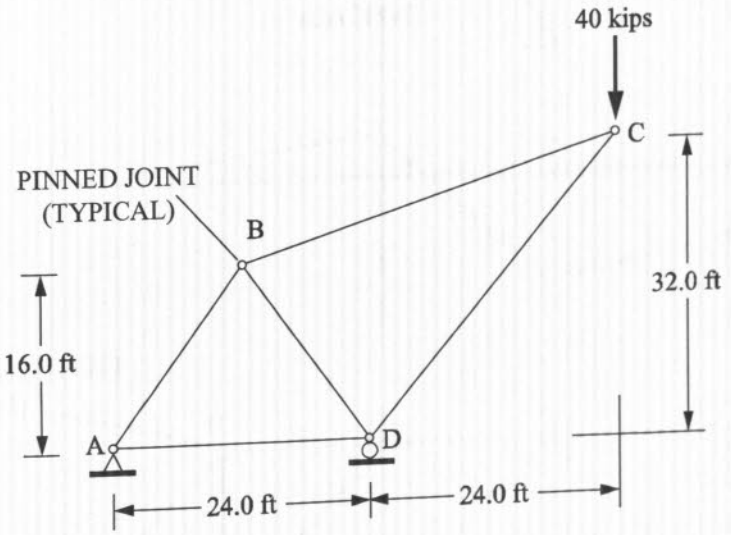
21. The 40-kip vertical load at Joint C in the steel truss shown below produces the forces given in the accompanying table. The cross-sectional area of each member is 4.0 in^2, and the length of each member is given in the table. The elastic modulus of steel is 29,000 ksi. The downward vertical displacement (in.) of Joint C is most nearly:

(A) 1.046
(B) 0.294
(C) 0.132
(D) 0.102

Member	Force, F (kips)	Length, L (in.)	$\frac{FL}{AE}$
AB	50.0	240	0.1034
BC	49.2	473	0.2008
CD	–75.0	480	–0.3103
AD	–30.0	288	–0.0745
BD	–25.0	240	–0.0517



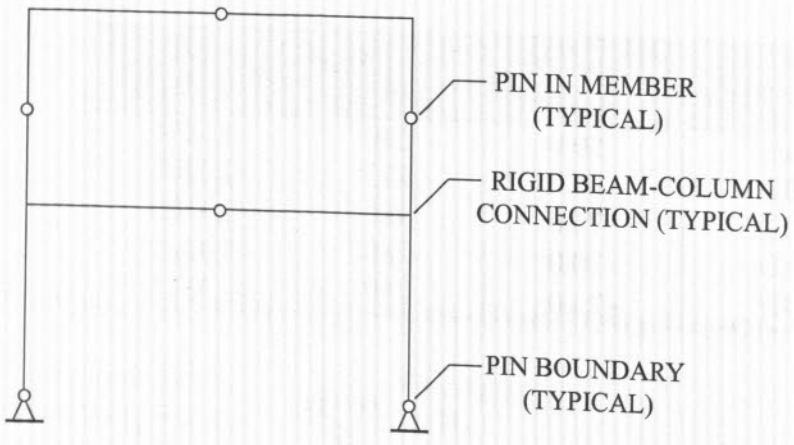
22. The frame in the figure below is:

