



FE CIVIL EXAM 04

Table of Contents

Problems..... 2
Solutions..... 42

Problems

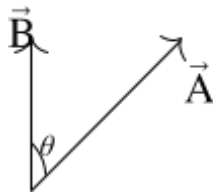
[Click here for Solutions](#)

1. Find the scalar triple product of $\vec{A} \cdot (\vec{B} \times \vec{C})$ if $\vec{A} = \hat{i}$, $\vec{B} = \hat{j}$ and $\vec{C} = \hat{k}$

- (A) -9
- (B) 1
- (C) 9
- (D) $\sqrt{5}$

2. Find the angle between the vectors $\vec{A} = \hat{i} + \hat{j}$ and $\vec{B} = \hat{j}$.

- (A) 45°
- (B) 60°
- (C) 90°
- (D) 30°



3. Which probability distribution is appropriate for modeling the number of successes in a fixed number of trials?

- (A) Binomial distribution
- (B) Normal distribution
- (C) Poisson distribution
- (D) Exponential distribution

4. Determine the unit vector in the direction of $\vec{B} = 2\hat{i} - 2\hat{j}$.

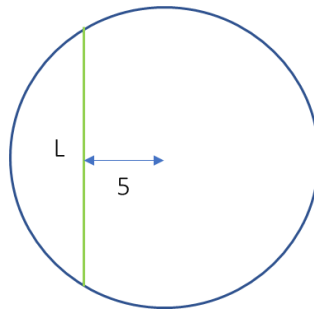
(A) $\frac{1}{\sqrt{2}}(\hat{i} - \hat{j})$

(B) $\frac{1}{\sqrt{8}}(\hat{i} - \hat{j})$

(C) $\frac{1}{2}(\hat{i} - \hat{j})$

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

5. What is the length of the chord of a circle with radius 13 units, located 5 units away from the center?



(A) 24 units

(B) 20 units

(C) 26 units

(D) 18 units

6. A game involves rolling a fair die. A player wins \$10 if the die shows a 6, loses \$5 if it shows a 1, and neither wins nor loses for any other outcome. What is the expected value of the game per roll?

A. $\$3/6$

B. $\$4/6$

C. $\$5/6$

D. $\$2/6$

7. Determine the vector projection of $\vec{A}$ onto $\vec{B}$ if $\vec{A} = 2\hat{i} - \hat{j}$ and $\vec{B} = \hat{i} + \hat{j}$

(A) $\frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$

(B) $\frac{3}{2}(\hat{i} + \hat{j})$

(C) $\frac{1}{\sqrt{2}}(2\hat{i} - \hat{j})$

(D) $\frac{1}{2}(\hat{i} + \hat{j})$

8. Given vectors $A = 2\hat{i} + 3\hat{j} - \hat{k}$ and $B = \hat{i} - 2\hat{j} + 4\hat{k}$, what is the scalar triple product $A \cdot (B \times A)$?

(A) 0

(B) 5

(C) -5

(D) 10

9. If $\vec{A} = 3\hat{i} + 2\hat{j} + \hat{k}$, find the projection of $\vec{A}$ onto the $\hat{i}$ axis

(A) 3

(B) 2

(C) 1

(D) 4

10. A construction contract specifies that disputes will be resolved through arbitration. Which of the following is true about arbitration in this context?

A. Arbitration is non-binding unless both parties agree to the outcome.

B. Arbitration decisions are subject to appeal in court.

- C. Arbitration is faster and more cost-effective than litigation.
- D. Arbitration allows public access to hearings and records.

11. What must a licensed engineer do if they discover a safety issue in a project they are working on?

- (A) Ignore it if it is not within their direct responsibility.
- (B) Attempt to fix it themselves without informing anyone
- (C) Wait until the project is completed before addressing it
- (D) Notify their employer or client and, if necessary, the appropriate authorities.

12. What is a common remedy for a breach of contract?

- (A) Awarding damages to the injured party
- (B) Ignoring the breach if it is minor
- (C) Allowing the breaching party to continue without penalty
- (D) Terminating the contract without any compensation

13. Why is licensure by comity important for engineers?

- (A) It allows engineers to practice internationally
- (B) It simplifies the process of obtaining a license in multiple states
- (C) It provides financial benefits
- (D) It is required for federal projects

14. An engineer is responsible for overseeing the construction of a new bridge. According to the standard of care, the engineer is expected to conduct regular inspections and testing of materials. However, the engineer fails to perform these inspections and testing at critical stages of the construction process. As a result, substandard materials are used, and construction defects go unnoticed, leading to a partial collapse of the bridge, causing significant damage and endangering lives. Which of the following best describes this situation?

- (A) The engineer has performed due diligence.
- (B) The engineer has breached the standard of care by failing to conduct necessary inspections and testing.
- (C) The engineer has adhered to the NSPE Code of Ethics by prioritizing project deadlines
- (D) The engineer is not responsible for the collapse because the contractor is solely to blame.

15. A construction company is considering two alternatives for equipment purchase. Option 1 has an initial cost of \$60,000 and annual operating costs of \$10,000. Option 2 has an initial cost of \$80,000 and annual operating costs of \$5,000. Both options have a useful life of 5 years. If the discount rate is 8 which option is more feasible?

- (A) Option 1
- (B) Option 2
- (C) Both are equally cost-effective
- (D) Cannot be determined from the given information

16. At what point does breakeven occur in breakeven analysis?

- (A) When total revenue equals total cost
- (B) When fixed costs equal variable costs
- (C) When marginal cost equals marginal revenue
- (D) When profit is maximized

17. For a life cycle cost analysis, which factor is considered the most critical when selecting between two competing projects?

- (A) Initial cost
- (B) Operating cost
- (C) Maintenance cost
- (D) Total cost of ownership

18. Two investment options, X and Y, have the following characteristics:

Option	Expected Return (\$)	Standard Deviation (\$)
X	10,000	2,000
Y	15,000	5,000

Which option has a lower risk per unit of return based on the coefficient of variation (CV)?

- A) X by 0.10
- B) Y by 0.10
- C) X by 0.13
- D) Y by 0.13

19. A project with an initial cost of \$70,000 and a salvage value of \$10,000 at the end of 5 years has an annual operating cost of \$15,000. If the discount rate is 6, calculate the Present Value.

- (A) \$114,000
- (B) \$119,400
- (C) \$125,707
- (D) \$130,000

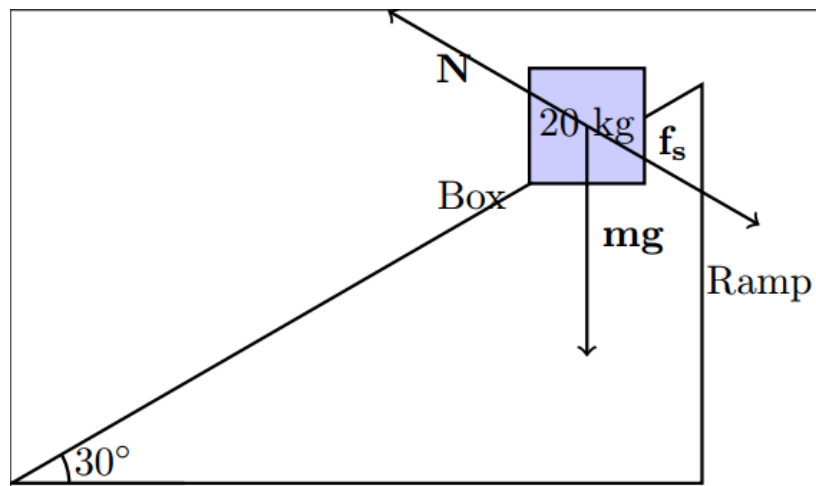
20. A company is considering expanding production from 10,000 units to 12,000 units. Fixed costs are \$100,000, and the variable cost per unit is \$25. If the selling price is \$50 per unit, what is the incremental profit from the additional units?

- A) \$30,000
- B) \$40,000
- C) \$50,000
- D) \$60,000

21. A renewable energy project requires an initial investment of \$250,000 and generates \$50,000 annually for 7 years. If the discount rate is 10 calculate its profitability index (PI).

- (A) 1.1
- (B) 1.2
- (C) 0.97
- (D) 2.3

22. A 20 kilogram box is positioned on a ramp that is sloped at an angle of 30 degrees relative to the horizontal. The static friction coefficient between the box and the ramp is 0.5. What is the greatest magnitude of the static frictional force?



- (A) 98.1 N
- (B) 169.7 N
- (C) 85.5 N
- (D) 49.0 N

23. A block with a weight of W is put on a flat surface with a static friction coefficient of μ_s . How strong is the horizontal force F that can be put on the block without moving it?

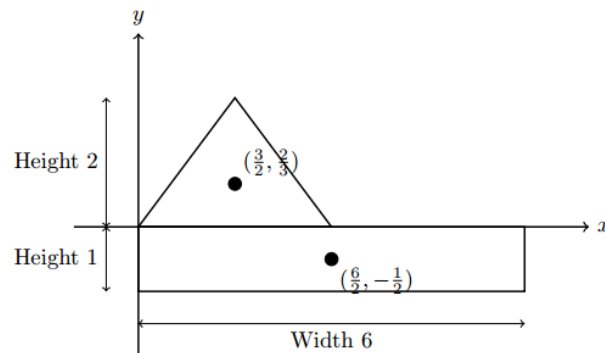
- (A) $\mu_s W$
- (B) $W\mu_s$
- (C) $\mu^s Wg$
- (D) $\mu^s W$

24. A composite area is made up of two shapes:

-A rectangle with a width of 6 m and a height of 1 m, positioned along the x-axis.

-A triangle with a base of 3 m (on top of the rectangle) and a height of 2 m.

Calculate the moment of inertia of this composite area about the base of the rectangle.

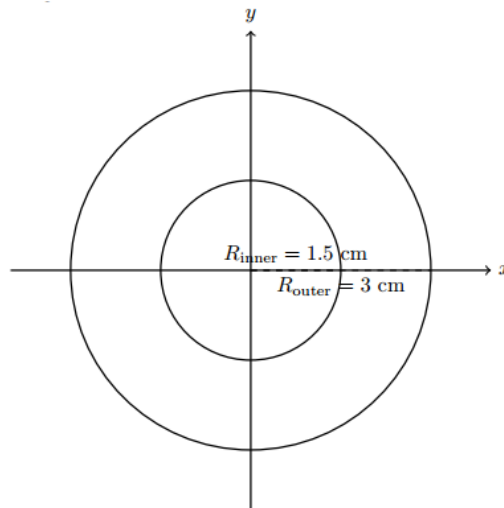


- (A) 0.75m^4
- (B) 6m^4
- (C) 11m^4
- (D) 3.63m^4

25. What's the ratio of tight side tension to the slack side tension (T_1/T_2) if the angle of wrap is 270 degrees and the friction coefficient is 0.35?

- (A) 1
- (B) 5.20
- (C) 225
- (D) 53.675

26. The outside diameter of an empty circle is 6 cm, and the inside diameter is 3 cm. Calculate the radius of gyration around its axis of rotation?



- (A) 3.677cm
- (B) 1.677cm
- (C) 5.02cm
- (D) 5.50 cm

27. Calculate the second moment of inertia about the centroidal axis of a beam with a flange width of 10 cm, web height of 20 cm, flange thickness of 2 cm, and web thickness of 1 cm.

- (A) 3200cm^4
- (B) 4100cm^4
- (C) 5400cm^4
- (D) 5520cm^4

28. Consider the theorem of parallel axis:

The area is A , and the distance between the center axis and the new axis is d . I_c is the moment of inertia about the center axis. How much mass is I on the new axis if I_c is 50 cm^4 , A is 10 cm^2 , and d is 5 cm ?

- (A) 100cm^4
- (B) 150cm^4
- (C) 200cm^4
- (D) 300 cm^4

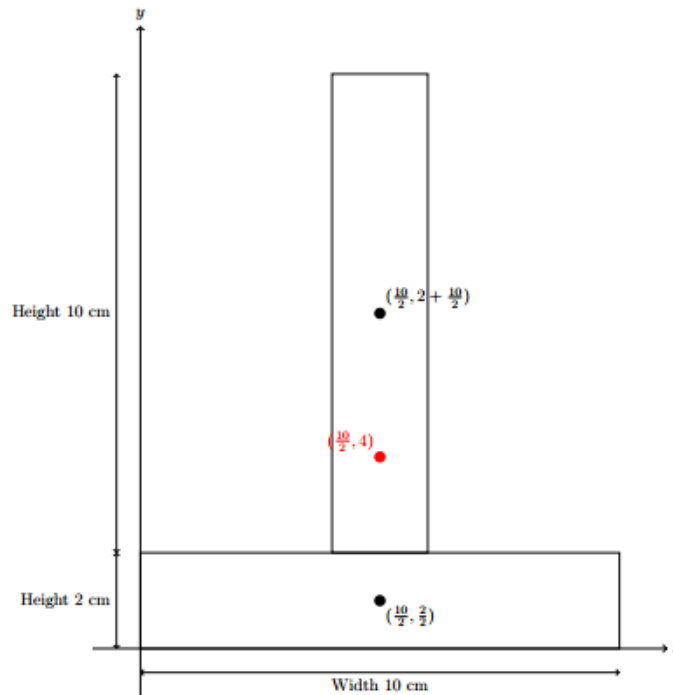
29. A belt encircles a pulley with a contact angle of 180 degrees (π radians). The static friction coefficient between the belt and the pulley is 0.25 . If the tension on the loose side of the belt is 100 N , what is the tension in the tight side?

- (A) 128.4N
- (B) 100N
- (C) 219N
- (D) 164.9N

30. A rough surface has a 10 kg box on it. If there is 0.4 coefficient of static friction between the box and the surface, how much force can be put on the box horizontally without moving it? ($G = 9.81\text{ m/s}^2$)

- (A) 75.275 N
- (B) 49.5 N
- (C) 98.1 N
- (D) 39.2 N

31. Think about a T-shaped piece that is made up of a base (10cm x 2cm) and web (2cm x 10cm). Find the section's moment of inertia around its central line.



- (A) 533.34 cm^4
- (B) 289.25 cm^4
- (C) 125 cm^4
- (D) 175 cm^4

32. Find the radius of gyration k for a solid sphere with radius R and mass M .

- (A) $R/3$
- (B) $R/\sqrt{2}$

(C) $R/\sqrt{3}$

(D) $2R$

33. The projectile is sent off at a 45° angle and at a speed of 30 m/s at first. How tall can it reach?

(A) 22.5 m

(B) 45 m

(C) 30.5 m

(D) 15 m

34. Considering an axis that is perpendicular to the rod and passes through its center, what is the mass moment of inertia of a thin rod with a length of L and a mass of m ?

