30 *Years*

Previous Solved Papers

GATE 2025

Mechanical Engineering

- Fully solved with explanations
- Analysis of previous papers
- Topicwise presentation
- Thoroughly revised & updated

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GATE - 2025

Mechanical Engineering

Topicwise Previous GATE Solved Papers (1995-2024)

Editions

1st Edition	:	2008
2nd Edition	:	2009
3rd Edition	:	2010
4th Edition	:	2011
5th Edition	:	2012
6th Edition	:	2013
7th Edition	:	2014
8th Edition	:	2015
9th Edition	:	2016
10th Edition	:	2017
11th Edition	:	2018
12th Edition	:	2019
13th Edition	:	2020
14th Edition	:	2021
15th Edition	:	2022
16th Edition	:	2023
17th Edition	**:**	**2024**

Preface

B. Singh (Ex. IES)

Over the period of time the GATE examination has become more challenging due to increasing number of candidates. Though every candidate has ability to succeed but competitive environment, in-depth knowledge, quality guidance and good source of study is required to achieve high level goals.

The new edition of **GATE 2025 Solved Papers : Mechanical Engineering** has been fully revised, updated and edited. The whole book has been divided into topicwise sections.

At the beginning of each subject, analysis of previous papers are given to improve the understanding of subject.

I have true desire to serve student community by way of providing good source of study and quality guidance. I hope this book will be proved an important tool to succeed in GATE examination. Any suggestions from the readers for the improvement of this book are most welcome.

B. Singh (Ex. IES)
Chairman and Managing Director
MADE EASY Group

GATE-2025

Mechanical Engineering

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Engineering Mechanics

UNIT

II

CONTENTS

Engineering Mechanics

Syllabus

Free-body diagrams and equilibrium; friction and its applications including rolling friction, belt-pulley, brakes, clutches, screw jack, wedge, vehicles, etc.; trusses and frames; virtual work; kinematics and dynamics of rigid bodies in plane motion; impulse and momentum (linear and angular) and energy formulations; Lagrange's equation.

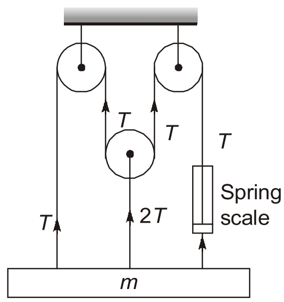
Analysis of Previous GATE Papers

Exam Year	1 Mark Ques.	2 Marks Ques.	3 Marks Ques.	5 Marks Ques.	Total Marks
1995	–	1	–	–	**2**
1996	2	3	–	–	**8**
1997	–	1	–	–	**2**
1998	1	–	–	–	**1**
1999	–	1	–	–	**2**
2000	2	–	–	–	**2**
2003	5	–	–	–	**5**
2004	–	3	–	–	**6**
2005	2	4	–	–	**10**
2006	–	2	–	–	**4**
2007	1	1	–	–	**3**
2008	1	2	–	–	**5**
2009	1	1	–	–	**3**
2011	1	2	–	–	**5**
2012	2	3	–	–	**8**
2013	–	1	–	–	**2**
2014 Set-1	1	2	–	–	**5**
2014 Set-2	1	2	–	–	**5**
2014 Set-3	1	3	–	–	**7**

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
2014 Set-4	–	4	**8**
2015 Set-1	3	4	**11**
2015 Set-2	1	2	**5**
2015 Set-3	2	3	**8**
2016 Set-1	2	2	**6**
2016 Set-2	1	3	**7**
2016 Set-3	2	3	**8**
2017 Set-1	2	1	**4**
2017 Set-2	–	1	**2**
2018 Set-1	1	2	**5**
2018 Set-2	1	1	**3**
2019 Set-1	1	2	**5**
2019 Set-2	2	1	**4**
2020 Set-1	1	1	**3**
2020 Set-2	2	1	**4**
2021 Set-1	1	2	**5**
2021 Set-2	–	2	**4**
2022 Set-1	1	3	**7**
2022 Set-2	2	2	**6**
2023	2	2	**6**
2024	2	2	**6**

1 FBD, Equilibrium, Plane Trusses and Virtual Work

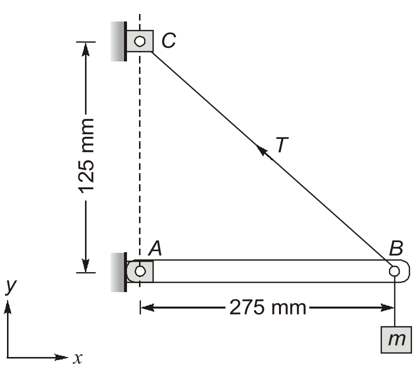
1.1 A spring scale indicates a tension T in the right hand cable of the pulley system shown in figure. Neglecting the mass of the pulleys and ignoring friction between the cable and pulley the mass m is



(a) $2T/g$ (b) $T(1 + e^{4\pi})/g$
(c) $4T/g$ (d) None of these

[1995 : 2 M]