(A) unstable

(B) stable and determinate

(C) indeterminate one degree

(D) indeterminate two degrees



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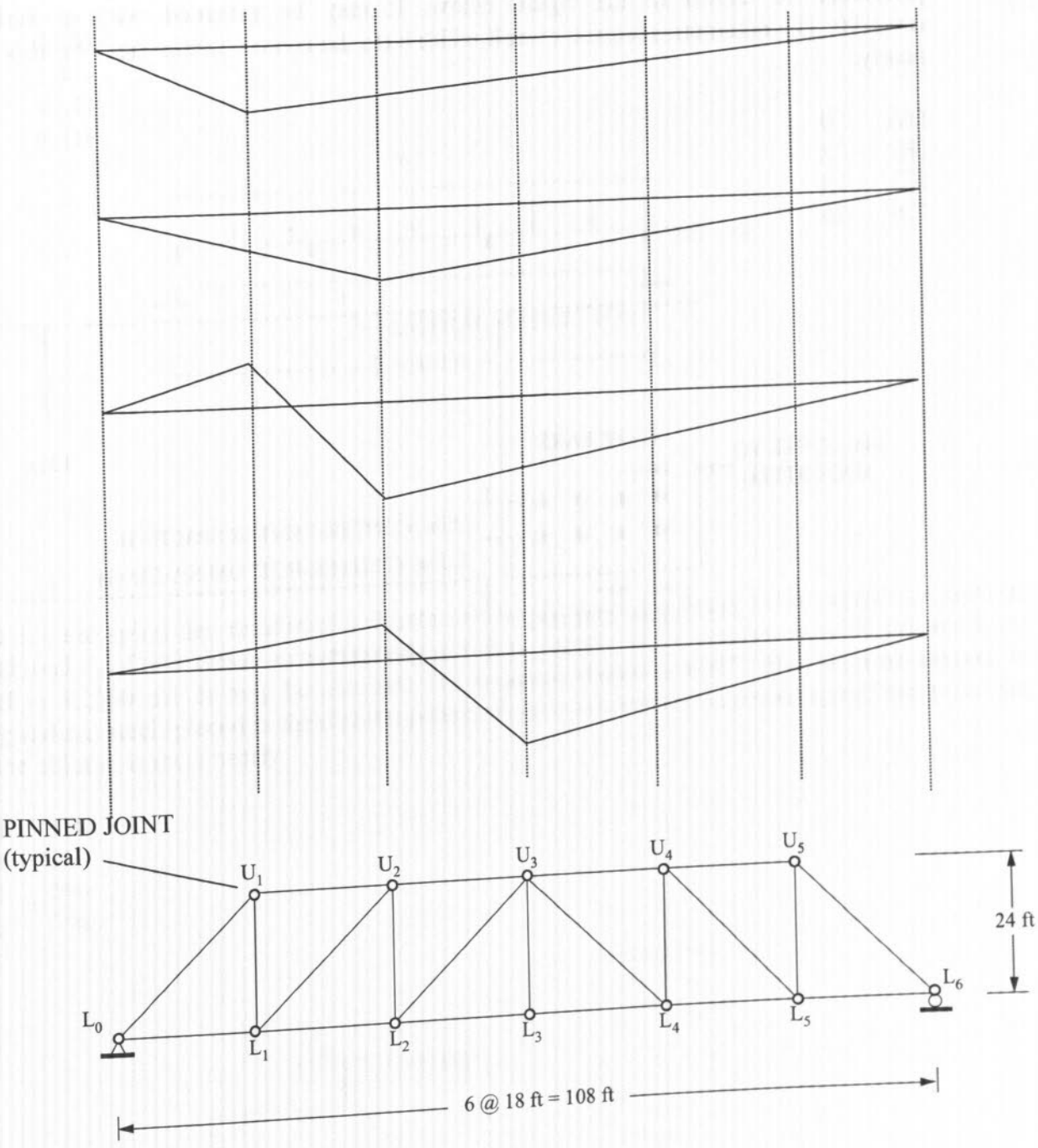
23. Which of the vertical-load influence lines shown below is correct for Member U_2U_3 of the truss shown below?

(A)

(B)

