MADE EASY PUBLICATIONS

POSTAL BOOK PACKAGE 2024

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CIVIL ENGINEERING

Objective Practice Sets

Structural Analysis

1 CHAPTER
Determinacy and Indeterminacy

Q.1 The number of degrees of freedom of a point in space is
(a) 3 (b) 6
(c) 9 (d) unlimited number

Q.2 The minimum number of overall equilibrium equations for plane truss analysis must be equal to
(a) 2 (b) 3
(c) 6 (d) unlimited number

Q.3 The number of compatibility conditions needed in the analysis of a statically determinate structure are
(a) 0 (b) 2
(c) 3 (d) 6

Q.4 Compatibility conditions are primarily governed by
(a) strains (b) stresses
(c) temperature (d) forces

Q.5 Geometrically unstable structures can be used in
(a) pin-connected systems
(b) temporary systems
(c) long spans
(d) earthquake zones

Q.6 If there are m unknown member forces, r unknown reaction components and j number of joints, then the degree of static indeterminacy of a pin-joined plane frame is given by
(a) $m + r + 2j$ (b) $m - r + 2j$
(c) $m + r - 2j$ (d) $m + r - 3j$

Q.7 A pin-jointed plane frame is unstable if
(a) $(m + r) < 2j$ (b) $m + r = 2j$
(c) $(m + r) > 2j$ (d) none of these
where m is number of members, r is reaction components and j is number of joints

Q.8 A rigid-jointed plane frame is stable and statically determinate if
(a) $(m + r) = 2j$ (b) $(m + r) = 3j$
(c) $(3m + r) = 3j$ (d) $(m + 3r) = 3j$

Q.9 Match **List-I** (Type of structure) with **List-II** (Static indeterminacy) and select the correct answer using the codes given below the lists:
Number of members = m
Number of joints = n
Number of reaction elements = r

List-I	List-II
A. Plane frame	1. $m + r - 3n$
B. Space truss	2. $6m + r - 6n$
C. Space frame	3. $6m + r - 3n$
	4. $3m + r - 3n$

Codes:

	A	B	C
(a)	1	2	3
(b)	4	3	2
(c)	2	1	3
(d)	4	1	2

Q.10 Consider the following statements:
1. A properly constrained rigid system has several degrees of freedom.
2. The number of degrees of freedom of a locomotive moving on a railway track is only two.
3. A floating ship has six degrees of freedom.
Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 3 only
(c) 2 only (d) 1 only

Q.11 Consider the following statements:
1. The displacement method is more useful when degree of kinematic indeterminacy is greater than the degree of static indeterminacy.

2. The displacement method is more useful when degree of kinematic indeterminacy is less than the degree of static indeterminacy.
3. The force method is more useful when degree of static indeterminacy is greater than the degree of kinematic indeterminacy.
4. The force method is more useful when degree of static indeterminacy is less than the degree of kinematic indeterminacy.

Which of these statements are correct?

(a) 1 and 3 (b) 2 and 3
(c) 1 and 4 (d) 2 and 4

Q.12 An statically indeterminate building frame may be converted to a statically determinate one by assuming

(a) hinges at mid-height of columns
(b) hinges at the mid-span of the beams
(c) hinges at both mid-height of columns and mid-span of beams
(d) one support as fixed at base and other support on rollers

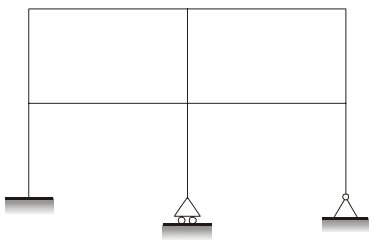
Q.13 Consider the following statements:

1. An statically indeterminate structure is not economical from the material stand-point in comparison to a statically determinate structure.
2. If '*n*' redundants in a statically indeterminate structure of '*n*' degree of static indeterminacy are removed, the structure will become statically determinate but unstable.
3. In the rigid frame analysis, the axial effects are ignored as their influence is negligibly small compared to bending and shear effects.

Which of these statements is/are correct?