1.2 A mass 35 kg is suspended from a weightless bar AB which is supported by a cable CB and a pin at A as shown in figure. The pin reactions at A on the bar AB are

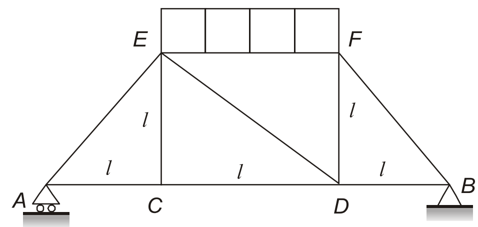


(a) $R_x = 343.4$ N, $R_y = 755.4$ N
(b) $R_x = 343.4$ N, $R_y = 0$
(c) $R_x = 755.4$ N, $R_y = 343.4$ N
(d) $R_x = 755.4$ N, $R_y = 0$ [1997 : 2 M]

1.3 A truss consists of horizontal members (AC, CD, DB and EF) and vertical members (CE and DF) having length l each. The members AE, DE and BF are inclined at 45° to the horizontal. For the uniformly distributed load p per unit length on the members EF of the truss shown in figure given below, the force in the member CD is

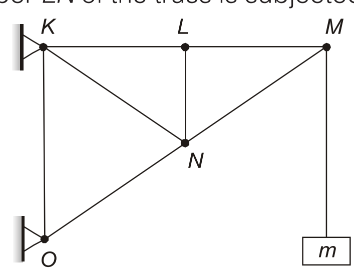
(a) $\frac{pl}{2}$ (b) pl

(c) 0 (d) $\frac{2pl}{3}$



[2003 : 1 M]

1.4 The figure shows a pin-jointed plane truss loaded at the point M by hanging a mass of 100 kg. The member LN of the truss is subjected to a load of

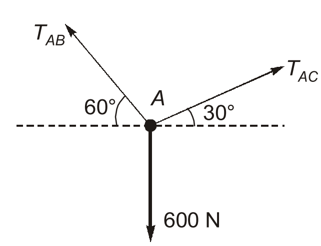


(a) 0 Newton
(b) 490 Newtons in compression
(c) 981 Newtons in compression
(d) 981 Newtons in tension [2003 : 1 M]

1.5 If a system is in equilibrium and the position of the system depends upon many independent variables, the principle of virtual work states that the partial derivatives of its total potential energy with respect to each of the independent variable must be

(a) –1.0 (b) 0
(c) 1.0 (d) ∞ [2006 : 2 M]

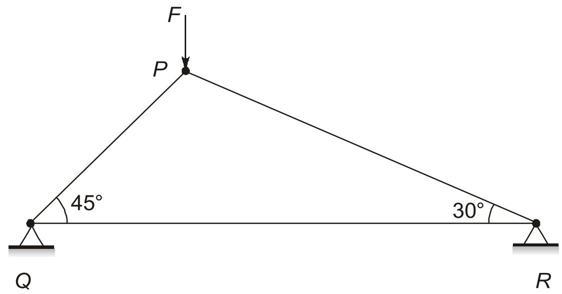
1.6 If point A is in equilibrium under the action of the applied forces, the values of tensions T_{AB} and T_{AC} are respectively.



(a) 520 N and 300 N (b) 300 N and 520 N
(c) 450 N and 150 N (d) 150 N and 450 N

[2006 : 2 M]

1.7 Consider a truss *PQR* loaded at *P* with a force *F* as shown in the figure.

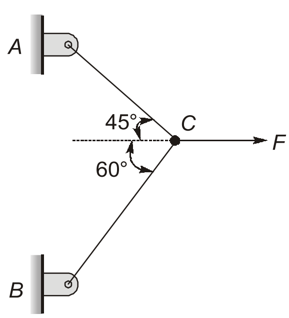


The tension in the member *QR* is

(a) 0.5 F (b) 0.63 F
(c) 0.73 F (d) 0.87 F [2008 : 2 M]

Common Data Questions (1.8 and 1.9):

Two steel truss members, *AC* and *BC*, each having cross sectional area of 100 mm^2, are subjected to a horizontal force *F* as shown in figure. All the joints are hinged.



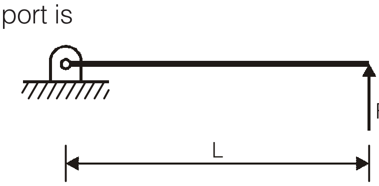
1.8 If *F* = 1 kN, the magnitude of the vertical reaction force developed at the point *B* in kN is

(a) 0.63 (b) 0.32
(c) 1.26 (d) 1.46 [2012 : 2 M]

1.9 The maximum force *F* in kN that can be applied at *C* such that the axial stress in any of the truss members DOES NOT exceed 100 MPa is

