DETAILED SOLUTIONS

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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 8

Section A : CPM PERT + Hydrology & Water Resource Engineering [All Topics]

Section B : Design of Steel Structure-I + Surveying and Geology-I [Part Syllabus]

Section C : Solid Mechanics-II [Part Syllabus]

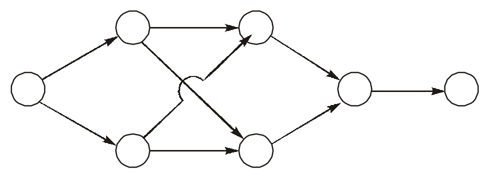
1.	(a)	16.	(c)	31.	(c)	46.	(b)	61.	(b)
2.	(c)	17.	(a)	32.	(a)	47.	(d)	62.	(b)
3.	(b)	18.	(b)	33.	(c)	48.	(d)	63.	(d)
4.	(d)	19.	(b)	34.	(b)	49.	(b)	64.	(d)
5.	(b)	20.	(a)	35.	(b)	50.	(d)	65.	(a)
6.	(c)	21.	(d)	36.	(a)	51.	(d)	66.	(d)
7.	(a)	22.	(c)	37.	(d)	52.	(a)	67.	(d)
8.	(a)	23.	(a)	38.	(b)	53.	(b)	68.	(c)
9.	(c)	24.	(a)	39.	(c)	54.	(d)	69.	(c)
10.	(b)	25.	(d)	40.	(c)	55.	(c)	70.	(a)
11.	(d)	26.	(a)	41.	(d)	56.	(b)	71.	(b)
12.	(c)	27.	(c)	42.	(d)	57.	(a)	72.	(a)
13.	(a)	28.	(d)	43.	(c)	58.	(d)	73.	(d)
14.	(a)	29.	(b)	44.	(a)	59.	(c)	74.	(a)
15.	(b)	30.	(c)	45.	(a)	60.	(c)	75.	(c)

DETAILED EXPLANATIONS

Section A : CPM PERT + Hydrology & Water Resource Engineering

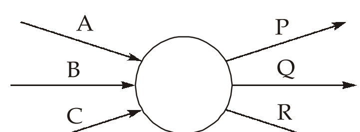
1. (a)

Arrows should normally not cross each other. If the situation is unavoidable, the length of the arrow should be broken to bridge over the other as shown below.



2. (c)

Wagon wheel error:



As per the above figure, each of activities *P*, *Q* and *R* cannot start until all the three activities *A*, *B* and *C* are completed.
But in reality, this may not be the situation. There is no error visible in the construction of diagram. Logical error has crept into it also known as wagon wheel error.

3. (b)

Total direct cost (Normal of the project) = 250 + 350 + 300 + 700

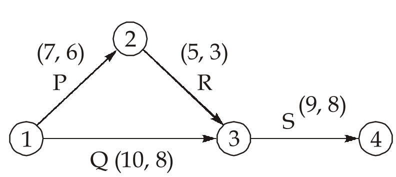
$$= \text{Rs. } 1600$$

$$\text{Cost slope of } P = \frac{350-250}{7-6} = \text{Rs. } 100/\text{day}$$

$$\text{Cost slope of } Q = \frac{500-350}{10-8} = \text{Rs. } 75/\text{day}$$

$$\text{Cost slope of } R = \frac{400-300}{5-3} = \text{Rs. } 50/\text{day}$$

$$\text{Cost slope of } S = \frac{950-700}{9-8} = \text{Rs. } 250/\text{day}$$



S.No.	Description	Duration	Indirect cost (Rs.)	Direct cost (Rs)	Total Project cost (Rs)	Remarks (Rs)
1.	All normal	21	3990	1600	5590	Normal duration
2.	Crashing R by 2 days	19	3610	1700	5310	
3.	Crashing P and Q each by 1 day simultaneously	18	3420	1875	5295	Optimum duration
4.	Crashing S by 1 day	17	3230	2125	5355	Minimum duration

∴ Optimum duration = 18 days
Minimum duration = 17 days

4. (d)

- Dragline is an actuator type equipment which is rope operated and boom fitted used on marshy and underwater areas.
- Scrapper is an earth hauling and cutting equipment.