(A) $\frac{1}{3}mL^2$

(B) $\frac{1}{12}mL^2$

(C) $\frac{1}{8}mL^2$

(D) mL^2

35. A particle's velocity is $\mathbf{v} = (3, 4, 5)\text{m/s}$ and its acceleration is $\mathbf{a} = (1, 0, -1)\text{m/s}^2$. It is going along a curved route. What will be the acceleration's tangential component?

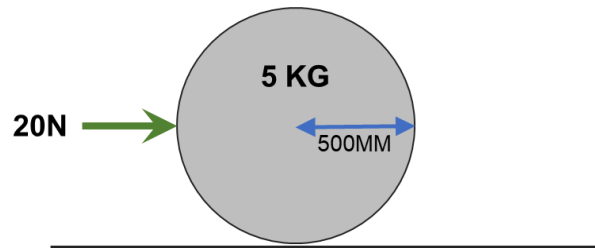
(A) $2\sqrt{5}\text{ m/s}^2$

(B) 7.5 m/s^2

(C) 1 m/s^2

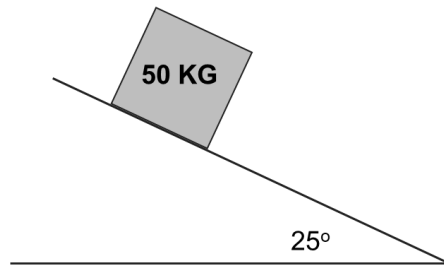
(D) 0 m/s^2

36. A uniform solid disk of mass 5 kg and radius 0.5 m is subjected to a force of 20 N at its edge. If the disk is initially at rest and rolls without slipping, what is its angular acceleration?



- (A) 16 rad/s^2
- (B) 20 rad/s^2
- (C) 24 rad/s^2
- (D) 32 rad/s^2

37. A 50 kg box is sliding down a 25-degree inclined plane with a constant velocity. What is the coefficient of kinetic friction between the box and the plane?



- (A) 0.47
- (B) 0.53
- (C) 0.62
- (D) 0.42

38. A rectangular element is subjected to a normal stress of $\sigma_x = 50 \text{ MPa}$ and $\sigma_y = 30 \text{ MPa}$ and a shear stress of $\tau_{xy} = 20 \text{ MPa}$. Calculate the principal stresses.

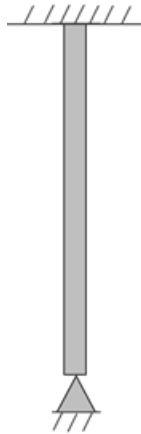
- (A) 31.74 MPa and 19.85 MPa
- (B) 245 MPa and 45 MPa

- (C) 225 MPa and 55.25 MPa
- (D) 62.36 MPa and 17.64 MPa

39. A cylindrical shaft of radius 0.05 m is subjected to a torsional stress. If the modulus of rigidity G is 80 GPa and the angle of twist is 0.01 rad over a length of 1 m, what is the shear stress?

- (A) 40 MPa
- (B) 80 MPa
- (C) 60 MPa
- (D) 100 MPa

40. A steel column having pin support at bottom and fixed support at top. The length of the column is 4 meters. Radius of gyration is 50 mm and Area of the section is $200 \times 200 \text{ mm}^2$. Find the buckling value?. ($E = 200 \times 10^3 \text{ MPa}$)

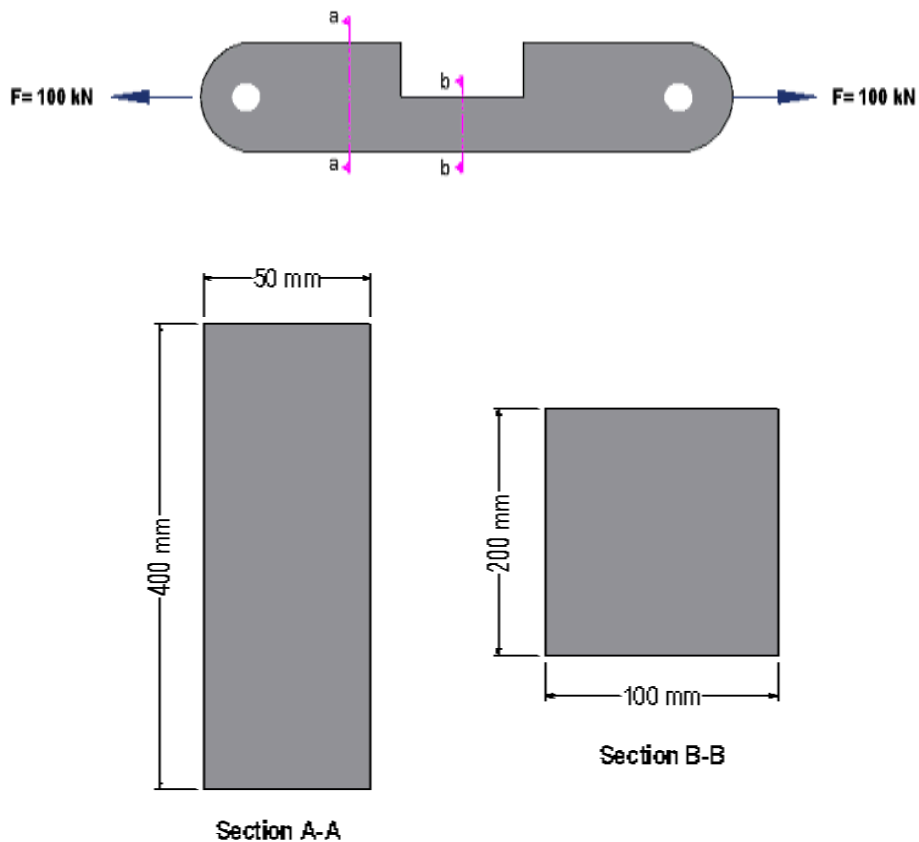


- (A) 35000 kN
- (B) 25160 kN
- (C) 87460 kN
- (D) 12325 kN

41. When a tensile load is applied to a brass cylindrical rod with a modulus of elasticity of 100 GPa, the rod deforms by 0.01 m. What kind of stress does a rod have if its initial length was 2 meters?

- (A) 110 MPa
- (B) 2.75 MPa
- (C) 500 MPa
- (D) 15 MPa

42. A steel link with two cross-sections having size of 50mm x 400 mm of outer segment and size of 100mm x 200mm of central segment. A normal tensile force 100 kN was applied to the link. The stress will be;



- (A) Maximum in the central segment
- (B) Minimum in the central segment
- (C) Same in both segments
- (D) Minimum in the outer segment

43. A composite bar is made up of two segments, each measuring two meters and three meters in length and having elasticity moduli of 100 GPa and 150 GPa, respectively. Determine the amount of deformation in each segment if the total load applied is 50 kN.

- (A) 0.01 m and 0.02 m
- (B) 0.015 m and 0.025 m
- (C) 0.02 m and 0.01 m
- (D) 0.025 m and 0.015 m

44. A uniformly distributed load of 5 kN/m is applied to a 6 m long simply supported beam. Determine the beam's maximum deflection. $EI = 500 \times 10^6 \text{ Nm}^2$

- (A) 17.07 mm
- (B) 0.169 mm
- (C) 23 mm
- (D) 0.385 mm

45. A plane element is subjected to normal stresses $\sigma_x = 70 \text{ MPa}$ and $\sigma_y = 20 \text{ MPa}$, and a shear stress $\tau_{xy} = 25 \text{ MPa}$. Calculate the normal stress on a plane inclined at 30° to the x-axis.

- (A) 79.15 MPa
- (B) 65.36 MPa
- (C) 7 MPa
- (D) 750 MPa

46. Two materials with a modulus of elasticity of 120 GPa and 80 GPa combine to form a composite beam. How is the load divided between the two materials if the beam is carrying a 10 kN total load?

- (A) 1 kN and 3 kN
- (B) 6 kN and 4 kN
- (C) 11 kN and 2 kN
- (D) 5 kN and 5 kN

47. A concrete cylinder with a diameter of 100 mm and a length of 200 mm is subjected to a compressive load of 500 kN. The cylinder shortens by 1 mm. Calculate the engineering stress, engineering strain, and modulus of elasticity.

- (A) 63.66 MPa, 0.005, 12.73 GPa
- (B) 25.5 MPa, 0.015, 11.36 GPa
- (C) 101.2 MPa, 0.003, 13.00 GPa
- (D) 73.66 MPa, 0.075, 15.50 GPa

48. Calculate the Brinell hardness number for a material if a load of 500 kgf is applied on a 10 mm diameter indenter and the diameter of the indentation is 3 mm.

- (A) 69.14
- (B) 90.03
- (C) 93.85
- (D) 97.62

49. Determine the critical angle for total internal reflection at the interface between water (refractive index = 1.33) and air (refractive index = 1).

- (A) 8.75°
- (B) 29.15°
- (C) 55.39°

(D) 48.75°

50. A steel bar with a diameter of 20 mm and a length of 500 mm is subjected to a tensile load of 80 kN. If the bar elongates by 8 mm before fracture, calculate the percent elongation.

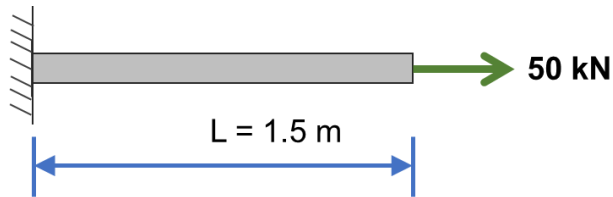
(A) 1.2%

(B) 0.6%

(C) 8.6%

(D) 1.6%

51. A steel rod with an initial diameter of 20 mm and an initial length of 1.5 m is subjected to a tensile force of 50 kN. Given that the modulus of elasticity (E) = 200 GPa, determine the elongation of the rod.



(A) 0.50 mm

(B) 0.71 mm

(C) 1.19 mm

(D) 1.58 mm

52. Determine the ultimate tensile strength of a material given that a specimen with a diameter of 10 mm fails under a load of 50 kN.

(A) 853.62 MPa

(B) 525 MPa

(C) 636.62 MPa

(D) 175.83 MPa

53. The diffusion coefficient of carbon in iron at 900°C is given as $1.2 \times 10^{-11} \text{ m}^2/\text{s}$. If the temperature is increased to 1000°C , and assuming an activation energy of 140 kJ/mol , what is the new diffusion coefficient? (Use $R = 8.314 \text{ J/mol}\cdot\text{K}$).

- A) $2.5 \times 10^{-11} \text{ m}^2/\text{s}$
- B) $3.7 \times 10^{-11} \text{ m}^2/\text{s}$
- C) $1.8 \times 10^{-11} \text{ m}^2/\text{s}$
- D) $2.2 \times 10^{-11} \text{ m}^2/\text{s}$

54. Determine the center of pressure for a vertical rectangular surface 4 meters high and 2 meters wide submerged vertically in water, with its top edge at the surface.

- (A) 0.76 m
- (B) 2.667 m
- (C) 3 m
- (D) 0.015 m

55. Calculate the force exerted by water on a vertical rectangular plate submerged to a depth of 3 meters. The width of the plate is 2 meters and the height is 3 meters.

- (A) 15852 N
- (B) 15300 N
- (C) 98630 N
- (D) 88290 N

56. Using Archimedes' principle, determine the weight of an object that displaces 0.05 m^3 of water.

- (A) 510.5 N
- (B) 490.5 N
- (C) 398.3 N

(D) 103.8 N

57. A rectangular gate 2 meters high and 1 meter wide is located in a dam. The top of the gate is 4 meters below the water surface. Calculate the force on the gate and the center of pressure.

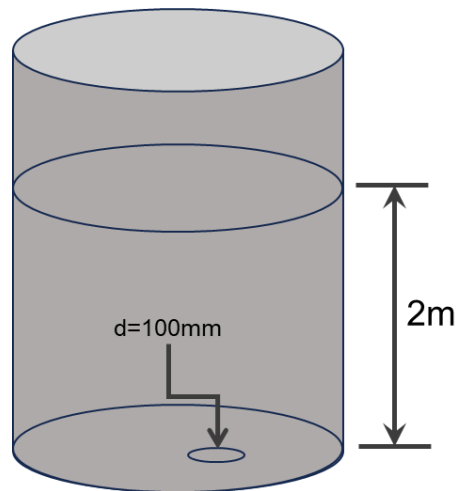
(A) 1.5 m

(B) 5.07 m

(C) 3 m

(D) 7.36 m

58. A tank contains water (density 1000 kg/m^3) to a depth of 2 meters. At the bottom of the tank, there is a circular opening with a diameter of 0.1 meters. What is the force (in N) exerted by the water on the circular opening? (Assume $g = 9.81 \text{ m/s}^2$)



(A) 154 N

(B) 196 N

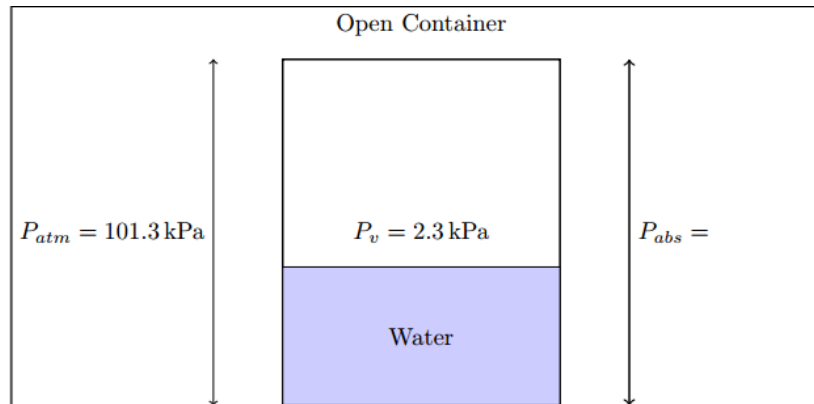
(C) 240 N

(D) 314 N

59. A wooden block with a density of 600 kg/m^3 and a volume of 0.2 m^3 floats in water. Calculate the buoyant force acting on the block.

- (A) 1500 N
- (B) 1790 N
- (C) 1823 N
- (D) 1177 N

60. If the vapor pressure of water at 20°C is 2.3 kPa , calculate the absolute pressure at the surface of the water in an open container where the atmospheric pressure is 101.3 kPa .



- (A) 103.6 kPa
- (B) 104.9 kPa
- (C) 110 kPa
- (D) 101.3 kPa

61. A circular hatch of diameter 1.5 meters is located at the bottom of a tank filled with water to a height of 5 meters. Calculate the force on the hatch.

- (A) 86621.85 N
- (B) 17853.12 N
- (C) 86320.55 N

(D) 78250.15 N

62. Determine the volume of a cone with a base radius of 3 m and a height of 10 m.

(A) 94.25 m^3

(B) 85.32 m^3

(C) 78.96 m^3

(D) 12.36 m^3

63. Calculate the volume of earth using the Prismoidal Formula between three sections with areas 40 m^2 , 70 m^2 , and 90 m^2 , spaced 20 m apart.