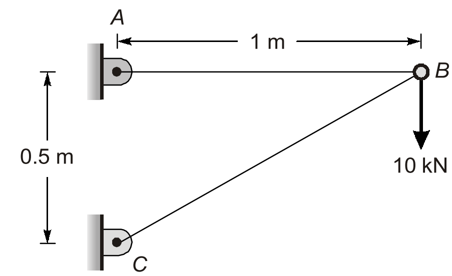
(a) 8.17 (b) 11.15
(c) 14.14 (d) 22.30 [2012 : 2 M]

1.10 A pin jointed uniform rigid rod of weight *W* and length *L* is supported horizontally by an external force *F* as shown in the figure below. The force *F* is suddenly removed. At the instant of force removal, the magnitude of vertical reaction developed at the support is



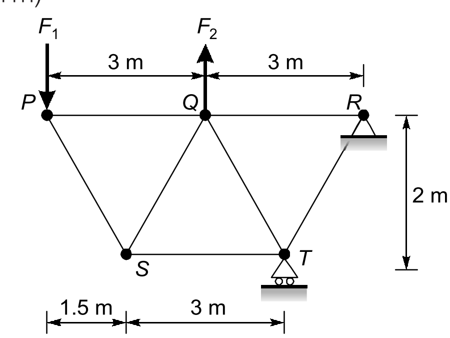
(a) zero (b) *W*/4
(c) *W*/2 (d) *W* [2013 : 2 M]

1.11 A two member truss *ABC* is shown in the figure. The force (in kN) transmitted in member *AB* is _____.



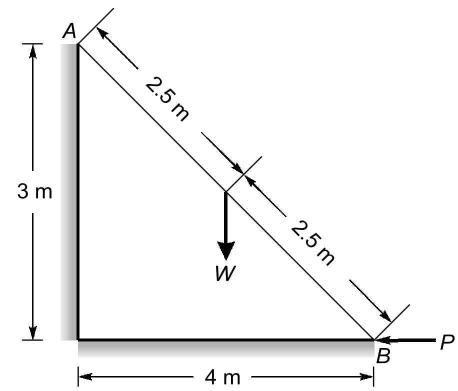
[2014 : 1 M, Set-2]

1.12 For the truss shown in the figure, the forces F_1 and F_2 are 9 kN and 3 kN, respectively. The force (in kN) in the member *QS* is (All dimensions are in m)



(a) 11.25 tension (b) 11.25 compression
(c) 13.5 tension (d) 13.5 compression
[2014 : 2 M, Set-4]

1.13 A ladder *AB* of length 5 m and weight (W) 600 N is resting against a wall. Assuming frictionless contact at the floor (B) and the wall (A), the magnitude of the force *P* (in newton) required to maintain equilibrium of the ladder is _______.

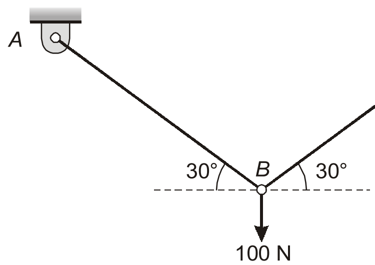


[2014 : 2 M, Set-4]

1.14 In a statically determinate plane truss, the number of joints (j) and the number of members (m) are related by

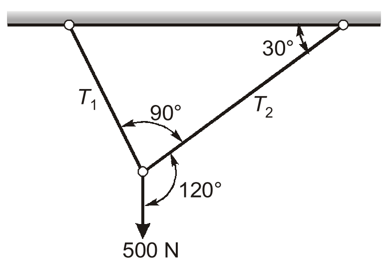
(a) $j = 2m - 3$ (b) $m = 2j + 1$
(c) $m = 2j - 3$ (d) $m = 2j - 1$
[2014 : 1 M, Set-4]

1.15 Two identical trusses support a load of 100 N as shown in the figure. The length of each truss is 1.0 m, cross-sectional area is 200 mm^2; Young's modulus E = 200 GPa. The force in the truss AB (in N) is ______



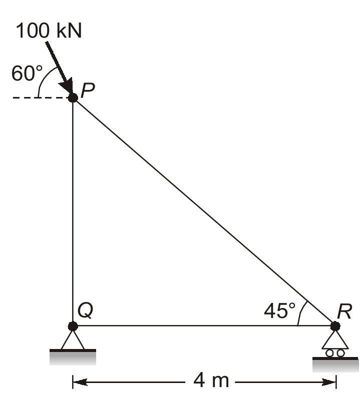
[2015 : 1 M, Set-1]

1.16 A weight of 500 N is supported by two metallic ropes as shown in the figure. The values of tensions T_1 and T_2 are respectively



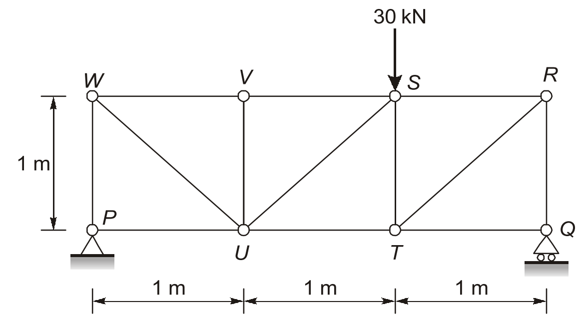
(a) 433 N and 250 N
(b) 250 N and 433 N
(c) 353.5 N and 250 N
(d) 250 N and 353.5 N [2015 : 1 M, Set-3]