5. (b)

$$\text{Average speed} = \frac{2\times 6+2\times 8+2\times 10}{6} = 8 \text{ km/h}$$

$$\text{Area to be graded per hour} = \frac{\text{Width graded per pass} \times \text{Average speed} \times \eta}{\text{Number of passes}}$$

$$= \frac{W\times 8\times 1000\times 0.75}{6}$$

Number of hours required to grade and finish 30 km long and 3W wide area

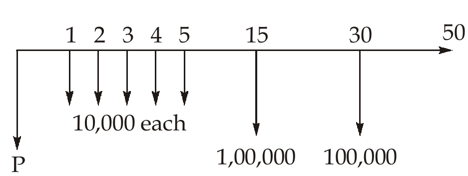
$$= \frac{\text{Total area}}{\text{Area/hr.}}$$

$$= \frac{30\times 1000\times 3W}{(W\times 8\times 1000\times 0.75)/6} = 90 \text{ hours}$$

6. (c)

Event has no place in A-O-N network and A-O-N system completely eliminates the use of dummy activity.

7. (a)



Let A be the equivalent uniform annual cost over the entire 50 years period.

$$P = \text{(Present worth of various maintenance cost)}$$

$$\Rightarrow \quad P = 10,000\left(\frac{P}{A}, 10\%, 5\right) + 100,000\left(\frac{P}{F}, 10\%, 15\right)$$

$$+100,000\left(\frac{P}{F}, 10\%, 30\right)$$

$\Rightarrow \quad P = 10{,}000(3.7908) + 100{,}000(0.2394) + 100{,}000\ (0.0573)$

$= 37908 + 23940 + 5730 = 67{,}578$

$\therefore \quad A = 67{,}578(A/P, 10\%, 50)$

$= 67578(0.1009) = \text{Rs. } 6{,}818.62 \simeq \text{Rs. } 6818$

8. (a)

Limitation of breakeven chart is that Breakeven chat is a tool for short run analysis.

9. (c)

10. (b)

11. (d)

In one cycle, volume of excavating material = 2.25 m^3 loose,

Swell = 25%

$$\text{Bank measure volume of one cycle} = \frac{2.25}{1.25} = 1.8\ m^3$$

$\therefore$ 10 minutes is idle time for every one hour

Actual time/hr = 50 mins. = 50 × 60 sec.

$$\text{Number of cycles being performed per hour} = \frac{50 \times 60}{27}$$

Output of shovel = Bank measure volume in one cycle in cum × number of cycles/hr

$$= \frac{1.8 \times 50 \times 60}{27} = 200\ m^3/hr$$

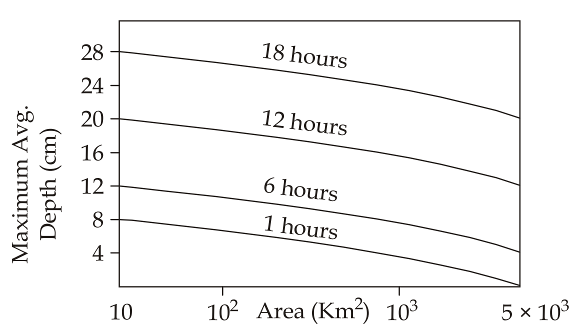
12. (c)

Since the fixed fee covers the contractor's overhead charges and profit, the contractor will try to finish the work as early as possible, so the owner gets advantage of early completion which is the merit of this type of contract.

13. (a)

14. (a)

15. (b)



Typical DAD curves

16. (c)

The chief advantage of the Sunken pan is that radiation and aerodynamic characteristics are similar to those of a lake.