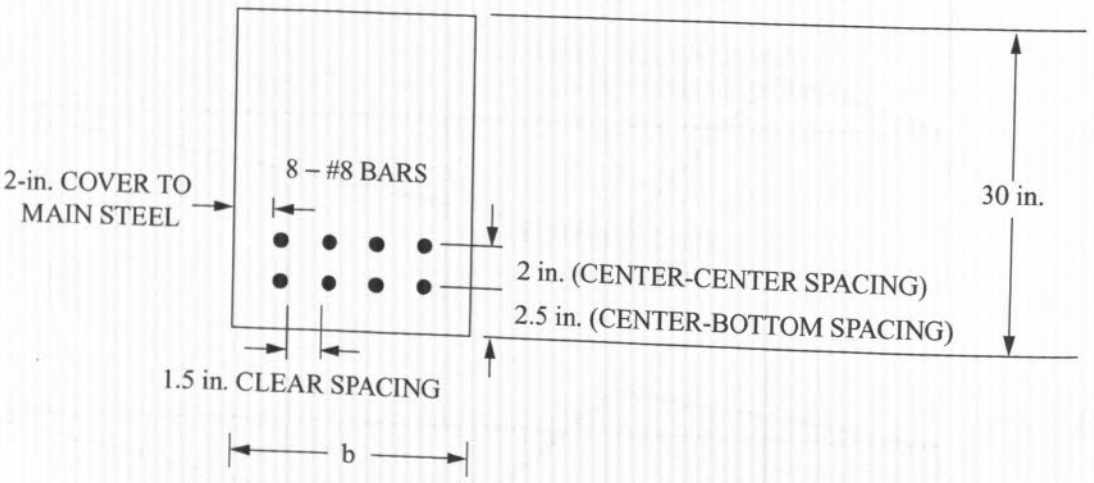
(C)

(D)



24. A reinforced concrete beam is subjected to a factored moment Mu = 648 ft-kips. For concrete $f_c' = 4{,}000$ psi, and for steel $f_y = 60{,}000$ psi. The beam is reinforced with eight #8 bars in two rows, positioned as shown in the figure below. It may be assumed without verification that $\phi = 0.90$. The minimum adequate overall width b (to the nearest whole inch) for this beam is most nearly:

(A) 10
(B) 12
(C) 13
(D) 15



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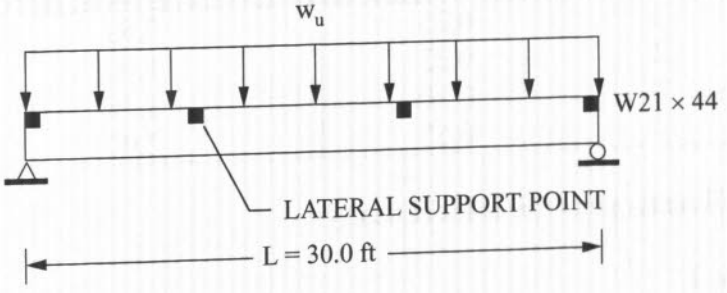
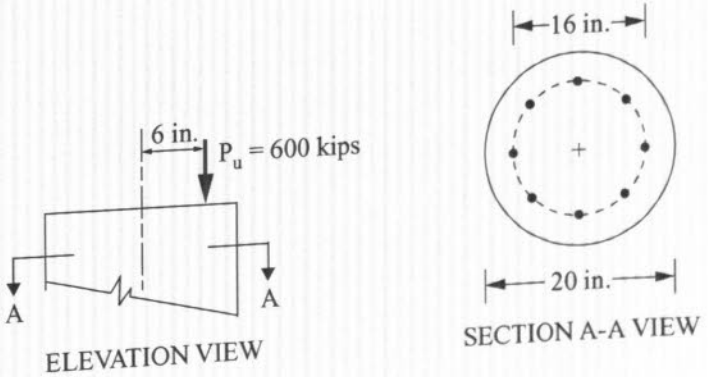
25. The W21 × 44 steel beam shown in the figure below has its compression flange laterally braced at the one-third points over its full length. Assume F_y = 50 ksi and C_b = 1.0 for the critical segment. The maximum factored load w_u (kips/ft) that the beam can carry for this length is most nearly:

(A) 2.187
(B) 2.444
(C) 3.191
(D) 3.548



26. The circular spiral-tied reinforced concrete column shown in the figure below supports a factored axial load P_u of 600 kips at an eccentricity of 6.0 in. Assume f_c' for concrete is 4,000 psi, and f_y for steel is 60,000 psi. It may be assumed the resistance factor ϕ = 0.7. The required amount of longitudinal steel (placed in the circular pattern shown) expressed as a percentage of the gross area of the column is most nearly:

(A) 1%
(B) 2%
(C) 5%
(D) 7%



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27. The average production of the excavator is the controlling factor in a highway ditch cleaning contract. Excavators with four different size buckets are available as rental units. The hourly rental rate is directly proportional to the bucket capacity of the excavator. Assume that production (loose yd^3/hr) is equal to (excavator cycles per hour) × (average bucket payload in LCY per cycle). The excavator characteristics are as follows:

Excavator	Minimum Cycle Time (min)	Average Bucket Payload (LCY)
1	0.25	0.50
2	0.33	1.00
3	0.50	1.75
4	0.58	2.00

The optimally efficient excavator is most nearly:

(A) Excavator 1

(B) Excavator 2

(C) Excavator 3

(D) Excavator 4

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28. Which type of contract is best suited for emergency conditions where the scope of service and materials cannot be accurately determined in advance?