1.17 For the truss shown in figure, the magnitude of the force in member PR and the support reaction at R are respectively



(a) 122.47 kN and 50 kN
(b) 70.71 kN and 100 kN
(c) 70.71 kN and 50 kN
(d) 81.65 kN and 100 kN [2015 : 2 M, Set-1]

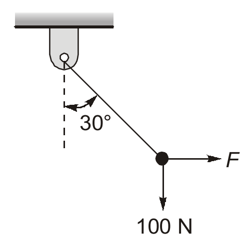
1.18 For the truss shown in the figure, the magnitude of the force (in kN) in the member SR is



(a) 10 (b) 14.14
(c) 20 (d) 28.28

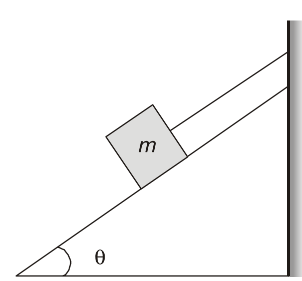
[2015 : 2 M, Set-2]

1.19 A rigid ball of weight 100 N is suspended with the help of a string. The ball is pulled by a horizontal force F such that the string makes an angle of 30° with the vertical. The magnitude of force F (in N) is_______.



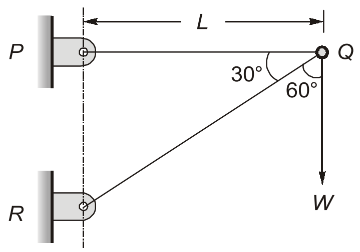
[2016 : 1 M, Set-1]

1.20 A block of mass m rests on an inclined plane and is attached by a string to the wall as shown in the figure. The coefficient of static friction between the plane and the block is 0.25. The string can withstand a maximum force of 20 N. The maximum value of the mass (m) for which the string will not break and the block will be in static equilibrium is _______ kg.
Take cos θ = 0.8 and sin θ = 0.6.
Acceleration due to gravity g = 10 m/s^2



[2016 : 2 M, Set-1]

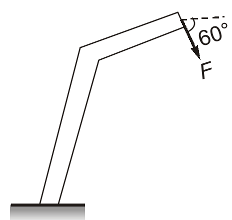
1.21 A two member truss PQR is supporting a load W. The axial forces in members PQ and QR are respectively



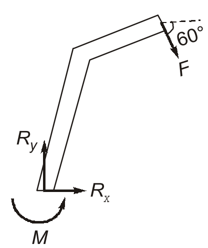
(a) $2W$ tensile and $\sqrt{3}W$ compressive
(b) $\sqrt{3}W$ tensile and $2W$ compressive
(c) $\sqrt{3}W$ compressive and $2W$ tensile
(d) 2W compressive and $\sqrt{3}W$ tensile

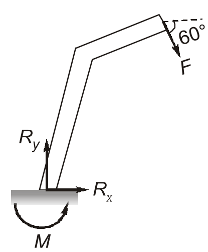
[2016 : 2 M, Set-1]

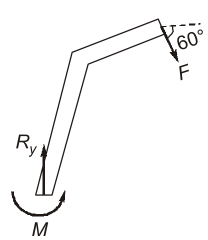
1.22 A force F is acting on a bent bar which is clamped at one end as shown in the figure.

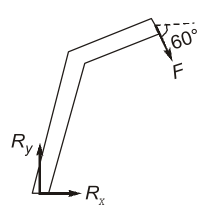


The CORRECT free body diagram is

(a)


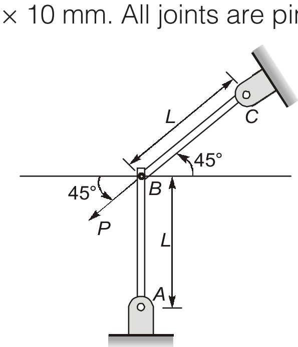
(b)


(c)


(d)


[2016 : 1 M, Set-3]

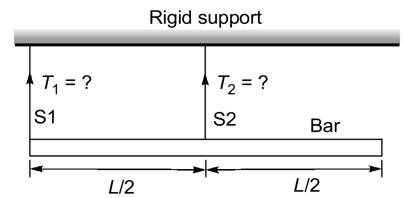
1.23 In the figure, the load P = 1 N, length L = 1 m, Young's modulus E = 70 GPa, and the cross-section of the links is a square with dimension 10 mm × 10 mm. All joints are pin joints.



The stress (in Pa) in the AB is_______
(Indicate compressive stress by a negative sign and tensile stress by a positive sign.)