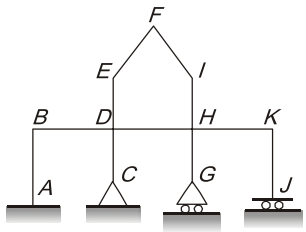
(a) 1 only (b) 1 and 2
(c) 3 only (d) 2 and 3

Q.14 What is the kinematic indeterminacy for the frame shown below? (Members are in extensible)



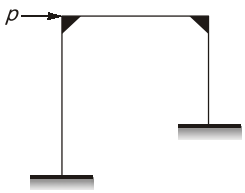
(a) 6 (b) 11
(c) 12 (d) 21

Q.15 Neglecting axial deformation, the kinematic indeterminacy of the structure shown in the figure below is:



(a) 12 (b) 14
(c) 20 (d) 22

Q.16



The portal frame shown in the above figure is statically indeterminate to the

(a) first degree (b) second degree
(c) third degree (d) None of the above

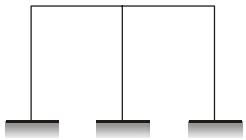
Q.17 Match **List-I** (Structure) with **List-II** (Degree of static indeterminacy) and select the correct answer using the codes given below the lists:

List-I

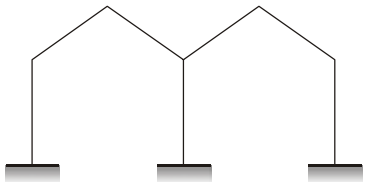
A.

B.

C.



D.



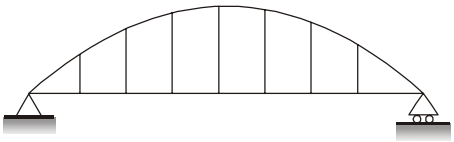
List-II

1. Three
2. Six
3. Two
4. Four

Codes:

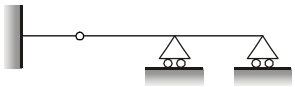
	A	B	C	D
(a)	1	3	2	2
(b)	3	1	2	4
(c)	3	1	4	2
(d)	1	3	4	2

Q.18 The static indeterminacy of the rigid frame shown is



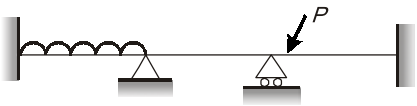
(a) 21 (b) 23
(c) 24 (d) 19

Q.19 The degree of indeterminacy of the beam given below is



(a) zero (b) one
(c) two (d) three

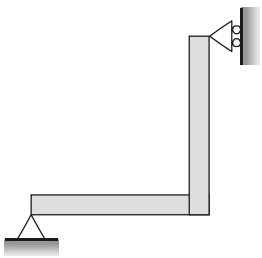
Q.20 What is the total degree of indeterminacy in the continuous prismatic beam shown in the figure below?



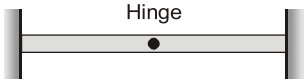
(a) 1 (b) 2
(c) 3 (d) 4

Q.21 Which one of the following structures is statically determinate and stable?

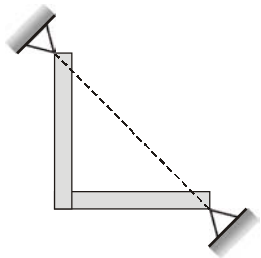
(a)



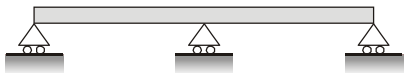
(b)



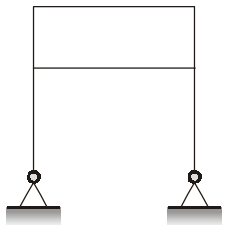
(c)



(d)

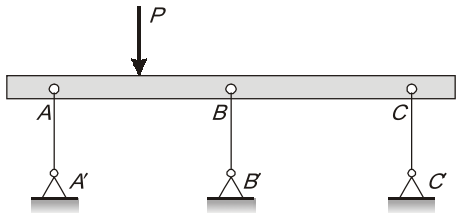


Q.22 What is the degree of Kinematic indeterminacy of the frame shown in figure? Neglect axial deformation.