17. (a)

By constant rate injection method,

$$Q = \frac{Q_t(C_1 - C_2)}{C_2 - C_0}$$

$$Q_t = 10\ \text{cm}^3/\text{s} = 10 \times 10^{-6}\ \text{m}^3/\text{s}$$

$$C_1 = 0.025\ \text{g}/l,\ C_2 = 5 \times 10^{-9}\text{g}/l,\ C_0 = 0$$

$$Q = \frac{10 \times 10^{-6}}{5 \times 10^{-9}}(0.025 - 5 \times 10^{-9}) = 50\ \text{m}^3/\text{s}$$

18. (b)

In float gauge recorder a float operating in a stilling well is balanced by means of a counter weight over the pulley of a recorder.

19. (b)

$$\text{Form factor} = \frac{A}{L^2}$$

$$\text{Compactness coefficient} = \frac{0.2821P}{\sqrt{A}}$$

$$\text{Circulatory ratio} = \frac{12.57A}{P^2}$$

$$\text{Elongation ratio} = \frac{1.128\sqrt{A}}{L}$$

Directions for Question 20 and 21: The peak of flood hydrograph due to a 3h duration isolated storm in a catchment is 320 m^3/s. The total depth of rainfall is 5.6 cm, with an average infiltration loss of 0.2 cm/h and constant base flow of 20 m^3/s.

20. (a)

Duration of rainfall excess = 3h

Total depth of rainfall = 5.6 cm

Loss @ 0.2 cm/h for 3 h = 0.6 cm

∴ Rainfall excess = 5.6 – 0.6 = 5.0 cm

Peak of flood hydrograph = 320 m^3/s

Base flow = 20 m^3/s

Peak of DRH = 300 m^3/s

$$\text{Peak of 3 h unit hydrograph} = \frac{\text{Peak of DRH}}{\text{Rainfall excess}} = \frac{300}{5.0} = 60\ \text{m}^3/\text{s}$$

21. (d)

$$\text{Let, } B = \text{Base width of 3 h UH in hours}$$

Volume represented by the area of UH = Volume of 1 cm depth over the catchment

$$\text{Area of UH} = (\text{Area of catchment} \times 1\text{ cm})$$

$$\therefore \quad \frac{1}{2} \times B \times 60 \times 60 \times 60 = 702 \times 10^6 \times \frac{1}{100}$$

$$\Rightarrow \quad B = \frac{702 \times 10^4}{10.8 \times 10^3}$$

$$\Rightarrow \quad B = 65 \text{ hours}$$

22. (c)

To estimate flood magnitude with a return period *T* by Log-Pearson Type-III method we need mean, standard deviation, coefficient of skew of logarithm of discharge data and number of years of data. So, the most appropriate option is (c).

23. (a)

If $x = 0.5$, equal weight is given to inflow and outflow, and the result is a uniformly progressive wave that does not attenuate as it moves though reach and has a reduced peak.

24. (a)

Hygrometer is a device used to measure the amount of water vapour in the air or humidity.

25. (d)

In contour border irrigation the drainage channels run perpendicular to contour.

Drip irrigation does not completely eliminate evapotranspiration.

26. (a)

27. (c)

Excessive long furrows may result in too much percolation near the upper end and too little water near the down end slope.

28. (d)

$$\text{Available moisture} = \text{Field capacity} - \text{Permanent wilting point}$$
$$= 30 - 15 = 15\%$$
$$\text{Readily available moisture} = 0.8 \times 15 = 12\%$$
$$\text{Optimum moisture} = 30 - 12 = 18\%$$

Depth of water stored in root zone between FC and OMC.