(A) 1980.5 m^3

(B) 1366.6 m^3

(C) 2750 m^3

(D) 2780 m^3

64. Determine the cut and fill volume for a project site with cut areas 60 m^2 and 90 m^2 , and fill areas 50 m^2 and 80 m^2 , spaced 30 m apart.

(A) 2250 m^3 , 1950 m^3

(B) 2100 m^3 , 950 m^3

(C) 250 m^3 , 150 m^3

(D) 3010 m^3 , 4200 m^3

65. A point is given in polar coordinates as $P(r = 350, \theta = 60^\circ)$. The point is then translated by $(-50, +75)$ in Cartesian coordinates. What are the final Cartesian coordinates?

(A) (125, 378.1)

(B) (225, 378.1)

(C) (175, 303.1)

(D) (125, 228.1)

66. Using the Average End Area Method, calculate the volume of earth between cross-sections with areas of 30 m^2 and 70 m^2 , spaced 50 m apart.

(A) 2500 m^3

(B) 1520 m^3

(C) 2325 m^3

(D) 1863 m^3

67. Calculate the volume of a pyramid with a base area of 40 m^2 and a height of 15 m.

(A) 250 m^3

(B) 160 m^3

(C) 132 m^3

(D) 200 m^3

68. A bearing of N 40° W is given. What is the corresponding azimuth angle?

A. 320°

B. 140°

C. 220°

D. 40°

69. A stormwater treatment device removes 85 of the total suspended solids (TSS) from a runoff volume of 1200 m^3 with an initial TSS concentration of 180 mg/L . Calculate the mass of TSS removed.

(A) 108.3 kg

(B) 286 kg

(C) 183.6 kg

(D) 250 kg

70. A watershed has an area of 500 hectares, and a storm event results in 5 cm of rainfall over the entire watershed in 3 hours. If 40% of the rainfall infiltrates and the rest contributes to runoff, estimate the total runoff volume in cubic meters (m^3).

A. 100,000 m^3

B. 150,000 m^3

C. 200,000 m^3

D. 250,000 m^3

71. In the context of stormwater management, what is the significance of the Rational Method?

(A) It is used to calculate the evaporation rate of stormwater.

(B) It estimates peak discharge from small urban catchments based on rainfall intensity, catchment area, and runoff coefficient.

(C) It determines the infiltration capacity of different soil types.

(D) It measures the total volume of stormwater runoff over a given period.

72. Calculate the adsorption capacity of activated carbon if 500 mg of carbon removes 200 mg of contaminant from 1 liter of water.

(A) 0.4 mg/mg

(B) 0.9 mg/mg

(C) 0.7 mg/mg

(D) 0.3 mg/mg

73. A stormwater sample has a biochemical oxygen demand (BOD) concentration of 150 mg/L. If the runoff volume is 800 m^3 , calculate the total mass of BOD in the runoff.

- (A) 111kg
- (B) 120kg
- (C) 329kg
- (D) 128kg

74. A rectangular sedimentation tank has a length of 40 meters, a width of 20 meters, and a depth of 4 meters. If the tank is designed to treat a flow rate of 10,000 cubic meters per day, calculate the detention time in hours.

- A. 7.68 hours
- B. 8.12 hours
- C. 9.16 hours
- D. 10.24 hours

75. A detention basin has an outflow structure that uses an orifice. The orifice has a diameter $d = 1.5$ ft, discharge coefficient $C_d = 0.62$, and head above the center of the orifice $H = 6$ ft. Determine the peak discharge through the orifice.

- A. 11.5 cfs
- B. 21.5 cfs
- C. 44.8 cfs
- D. 33.9 cfs

76. A surface water system receives precipitation (P) of 5 inches and surface inflow (Q_{in}) of 10 cfs. The surface water outflow (Q_{out}) is 8 cfs, no groundwater inflow (Q_g), evaporation (E_s) is 1 inch, transpiration (T_s) is 0.5 inches, and infiltration (I) is 0.5 inches. Calculate the change in water storage (ΔS_s) of the system in inches. The area of surface water inflow and outflow is 43,200 sft. Assume a time duration of 1 hour.

- A. 4 inches
- B. 5 inches
- C. 6 inches

7 inches

77. Calculate the drawdown after 1 hr, with the following data for a well from an unconfined aquifer: specific yield of 0.15, $r_w = 0.2$ m, $Q = 0.01$ m³/s.

- (A) 2027.5m
- (B) 2010.3m
- (C) 1909.8m
- (D) 1763.1m

78. A wastewater sample has a pH of 6.0. What is the approximate concentration of hydrogen ions [H⁺] in moles/L?

- A. 1×10^{-6}
- B. 1×10^{-8}
- C. 6
- D. 8

79. A flood wave travels through a reservoir with an inflow hydrograph given by $Q_{in(t)} = 50 + 10t$ m³/s. If the outflow is constant at 100 m³/s, determine the storage volume change over a period of 4 hours

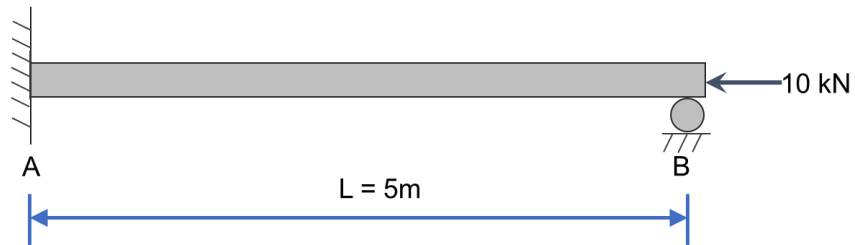
- (A) 1036080000 m³
- (B) 2015000000 m³
- (C) undefined
- (D) None of the above

80. A bioretention cell is designed to treat stormwater runoff from a drainage area of 2 hectares. The average rainfall depth is 30 mm. Calculate the volume of runoff to be treated.

- (A) 600 m³
- (B) 656 m³
- (C) 183 m³

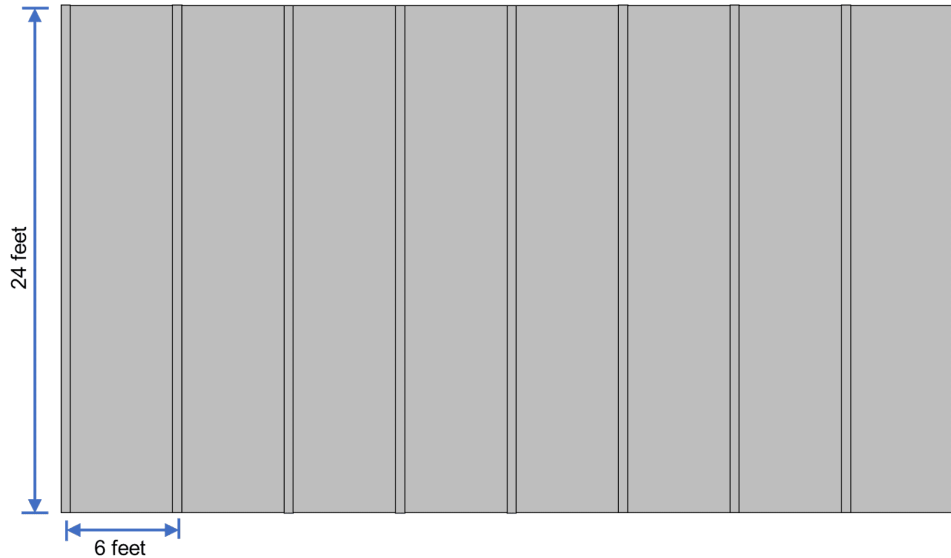
(D) 709 m^3

81. A horizontal beam AB is fixed at A and supported by a roller at B. The beam has a length of 5 m, and a horizontal force of 10 kN is applied at B. Using the flexibility method, determine the horizontal reaction at A.



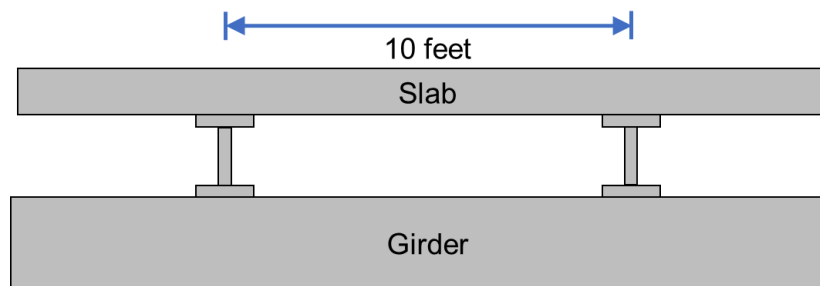
- (A) 2.5 kN
- (B) 5 kN
- (C) 7.5 kN
- (D) 10 kN

82. A warehouse roof is supported by joists spaced 6 ft apart, carrying a roof live load of 20 psf and a roof dead load of 15 psf. The joists span 24 ft between supports. Determine the load per joist due to factored loads using the ASCE 7 load combination: $1.2D + 1.6L$



- A. 6.8 kips
- B. 7.2 kips
- C. 7.6 kips
- D. 8.0 kips

83. A girder supports two beams, each carrying a tributary width of 10 feet. The live load is 40 psf, and the dead load is 25 psf. Determine the factored load per foot of the girder using: $w_u = 1.2D + 1.6L$

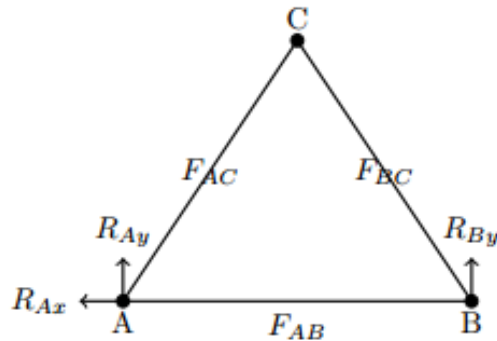


- A. 1700 lb/ft
- B. 1800 lb/ft

C. 1880 lb/ft

D. 2000 lb/ft

84. Analyze the stability of the truss shown below.



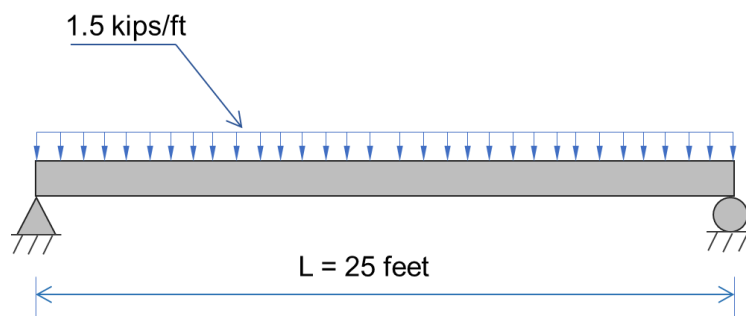
(A) Statically indeterminate and unstable

(B) statically indeterminate and stable

(C) statically determinate and stable

(D) Cannot be determined

85. A simply supported beam spans 25 feet and supports a uniformly distributed load of 1.5 kips/ft. What is the total load transferred to each support?



(A) 37.50 kips

- (B) 18.75 kips
- (C) 25.50 kips
- (D) 12.75 kips

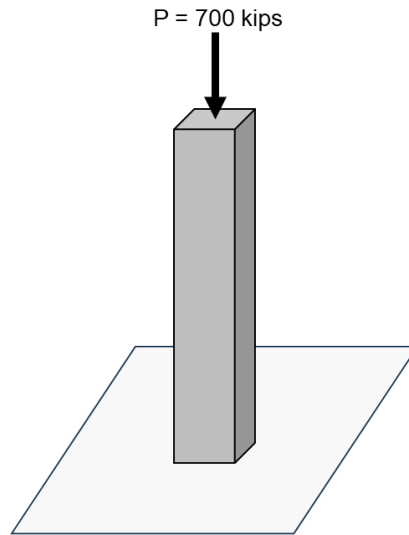
86. A simply supported W18x50 beam (per AISC Steel Manual) has a clear span of 25 ft and is laterally unsupported over its entire length. The beam is made of A992 steel ($F_y = 50$ ksi, $E = 29,000$ ksi). Determine the nominal flexural strength, M_n , considering lateral-torsional buckling (LTB). Assume:

- Lateral unbraced length, $L_b = 20$ ft
- Plastic moment capacity, $M_p = 515$ ft-kips
- Elastic buckling moment, $M_{cr} = 135$ ft-kips
- Lateral-torsional buckling modification factor, $C_b = 1.0$
- Plastic limit length: $L_p = 3.0$ ft
- Limiting unbraced length: $L_r = 25$ ft

What is the available moment capacity M_n ?

- A. 121.36 kips-ft
- B. 141.36 kips-ft
- C. 221.36 kips-ft
- D. 321.36 kips-ft

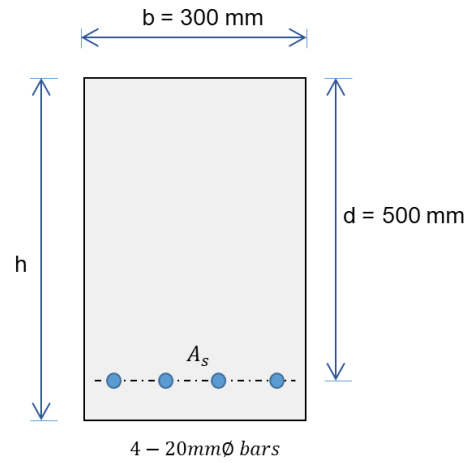
87. A steel column with a design compressive strength $\phi P_n = 800$ kips is subjected to a factored axial load of 700 kips. Is the column adequate to carry the load?



- A. Yes, because $\phi P_n > 700$ kips
- B. No, because $\phi P_n < 700$ kips
- C. Yes, because $\phi P_n < 700$ kips
- D. No, because $\phi P_n > 700$ kips

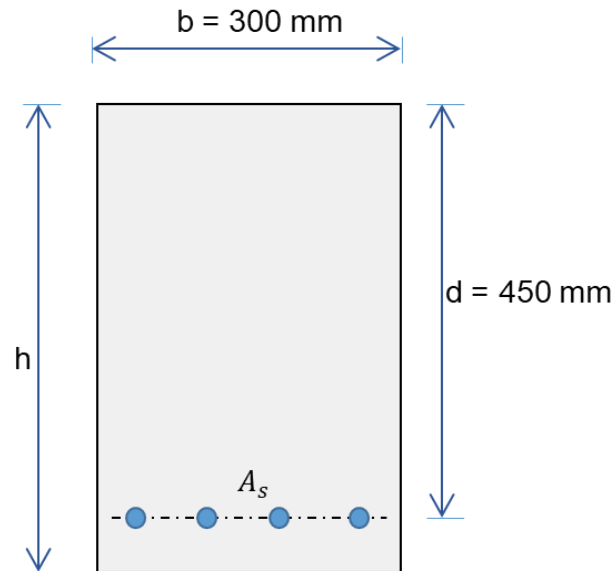
88. A simply supported rectangular beam has a width $b = 300$ mm, an effective depth $d = 500$ mm, and is reinforced with 4 rebars of 20 mm diameter (total reinforcement area A_s). The concrete compressive strength is $f'_c = 28$ MPa, and the steel yield strength is $f_y = 420$ MPa.