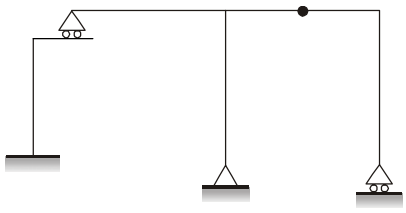
(a) 14 (b) 12
(c) 10 (d) 8

Q.23 The beam supported by 3 links and loaded as shown in the figure is



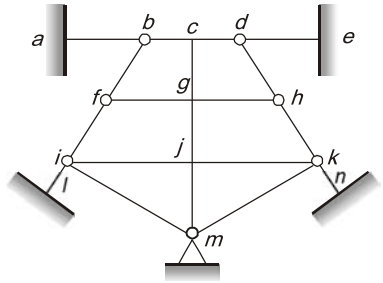
(a) stable and determinate
(b) unstable
(c) stable and indeterminate
(d) unstable but determinate

Q.24 A plane structure shown in the figure is



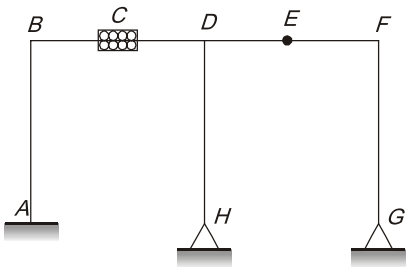
(a) stable and determinate
(b) stable and indeterminate
(c) unstable and determinate
(d) unstable and indeterminate

Q.25 The degree of static indeterminacy of the hybrid plane frame as shown in figure is



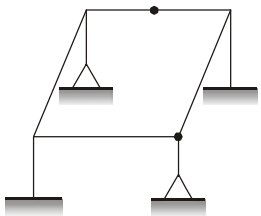
(a) 10 (b) 11
(c) 12 (d) 13

Q.26 A plane frame *ABCDEFGH* shown in figure has a clamp support at *A*, hinge supports at *G* and *H*, axial force release at *C* and moment release (hinge) at *E*. The static (d_s) and kinematic (d_k) indeterminacies respectively are



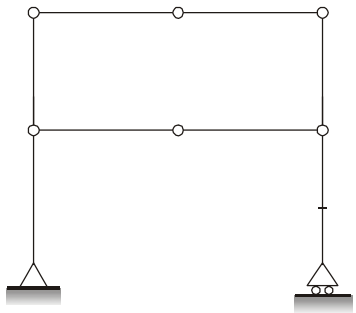
(a) 4, 9 (b) 3, 11
(c) 2, 12 (d) 1, 14

Q.27 The statical indeterminacy for the given 3*D* frame is



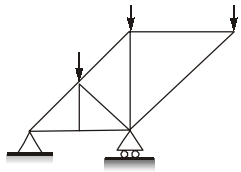
(a) 8 (b) 6
(c) 9 (d) 12

Q.28 The plane pin-jointed structure shown in figure below is



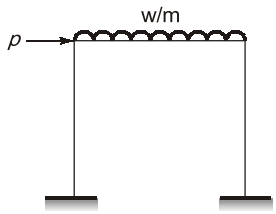
(a) externally indeterminate
(b) internally indeterminate
(c) determinate
(d) mechanism

Q.29 The pin-jointed frame shown in the figure is:



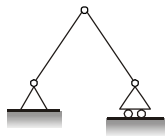
(a) a perfect frame
(b) a redundant frame
(c) a deficient frame
(d) None of the above

Q.30 The frame shown in the given figure has

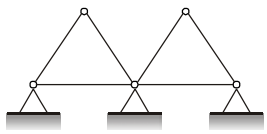


(a) one unknown reaction component
(b) two unknown reaction components
(c) three unknown reaction components
(d) six unknown reaction components

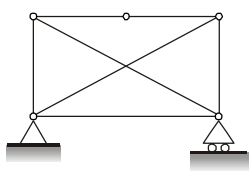
Q.31 Consider the following pin-jointed plane frames



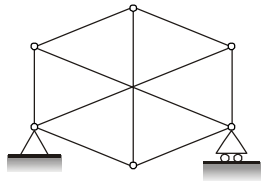
1.



2.



3.



4.

8. (c)

For rigid jointed plane frame

$3m + R > 3j \rightarrow$ Indeterminate and over stiff

$3m + R = 3j \rightarrow$ Stable and determinate

$3m + R < 3j \rightarrow$ Unstable but determinate

9. (d)

Type of structure	No. of Unknowns	No. of equations	Degree of indeterminacy
Plane frame	3 m + r	3 n	3 m + r – 3 n
Space truss	m + r	3 n	m + r – 3 n
Space frame	6 m + r	6 n	6 m + r – 6 n

10. (b)

A properly contained rigid system has finite degrees of freedom. The number of degree of freedom of a locomotive moving on a railway track is one. Hence, statement 1 and 2 are incorrect.

11. (d)

Force method is useful when $D_s < D_k$.

Displacement method is useful when $D_k < D_s$.