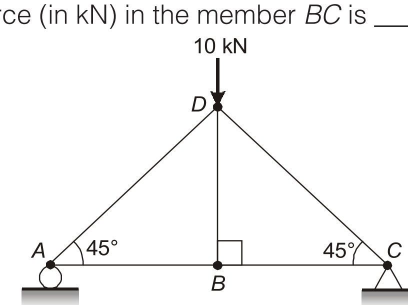
[2016 : 2 M, Set-2]

1.24 A bar of uniform cross section and weighing 100 N is held horizontally using two massless and inextensible strings S_1 and S_2 as shown in the figure.



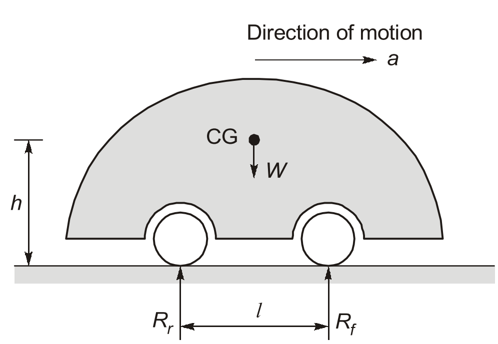
(a) T_1 = 100 N and T_2 = 0 N
(b) T_1 = 0 N and T_2 = 100 N
(c) T_1 = 75 N and T_2 = 25 N
(d) T_1 = 25 N and T_2 = 75 N [2018 : 1 M, Set-1]

1.25 A truss is composed of members AB, BC, CD, AD and BD, as shown in the figure. A vertical load of 10 kN is applied at point D. The magnitude of force (in kN) in the member BC is _______.



[2019 : 2 M, Set-1]

1.26 A car is having weight W is moving in the direction as shown in the figure. The centre of gravity (CG) of the car is located at height h from the ground, midway between the front and rear wheels. The distance between the front and rear wheels, is l. The acceleration of the car is a, and acceleration due to gravity is g. The reactions on the front wheels (R_f) and rear wheels (R_r) are given by



(a) $R_f = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a;\ R_r = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a$

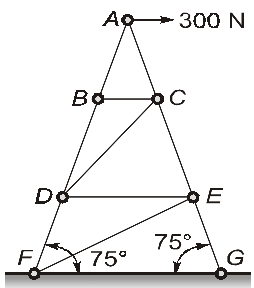
(b) $R_f = R_r = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a$

(c) $R_f = R_r = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a$

(d) $R_f = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a;\ R_r = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a$

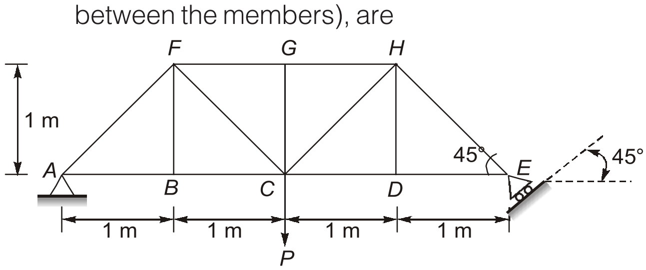
[2019 : 2 M, Set-1]

1.27 The figure shows an idealized plane truss. If a horizontal force of 300 N is applied at point *A*, then the magnitude of the force produced in member *CD* is ________ N.



[2019 : 1 M, Set-2]

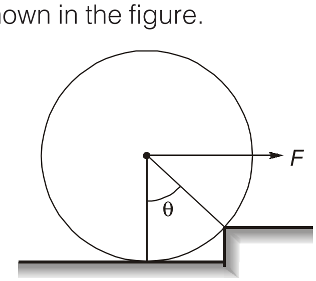
1.28 The members carrying zero force (i.e. zero-force members) in the truss shown in the figure, for any load $P > 0$ with no appreciable deformation of the truss (i.e. with no appreciable change in angles between the members), are



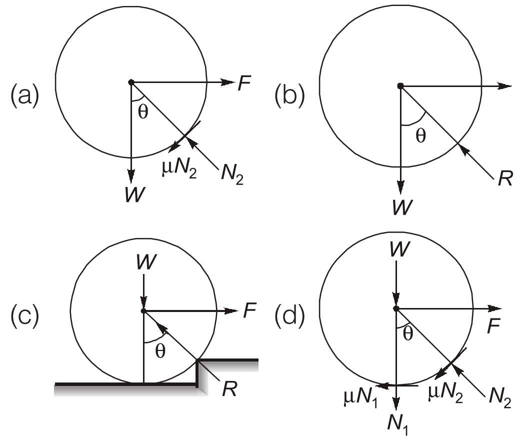
(a) BF, DH and GC only
(b) BF, DH, GC, CD and DE only
(c) BF and DH only
(d) BF, DH, GC, FG and GH only

[2020 : 1 M, Set-1]

1.29 An attempt is made to pull a roller of weight *W* over a curb (step) by applying a horizontal force *F* as shown in the figure.