(A) Lump sum

(B) Bonding

(C) Unit pricing

(D) Cost plus percentage fee

29. A steel bar is tested in tension at a stress less than the yield strength. The modulus of elasticity is most nearly:

(A) axial stress divided by change in length

(B) axial load divided by change in length

(C) axial stress divided by axial strain

(D) axial load divided by axial deformation

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

Water	305 lb/yd^3
Cement	693 lb/yd^3
Coarse aggregate (SSD)	1,674 lb/yd^3
Fine aggregate (SSD)	1,100 lb/yd^3

The properties of the aggregates are:

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

The amount of water (lb/yd^3) that would be used in the final mix is most nearly:

(A) 206
(B) 222
(C) 305
(D) 388

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

CIVIL
AFTERNOON SOLUTIONS

ANSWERS TO THE CIVIL AFTERNOON SAMPLE QUESTIONS

Detailed solutions for each question begin on the next page.

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

CIVIL AFTERNOON SOLUTIONS

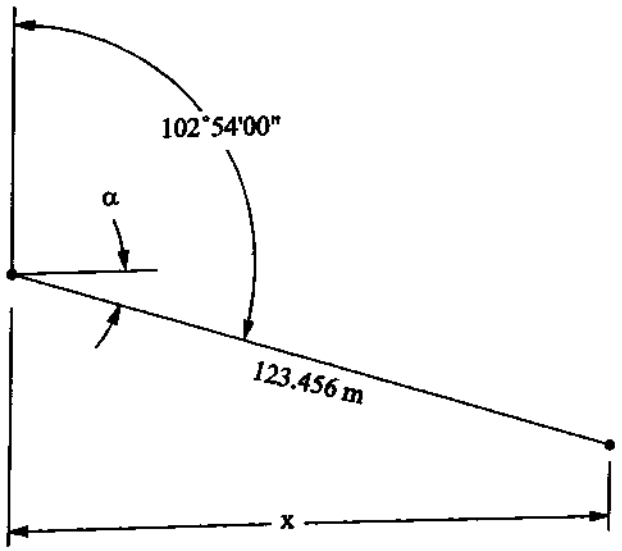
1. $= 102°54'00" - 90°00'00"$

$= 12.9°$

$\cos 12.9° = \frac{x}{123.456}$

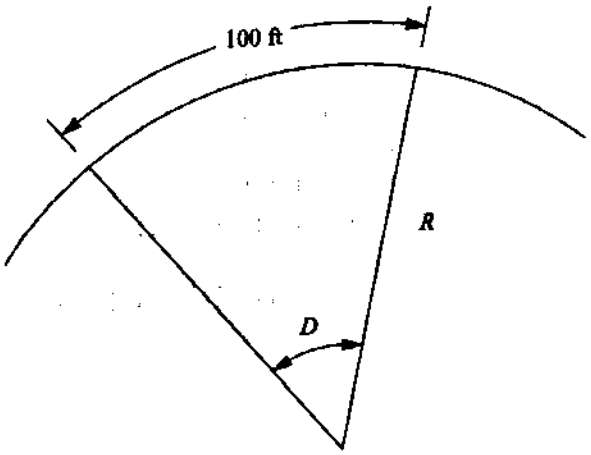
$x = (123.456)(0.975)$

$= 120.340$ m



THE CORRECT ANSWER IS: (D)

2. The Degree of Curve is defined as shown in the following figure.



THE CORRECT ANSWER IS: (A)