12. (c)

There are two methods of approximate analysis:

(i) Portal method for low rise buildings.

(ii) Cantilever method for tall buildings.

Both methods assume an inflection point located at mid height of each column and an inflection point located at the centre of each beam.

13. (c)

An indeterminate structure develops less maximum bending moment over the span. So it requires less cross-section to resist and more economical from material stand point. It is not necessary that removal of n redundants result in unstable structure.

14. (b)

Degree of kinematic indeterminacy for a plane rigid frame having inextensible member is given by

$$D_k = 3j - r_e - m$$

where m = Total number of inextensible members

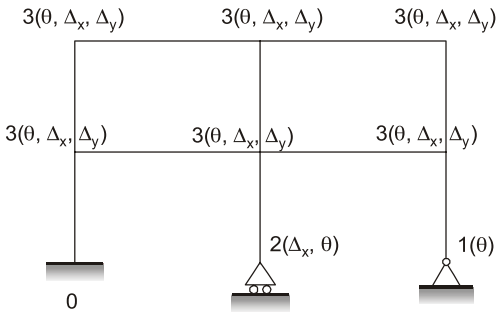
Here, $j = 9$

$r_e = 3 + 1 + 2 = 6$

$m = 10$

$\therefore \quad D_k = 3 \times 9 - 6 - 10 = 11$

Method-1:



For extensible members,

$D_k = 3 + 3 + 3 + 3 + 3 + 3 + 0 + 2 + 1$

$= 21$

Method-2:

Degree of kinematic indeterminacy for a plane rigid frame having extensible members is given by

$$D_k = 3j - r_e$$

Here, $j = 9$

$r_e = 3 \quad 1 + 2 = 6$

$\therefore \quad D_k = (3 \times 9) - 6 = 21$

15. (b)

Kinematic indeterminacy means degree of freedom of structure at various joints.

No rotation or translation is possible at A so degree of freedom at A is zero. There is a possibility of rotation at C but no translation so degree of freedom is one. At G, both rotation and translation is possible so degree of freedom is 2. At J no rotation but translation so d.o.f. is 1. At B, D, H and K there are 4 rotations and 1 translation so d.o.f. is 5. At E, F and I there are three rotations and two translations so d.o.f. is 5.

So kinematic indeterminacy

$$= 0 + 1 + 2 + 1 + 5 + 5 = 14$$

Alternate:

From direct formula

External reactions

$$r_e = 3 + 2 + 1 + 2 = 8$$

Number of members (m) = 11

Number of rigid joints (j) = 9

Number of hinged joints (j') = 2

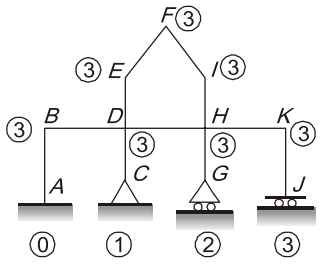
There are no internal hinges so number of releases is zero.

$$r_r = 0$$

Degree of kinematic indeterminacy (assuming inextensible members).

$$D_K = 3(j + j') - (r_e + r_r) - m$$
$$= 3 \times (9 + 2) - 8 - 11$$
$$= 33 - 19 = 14$$

Method-1:



Considering axial deformation,

At joints B, D, H, K, E, F, I, degree of freedom = 3 i.e., One rotation and Z translations.

At A, dof = 0

At C, dof = 1 (i.e., rotation)

At G, dof = 2 (i.e., 1 rotation and 1 translation)

At J, dof = 1 (i.e, 1 translation)

Now, D_k (in extensble) = D_k (extensible) – No. of axially rigid members

= (0 + 1 + 2 + 1 + 3 + 3 + 3 + 3 + 3 + 3 + 3 – 1)

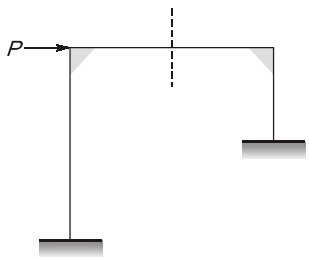
= 14.

16. (c)

Degree of static indeterminacy = $r_e - 3$

$= 6 - 3 = 3$

Alternate Solution :



D_s = 3 × no. of cuts – reactions added to make stable cantilevers

$= (3 \times 1) - 0$

$\Rightarrow \quad D_s = 3$

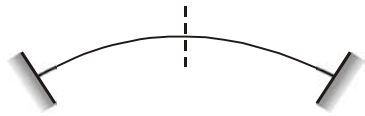
17. (a)

$$D_s = (3 \times C) - 9$$

Where C = no. of cuts

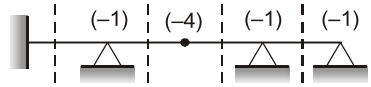
and n = reactions added to make stable cantilevers

A.