Using ACI Strength Design Method, determine the design moment capacity ϕM_n of the beam. Assume that the strain in steel is sufficient to reach yield. (use $\phi = 0.9$ (Strength Reduction Factor)).



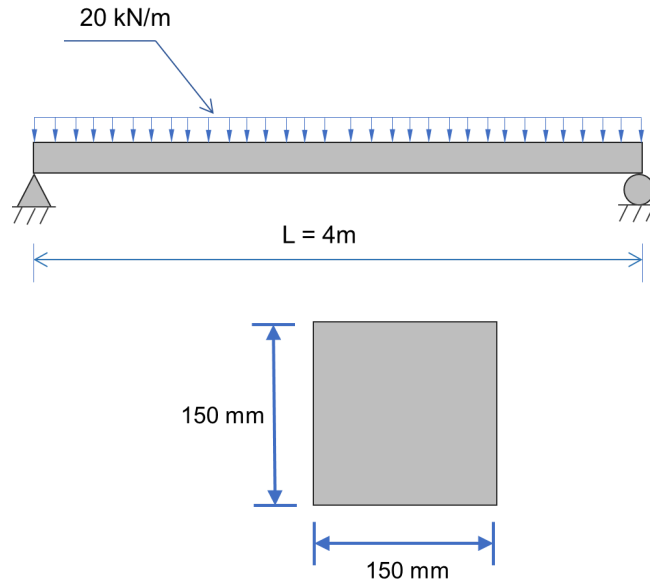
- A. 219.78 kN-m
- B. 232.48 kN-m
- C. 242.48 kN-m
- D. 252.48 kN-m

89. A rectangular beam with a width of 300 mm and an effective depth of 450 mm is designed using concrete with $f'_c = 28 \text{ MPa}$. What is the minimum area of tension steel ($A_{s,min}$) required as per ACI 318? ($f_y = 420 \text{ MPa}$)



- A. 450 mm^2
- B. 540 mm^2
- C. 630 mm^2
- D. 720 mm^2

90. A simply supported beam of length 4m carries a uniformly distributed load of 20 kN/m. The beam has a square cross-section with a side length of 150mm. What is the maximum bending stress in the beam?



- A. 71.1 MPa
- B. 26.7 MPa
- C. 35.6 MPa
- D. 53.3 MPa

91. What is the critical shear strength of a soil with an effective cohesion (c') of 15 kPa and an effective angle of internal friction (ϕ') of 25° under a normal stress (σ') of 80 kPa in drained conditions?

- (A) 35.73 kPa
- (B) 25.0 kPa
- (C) 52.28 kPa
- (D) 45.51 kPa

92. For a soil with an undrained shear strength (τ_u) of 80 kPa, what would be the shear strength (τ) on a plane where the normal stress (σ) is 150 kPa in undrained conditions?

- (A) 130 kPa

- (B) 70 kPa
- (C) 50 kPa
- (D) 80 kPa

93. For a retaining wall, the mobilized shear force is a function of which of the following factors?

- (A) Wall friction angle
- (B) Soil cohesion
- (C) Overburden pressure
- (D) All of the above

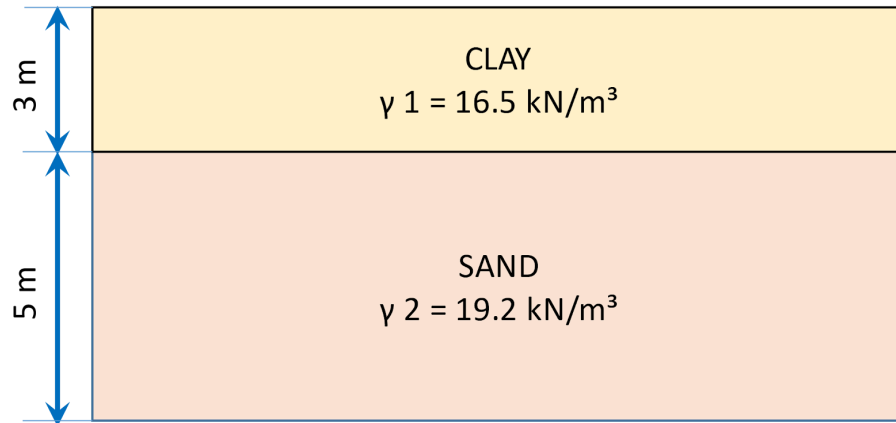
94. For a slope with a height of 10 m and a critical slip surface, the factor of safety (FOS) is found to be 1.2. If the required FOS for design is 1.5, what is the necessary increase in the resisting force?

- (A) 20%
- (B) 25%
- (C) 30%
- (D) 50%

95. What is the ultimate bearing capacity (q_u) of a strip footing resting on a sandy soil with an effective unit weight (γ') of 18 kN/m^3 , a footing width (B) of 2 m, and a depth of footing (D) of 1.5 m? The bearing capacity factors are $N_q = 22$ and $N_\gamma = 19$.

- (A) 79.2 kPa
- (B) 936 kPa
- (C) 158.4 kPa
- (D) 198 kPa

96. A soil profile consists of 3 m of clay with a unit weight of 16.5 kN/m^3 , 5 m of sand with a unit weight of 19.2 kN/m^3 . Determine the effective stress (σ') at the bottom of the sand layer.



- A. 145.5 kN/m^2
- B. 148.3 kN/m^2
- C. 152.1 kN/m^2
- D. 155.6 kN/m^2

97. Using Terzaghi's bearing capacity equation, what is the ultimate bearing capacity (q_u) for a circular footing with a diameter (D) of 1.5 m on a soil with a cohesion (c) of 25 kPa, a unit weight (γ) of 20 kN/m^3 , and an internal friction angle (ϕ) of 30° ? The bearing capacity factors are $N_c=30.14$, $N_q = 18.4$, and $N_\gamma = 15.1$.

- (A) 1532 kPa
- (B) 1044 kPa
- (C) 1212 kPa
- (D) 1336 kPa

98. For a soil sample, the D_{10} is 0.12 mm, D_{30} is 0.3 mm, and D_{60} is 0.6 mm. What is the Coefficient of Curvature (C_c)?

- (A) 0.62

- (B) 0.75
- (C) 1.25
- (D) 2.50

99. A triaxial test on a saturated clay sample shows an undrained shear strength (τ_u) of 150 kPa. If the confining pressure (σ_3) is 100 kPa, what is the deviator stress (σ_d) at failure?

- (A) 50 kPa
- (B) 150 kPa
- (C) 250 kPa
- (D) 300 kPa

100. If the allowable bearing capacity (q_{allow}) for a square footing is required to be calculated with a factor of safety (FS) of 3, what is the allowable bearing capacity given an ultimate bearing capacity (q_u) of 450 kPa?

- (A) 150 kPa
- (B) 200 kPa
- (C) 300 kPa
- (D) 75 kPa

101. During a consolidated-drained triaxial test, a soil specimen exhibits a peak shear strength (τ_p) of 120 kPa under an effective confining stress (σ'_3) of 200 kPa. If the angle of internal friction (ϕ') is 30° , what is the effective cohesion (c')?

- (A) 34.6 kPa
- (B) 4.6 kPa
- (C) 44.6 kPa
- (D) 7.2 kPa

102. For an unsignalized intersection with a critical gap of 5 seconds and an average follow-up time of 3 seconds, determine the maximum capacity for a single lane.

- (A) 600 vehicles/hour
- (B) 700 vehicles/hour
- (C) 800 vehicles/hour
- (D) 450 vehicles/hour

103. The number of trips (T) between two zones is calculated using the gravity model formula:

$$T = \frac{K \times O \times D}{F}$$

Where:

O= 1500 is the number of trips originating from Zone 1.

D=2000 is the number of trips destined for Zone 2.

F= 5 is the friction factor between the zones.

K is a constant, which is 0.0012.

What is the total number of trips between Zone 1 and Zone 2?

- A. 360
- B. 450
- C. 720
- D. 900

104. An existing flexible pavement has a Structural Number (SN) of 2.2. The required SN for the new traffic load is 6.8. If the overlay material has a structural layer coefficient of 0.45, what will be the required overlay thickness (D) in mm?

- A. 150
- B. 190
- C. 230
- D. 260

105. Calculate the capacity of a signalized intersection approach with an effective green time of 40 seconds and a cycle length of 120 seconds. The saturation flow rate is 1800 vehicles/hour.

- (A) 600 vehicles/hour
- (B) 800 vehicles/hour
- (C) 1000 vehicles/hour
- (D) 1200 vehicles/hour

106. A vehicle is observed traveling on a 2 km road section with the following speeds (in km/h) recorded at equal time intervals: 40, 45, 60 and 50. What is the Space Mean Speed (SMS)?

- A. 58.39 km/hour
- B. 36.43 km/hour
- C. 60.93 km/hour
- D. 47.68 km/hour

107. A plan view shows a square courtyard with sides of 30 feet. There is a circular fountain with a diameter of 10 feet in the center. Calculate the area of the courtyard excluding the fountain.

- (A) 821.46 square feet
- (B) 850.55 square feet
- (C) 900.36 square feet
- (D) 950.79 square feet

108. Calculate the runoff (Q) from a 200 m long and 10 m wide section of pavement with a runoff coefficient (C) of 0.85 and a rainfall intensity (i) of 25 mm/hr.

(A) $4.25 \text{ m}^3/\text{hr}$

(B) $42.5 \text{ m}^3/\text{hr}$

(C) $425 \text{ m}^3/\text{hr}$

(D) $4250 \text{ m}^3/\text{hr}$

109. A bulldozer with a blade width of 12 feet and an operating speed of 3 mph is clearing soil with a cut depth of 0.5 feet. If the soil has a loose unit weight of 90 lb/ft^3 and a bulking factor of 1.2, what is the hourly production rate in cubic yards?

A. 6,350 CY/hr

B. 6,124 CY/hr

C. 5,234 CY/hr

D. 4,224 CY/hr

110. A construction project requires excavating 2,500 cubic yards of soil. A hydraulic excavator with a bucket capacity of 2.5 cubic yards operates at an efficiency of 80% and has a cycle time of 30 seconds per cycle. Assuming the excavator operates 8 hours per day, how many days will it take to complete the excavation?

A. 1.3 days

B. 2.2 days

C. 4.5 days

D. 5.1 days

Solutions

[Click here for Problems](#)

1. Problem

Correct Answer: (B) 1

Explanation: find the cross product of $\vec{B}$ and $\vec{C}$.

$$\vec{B} = \hat{j} = (0, 1, 0) \quad \vec{C} = \hat{k} = (0, 0, 1)$$

$$\vec{B} \times \vec{C} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

$$\vec{B} \times \vec{C} = \hat{i} \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} - \hat{j} \begin{vmatrix} 0 & 0 \\ 0 & 1 \end{vmatrix} + \hat{k} \begin{vmatrix} 0 & 1 \\ 0 & 0 \end{vmatrix}$$

$$\vec{B} \times \vec{C} = \hat{i}(1) - \hat{j}(0) + \hat{k}(0)$$

$$= \hat{i}$$

Now, find the dot product of $\vec{A}$ and $\vec{B} \times \vec{C}$

$$\vec{A} = \hat{i} = (1, 0, 0)$$

$$\vec{B} \times \vec{C} = \hat{i} = (1, 0, 0)$$

The dot product $\vec{A} \cdot (\vec{B} \times \vec{C})$ is:

$$\vec{A} \cdot (\vec{B} \times \vec{C}) = (1, 0, 0) \cdot (1, 0, 0)$$

Calculate the dot product:

$$\vec{A} \cdot (\vec{B} \times \vec{C}) = 1 \cdot 1 + 0 \cdot 0 + 0 \cdot 0 = 1$$

2. Problem

Correct Answer: (A) 45°

Explanation: The angle between the vectors $\vec{A} = \hat{i} + \hat{j}$ and $\vec{B} = \hat{j}$ can be found using the dot product formula:

$$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}|\cos\theta$$

$$\vec{A} \cdot \vec{B} = (\hat{i} + \hat{j}) \cdot \hat{j} = 1 \cdot 0 + 1 \cdot 1 = 1$$

The magnitudes are:

$$|\vec{A}| = \sqrt{(1)^2 + (1)^2} = \sqrt{2},$$

$$|\vec{B}| = 1$$

$$\cos\theta = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}||\vec{B}|} = \frac{1}{\sqrt{2} \cdot 1} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2}$$

Therefore,

$$\theta = \cos^{-1}\left(\frac{\sqrt{2}}{2}\right) = 45^\circ$$

3. Problem

Correct Answer: (A) Binomial distribution

Explanation: The binomial distribution is widely used in statistics to model the number of successes in a fixed number of trials. Here are the key reasons why it is appropriate for such scenarios:

- The binomial distribution applies to experiments or processes where the number of trials, n , is fixed and known in advance.
- Each trial results in one of two possible outcomes: success (often coded as 1) or failure (often coded as 0). This binary nature of outcomes aligns perfectly with the structure of the binomial distribution.

- Mathematical Representation: $P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}$

4. Problem

Correct Answer: (A) $\frac{1}{\sqrt{2}} (\hat{i} - \hat{j})$

Explanation: The unit vector in the direction of $\vec{B} = 2\hat{i} - 2\hat{j}$ is found by dividing the vector by its magnitude:

$$|\vec{B}| = \sqrt{(2)^2 + (-2)^2}$$

$$= \sqrt{4 + 4}$$

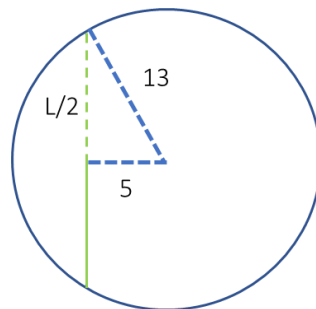
$$= \sqrt{8} = 2\sqrt{2}$$

$$\hat{B} = \frac{\vec{B}}{|\vec{B}|} = \frac{2\hat{i} - 2\hat{j}}{2\sqrt{2}} = \frac{1}{\sqrt{2}} (\hat{i} - \hat{j})$$

5. Problem

Correct Answer: (A) 24 units

Explanation:



Using the Pythagorean Theorem for the right triangle formed by the radius, distance to the chord, and half the chord length:

$$\left(\frac{L}{2}\right)^2 + 5^2 = 13^2$$

$$\frac{L^2}{4} + 25 = 169$$

$$\frac{L^2}{4} = 144$$

Correct Answer: A) $L = 24$

6. Problem

Correct Answer: C) \$5/6

To calculate the expected value, we'll multiply the probability of each outcome by its corresponding payoff and sum the results.