3. Find the area of the fractional part of the circle.

$A = \pi r^2$

$A = \pi(500)^2$

$\text{Fraction of circle} = \dfrac{36°48'}{360°} = 0.1022$

$\text{Area of fraction of circle} = 0.1022 \times \pi \times (500)^2 = 80,285 \text{ m}^2$

Shaded area = total area – fraction of circle

$= 83,164 - 80,285$

$= 2,879 \text{ m}^2$

THE CORRECT ANSWER IS: (A)

4. Refer to the earthwork formulas in the Civil Engineering section of *FE Reference Handbook.*

Volume to be excavated = 130[322 + (4)(395) + 418]/[(6)(27)] = 1,862 yd^3

THE CORRECT ANSWER IS: (C)

5. $V_{full} = \dfrac{1.486}{0.013} R^{2/3} s^{1/2}$

where $R = \dfrac{D}{4} = \dfrac{1.0}{4} = 0.25$

and $s = 0.005$

$V_{full} = 114.3(0.25)^{2/3}(0.005)^{1/2}$

$V_{full} = 114.3(0.3968)(0.0707) = 3.208 \text{ ft/sec}$

From the hydraulic elements graph in the Civil Engineering section of the *FE Reference Handbook*, the velocity in a pipe flowing half full is the same as for a pipe flowing full.

THE CORRECT ANSWER IS: (C)

6. Use Hazen-Williams equation.

$$V = (1.318)CR^{0.63}S^{0.54}$$

$$S = \left[\frac{V}{1.318CR^{0.63}}\right]^{1/0.54} \lim_{x\to\infty}$$

$$H_L = SL = \left[\frac{10}{(1.318)(150)\left(\frac{1/12}{4}\right)^{0.63}}\right]^{1/0.54}(500) = 182\,\text{ft}$$

THE CORRECT ANSWER IS: (C)

7. $$H_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

For the same piping system and velocity, H_L is proportional to f. For this case, the Reynolds number is very large, corresponding with fully turbulent flow conditions. Referring to the Moody Diagram in the Fluid Mechanics section of the *FE Reference Handbook*, it is apparent that f depends on pipe roughness but not Reynolds number for e/D = 0.001 and Reynolds numbers > 10^6. Thus, $f \cong 0.02$ for both applications, and pressure drops are equal.

THE CORRECT ANSWER IS: (A)

8.

$$A = \frac{\pi(2.5)^2}{4} = 4.91 \text{ ft}^2$$

$$R = \frac{D}{4} = \frac{2.5}{4} = 0.625 \text{ ft}$$

$$S = \frac{105 - 103.5}{400} = 0.00375$$

$$Q = \frac{1.486}{0.013}(4.91)(0.625)^{2/3}(0.00375)^{1/2}$$

$$Q = 25.12 \text{ cfs}$$

THE CORRECT ANSWER IS: (B)

9. Dry unit weight of embankment material $= 122\left(\frac{100}{116.7}\right)$

$= 104.5$ pcf

$= \frac{104.5}{106}(320,000)$

$= 315{,}470 \text{ yd}^3$

THE CORRECT ANSWER IS: (B)

10. Draw Mohr's circle and solve.

Sin Φ = [(400 – 80)/2]/[(80 + (400 – 80)/2)] = 160/240 = 0.6667

$\Phi = 41.8°$

THE CORRECT ANSWER IS: (B)

11. $K_p = \tan^2 (45 + \Phi/2) = 1.732$

$P_p = 0.5\ (125)(12 \times 12)(1.732 \times 1.732) = 26{,}998\ lb/ft^2$

THE CORRECT ANSWER IS: (D)

12. $t = T\ H_{dr}^2/c_v = 1.2\ (5 \times 5)/0.16 = 187.5$ days

THE CORRECT ANSWER IS: (C)

13. The balanced equation is: $C_6H_6 + 7.5O_2 \rightarrow 6CO_2 + 3H_2O$

$$500\ mg/L\ Bz\left(\frac{1\ m\ mole\ Bz}{78\ mg\ Bz}\right)\left(\frac{7.5\ m\ mole\ O_2}{m\ mole\ Bz}\right)\left(\frac{32\ mg\ O_2}{m\ mole\ O_2}\right) = 1{,}540\ mg/L$$

THE CORRECT ANSWER IS: (D)