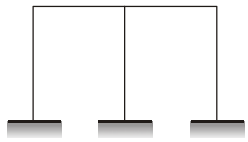
$D_s = (3 \times 1) - 0 = 3$

B.



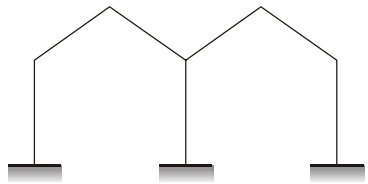
$D_s = (3 \times 3) - 1 - 4 - 1 - 1 = 2$

C.



$D_s = (3 \times 2) - 0 = 6$

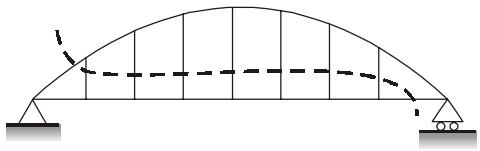
D.



$D_s = (3 \times 2) - 0 = 6$

Hence, option (a) is correct.

18. (c)



Number of cuts required to open the frame (C) = 9

Number of restraints required

$= 1 + 2 = 3$

$$D_s = 3C - r_e$$
$$= 3 \times 9 - 3 = 24$$

19. (b)

$$D_S = r_e + 3m - r_r - 3(j + j')$$
$$r_e = 3 + 1 + 1 = 5$$
$$m = 3,\ j = 3,\ j' = 1$$

The hinge will create 2 members.

Number of internal reaction components released.

$$r_r = 1.0$$

$$\therefore \quad D_s = 5 + 9 - 1.0 - 3 \times (3 + 1) = 1.0$$

20. (d)

Total number of external reactions,

$$r_e = 3 + 1 + 1 + 3 = 8$$

Total number of equilibrium equations for inclined loading on the beam = 3

$\therefore$ Total degrees of indeterminacy

$$= r_e - 3 = 8 - 3 = 5$$

Had this loading been vertical,

$$r_e = 2 + 1 + 1 + 2 = 6$$

Equilibrium equations = 2

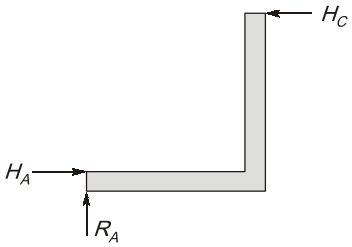
$\therefore$ Total degree of indeterminacy

$$= r_e - 2 = 6 - 2 = 4$$

21. (a)

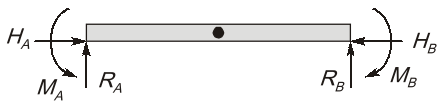
A structure will be statically determinate if the external reactions can be determined from force-equilibrium equations. A structure is stable when the whole or part of the structure is prevented from large displacements on account of loading.

- Member (a) is stable, since reactions are non-parallel and non-concurrent.



Also, it is determinate as there are 3 reaction components which can be determined by two force equilibrium conditions and one moment equilibrium condition.

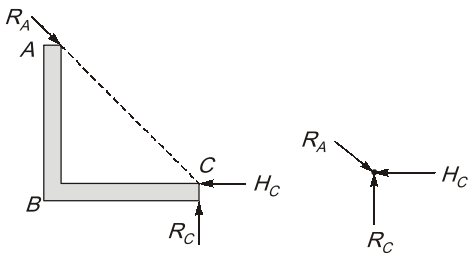
- Member (b) is stable but statically indeterminate to second degree.



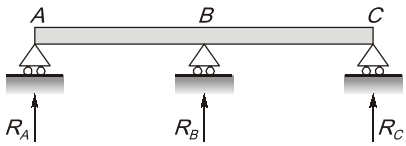
From above, reactions are non-parallel and non-concurrent

$\therefore$ It is stable.

- Member (c) is unstable since all the reactions are concurrent at C.