Possible Outcomes and Payoffs:

- Roll a 6: Win \$10, probability 1/6
- Roll a 1: Lose \$5, probability 1/6
- Roll any other number (2, 3, 4, 5): No gain or loss, probability 4/6

Expected Value (EV):

EV = (Probability of winning * Winnings) + (Probability of losing * Losses)
+ (Probability of no gain/loss * 0)

$$EV = (1/6 * \$10) + (1/6 * -\$5) + (4/6 * \$0)$$

$$EV = \$10/6 - \$5/6 + \$0$$

$$EV = \$5/6$$

Therefore, the expected value of the game per roll is \$5/6

7. Problem

Correct Answer: (D) $\frac{1}{2}(\hat{i} + \hat{j})$

Explanation: The projection of $\vec{A}$ onto $\vec{B}$ is given by:

$$\text{Projection} = \frac{\vec{A} \cdot \vec{B}}{|\vec{B}|^2} \vec{B}$$

Calculating the dot products:

$$\vec{A} \cdot \vec{B} = 2 \cdot 1 + (-1) \cdot 1 = 1$$

$$\vec{B} \cdot \vec{B} = 1 \cdot 1 + 1 \cdot 1 = 2$$

$$\text{Projection} = \frac{1}{2} (\hat{i} + \hat{j})$$

8. Problem

Correct Answer: A) 0

Explanation:

Given vectors $A = 2i + 3j - k$ and $B = i - 2j + 4k$, we need to compute $B \times A$ using the cross product formula:

$$B \times A = \begin{vmatrix} i & j & k \\ 1 & -2 & 4 \\ 2 & 3 & -1 \end{vmatrix}$$

Now, let's expand the determinant:

$$\begin{aligned} B \times A &= i [(-2)(-1) - (4)(3)] - j [(1)(-1) - (4)(2)] + k [(1)(3) - (-2)(2)] \\ &= i [2 - 12] - j [-1 - 8] + k [3 + 4] \\ &= i [-10] - j [-9] + k [7] \end{aligned}$$

So, $B \times A = -10i + 9j + 7k$.

Now, compute the dot product $A \cdot (B \times A)$:

$$\begin{aligned} A \cdot (B \times A) &= (2i + 3j - k) \cdot (-10i + 9j + 7k) \\ &= (2)(-10) + (3)(9) + (-1)(7) \\ &= 0 \end{aligned}$$

Correct Answer: A) 0

9. Problem

Correct Answer: (A) 3

Explanation: The projection of $\vec{A} = 3\hat{i} + 2\hat{j} + \hat{k}$ onto the $\hat{i}$ axis is simply the $\hat{i}$ component of $\vec{A}$:

Projection = 3

10. Problem

Answer: C) Arbitration is faster and more cost-effective than litigation.

Arbitration is typically used as an alternative to litigation due to its speed and cost-effectiveness. It is binding unless stated otherwise, decisions are rarely appealable, and the process is private, unlike public court proceedings.

11. Problem

Answer: (D)

Explanation: A licensed engineer must notify their employer or client and, if necessary, the appropriate authorities if they discover a safety issue.

12. Problem

Answer: (A) Awarding damages to the injured party.

Explanation: A common remedy for a breach of contract is awarding damages to the injured party.

13. Problem

Answer: B) It simplifies the process of obtaining a license in multiple states

Explanation: Licensure by comity allows engineers licensed in one state to obtain licensure in another state more easily.

14. Problem

Answer: B) The engineer has breached the standard of care by failing to conduct necessary inspections and testing

Explanation:

Option A is incorrect because performing due diligence would require the engineer to conduct regular inspections and testing.

Option C is incorrect because adhering to the NSPE Code of Ethics requires prioritizing public safety, health, and welfare, not project deadlines.

Option D is incorrect because the engineer shares responsibility for the collapse due to their failure to fulfill their duty of care.

15. Problem

Correct Answer: (A) Option 1

Explanation:

Calculate present Value of Costs for both options:

$$PV_{annuity} = C \times \frac{1 - (1+r)^{-n}}{r}$$

where:

- C = annual operating cost
- r = discount rate
- n = useful life

For option 1:

$$\begin{aligned} PV_{annuity,1} &= 10,000 \times \frac{1 - (1 + 0.08)^{-5}}{0.08} \\ PV_{annuity,1} &= 10,000 \times \frac{1 - (1.08)^{-5}}{0.08} \\ PV_{annuity,1} &= 10,000 \times \frac{1 - 0.68058}{0.08} \\ PV_{annuity,1} &= 10,000 \times \frac{0.31942}{0.08} \\ PV_{annuity,1} &= 10,000 \times 3.99275 = 39,927.50 \end{aligned}$$

Total present value for Option 1:

$$PV_{total,1} = C_{0,1} + PV_{annuity,1} = 60,000 + 39,927.50 = 99,927.50$$

For Option 2:

$$PV_{annuity,2} = 5,000 \times \frac{1 - (1 + 0.08)^{-5}}{0.08}$$

$$PV_{annuity,2} = 5,000 \times \frac{1 - (1.08)^{-5}}{0.08}$$

$$PV_{annuity,2} = 5,000 \times \frac{1 - 0.68058}{0.08}$$

$$PV_{annuity,2} = 5,000 \times \frac{0.31942}{0.08}$$

$$PV_{annuity,2} = 5,000 \times 3.99275 = 19,963.75$$

$$PV_{total,2} = C_{0,2} + PV_{annuity,2} = 80,000 + 19,963.75 = 99,963.75$$

The present value of costs for Option 1 is \$99,927.50, and for Option 2 is \$99,963.75. Since the present value of costs for Option 1 is lower than that for Option 2, Option 1 is more feasible.

16. Problem

Correct Answer: (A)

Explanation: When total revenue equals total cost

17. Problem

Correct Answer: (D) Total cost of ownership

Explanation: The total cost of ownership includes all costs associated with the project over its entire life cycle, making it the most critical factor in life cycle cost analysis.

18. Problem

Correct Answer: C) X by 0.13

Calculate the CV for each option.

$$CV = \sigma / E (\text{Return})$$

For Option X:

$$CV_x = 2,000 / 10,000 = 0.20$$

For Option Y:

$$CV_y = 5,000 / 15,000 = 0.33$$

Compare CV values.

Option X has a lower CV (0.20) compared to Option Y (0.33), meaning it has a lower risk per unit of return.

$$= 0.33 - 0.20 = 0.13$$

19. Problem

Correct Answer: (C) \$125,707

Explanation: Calculate the present value of the initial cost, operating costs, and salvage value.

$$\begin{aligned} PV &= 70000 + 15000 \times \left(\frac{1 - (1 + 0.06)^{-5}}{0.06} \right) - \frac{10000}{(1 + 0.06)^5} \\ &= 70000 + 15000 \times 4.212 - 7473 \approx 70000 + 63180 - 7473 = 125707 \end{aligned}$$

20. Problem

Correct Answer: C) \$50,000

Incremental revenue:

$$\begin{aligned} \text{Revenue from Additional Units} &= (\text{Selling Price} - \text{Variable Cost}) \times \\ \text{Incremental Units} \\ \text{Revenue from Additional Units} &= (50 - 25) \times (12,000 - \\ &\quad 10,000) \\ \text{Revenue from Additional Units} &= 25 \times 2,000 = 50,000 \end{aligned}$$

Since fixed costs are not affected by the production increase, the incremental profit is:

$$\text{Incremental Profit} = \text{Revenue from Additional Units} = 50,000$$

21. Problem

Correct Answer: (C) 0.97

Explanation: The correct answer is (c) 0.97. The profitability index is calculated as the present value of future cash flows divided by the initial investment.

$$PV A = R \times \frac{1 - (1 + r)^{-n}}{r} = 50,000 \times \frac{1 - (1 + 0.10)^{-7}}{0.10} = 243,420$$

$$PI = \frac{243,420}{250,000} = 0.9737$$

22. Problem

Correct Answer: (C) 85.5 N

Explanation: $F_{\max} = \mu_s N = \mu_s mg \cos \theta = (0.5)(20)(9.81) \cos 30^\circ$
 $= 85.5 \text{ N}$

23. Problem

Correct Answer: (A) $\mu_s W$

Explanation: Static friction resists the applied horizontal force up to a maximum limit, given by $F_{\max} = \mu_s N$

where μ_s is the coefficient of static friction and N is the normal force between the block and the surface.

Since the block is on a flat horizontal surface, the normal force N is equal to the block's weight W . To prevent the block from moving, the applied horizontal force F must not exceed the maximum static friction force. Therefore: $F \leq F_{\max} = \mu_s W$

The maximum horizontal force that can be applied without moving the block is: $\mu_s W$

24. Problem

Correct Answer: (C) 11 m^4

Explanation: $I_{\text{triangle}} + I_{\text{rectangle}} + A_{\text{triangle}} \cdot d_1^2 + A_{\text{rectangle}} \cdot d_2^2$

$$I_{\text{triangle}} = \frac{bh^3}{36} = \frac{3 \cdot (2)^3}{36} = \frac{3 \cdot 8}{36} = 0.67 \text{ m}^4$$

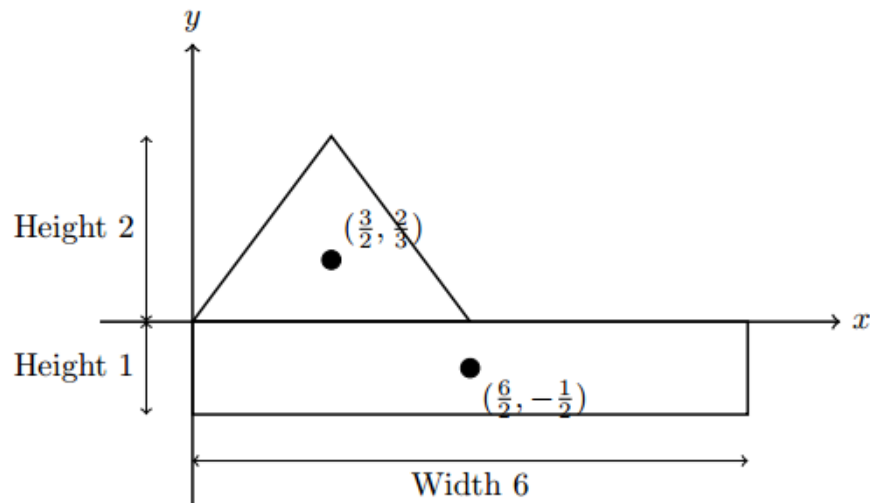
$$I_{\text{rectangle}} = \frac{bh^3}{12} = \frac{6 \cdot (1)^3}{12} = \frac{6}{12} = 0.5 \text{ m}^4$$

$$d_1 = \frac{h}{3} + 1 \rightarrow 1.67 \text{ m} \quad d_2 = \frac{1}{2} \text{ m}$$

$$A_{\text{triangle}} \cdot d_1^2 = \frac{b \cdot h}{2} \times 1.67^2 = 8.36 \text{ m}^4$$

$$A_{\text{rectangle}} \cdot d_2^2 = b_2 \cdot h_2 \times 0.5^2 = 1.5 \text{ m}^4$$

$$I_{\text{tot}} = 0.67 + 0.5 + 8.36 + 1.5 = 11 \text{ m}^4$$



25. Problem

Correct Answer: (B) 5.20

Explanation: $\frac{T_1}{T_2} = e^{\mu\theta}$

$$T_1/T_2 = e^{0.35 \cdot 3\pi/2} = e^{1.6493} \approx 5.20$$

26. Problem

Correct Answer: (B) 1.677cm

Explanation:

Outer radius $R_{\text{outer}} = 3 \text{ cm}$

Inner radius $R_{\text{inner}} = 1.5 \text{ cm}$

$$A = \pi(R_{\text{outer}}^2 - R_{\text{inner}}^2) = \pi(9 - 2.25) = \pi \times 6.75$$

$$I_z = \frac{\pi}{4}(R_{\text{outer}}^4 - R_{\text{inner}}^4) = \frac{\pi}{4}(81 - 5.0625) = \frac{\pi}{4} \times 75.9375$$

$$k = \sqrt{\frac{I}{A}} = \sqrt{\frac{\frac{\pi}{4} \times 75.9375}{\pi \times 6.75}} = \sqrt{\frac{75.9375}{4 \times 6.75}} = \sqrt{\frac{75.9375}{27}} \approx \sqrt{2.8125}$$

$$\approx 1.677 \text{ cm}$$

27. Problem

Correct Answer: (D) 5520 cm⁴

Explanation: Calculate moment of inertia of each flange:

$$A = b_f \times t_f = 10 \times 2 = 20 \text{ cm}^2$$

$$I_{\text{flange}} = \frac{b_{\text{flange}} \times t_{\text{flange}}^3}{12} \rightarrow \frac{10 \cdot 2^3}{12} = 6.67 \text{ cm}^4$$

Using the parallel axis theorem to transfer each flange's moment of inertia to the centroidal axis of the entire section, the distance d from the centroid of each flange to the section centroid is:

$$d(\text{bottom flange}) = 12 - 1 = 11\text{cm} \quad d(\text{top flange}) = 23 - 12 = 11\text{cm}$$

$$\text{So, for each flange: } I_{\text{flange, tot}} = I_{\text{flange}} + A_{\text{flange}} \cdot d^2 = 6.67 + 20 \cdot 11^2$$

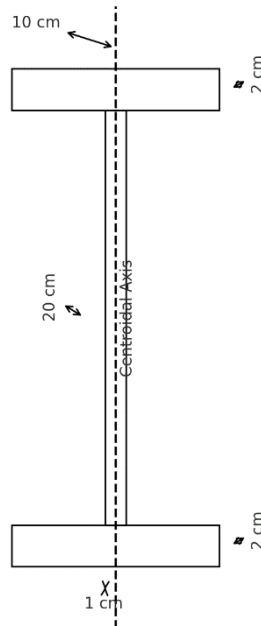
$$= 2426.67 \text{ cm}^4 \Rightarrow \text{Since there are 2 flanges, the total contribution is:}$$

$$I_{\text{flanges}} = 2 \times 2426.67 = 4853.34 \text{ cm}^4$$

$$I_{\text{web}} = \frac{t_{\text{web}} \cdot h_{\text{web}}^3}{12} = \frac{1 \cdot (20)^3}{12} = \frac{1 \cdot 8000}{12} = 666.67 \text{ cm}^4$$

$$I_{\text{total}} = I_{\text{flanges}} + I_{\text{web}} = 4853.34 + 666.67 = 5520 \text{ cm}^4$$

I-Beam Cross-Section



28. Problem

Correct Answer: (D) 300cm^4

Explanation: $I = I_c + Ad^2 = 50 + 10 \cdot (5)^2$

$$= 50 + 10 \cdot 25 = 50 + 250$$

$$= 300\text{cm}^4$$

29. Problem

Correct Answer: (C) 219 N

Explanation: $t_1 = t_2 e^{\mu\theta} = 100e^{0.25\pi} \approx 100 \cdot 2.19 = 219 \text{ N}$