14. $\Sigma Q_i C_i = Q_T\ C_{ave}$

Inflow = $Q_4 = 0.1(4.0 + 0.8 + 0.2) = 0.5$ million liters per day

$C_4 = 0$

$$C_{ave} = \frac{\sum Q_i C_i}{Q_T} = \frac{4(200) + 0.8(300) + 0.2(500)}{(4.0 + 0.8 + 0.2 + 0.5)} = 207\ mg/L$$

THE CORRECT ANSWER IS: (B)

15. Influent BOD_5 = 200 mg/L = (200 mg/L)(5 MGD)(8.34 lb/MG/mg/L) = 8,340 lb/day

BOD_5 removed by primary clarifiers = 8,340 × 0.35 = 2,919

BOD_5 in effluent = 8,340 × 0.05 = 417

BOD_5 removed in biological reaction = 8,340 – 2,919 – 417 = 5,004 lb/day

THE CORRECT ANSWER IS: (B)

16. The aeration basin volume is equal to the product of the hydraulic detention time and the wastewater flow rate.

$$\text{Volume} = \frac{(10\text{ hr})(5{,}000{,}000\text{ gal/day})}{24\text{ hr/day}} = 2{,}083{,}333\text{ gal}$$

THE CORRECT ANSWER IS: (C)

17. Interchange loop ramps on a traditional clover leaf ramp are always low speed, often with 25 mph advisory speed limits, rarely in excess of 30 mph.

THE CORRECT ANSWER IS: (C)

18.
$$\begin{aligned}\text{Distance} &= \frac{V^2}{30\left[(a/32.2)\pm G\right]} + 1.47Vt;\ a = f(32.2)\\ &= \frac{50^2}{30[0.65-0.10]} + 1.47(50\times 1.5)\\ &= 151.52 + 110.25\\ &= 261.8\end{aligned}$$

THE CORRECT ANSWER IS: (D)

19.
$$\text{Spacing} = \frac{3{,}600\text{ sec/hr}}{1{,}400\text{ vehicles/hr}} = 2.57\text{ sec/vehicle}$$

THE CORRECT ANSWER IS: (A)

20. $X_m = \dfrac{g_1 L}{g_1 - g_2} = \dfrac{(-1.5)(6)}{-4} = 2.25$ stations

$\text{PVC station} = \text{PVI station} - \dfrac{L}{2} = (32{+}00) - (3.00) = 29{+}00$

$\text{Low point} = \text{PVC station} + X_m = (29{+}00) + 2.25 = 31{+}25$

THE CORRECT ANSWER IS: (B)

21. Apply a downward 1-kip load (unit load) at Joint C and compute forces f in bars.
(Note: this can easily be done by dividing each F force by 40).

Multiply each member's change in length $\Delta L = \dfrac{FL}{AE}$ by its force f in the table below,

(be sure to use the signed values of $\Delta L = \dfrac{FL}{AE}$ and f).

Then, sum $f \cdot \dfrac{FL}{AE}$ to get the displacement at Joint C.

$\Sigma f \cdot \dfrac{FL}{AE} = +1.0464$ in. down

Member	F (kips)	L (in.)	$\frac{FL}{AE}$	f	$f \cdot \frac{FL}{AE}$
AB	50.0	240	0.1034	1.25	0.1292
BC	49.2	473	0.2008	1.231	0.2472
CD	–75.0	480	–0.3103	–1.875	0.5818
AD	–30.0	288	–0.0745	–0.75	0.0559
BD	–25.0	240	–0.0517	–0.625	0.0323
					$\Sigma = 1.0464$