$$= \frac{\gamma_d}{\gamma_w} \times d \times (\text{FC} - \text{OMC})$$

$$= \frac{1.2}{1.0} \times (0.6\text{ m})(0.30 - 0.18)\text{ m}$$

$$= 0.0864 \text{ m} = 8.64 \text{ cm}$$

$\because$ 1.2 cm of water is utilised by the plant in 1 day

$$\Rightarrow \quad 8.64 \text{ cm is utilised in } \frac{8.64}{1.2} = 7.2 \simeq 7 \text{ days}$$

29. **(b)**

30. **(c)**

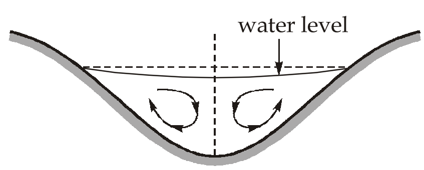
Type of soil		Maximum permissible velocity in unlined canals (m/s)
Rock and gravel	:	1.5 m/s
Murum, hard soil etc.	:	1.0 to 1.1 m/s
Sandy loam, black cotton soil etc.	:	0.6 to 0.9 m/s
Very light loose sand to average sandy soil	:	0.3 to 0.6 m/s
Ordinary soil	:	0.6 to 0.9 m/s

31. **(c)**

In steep terrain water is drained out quickly while on flat or irregular terrain drainage is very poor which leads to greater retention of water on the land, causing more percolation and raised water table.

32. **(a)**

In a straight reach velocity is higher in the middle, the water surface level will be lower in the middle and higher at edges as shown below.



33. **(c)**

As per Kennedy's theory, $V = 0.55\ my^{0.64}$

$\Rightarrow$ $V = 0.55 \times 1.2 \times (2.5)^{0.64}$ $(m = 1.2, y = 2.5 \text{ m})$

$\Rightarrow$ $V = 1.188$ m/s

34. **(b)**

Simple vertical drop type and Sarda type falls is a high crested fall in which the nappe impinges into the water cushion below. There is no clear hydraulic jump and the energy dissipation is brought about by the turbulent diffusion, as high velocity jet enters the deep pool of water downstream.

35. **(b)**

- The minimum recommended freeboard for lined canals carrying discharge of more than 10 cumecs is 0.75 m
- A lined alluvial canal is best designed on the basis of Manning's formula.

36. **(a)**

37. **(d)**

Flexibility is the ratio of rate of change of discharge of outlet to rate of change of discharge of distributary

Sensitivity is the ratio of rate of change of discharge of outlet to rate of change of water level of distributary.

38. (b)

39. (c)

Statement I is correct and statement II is false. In resource levelling the project duration may be extended to the minimum possible such that the demand actually agrees with the availability.

40. (c)

As far as possible weirs should be assigned at right angles to the direction of main river current. This ensures lesser length of the weirs, better discharging capacity and lesser cost.

Section B : Design of Steel Structure-I + Surveying and Geology-I

41. (d)

Refer IS 875 (Part II): 1987

42. (d)

Fire resistance of a steel member is a function of its mass, geometry and the actions to which it is subjected, structural support conditions, fire protection measures adopted and the fire to which it is exposed.

43. (c)

Strength of bolt:

Since angle is jointed with plate

∴ Bolt is in single shear

Strength of bolt in single shear

$$= 1 \times \frac{400}{\sqrt{3}} \times \frac{1}{1.25} \times \frac{\pi}{4} \times 16^2 = 37.146 \times 10^3 \text{ N}$$

Strength of bolt in bearing

$$= 2.5\, K_b \times \frac{f_u}{1.25} \times d \times t \qquad (\text{Given } K_b = 1)$$

$$= 2.5 \times 1 \times \frac{400}{1.25} \times 16 \times 8 = 102.4 \times 10^3 \text{ N}$$

∴ Bolt value $= 37.146 \times 10^3$ N

∴ Number of bolts required $= \dfrac{1.5 \times 70 \text{ kN}}{37.146 \text{ kN}} = 2.83 \simeq 3$

∴ 3 bolts are required.