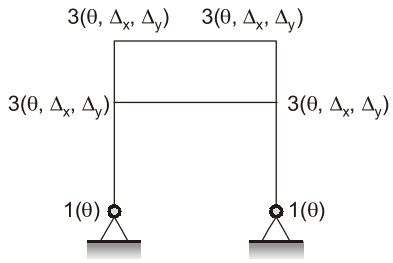


- Beam (d) is unstable, since all three reactions are parallel.



22. (d)

Method-1:



D_k = (inextensible) = D_k (extensible) – No. of axially rigid members

$\Rightarrow$ $D_k = (3 + 3 + 3 + 3 + 1 + 1) - 6$

$= 8$

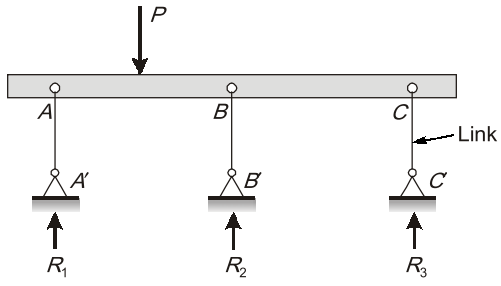
Method-2:

$D_k = 3j - m - r$

$= (3 \times 6) - 6 - (2 + 2)$

$= 8$

23. (c)



$D_{se} = 3 - 2 = 1$

$\Sigma F_y = 0$ & $\Sigma M = 0$

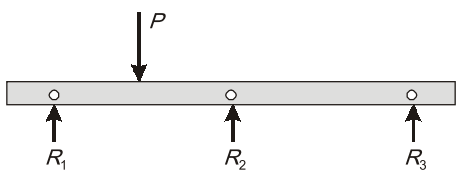
$D_{si} = 0$

$\therefore$ $D_s = 1$

(Indeterminate of degree 1)

Note : Link will carry only axial force (AA', BB', CC')

FBD:

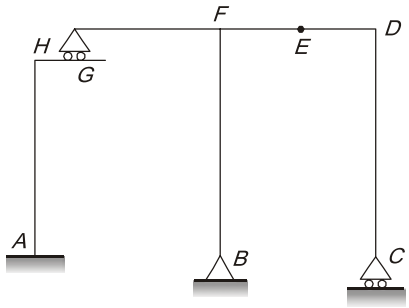


All reactions are parallel, but the structure is stable only for vertical loading.

Note : For general loading the structure is unstable.

24. (a)

Method-1: By formula



Static determinacy

$D_s = 3m + r_e - 3j - r_r$

$= (3 \times 7) + (3 + 2 + 1) - (3 \times 8)$

$- [1 \text{ (at } E) + 2 \text{ (at } G)]$

$= 0$

$\Rightarrow$ The structure is stable and determinate.

Method-II (By Cantilever Method)

$D_s = 3C - R$

Where 'R' is the number of release in a structure

$= 3 \times 2 - [1 \text{ (at B)} + 2 \text{ (at C)}$

$+ 1 \text{ (ast E)} + 2 \text{ (at G)}]$

$= 0$

25. (d)

$D_s = D_{se} + D_{si}$

$D_{se} = r_e - 3 = 14 - 3 = 11$

$D_{si} = 3c - r_r$

$= 3 \times 6 - \Sigma(m_f - 1)$

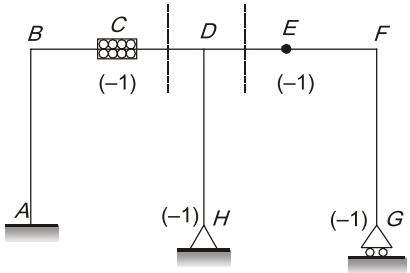
$= 18 - (2 + 2 + 3 + 2 + 3 + 2 + 2)$

$= 18 - (16) = 2$

$\therefore \quad D_s = 11 + 2 = 13$

26. (c)

(i) D_s



Method-1:

D_s = (3 × no. of cuts) – No. of axially rigid members

$= (3 \times 2) - 1 - 1 - 1 - 1$

$= 2$

Method-2:

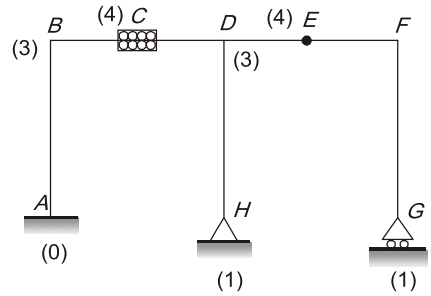
$D_s = 3m + r_e - 3j - \Sigma(m' - 1)$

Where m′ = member meeting at rigid joint

$\therefore \quad D_s = 3 \quad 7 + 6 - 3 \quad 8 - 1$

$= 21 + 6 - 29 = 2$

(ii) D_k



Method-1: By counting DOFs of joints

$D_k = 3 + 4 + 4 + 3 + 1 + 1 + 3$

$= 19$ (fro extensible members)