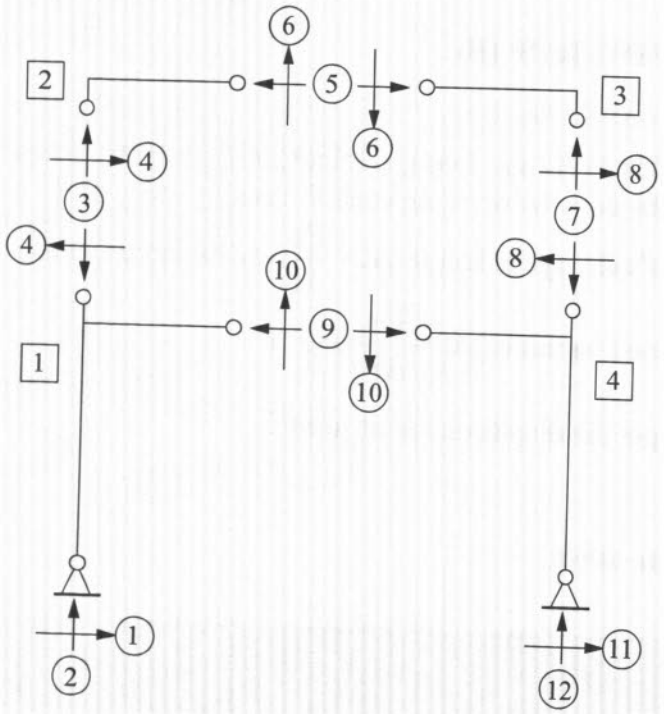
THE CORRECT ANSWER IS: (A)

22. Unknown reactions and internal forces at internal pins: $6 \times 2 = 12$

Rigid body components (shown as FBDs) @ 3 equations per component: 4

Number of equations: $4 \times 3 = 12$

There are 12 equations and 12 unknowns → determinate (stable by member arrangement).

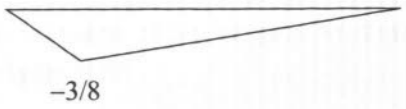


[1] RIGID BODY

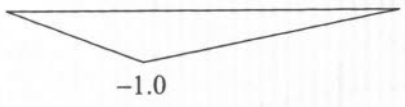
(1) UNKNOWN FORCE

THE CORRECT ANSWER IS: (B)

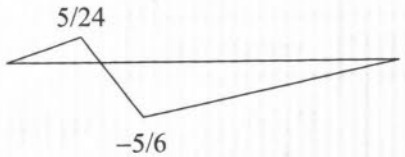
23. (A)



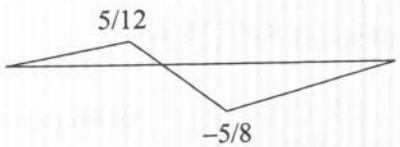
(B)



(C)



(D)



THE CORRECT ANSWER IS: (B)

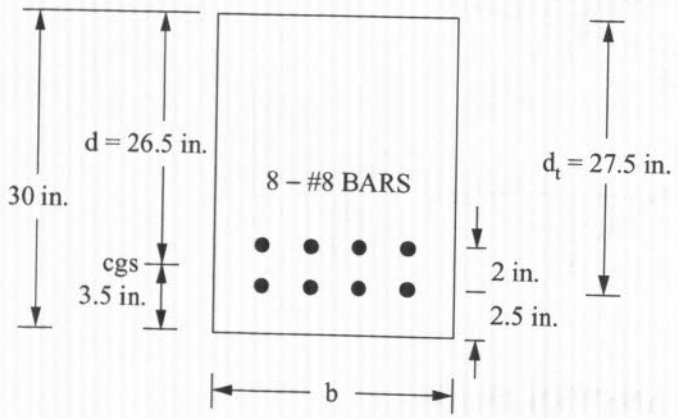
24. $M_n = \frac{M_u}{\phi} = A_s f_y \left(d - \frac{a}{2}\right) = A_s f_y \left(d - \frac{1}{2} \times \frac{A_s f_y}{0.85 f_c' b}\right)$

where $A_s = 8 \times 0.79 \text{ in}^2 = 6.32 \text{ in}^2$

$d = 30 - 3.5 = 26.5$ in. (do not use $d_t = 27.5$ in.)

$$\frac{648 \times 12}{0.9} = 6.32 \times 60 \left(26.5 - \frac{1}{2} \times \frac{6.32 \times 60}{0.85 \times 4 \times b}\right)$$