30. Problem

Correct Answer: (D) 39.2 N

Explanation: $F_{\text{max}} = \mu_s mg = (0.4)(10)(9.81) = 39.2 \text{ N}$

31. Problem

Correct Answer: (A) 533.34

Explanation:

- Area of the base $A_{\text{base}} = 10 \times 2 = 20 \text{ cm}^2$

- Area of the web $A_{\text{web}} = 2 \times 10 = 20 \text{ cm}^2$

Distances to centroids: $y_{\text{base}} = 1 \text{ cm}$ - $y_{\text{web}} = 7 \text{ cm}$

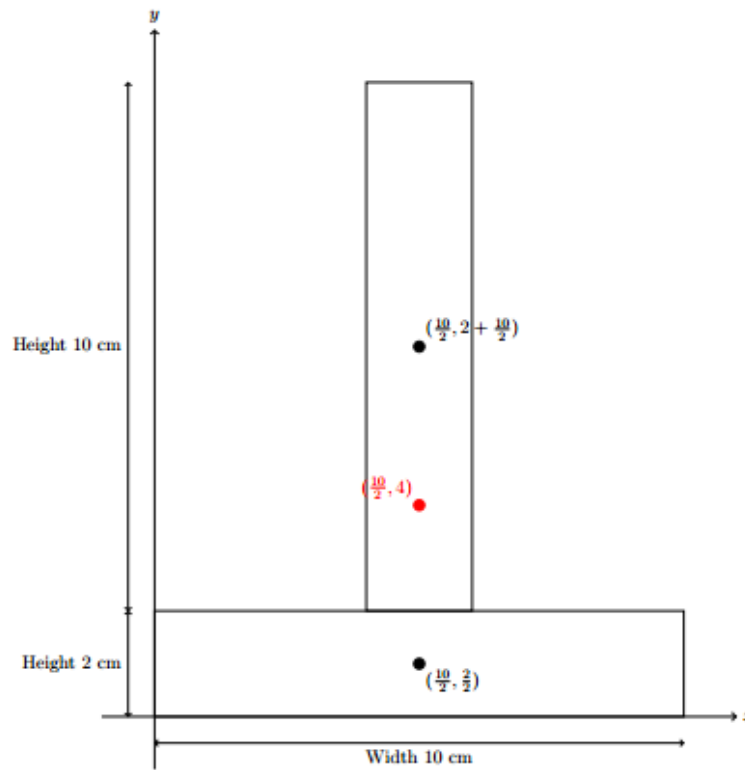
Centroid of the T-section:

$$\bar{y} = \frac{A_{\text{base}} y_{\text{base}} + A_{\text{web}} y_{\text{web}}}{A_{\text{base}} + A_{\text{web}}} = \frac{20 \times 1 + 20 \times 7}{20 + 20} = 4$$

$$I_{\text{base, centroid}} = \frac{1}{12}bh^3 = 6.67\text{cm}^4 \rightarrow I_{\text{base, total}} = I_{\text{base, centroid}} + A_{\text{base}} d_{\text{base}}^2 = 186.67\text{cm}^4$$

$$I_{\text{web, centroid}} = \frac{1}{12}bh^3 = 166.67\text{cm}^4 \rightarrow I_{\text{web, total}} = I_{\text{web, centroid}} + A_{\text{web}} d_{\text{web}}^2 = 346.67\text{cm}^4$$

$$I_{total} = I_{base, total} + I_{web, total} = 533.34 \text{ cm}^4$$



32. Problem

Correct Answer: (B) $\frac{R}{\sqrt{2}}$.

Explanation: The radius of gyration k is given by:

$$k = \sqrt{\frac{I}{M}}$$

where $I = \frac{2}{3}MR^2$.

$$k = \sqrt{\frac{3MR^2}{M}} = \sqrt{\frac{2}{5}R^2} = \frac{R}{\sqrt{5/2}} = \frac{R}{\sqrt{2.5}} \approx \frac{R}{\sqrt{2}}$$

33. Problem

Correct Answer: (A) 22.5 m

Explanation:

$$v_y = v \sin \theta = 30 \text{ m/s} \times \sin 45^\circ = 30 \text{ m/s} \times \frac{\sqrt{2}}{2} = 15\sqrt{2} \text{ m/s}$$

$$h = \frac{v_y^2}{2g} = \frac{(15\sqrt{2} \text{ m/s})^2}{2 \times 9.81 \text{ m/s}^2}$$

$$h = \frac{450}{19.62}$$

$$h = 22.5 \text{ m}$$

34. Problem

Correct Answer: (A) $\frac{1}{3} \text{ mL}^2$

Explanation: The parallel axis theorem states,

$$I = I_{cm} + md^2 \quad (\text{L is the length, m is the mass})$$

For a rod:

$$I_{cm} = \frac{1}{12}mL^2, d = \frac{L}{2}$$

$$I = \frac{1}{12}mL^2 + m\left(\frac{L}{2}\right)^2 = \frac{1}{12}mL^2 + \frac{1}{4}mL^2 = \frac{1}{3}mL^2$$

35. Problem

Correct Answer: (D) 0 m/s^2

Explanation:

$$a_t = \frac{\mathbf{v} \cdot \mathbf{a}}{|\mathbf{v}|}$$
$$|\mathbf{v}| = \sqrt{3^2 + 4^2 + 5^2} = \sqrt{50}$$
$$\mathbf{v} \cdot \mathbf{a} = (3 \times 1) + (4 \times 0) + (5 \times -1) = 3 - 5 = -2$$
$$a_t = \frac{-2}{\sqrt{50}} = \frac{-2}{7.07} \approx 0 \text{ m/s}^2$$

36. Problem

Correct Answer: A) 16 rad/s^2

The moment of inertia of the disk about its center of mass is:

$$I = \frac{1}{2}(mr^2)$$

$$I = \frac{1}{2} \times 5 \times (0.5)^2 = 0.625 \text{ kg}\cdot\text{m}^2$$

The torque applied is:

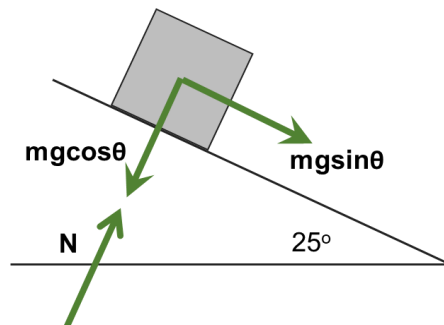
$$\tau = F \times r = 20 \times 0.5 = 10 \text{ N}\cdot\text{m}$$

The angular acceleration α is given by:

$$\tau = I \alpha \Rightarrow \alpha = \tau / I = 10 / 0.625 = 16 \text{ rad/s}^2$$

37. Problem

Correct Answer: A) 0.47



Since the box is moving with constant velocity, the frictional force balances the component of the weight down the incline:

$$f_k = mg \sin\theta = \mu_k N$$

The normal force is:

$$N = mg \cos\theta = 50 \times 9.81 \times \cos(25^\circ) = 444.5 \text{ N}$$

The component of the weight down the incline is:

$$mg \sin\theta = 50 \times 9.81 \times \sin(25^\circ) = 207.2 \text{ N}$$

Using $f_k = \mu_k N$, solve for μ_k :

$$\mu_k = 207.2 / 444.5 \approx 0.47$$

38. Problem

Correct Answer: (D) 62.36 MPa, 17.64 MPa

Explanation: Calculate principal stresses:

$$\begin{aligned}\sigma_{1,2} &= \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \\ \sigma_{1,2} &= \frac{50 + 30}{2} \pm \sqrt{\left(\frac{50 - 30}{2}\right)^2 + 20^2} \\ \sigma_{1,2} &= 40 \pm \sqrt{10^2 + 20^2} \\ \sigma_{1,2} &= 40 \pm \sqrt{100 + 400} \\ \sigma_{1,2} &= 40 \pm \sqrt{500} \\ \sigma_{1,2} &= 40 \pm 22.36\end{aligned}$$

$$\sigma_1 = 62.36 \text{ MPa}, \sigma_2 = 17.64 \text{ MPa}$$

39. Problem

Correct Answer: (A) 40 MPa

Explanation: $\tau = G\gamma$ where $\gamma = \frac{r\theta}{L} = \frac{0.05 \times 0.01}{1} = 0.0005$

$$\tau = 80 \times 10^9 \text{ Pa} \times 0.0005 = 40 \text{ MPa}$$

40. Problem

Correct Answer: B) 25160 kN

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2}$$

$$I = Ar^2$$

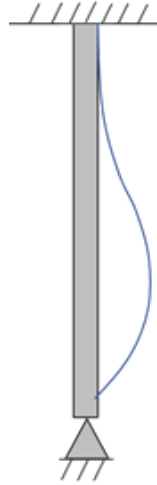
$$A = 40000 \text{ mm}^2, E = 200 \times 10^3 \text{ MPa}$$

$$L_{eff} = KL = 0.7 \times 4000 = 2800$$

$$\lambda = \frac{KL}{r} = \frac{L_{eff}}{r} = \frac{2800}{50} = 56$$

$$P_{cr}/A = \frac{\pi^2 E}{\lambda^2} = \frac{\pi^2 \times 200 \times 10^3}{56^2} = 629$$

$$P_{cr} = 629 \times 40000 = 25160 \text{ kN}$$



41. Problem

Correct Answer: (C) 500 MPa

Explanation:

$$\epsilon = \frac{\Delta L}{L_0} = \frac{0.01m}{2m} = 0.005 \rightarrow \sigma = E\epsilon = 100 \times 10^9 \text{ Pa} \times 0.005 = 500 \times 10^6 \text{ Pa} = 500 \text{ MPa}$$

42. Problem

Correct Answer: C) Same in both segments

The cross-sectional area of both segments is the same, so the stress will also be the same.

43. Problem

Correct Answer: (C) 0.02 m and 0.01 m

Explanation:

$$\delta_1 = \frac{PL_1}{AE_1}, \delta_2 = \frac{PL_2}{AE_2}$$

Since the cross-sectional area A is the same and assuming equal area,

$$\delta_1 = \frac{50 \times 10^3 N \times 2m}{A \times 100 \times 10^9 Pa}, \delta_2 = \frac{50 \times 10^3 N \times 3m}{A \times 150 \times 10^9 Pa}$$

Thus, the deformations are proportional to the inverses of the moduli,

$$\delta_1 = 0.02 \text{ m}, \delta_2 = 0.01 \text{ m}$$

44. Problem

Correct Answer: (B) 0.169 mm

Explanation:

$$\delta_{max} = \frac{5wL^4}{384EI} = \frac{5 \times 5 \times 10^3 N/m \times (6m)^4}{384 \times 500 \times 10^6 N \cdot m^2} = 0.169 \text{ mm}$$

45. Problem

Correct Answer: (A) 79.15 MPa

Explanation: Use transformation equations:

$$\sigma_{\theta} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\sigma_{30^\circ} = \frac{70 + 20}{2} + \frac{70 - 20}{2} \cos 60^\circ + 25 \sin 60^\circ$$

$$\sigma_{30^\circ} = 45 + 25 \times 0.5 + 25 \times 0.866$$

$$\sigma_{30^\circ} = 45 + 12.5 + 21.65$$

$$\sigma_{30^\circ} = 79.15 \text{ MPa}$$

46. Problem

Correct Answer: (B) 6 kN and 4 kN

Explanation:

The load is distributed in proportion to the modulus of elasticity:

$$\text{Load ratio} = \frac{E_1}{E_1 + E_2} \text{ and } \frac{E_2}{E_1 + E_2}$$

$$\text{Load on material 1} = \frac{120}{120 + 80} \times 10 \text{ kN} = 6 \text{ kN}$$

$$\text{Load on material 2} = \frac{80}{120 + 80} \times 10 \text{ kN} = 4 \text{ kN}$$

47. Problem

Correct Answer: (A) 12.73 GPa

Explanation:

$$A = \pi \left(\frac{100\text{mm}}{2} \right)^2 = \pi (50\text{mm})^2 = 2500\pi \text{mm}^2 \approx 7854\text{mm}^2$$

$$\sigma_{eng} = \frac{500,000\text{N}}{7854\text{mm}^2} \approx 63.66\text{MPa}$$

$$\epsilon_{eng} = \frac{1\text{mm}}{200\text{mm}} = 0.005$$

$$\text{Modulus of elasticity} = \frac{\text{Stress}}{\text{Strain}} = \frac{63.66\text{MPa}}{0.005} = 12,732\text{MPa} = 12.73\text{GPa}$$

48. Problem

Correct Answer: (A) 69.14

Explanation:

$$\text{Brinell hardness number (BHN)} = \frac{2F}{\pi D \left(D - \sqrt{D^2 - d^2} \right)}$$

Where, D = diameter indenter

d = diameter of the indentation

F = Load

$$= \frac{2 \times 500}{\pi \times 10 \left(10 - \sqrt{10^2 - 3^2} \right)} = 69.14$$

49. Problem

Correct Answer: (D) 48.75°

Explanation: Critical angle = $\sin^{-1}(n_{\text{air}}/n_{\text{water}})$

$$= \sin^{-1}(1/1.33) = 48.75^\circ$$

50. Problem

Correct Answer: (D) 1.6%

Explanation:

$$\% \epsilon = \frac{\Delta L}{L_0} \times 100$$

$$\% \epsilon = \frac{8}{500} \times 100 = 1.6 \%$$

51. Problem

Correct Answer: C) 1.19 mm

The engineering stress is calculated as:

$$\sigma = \frac{P}{A} = \frac{50 \times 10^3}{\pi (20 \times 10^{-3})^2 / 4} = 159.15 \text{ MPa}$$

Strain is given by Hooke's Law:

$$\epsilon = \frac{\sigma}{E} = \frac{159.15}{200 \times 10^3} = 7.95 \times 10^{-4}$$

Elongation (ΔL) is:

$$\Delta L = \epsilon L = 7.95 \times 10^{-4} \times 1.5 = 0.00119 \text{ m} = 1.19 \text{ mm}$$

52. Problem

Correct Answer: (C) 636.62 MPa

Explanation: Ultimate tensile strength = Load/Cross-sectional area

$$= \frac{50 \times 10^3 \text{ N}}{\pi \left(\frac{10}{2}\right)^2} = 636.62 \text{ MPa}$$