44. (a)

Shear strength of HSFG bolts

$V_{nsf} = \mu_f \eta_e K_h F_o$

K_h = 1.0 for fasteners in clearance holes

= 0.85 for fasteners in oversized and short slotted holes and for fasteners in long slotted holes loaded perpendicular to slot.

= 0.7 for fastners in long slotted holes loaded parallel to slot.

μ_f = slip factor

η_e = no. of interfaces offering frictional resistance to slip
F_o = minimum bolt tension at installation = $A_n b f_o$
where f_o = $0.7\, f_{ub}$

45. (a)

For *Fe* 410 steel : f_u = 410 MPa
For field weld : Partial safety factor for material γ_{mw} = 1.5

Size of weld S = 8 mm

Effective throat thickness = $K.S = 0.7 \times 8 = 5.6$ mm

$$\text{Strength of weld per mm length} = 1 \times t_t \times \frac{f_u}{\sqrt{3}\gamma_{mw}} = 1 \times 5.6 \times \frac{410}{\sqrt{3} \times 1.5}$$

$$= 883.73 \text{ N/mm}$$

Total length of weld provided = $\pi d = \pi \times 200 = 628.32$ mm

$$\therefore \quad \text{Greatest twisting moment} = 883.73 \times 628.32 \times \frac{200}{2}$$

$$= 55526523.36 \text{ Nmm} \simeq 55.5 \text{ kNm}$$

46. (b)

For 20 mm dia. bolts, dia. of bolt hole = 22 mm
Net area of section 1 – 1

$$A_n = \left(60 \times 6 - 22 \times 5 + \frac{60^2 \times 4}{4 \times 60}\right) \times 8$$

$$\Rightarrow \quad A_n = 2480 \text{ mm}^2$$

$$\therefore \quad \text{Tensile strength} = \frac{0.9\, A_n f_u}{\gamma_{mb}} = \frac{0.9 \times 2480 \times 550}{1.25} \text{N} = 982.08 \text{ kN} \simeq 982 \text{ kN}$$

47. (d)

- The attachment of lug angle to the angle member should be capable of developing 40% in excess of that force.
- In case of channel member, the attachment of lug angles to the member should be capable of developing 20% in excess of that force.

48. (d)

All three statements viz. (a), (b) and (c) are correct.

49. (b)

The calculated weld length is placed as longitudinal fillet welds either on the two sides parallel to the axis of the load or on three sides i.e., transverse welds along with longitudinal welds.
A longitudinal fillet weld length should never be placed on one side only as there will be possibility of rotation.

50. (d)

$$\text{For single lacing } t_{min} = \frac{l_1}{40}$$

$$\text{For double lacing } t_{min} = \frac{l_1}{60}$$

$$\therefore \quad \text{Required percentage } \frac{\frac{l_1}{40} - \frac{l_1}{60}}{\frac{l_1}{60}} \times 100 = 50\%$$

51. (d)

$$\text{Length of line measured on plan} = L$$

$$\text{Actual length } l = 40{,}000\ L$$

$$\text{Measured length } l_1 = 45{,}000\ L$$

$$\text{Actual area } A = (40{,}000\ L)^2$$

$$\text{Measured area } A = (45{,}000\ L)^2$$

$$\%\ \text{error in area} = \frac{(45{,}000\ L)^2 - (40{,}000\ L)^2}{(40{,}000\ L)^2} \times 100 = 26.5\%$$

52. (a)

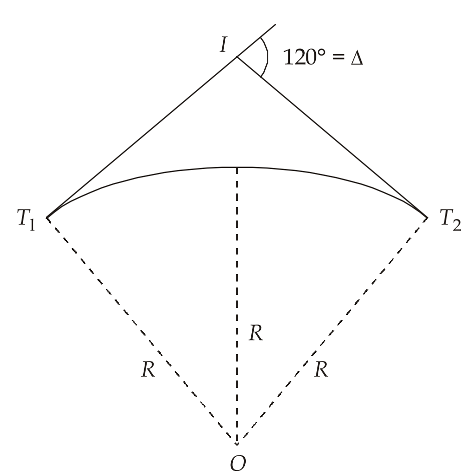
53. (b)

The accuracy to which measurements can be made with chain and tape varies with the methods used and precautions exercised. The precision of chaining for ordinary work ranges from 1/1000 to 1/30000 and precise measurements such as baseline may be of the order of 1 in 10^6.