$b = 14.98 \text{ in.} (\text{use } 15 \text{ in.})$

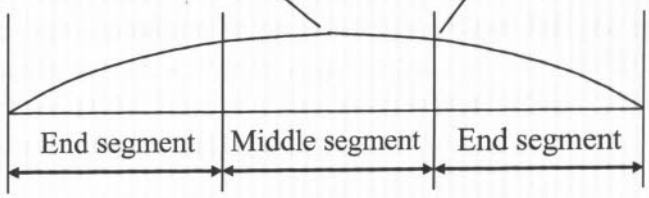


THE CORRECT ANSWER IS: (D)

25. It should be recognized that the middle unbraced segment is the critical segment. The justification for choosing this segment may be demonstrated by dividing the moment diagram into unbraced-length segments:

$M_u(max) = \frac{w_u L^2}{8}$ at midspan

At the one-third point, $M_u = \frac{8}{9} M_u\,(max)$



End segments: $L_b = L/3$

$M_u = \frac{8}{9} M_u\,(max)$

$C_b > 1.0$ due to shape of moment diagram

Middle segment: $L_b = L/3$

$M_u = M_u\,(max)$

$C_b \cong 1.0$ ($C_b = 1$ given in question statement)

The middle segment has greater M_u and smaller C_b (for the same unbraced length), so that the middle segment is the critical segment.

Solution details

Method 1 (computation) For bracing @ L/3: $L_b = 10.0$ ft and $C_b = 1.0$ (given)

From the Z_x table in the Civil Engineering section of the *FE Reference Handbook*, for W21 × 44:

$\phi M_p = 359$ ft-kips $\quad L_p = 4.45$ ft $\quad L_r = 12.0$ ft $\quad BF = 15.0$

Since: $L_p < L_b = 10 < L_p$:

$\phi M_n = \phi M_p - BF \times (L_b - L_p) = 359 - 15.0 \times (10.0 - 4.45) = 275.75$ ft-kips

$$w_u = \frac{8\phi Mn}{L^2} = \frac{8 \times 275.75}{(30)^2} = 2.444 \text{ kips/foot}$$

Method 2 (graphical) For bracing @ L/3: $L_b = 10.0$ ft and $C_b = 1.0$ (given)

From the Beam Design Moments curves in the Civil Engineering section of the *FE Reference Handbook*:

Enter horizontal axis at $L_b = 10.0$ ft, and read upward to W21 × 44 curve: $\phi M_n = 275$

$$w_u = \frac{8\phi Mn}{L^2} = \frac{8 \times 275}{(30)^2} = 2.444 \text{ kips/foot}$$

THE CORRECT ANSWER IS: (B)

26. Refer to the interaction diagram in the Civil Engineering section of the *FE Reference Handbook.*

$$\gamma = \frac{16}{20} = 0.8$$

$$f_c' = 4 \text{ ksi}$$

$$f_y = 60 \text{ ksi}$$

$$A_g = \frac{\pi(20)^2}{4} = 314.2$$

$$\frac{P_u}{\phi f_c' A_g} = \frac{600}{0.7(4)(314.2)} = 0.68$$

$$\frac{P_u e}{\phi f_c' A_g h} = \frac{600(6)}{0.7(4)(314.2)(20)} = 0.204$$

From interaction diagram: $\rho_g = 0.05 \rightarrow 5\%$

THE CORRECT ANSWER IS: (C)

27. Production of Excavator 3 $= \frac{60 \text{ min/hr}}{0.50 \text{ min cycle}} \times 1.75 \text{ LCY capacity} = 210 \text{ LCY/hr}$

Similar calculations for the other three excavators show they have lower production rates.

THE CORRECT ANSWER IS: (C)

28. Option (B) is not a type of contract. Options (A) and (C) are used when quantities are known.

THE CORRECT ANSWER IS: (D)

29. By definition, modulus of elasticity is axial stress divided by axial strain.

THE CORRECT ANSWER IS: (C)

30. 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 mix. The water added to the mix is the water computed for oven-dry aggregates (305 lb/yd^3) plus the excess water in each aggregate.

$$\text{Final water} = 305 - [(2.0\% - 0.5\%)/100] \times 1{,}674 - [(6.0\% - 0.7\%)/100] \times 1{,}100 = 221.6 \text{ lb/yd}^3$$

THE CORRECT ANSWER IS: (B)