53. Problem

Correct Answer: B) $3.7 \times 10^{-11} \text{ m}^2/\text{s}$

$$T_1 = 900 + 273 = 1173 \text{ K}$$

$$T_2 = 1000 + 273 = 1273 = 1273 \text{ K}$$

$$D = D_o e^{\frac{Q}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)}$$

$$D = 1.2 \times 10^{-11} e^{\frac{140000}{8.314} \left(\frac{1}{1173} - \frac{1}{1273} \right)}$$

$$D = 3.7 \times 10^{-11} \text{ m}^2/\text{s}$$

54. Problem

Correct Answer: (B) 2.667 m

Explanation:

$$\text{Center of pressure: } y_p = \frac{I_G}{Ay} + \bar{y}$$

$$\bar{y} \text{ (Centroid depth)} = \frac{h}{2} = \frac{4}{2} = 2 \text{ m}$$

$$I_G \text{ (Moment of inertia)} = \frac{bh^3}{12} = \frac{2 \times (4)^3}{12} = 10.67 \text{ m}^4$$

$$A \text{ (area of the rectangle)} = b \times h = 2 \times 4 = 8 \text{ m}^2$$

$$\text{Center of pressure: } y_p = \frac{10.67}{8 \times 2} + 2 = 2.667 \text{ m}$$

55. Problem

Correct Answer: (D) 88290 N

Explanation:

$$P = \rho gh$$

Where, P = pressure, ρ = density, h = depth, g = gravitational force

$$P_{\text{avg}} = \rho g (h_1 + h_2) / 2$$

$$P_{\text{avg}} = 1000 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times (0 + 3) / 2$$

$$P_{\text{avg}} = 1000 \times 9.81 \times 1.5$$

$$P_{\text{avg}} = 14715 \text{ Pa}$$

$$F = P_{\text{avg}} \times A$$

$$F = 14715 \text{ Pa} \times (2 \text{ m} \times 3 \text{ m})$$

$$F = 14715 \times 6$$

$$F = 88290 \text{ N}$$

56. Problem

Correct Answer: (B) 490.5 N

Explanation:

$$W = \rho_{\text{water}} g V$$

Where, W = Weight, ρ = density, V = Volume

$$W = 1000 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 0.05 \text{ m}^3$$

$$W = 490.5 \text{ N}$$

57. Problem

Correct Answer: (C) 5.07 m

Explanation:

$$F \text{ (force on the gate)} = \rho g A \bar{h}$$

Where, ρ = Density, g = gravitational force, A = area of the gate, $\bar{h}$ = depth of the centroid of the gate from the water surface

$$A = b \times h = 2 \times 1 = 2 \text{ m}^2$$

$$\bar{h} = 4 + \frac{2}{2} = 5 \text{ m}$$

$$F = 1000 \times 9.81 \times 2 \times 5 = 98100 \text{ N}$$

$$\text{Calculate the center of pressure: } h_p = \frac{I_G}{A \bar{h}} + \bar{h} \rightarrow I_G = \frac{b h^3}{12} = \frac{1 \times 2^3}{12} =$$

$$= 0.667 \text{ m}^4$$

$$h_p = \frac{0.667}{2 \times 5} + 5 = 5.07 \text{ m}$$

58. Problem

Correct Answer: A) 154 N

Force = Pressure * Area

$$\text{Pressure at the bottom: } P = \rho g h = 1000 * 9.81 * 2 = 19620 \text{ Pa}$$

$$\text{Area of the opening: } A = \pi r^2 = \pi * (0.05)^2 = 0.00785 \text{ m}^2$$

$$\text{Force: } F = 19620 * 0.00785 \text{ m}^2 = 154 \text{ N}$$

59. Problem

Correct Answer: (D) 1177 N

Explanation:

$$V_{sub} = V_{block} \times \frac{\rho_{block}}{\rho_{water}} \rightarrow 0.2 \times \frac{600}{1000} = 0.12 \text{ m}^3$$

$$F_b = g\rho_{water}V_{sub}$$

Where, F_b = Buoyant force, ρ = density, V = Volume

$$F_b = 9.81 \text{ m/s}^2 \times 1000 \text{ kg/m}^3 \times 0.12 \text{ m}^3$$

$$F_b = 1177 \text{ N}$$

60. Problem

Correct Answer: (D) 101.3 kPa

Explanation: When a container is open to the atmosphere, the total (absolute) pressure just above the water surface must equal the ambient atmospheric pressure—which already includes the partial pressure of water vapor. In other words, you do not add the vapor pressure on top of the full 101.3 kPa; the 2.3 kPa vapor pressure is part of that 101.3 kPa total.

61. Problem

Correct Answer: (A) 86621.85 N

Explanation:

$$A = \pi(D/2)^2$$

$$A = \pi(1.5/2)^2$$

$$A = \pi \times 0.752$$

$$A = 1.767 \text{ m}^2$$

$$P = \rho gh$$

Where, P = Pressure, ρ = Density, h = height, g = gravitational force

$$P = 1000 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 5 \text{ m}$$

$$P = 49050 \text{ Pa}$$

$$F = P \times A$$

$$F = 49050 \text{ Pa} \times 1.767 \text{ m}^2$$

$$F = 86621.85 \text{ N}$$

62. Problem

Correct Answer: (A) 94.25 m^3

Explanation:

$$V = \frac{1}{3} \pi r^2 h$$

$$V = \frac{1}{3} \pi (3)^2 \times 10$$

$$V = \frac{1}{3} \pi \times 9 \times 10$$

$$V = 30\pi$$

$$V = 94.25 \text{ m}^3$$

63. Problem

Correct Answer: (B) 1366.6 m^3

Explanation:

$$V = \frac{L}{6} (A_1 + 4A_m + A_2)$$

$$V = \frac{20}{6} (40 + 4 \times 70 + 90)$$

$$V = 20/6 (40 + 280 + 90)$$

$$V = 20/6 \times 410$$

$$V = 1366.6 \text{ m}^3$$

64. Problem

Correct Answer: (A) 2250 m^3 , 1950 m^3

Explanation:

Cut Volume:

$$V_c = [(A_{c1} + A_{c2}) / 2] \times L$$

$$V_c = [(60 + 90) / 2] \times 30$$

$$V_c = 75 \times 30$$

$$V_c = 2250 \text{ m}^3$$

Fill Volume:

$$V_f = [(A_{f1} + A_{f2}) / 2] \times L$$

$$V_f = [(50 + 80) / 2] \times 30$$

$$V_f = 65 \times 30$$

$$V_f = 1950 \text{ m}^3$$

65. Problem

Correct Answer: A) (125, 378.1)

Convert Polar to Cartesian:

$$x = r * \cos(\theta), y = r * \sin(\theta)$$

$$x = 350 * \cos(60^\circ) = 175,$$

$$y = 350 * \sin(60^\circ) = 303.1$$

Translate:

Now, translate the Cartesian coordinates by (-50, +75):

$$x' = x + (-50) = 175 - 50 = 125$$

$$y' = y + 75 = 303.1 + 75 = 378.1$$

Therefore, the final Cartesian coordinates of the point after the translation are approximately (125, 378.1).

66. Problem

Correct Answer: (A) 2500 m^3

Explanation:

$$V = [(A_1 + A_2)/2] \times L$$

$$V = [(30 + 70)/2] \times 50$$

$$V = 50 \times 50$$

$$V = 2500 \text{ m}^3$$

67. Problem

Correct Answer: (D) 200 m^3

Explanation:

$$V = 1/3 \times A \times h$$

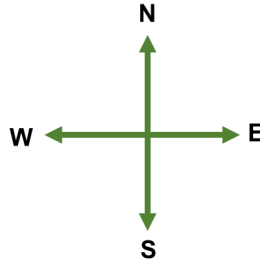
$$V = 1/3 \times 40 \times 15$$

$$V = 1/3 \times 600$$

$$V = 200 \text{ m}^3$$

68. Problem

Correct Answer: A) 320°



Imagine a compass. N 40° W means you start at North and move 40° towards West.

Since azimuths are measured clockwise from North, you can calculate the azimuth by subtracting the bearing angle from 360°.

$$\text{Azimuth} = 360^\circ - 40^\circ = 320^\circ$$

Therefore, the azimuth angle corresponding to a bearing of N 40° W is 320°

69. Problem

Correct Answer: (C) 183.6 kg

Explanation:

$$\begin{aligned} C_{\text{initial}} &= 180 \text{ mg/L}, V = 1200 \text{ m}^3 \rightarrow M_{\text{initial}} = C_{\text{initial}} \times V = 180 \text{ mg/L} \times 1200 \text{ m}^3 \\ &= 180 \times 10^{-3} \text{ g/L} \times 1200 \times 10^3 \text{ L} = 216000 \text{ g} = 216 \text{ kg} \end{aligned}$$

$$\text{Removal Efficiency} = 85\%$$

$$M_{\text{removed}} = M_{\text{initial}} \times \text{Removal Efficiency}$$

$$M_{\text{removed}} = 216 \text{ kg} \times 0.85; M_{\text{removed}} = 183.6 \text{ kg}$$

70. Problem

Correct Answer: B) 150,000 m³

Convert Watershed Area to Square Meters, 1 hectare = 10,000 m²

$$500 \text{ hectares} = 500 \times 10,000 = 5,000,000 \text{ m}^2$$

Convert Rainfall Depth to Meters, 5 cm = 0.05 m

Compute Total Rainfall Volume:

$$\begin{aligned} \text{Total Rainfall Volume} &= \text{Watershed Area} \times \text{Rainfall Depth} \\ &= 5,000,000 \times 0.05 = 250,000 \text{ m}^3 \end{aligned}$$

Compute Runoff Volume:

Since 40% infiltrates, 60% contributes to runoff:

$$\text{Runoff Volume} = 250,000 \times 0.60 = 150,000 \text{ m}^3$$

71. Problem

Correct Answer: (B) It estimates peak discharge from small urban catchments based on rainfall intensity, catchment area, and runoff coefficient.

Explanation: The Rational Method is used to estimate peak discharge from small urban catchments based on rainfall intensity, catchment area, and runoff coefficient. It provides a simple and effective way to calculate the maximum rate of runoff expected from a storm event. The Rational Method is particularly useful for designing stormwater drainage systems and determining the capacity of stormwater infrastructure.

72. Problem

Correct Answer: (A) 0.4 mg/mg

Explanation:

$$M_{\text{carbon}} = 500\text{mg}, M_{\text{contaminant}} = 200\text{mg}$$

$$V = 1\text{L} \rightarrow q = \frac{M_{\text{contaminant}}}{M_{\text{carbon}}} = \frac{200}{500} = 0.4\text{mg/mg}$$

73. Problem

Correct Answer: (B) 120 kg

Explanation:

$$C = 150\text{mg/L}, V = 800\text{m}^3 \rightarrow M = C \times V = 150\text{mg/L} \times 800\text{m}^3$$

$$M = 150 \times 10^{-3}\text{g/L} \times 800 \times 10^3\text{L} = 120000\text{g} = 120\text{kg}$$

74. Problem

Correct Answer: A) 7.68 hours

First, calculate the volume of the tank:

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth}$$

$$\text{Volume} = 40\text{ m} \times 20\text{ m} \times 4\text{ m} = 3,200\text{ m}^3$$

Next, convert the flow rate from cubic meters per day to cubic meters per hour:

$$\text{Flow rate} = 10,000\text{ m}^3 / 24\text{ hours} = 416.67\text{ m}^3/\text{hour}$$

Finally, calculate the detention time:

$$\text{Detention time} = \text{Volume} / \text{Flow rate}$$

$$\text{Detention time} = 3,200 / 416.67\text{ m}^3/\text{hour} = 7.68\text{ hours}$$

75. Problem

Correct Answer: B) 21.5 cfs

Use the orifice flow equation:

$$A = \pi \left(\frac{d}{2} \right)^2$$

$$A = 3.14 * \left(\frac{1.5}{2} \right)^2$$

$$A = 1.76\text{ ft}^2$$

Apply the orifice flow equation:

$$Q = C_d A \sqrt{2gH}$$

$$Q = 0.62 * 1.76 * \sqrt{2 * 32.2 * 6}$$

$$Q = 21.5 \text{ cfs}$$

76. Problem

Correct Answer: B) 5 inches

The change in storage due to Q_{in} and Q_{out} in inches is:

$$= \frac{10-8}{43200} * 60 * 60 * 12$$

$$2 \text{ inches}$$

Hydrologic Mass Balance:

$$P + Q_{in} - Q_{out} + Q_g - E_s - T_s - I = \Delta S_s$$

$$\Delta S_s = 5 + 2 + 0 - 1 - 0.5 - 0.5$$

$$\Delta S_s = 5 \text{ inches}$$

77. Problem

Correct Answer: (C) 1909.8 m

Explanation:

$$S = 0.15, Q = 0.01 \text{ m}^3/\text{s}, t = 3600 \text{ s} \rightarrow s_w = \frac{Qt}{S\pi r_w^2} = \frac{0.01 \times 3600}{0.15\pi(0.2)^2} = 1909.8 \text{ m}$$

78. Problem

Correct Answer: A) 1×10^{-6} mol/L

pH is defined as the negative logarithm (base 10) of the hydrogen ion concentration:

$$\text{pH} = -\log[\text{H}^+]$$

Therefore,

$$[\text{H}^+] = 10^{-\text{pH}}$$

$$[\text{H}^+] = 10^{-6}$$

$$[\text{H}^+] = 1 \times 10^{-6} \text{ mol/L}$$

79. Problem

Correct Answer: (A) 1036080000 m³

Explanation:

$$\begin{aligned} Q_{\text{in}}(t) &= 50 + 10t \\ t &= 4 \times 3600\text{s} \\ V_{\text{in}} &= \int_0^t Q_{\text{in}}(t) dt \\ V_{\text{in}} &= \int_0^{14400} (50 + 10t) dt \\ V_{\text{in}} &= [50t + 5t^2]_0^{14400} \\ V_{\text{in}} &= 50 \times 14400 + 5 \times (14400)^2 \\ V_{\text{in}} &= 720000 + 5 \times 207360000 \\ V_{\text{in}} &= 720000 + 1036800000 \\ V_{\text{in}} &= 1037520000\text{m}^3 \\ V_{\text{out}} &= Q_{\text{out}} \times t \\ Q_{\text{out}} &= 100\text{m}^3/\text{s} \\ V_{\text{out}} &= 100 \times 14400 \\ V_{\text{out}} &= 1440000\text{m}^3 \\ \Delta V &= V_{\text{in}} - V_{\text{out}} \\ \Delta V &= 1037520000 - 1440000 \\ \Delta V &= 1036080000\text{m}^3 \end{aligned}$$

80. Problem

Correct Answer: (A) 600 m^3

Explanation:

$$A = 2 \times 10^4 \text{ m}^2, d = 30 \times 10^{-3} \text{ m} \rightarrow V = A \times d = 2 \times 10^4 \text{ m}^2 \times 30 \times 10^{-3} = 600 \text{ m}^3$$

81. Problem

Correct Answer: D) 10kN

Identify the Indeterminacy

The beam AB is fixed at A and has a roller at B.

The roller at B allows only a vertical reaction (no horizontal reaction at B).

The horizontal reaction at A (R_A) is indeterminate to the first degree.

Remove the Indeterminate Reaction

Remove the horizontal reaction at A (R_A) and replace it with a unit load at A.

This will allow us to use the flexibility method to find R_A .