54. (d)

The meridian passing through the most westerly station is termed as the reference meridian. The perpendicular distance of the mid-point of a line passing through this from the reference meridian is reckoned as meridian distance or longitude of the line.

55. (c)



Chainage of I = 350 + 12
= 350 (chains) + 12 links

Deflection angle Δ = 120°

Tangent length = $R \tan \frac{\Delta}{2} = 400 \tan 60° = 692.82$ m

Length of curve = $\frac{\pi R \Delta}{180°} = \frac{\pi \times 400 \times 120}{180} = 837.76$ m

Chainage of $P.I.$ = 350 (chains) + 12 (lines) = (350 × 20) + (0.12 × 20) = 7002.4 m

Deducting tangent length = 692.82 m

Chainage of $P.C.$ = 7002.4 – 692.82 = 6309.58 m

Adding curve length = + 837.76 m

Chainage of $P.T.$ = 6309.58 + 837.76 = 7147.34 m

∴ Chainage of $P.C.$ = (315 + 48)

Chainage of $P.T.$ = (357 + 37)

56. (b)

Instrument at A

Apparent difference of levels = 2.005 – 1.275 = 0.73 m

Instrument at B

Apparent difference of levels = 1.660 – 1.040 = 0.62 m

Difference of levels between A and B = $\frac{0.73 + 0.62}{2} = 0.675$ m

Collimation error when instrument is at B:

Correct reading on B = 1.660 m

Correct reading on A will be = 1.660 – 0.675 = 0.985 m

Observed reading on A = 1.040 m

∴ Amount of inclination = 1.040 – 0.985
= 0.055 m

Inclination of line of collimation, $\tan \alpha = \frac{0.055}{100} = 0.00055$

∴ α = 0.00055 rad (tan α being very small)

57. (a)

While taking observation, both the verniers are read, it eliminates the error due to the axis of the vernier plate not coinciding with the axis of the main plate.

58. (d)

59. (c)

$$V = \frac{d}{3}\left[(A_1 + A_n + 4(A_2 + A_4 + ...) + 2(A_3 + A_5 + ...)\right]$$

$$\Rightarrow \quad V = \frac{45}{3}\left[(25 + 35) + 4(45 + 65) + 2 \times (55)\right]$$

$$\Rightarrow \quad V = 9150 \text{ m}^3$$

60. (c)

When the stadia rod is inclined away from the telescope and inclined upwards, the apparent stadia intercept increases, resulting in a larger measured value.

61. (b)

62. (b)

Both statements are correct and statement II is not the correct explanation of statement (I).

63. (d)

Statement-I is false but Statement-II is true.

The absence of measurements (field notes) are inconvenient, if the survey is to be replotted to some different scale.

This is a major disadvantage of plane table surveying.

Section C : Solid Mechanics-II

64. (d)

Permissible torque T_1 based on permissible shear stress

$$T_1 = \frac{\pi d^3 \tau_{allow}}{16}$$

$$= \frac{\pi}{16} \times (0.050)^3 \times 60 \times 10^6 = 1472.62 \text{ Nm} \simeq 1473 \text{ N-m.}$$

Now, based on allowable angle of twist per unit length, torque is,

$$T_2 = GI_p\theta = (80\ GPa) \times \left(\frac{\pi}{32} \times 0.050^4\right) \times \left(\frac{2\times\pi}{180}\right) \times \left(\frac{10^9\ Pa}{1GPa}\right)$$

$$T_2 = 1713.47 \simeq 1714 \text{ N-m}$$

$\therefore$ Permissible torque $=$ min. (1473 and 1714)