D_k (inextensible)

$= D_k$ (extensible) – No. of axially rigid members

$= 19 - 7 = 12$

Hence, the correct option is (c)

27. (c)

Method-1:

For rigid space frame (3D)

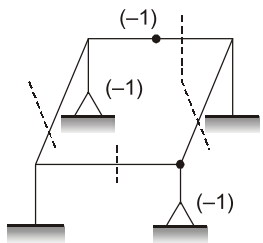
$D_S = 6m + r - 6j - \Sigma(m' - 1) \times 3$

$= 6 \times 9 + 18 - 6 \times 9$

$- (3 \times 1 + 3 \times 2)$

$= 54 + 18 - 54 - 9 = 9$

Method-2:



D_s = (3 × no. of cuts) – No. of reactions added to make stable cantilevers

$= (3 \times 4) - 1 - 1 - 1$

$= 9$

28. (c)

$m + r = 8 + 3 = 11$ and $2j = 16$

$\therefore \quad m + r < 2j$

$\Rightarrow$ Unstable but determinate structure.

29. (a)

Degree of indeterminacy

$$n = (m + r_e) - 2j,\ r_e = 3$$
$$= (9 + 3) - 2 \times 6 = 0$$

Since the degree of indeterminacy is zero and the frame is stable so it is a perfect frame.

Key Points:

(i) If $m > 2j - 3$, truss is stable and internally indeterminate.

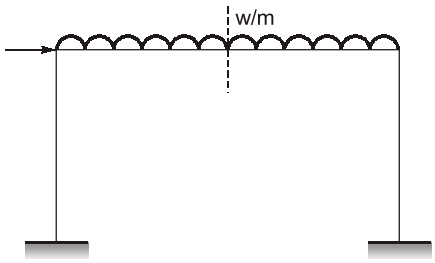
(ii) If $m < 2j - 3$, truss is internally unstable.

30. (c)

Degree of static indeterminacy

$$= r_e - 3 = 6 - 3 = 3$$

Alternate Solution:



D_s = (3 × no. of cuts) – no. of reactions added to make stable cantilevers

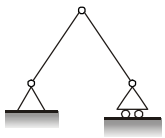
$= (3 \times 1) - 0$

$= 0$

As, $D_s = 3$

Hence, unknown reactions component are three.

31. (c)

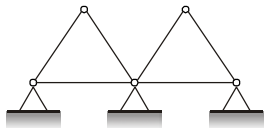
1. 

m + r = 2 + (2 + 1) = 5

and 2j = (2 × 3) = 6

∴ m + r < 2j

⇒ Unstable frame

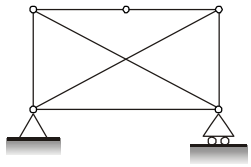
2. 

m + r = 6 + (2 + 2 + 2) = 12

and 2j = (2 × 5) = 10

∴ m + r > 2j

⇒ Stable frame

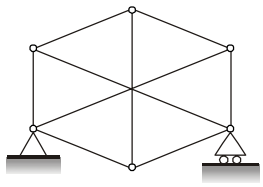
3. 

m + r = 6 + (2 + 1) = 9

and 2j = (2 × 4) = 8

∴ m + r > 2j

⇒ Stable frame

4. 

m + r = 9 + (2 + 1) = 12

and 2j = (2 × 6) = 12

∴ m + r = 2j

⇒ Stable frame

32. (b)

The degree of indeterminacy = 2 – 3 = –1

So the structure is deficient and unstable. It is a mechanism.

33. (d)

External indeterminacy,

$D_{se} = r_e - 3$

$r_e = 2 + 2 + 1 = 5$

$\therefore \quad D_{se} = r_e - 3 = 5 - 3 = 2$

Internal indeterminacy

$D_{si} = m - (2j - 3)$

No. of members, $m = 21$

Number of joints, $j = 11$

$\therefore \quad D_{si} = 21 - (2 \times 11 - 3)$

$= 21 - 19 = 2$

$\therefore \quad D_s = D_{se} + D_{si} = 2 + 2 = 4$