Calculate Displacements

Using the flexibility method:

Displacement at B due to the applied force $P=10 \text{ kN}$:

$$\Delta_p = PL/AE$$

$$\Delta_p = 10 \times 5/AE = 50/AE$$

Displacement at B due to a unit load at A:

$$\Delta_1 = 1 \times 5/AE = 5/AE$$

Step 4: Apply Compatibility Condition

The net displacement at B must be zero (since B is supported by a roller).

Using compatibility equation:

$$\Delta_p + R_A \Delta_1 = 0$$

Substituting values:

$$50/AE + R_A \times 5/AE = 0$$

Solving for R_A :

$$R_A = -50/5 = -10 \text{ kN}$$

The negative sign indicates that the reaction at A is opposite to the applied force.

82. Problem

Correct Answer: B) 7.2 kips

Tributary width per joist: $b_t = 6 \text{ ft}$

Factored roof load per unit area:

$$w_u = 1.2(15) + 1.6(20) = 18 + 32 = 50 \text{ psf}$$

Factored load per joist:

$$P_u = w_u \times b_t \times L = 50 \times 6 \times 24 = 7200 \text{ lbs} = 7.2 \text{ kips}$$

83. Problem

Correct Answer: C) 1880 lb/ft

Calculate Dead and Live Loads per Beam:

$$w_D = 25 \times 10 = 250 \text{ lb/ft}$$

$$w_L = 40 \times 10 = 400 \text{ lb/ft}$$

Calculate Factored Load per Beam:

$$w_u = 1.2(250) + 1.6(400) = 300 + 640 = 940 \text{ lb/ft}$$

Total Load on the Girder (2 Beams):

$$w_{\text{girder}} = 2 \times 940 = 1880 \text{ lb/ft}$$

84. Problem

Correct Answer: (C) statically determinate and stable

Explanation:

For the triangular truss:

Number of members (m) = 3 (AB, BC, CA)

Number of joints (j) = 3 (A, B, C)

Number of reactions (r) = 3 (assuming the truss is supported by a pinned joint and a roller joint which provide 3 reactions)

Substituting these values into the equation:

$$3+3=2\times 3$$

$$6 = 6$$

Since the equation is satisfied, the truss is statically determinate and stable.

85. Problem

Correct Answer: B) 18.75 kips

The total load on the beam is the product of the distributed load and the span.

$$\text{Total load} = 1.5 \text{ kips/ft} \times 25 \text{ ft} = 37.5 \text{ kips}$$

For a simply supported beam, each support carries half the total load.

$$\text{Load per support} = 37.5 \text{ kips} / 2 = 18.75 \text{ kips}$$

86. Problem

Correct Answer: C) 221.36 kips-ft

Lateral-torsional buckling (LTB) governs when the unbraced length L_b is large. The available nominal moment capacity M_n is determined as follows:

$$M_n = C_b M_p - \left(\frac{C_b M_p - M_{cr}}{L_r - L_p} \right) (L_b - L_p)$$

For W18x50:

Plastic moment capacity: $M_p = 515 \text{ ft-kips}$

Critical buckling moment: $M_{cr} = 135 \text{ ft-kips}$

Lateral-torsional buckling modification factor: $C_b = 1.0$

Lateral unbraced length: $L_b = 20$ ft

Plastic limit length: $L_p = 3.0$ ft

Limiting unbraced length: $L_r = 25$ ft

$$M_n = (1)(515) - \left(\frac{(1)(515) - (135)}{25 - 3} \right) (20 - 3) = 221.36 \text{ kips} - \text{ft}$$

87. Problem

Correct Answer: A) Yes, because $\phi P_n > 700$ kips

Explanation:

The column is adequate if the design compressive strength (ϕP_n) is greater than or equal to the factored axial load. Here, 800 kips $>$ 700 kips, so the column is adequate.

88. Problem

Correct Answer: A) 219.78 kN-m

Reinforcement: 4 bars of 20 mm dia:

$$A_s = 4 \times \pi/4(20^2) = 1256 \text{ mm}^2$$

Find the depth of compression block a:

$$a = A_s f_y / (0.85 f_c' b)$$

$$a = 1256 \times 420 / (0.85 \times 28 \times 300) = 73.88 \text{ mm}$$

Calculate Nominal Moment Capacity M_n :

$$M_n = A_s f_y (d - a/2)$$

$$M_n = (1256 \times 420) \times (500 - 73.88/2) = 244.2 \text{ kN-m}$$

Calculate Factored Moment Capacity ϕM_n :

$$\phi M_n = 0.9 \times 244.2 = 219.78 \text{ kN-m}$$

89. Problem

Correct Answer: A) 450 mm²

Use the ACI formula for minimum steel area:

$$A_{s,min} = \frac{0.25\sqrt{f_c}}{f_y} b_w d \geq \frac{1.4}{f_y} b_w d$$

$$A_{s,min} = \frac{0.25\sqrt{f_c}}{f_y} b_w d = \frac{0.25\sqrt{28}}{420} 300 \times 450 = 425.2 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{f_y} b_w d = \frac{1.4}{420} 300 \times 450 = 450 \text{ mm}^2$$

$$A_{s,min} = (425.2, 450) = 450 \text{ mm}^2$$

90. Problem

Correct Answer: A) 71.1 MPa

Maximum Moment: For a simply supported beam with a UDL, $M_{\max}$:

$$M_{\max} = (wL^2)/8 = (20 \text{ kN/m} * (4\text{m})^2)/8 = 40 \text{ kNm}$$

Section Modulus (S): For a square section, S:

$$S = (bh^2)/6 = (150\text{mm} * (150\text{mm})^2)/6 = 562,500 \text{ mm}^3$$

Maximum Bending Stress ($\sigma_{\max}$):

$$\sigma_{\max} = M/S = (40 * 10^6 \text{ Nmm}) / 562,500 \text{ mm}^3 = 71.1 \text{ MPa}$$

91. Problem

Correct Answer: (C) 52.28 kPa

Explanation:

$$\tau = c' + \sigma' \tan \phi' = 15 \text{ kPa} + 80 \text{ kPa} \tan 25^\circ = 15 \text{ kPa} + 80 \text{ kPa} \times 0.466 = 52.28 \text{ kPa}$$

92. Problem

Correct Answer: (D) 80 kPa

Explanation: In undrained conditions, the shear strength (τ_u) is independent of the normal stress and equals the undrained shear strength.

$$\tau = \tau_u = 80 \text{ kPa}$$

93. Problem

Correct Answer: (D) All of the above

Explanation: Mobilized shear force depends on the wall friction angle, soil cohesion, and overburden pressure. These factors influence the resistance of the soil against the movement of the wall.

94. Problem

Correct Answer: (B) 25%

Explanation: The factor of safety (FOS) is given by:

$$FOS = \frac{\text{Resisting Force}}{\text{Driving Force}}$$

To increase the FOS from 1.2 to 1.5, the increase in the resisting force can be calculated as:

$$\text{Increase} = \left(\frac{1.5}{1.2} - 1 \right) \times 100\% = (1.25 - 1) \times 100\% = 25\%$$

95. Problem

Correct Answer: (B) 936 kPa

Explanation: $q_u = c' N_c + \gamma' D N_q + 0.5 \gamma' B N_\gamma$

For sandy soil ($c' = 0$):

$$q_u = \gamma' D N_q + 0.5 \gamma' B N_\gamma = 18 \text{ kN/m}^3 \times 1.5 \text{ m} \times 22 + 0.5 \times 18 \text{ kN/m}^3 \times 2 \text{ m} \times 19 = 936 \text{ kPa}$$

96. Problem

Correct Answer: A) 145.5 kN/m^2

Total effective stress at $z = 8 \text{ m}$ is:

$$\sigma = (\gamma_1 \times H_1) + (\gamma_2 \times H_2)$$

Substituting values:

$$\sigma = (16.5 \times 3) + (19.2 \times 5)$$

$$\sigma = 49.5 + 96$$

$$\sigma = 145.5 \text{ kN/m}^2$$

97. Problem

Correct Answer: (A) 1532 kPa

Explanation: $q_u = cN_c + qN_q + 0.5\gamma B N_\gamma$

$$q = \gamma D = 20 \text{ kN/m}^3 \times 1.5 \text{ m} = 30 \text{ kPa}$$

For a circular footing:

$$q_u = 25 \text{ kPa} \times 30.14 + 30 \text{ kPa} \times 18.4 + 0.5 \times 20 \text{ kN/m}^3 \times 1.5 \text{ m} \times 15.1$$

$$q_u = 753.5 + 552 + 226.5 = 1532 \text{ kPa}$$

98. Problem

Correct Answer: (C) 1.25

Explanation:

$$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(0.3)^2}{0.12 \times 0.6} = 1.25$$

99. Problem

Correct Answer: (D) 300 kPa

Explanation: In undrained conditions for a saturated clay, the deviator stress (σ_d) at failure is equal to twice the undrained shear strength.

$$\sigma_d = 2\tau_u = 2 \times 150kPa = 300kPa$$

100. Problem

Correct Answer: (A) 150 kPa

Explanation: $q_{allowe} = \frac{q_u}{FS} = \frac{450kPa}{3} = 150kPa$

101. Problem

Correct Answer: (B) 4.6 kPa

Explanation: Using the Mohr-Coulomb failure criterion for effective stress:

$$\tau_p = c' + \sigma_3' \tan \phi'$$

Rearranging for c' :

$$c' = \tau_p - \sigma_3' \tan \phi' = 120kPa - 200kPa \tan 30^\circ = 120kPa - 200kPa \times 0.577 = 4.6kPa$$

102. Problem

Correct Answer: (D) 450 vehicles/hour

Explanation: The capacity C is given by:

$$C = \frac{3600}{t_c + t_f} = \frac{3600}{5+3} = \frac{3600}{8} = 450 \text{ vehicles / hour}$$

103. Problem

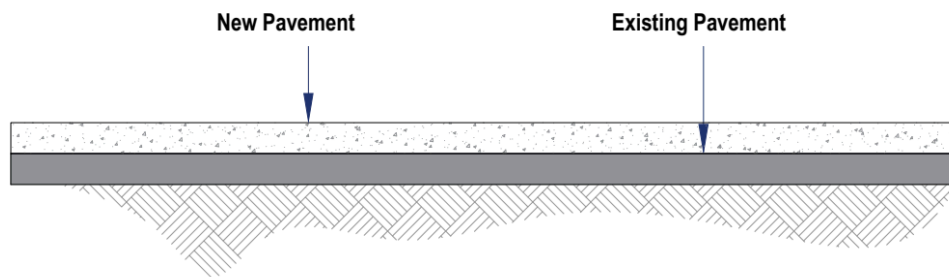
Correct Answer: C) 720

$$T = \frac{K \times O \times D}{F} = \frac{0.0012 \times 1500 \times 2000}{5} = 720 \text{ trips}$$

104. Problem

Correct Answer: D) 260

Solution:



$$D = \frac{SN_{required} - SN_{existing}}{a}$$

$$SN_{required} = 6.8$$

$$SN_{existing} = 2.2$$

Structural Layer Coefficient, $a = 0.45$

$$D = \frac{6.8 - 2.2}{0.45} = 10.22 \text{ inches}$$

$$D = 10.22 \times 25.4 = 259.588 \approx 260 \text{ mm}$$

105. Problem

Correct Answer: (A) 600 vehicles/hour

Explanation: $C = \frac{g}{c} \times S = \frac{40}{120} \times 1800 = \frac{1}{3} \times 1800 = 600 \text{ vehicles / hour}$

106. Problem

Correct Answer: D) 47.68 km/hour

The Space Mean Speed (SMS) is given by;

$$SMS = \frac{n}{\Sigma\left(\frac{1}{v_i}\right)}$$

Where n=4 and speeds are 40, 45, 60, 50

$$SMS = \frac{4}{\left(\frac{1}{40} + \frac{1}{45} + \frac{1}{60} + \frac{1}{50}\right)}$$

$$SMS = 47.68 \text{ km/hr}$$

107. Problem

Correct Answer: (A) 821.46 square feet

Explanation: Area of the square courtyard = Side²

$$= 30 \text{ feet} \times 30 \text{ feet}$$

$$= 900 \text{ square feet}$$

$$\begin{aligned} \text{Area of the circular fountain} &= \pi \times \left(\frac{\text{Diameter}}{2}\right)^2 \\ &= \pi \times \left(\frac{10 \text{ feet}}{2}\right)^2 = \pi \times 5^2 = 25\pi \approx 78.54 \text{ square feet} \end{aligned}$$

$$\text{Area excluding fountain} = 900 \text{ square feet} - 78.54 \text{ square feet}$$

$$= 821.46 \text{ square feet}$$

108. Problem

Correct Answer: (B) $42.5 \text{ m}^3/\text{hr}$

Explanation: $Q = CiA$

Where:

- Q = discharge (m^3/hr)

- C = runoff coefficient (0.85)

- i = rainfall intensity ($25 \text{ mm/hr} = 0.025 \text{ m/hr}$)

- A = area ($200 \text{ m} \times 10 \text{ m} = 2000 \text{ m}^2$)

$$Q = 0.85 \times 0.025 \times 2000 = 42.5 \text{ m}^3/\text{hr}$$

109. Problem

Correct Answer: D) 4,224 CY/hr

Convert speed to ft/min:

$$3 \times 5280 \div 60 = 264 \text{ ft/min}$$

Calculate volume per pass (ft^3/min):

$$V = \text{Blade Width} \times \text{Speed} \times \text{Cut Depth}$$

$$V = 12 \times 264 \times 0.5 = 1,584 \text{ ft}^3/\text{min}$$

Convert to cubic yards per hour:

$$(1,584/27) \times 60 \times 1.2 = 4,224 \text{ CY/hr}$$

110. Problem

Correct Answer: A) 1.3 days

Calculate effective bucket volume per cycle:

$$V_{\text{eff}} = \text{Bucket Capacity} \times \text{Efficiency}$$

$$V_{\text{eff}} = 2.5 \times 0.8 = 2.0 \text{ cubic yards}$$

Determine cycles per hour:

$$\text{Cycles per hour} = 3600 \text{ seconds} / \text{Cycle time in seconds}$$

$$\text{Cycles per hour} = 3600 / 30 = 120 \text{ cycles per hour}$$

Calculate hourly excavation rate:

$$Q_{\text{hour}} = V_{\text{eff}} \times \text{Cycles per hour}$$

$$Q_{\text{hour}} = 2.0 \times 120 = 240 \text{ cubic yards per hour}$$

Determine daily excavation rate:

$$Q_{\text{day}} = Q_{\text{hour}} \times 8 \text{ hours}$$

$$Q_{\text{day}} = 240 \times 8 = 1920 \text{ cubic yards per day}$$

Calculate required days:

$$\text{Days required} = \text{Total excavation volume} / Q_{\text{day}}$$

$$\text{Days required} = 2500 / 1920 \approx 1.3 \text{ days}$$