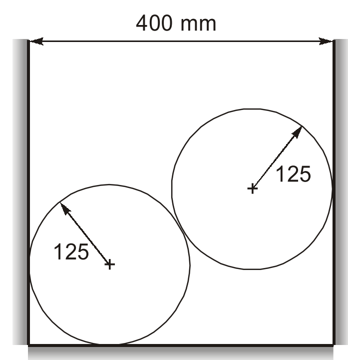


The coefficient of static friction between the roller and the ground (including the edge of the step) is μ. Identify the correct free body diagram (FBD) of the roller when the roller is just about to climb over the step.



[2020 : 1 M, Set-2]

1.30 Two smooth identical spheres each of radius 125 mm and weight 100 N rest in a horizontal channel having vertical walls. The distance between vertical walls of the channel is 400 mm.

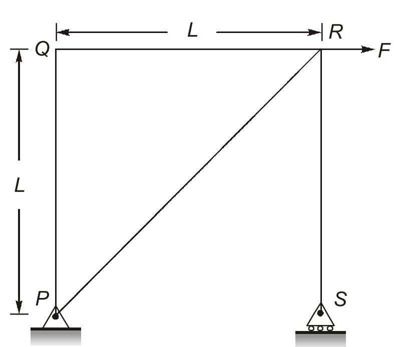


All dimensions are in mm

The reaction at the point of contact between two spheres is ________ N. [Round off to end one decimal place]

[2021 : 2 M, Set-1]

1.31 A plane truss *PQRS* ($PQ = RS$, and $\angle PQR = 90°$) is shown in the figure.

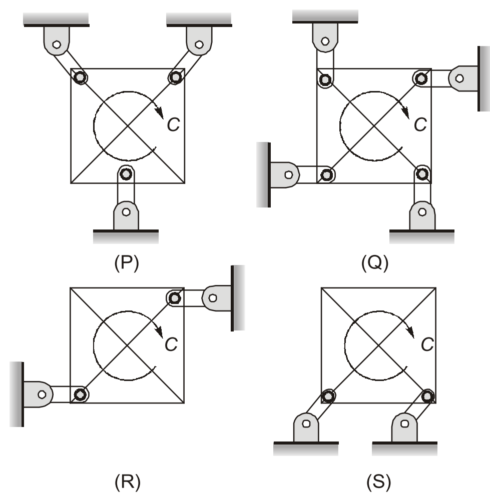


The forces in the members *PR* and *RS*, respectively, are _______.

(a) $F\sqrt{2}$ (tensile) and F(tensile)
(b) $F\sqrt{2}$ (tensile) and F (compressive)
(c) F(compressive) and $F\sqrt{2}$ (compressive)
(d) F(tensile) and $F\sqrt{2}$ (tensile)

[2021 : 1 M, Set-2]

1.32 A square plate is supported in four different ways (configurations (P) to (S) as shown in the figure). A couple moment *C* is applied on the plate. Assume all the members to be rigid and mass-less, and all joints to be frictionless. All support links of the plate are identical.

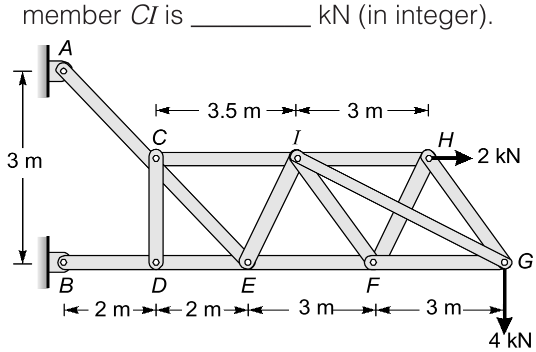


The square plate can remain in equilibrium in its initial state for which one or more of the following support configurations?

(a) Configuration (P) (b) Configuration (Q)
(c) Configuration (R) (d) Configuration (S)

[2022 : 1 M, Set-2]

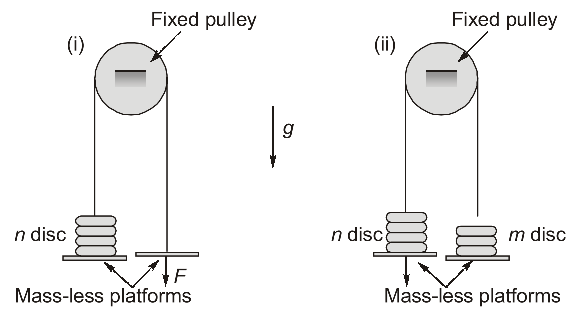
1.33 A structure, along with the loads applied on it, is shown in the figure. Self-weight of all the members is negligible and all the pin joints are friction-less. *AE* is a single member that contains pin *C*. Likewise, *BE* is a single member that contains pin *D*. Members *GI* and *FH* are overlapping rigid members. The magnitude of the force carried by member *CI* is _________ kN (in integer).