$\Rightarrow$ $T = 1473$ N-m

65. (a)

$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\mu\sigma_y}{E}$$

$$= \frac{10}{30\times10^3} - 0.3\times\frac{20}{30\times10^3} = 133 \times 10^{-6}$$

$$\varepsilon_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E} = \frac{20}{30\times10^3} - \frac{0.3\times10}{30\times10^3}$$

$$= 566 \times 10^{-6}$$

$$\frac{\gamma_{max}}{2} = \left|\frac{\varepsilon_x - \varepsilon_y}{2}\right|$$

$\Rightarrow$ $\gamma_{max} = 566 \times 10^{-6} - 133 \times 10^{-6}$

$\Rightarrow$ $\gamma_{max} = 433 \times 10^{-6}$

66. (d)

- The only way to obtain higher modes of buckling is to provide lateral support to the column at inflection points.
- Critical load of a column is proportional to the flexural rigidity EI and inversely proportional to square of the length.
- However the strength of material does not appear in the equation of critical load. Thus, the critical load is not increased by using a stronger material. However, the load carrying capacity can be increased by using a stiffer material.

67. (d)

Strain energy method can be used to analyze both linear and non-linear structures. In the case of linear structures, this method is called as the stiffness method.

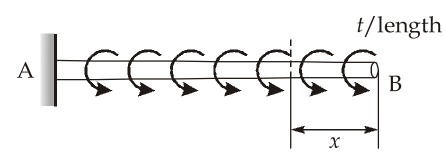
68. (c)

In the special case of pure torsion, the rate of change $\left(\frac{d\phi}{dx}\right)$ is constant along the length of the bar, because every cross-section is subjected to the same torque.

69. (c)

Guest and Tresca's theory also known as maximum shear stress theory has advantage that it can be represented graphically.

70. (a)



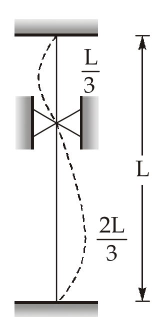
At x distance from free end.

Torque at section, $T_x = tx$

$$U = \int_0^L \frac{T_x^2 dx}{2GI_{P_x}} = \int_0^L \frac{(tx)^2 dx}{2GI_P} = \frac{t^2}{2GI_P}\int_0^L x^2 dx$$

$$= \frac{t^2 L^3}{6GI_P}$$

71. (b)



$$L_e = \frac{1}{\sqrt{2}}\left(\frac{2L}{3}\right) = \frac{\sqrt{2}\,L}{3}$$

72. (a)

$$\text{Principal stress } \sigma_1, \sigma_2 = \frac{\sigma}{2} \pm \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\therefore \quad \sigma_1 = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma_2 = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\text{Maximum shear stress} = \left|-\left(\frac{\sigma_1 - \sigma_2}{2}\right)\right| = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$= \frac{1}{2}\sqrt{\sigma^2 + 4\tau^2} = \frac{1}{2}\sqrt{30^2 + 4 \times 20^2} = 25 \text{ MPa}$$

73. (d)

A plane stress element will not be in condition of plane strain except when normal stresses are equal and opposite or hypothetically when Poisson's ratio is zero.

74. (a)

Both Statement-I and Statement-II are correct and Statement-II is the correct explanation of Statement-I:

Analysis of thick cylinder is done according to Lame's theory. One of the assumption of it is that the plane section perpendicular to longitudinal axis remains plane after fluid pressure is applied to it which means there will be no bending i.e. longitudinal strain is constant.

75. (c)

Statement I is correct but statement II is false.

Beams with thin walled open-cross-section like channels, angles, T-beams etc. are torsionally very weak. Therefore, it is important to locate shear centre(s) and to take into account the effect of twisting.

■■■■