[2022 : 2 M, Set-1]

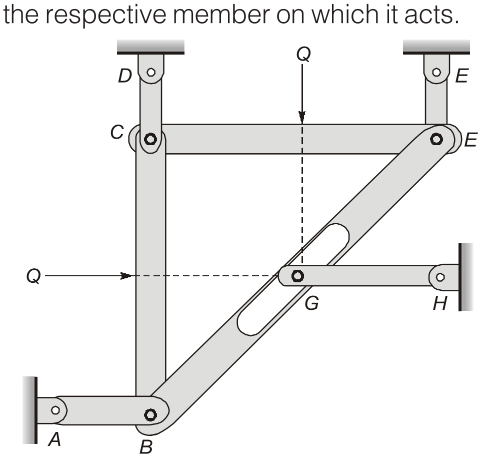
1.34 A rope with two mass-less platforms at its two ends passes over a fixed pulley as shown in the figure. Discs with narrow slots and having equal weight of 20 N each can be placed on the platforms. The number of discs placed on the left side platform is *n* and that on the right side platform is *m*.

It is found that for *n* = 5 and *m* = 0, a force *F* = 200 N (refer to part (i) of the figure) is just sufficient to initiate upward motion of the left side platform. If the force *F* is removed then the minimum value of *m* (refer to part (ii) of the figure) required to prevent downward motion of the left side platform is______ (in integer).



[2022 : 1 M, Set-2]

1.35 The lengths of members BC and CE in the frame shown in the figure are equal. All the members are rigid and lightweight, and the friction at the joints is negligible. Two forces of magnitude $Q > 0$ are applied as shown, each at the mid-length of the respective member on which it acts.



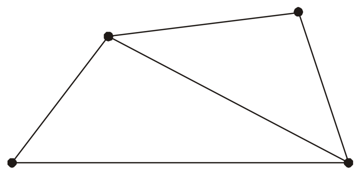
Which one or more of the following members do not carry any load (force)?

(a) AB (b) CD
(c) EF (d) GH

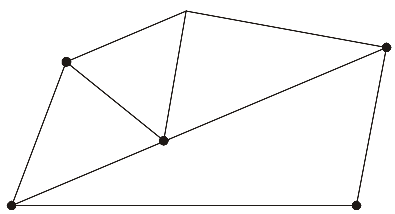
[2022 : 2 M, Set-2]

1.36 The options show frames consisting of rigid bars connected by pin joints. Which one of the frames is non-rigid?

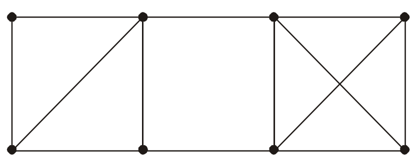
(a)



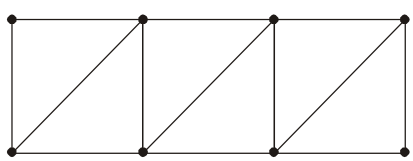
(b)



(c)

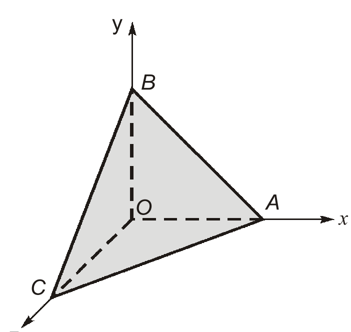


(d)



[2023 : 1 M]

1.37 A rigid massless tetrahedron is placed such that vertex O is at the origin and the other three vertices A, B, C lie on the coordinate axes as shown in the figure. The body is acted on by three point loads, of which one is acting at A along x-axis and another at point B along y-axis. For the body to be in equilibrium, the third point load acting at point O must be

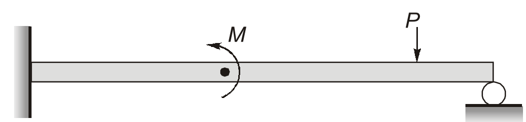


(a) In y-z plane but not along y or z axis
(b) along z-axis
(c) in z-x plane but not along z or x axis
(d) in x-y plane but not along x or y axis

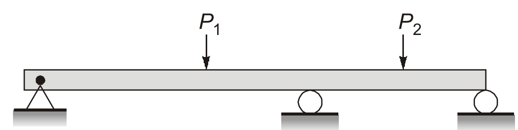
[2024 : 1 M]

1.38 Which of the following beam(s) is/are statically indeterminate?

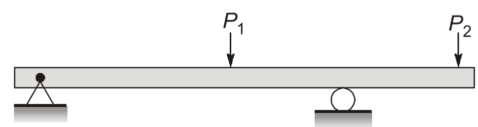
(a)



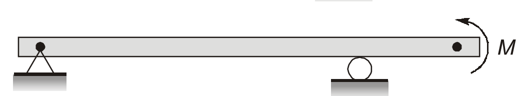
(b)



(c)

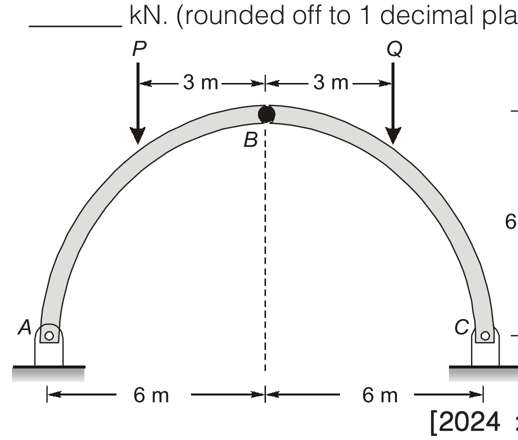


(d)



[2024 : 2 M]

1.39 A three-hinge arch ABC in the form of semi-circle is shown in the figure. The arch is in static equilibrium under vertical loads of P = 100 kN and Q = 50 kN. Neglect friction at all the hinges. The magnitude of the horizontal reaction at B is ________ kN. (rounded off to 1 decimal place)



[2024 : 2 M]

■■■■

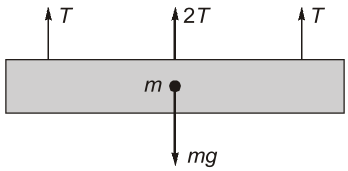
Answers FBD, Equilibrium, Plane Trusses and Virtual Work

1.1 (c)	**1.2** (d)	**1.3** (a)	**1.4** (a)	**1.5** (b)	**1.6** (a)	**1.7** (b)	**1.8** (a)	**1.9** (b)
1.10 (b)	**1.11** (20)	**1.12** (a)	**1.13** (400)	**1.14** (c)	**1.15** (100)	**1.16** (a)	**1.17** (c)	**1.18** (c)
1.19 (57.74)		**1.20** (5)	**1.21** (b)	**1.22** (a)	**1.23** (0)	**1.24** (b)	**1.25** (5)	**1.26** (d)
1.27 (0)	**1.28** (b)	**1.29** (b)	**1.30** (1.25)	**1.31** (b)	**1.32** (b, c, d)		**1.33** (18)	**1.34** (3)
1.35 (b, d)	**1.36** (c)	**1.37** (d)	**1.38** (a, b)	**1.39** (37.5)				

Explanations FBD, Equilibrium, Plane Trusses and Virtual Work

1.1 (c)

The free body diagram of mass m,



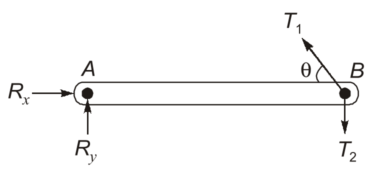
In equilibrium condition,

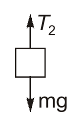
$$4T = mg$$

or $$m = \frac{4T}{g}$$

1.2 (d)

Since point A is hinge support, so there will be horizontal and vertical reactions at point A.





For block $T_2 = mg = 343.35\text{ N}$ ...(i)

$$\tan\theta = \frac{125}{275} = 0.4545$$

$$\theta = \tan^{-1}(0.4545) = 24.44°$$

For bar $\Sigma M_A = 0$

$$T_1 \sin\theta \times l = T_2 \times l$$

$$\Rightarrow T_1 = \frac{T_2}{\sin\theta} = \frac{343.35}{\sin 24.44°} = 829.74\text{ N}$$

$$\Sigma F_y = 0$$

$$+R_y - T_2 + T_1 \sin\theta = 0$$

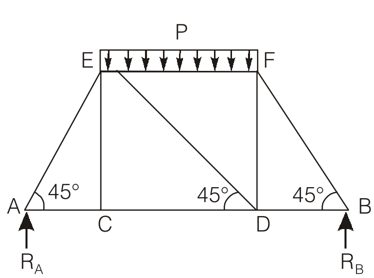
$$\therefore \quad R_y = 0$$

$$\Sigma F_x = 0$$

$$R_x - T_1\cos\theta = 0$$

$$R_x = 755.39\text{ N}$$

1.3 (a)



$$R_A + R_B = Pl$$

Taking moment about A

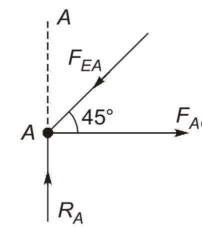
$$Pl(l + l/2) = R_B \times 3l$$

$$\therefore \quad R_B = \frac{Pl}{2}$$

$$\therefore \quad R_A = \frac{Pl}{2}$$

Joint A

Now at joint A



$$\Sigma F_V = 0$$

$$F_{EA} \sin 45° = \frac{Pl}{2}$$

$$\therefore \quad F_{EA} = \frac{Pl}{\sqrt{2}}$$

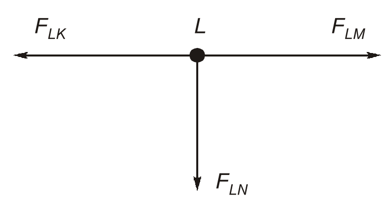
$$F_{AC} = F_{EA}\cos 45° = \frac{Pl}{\sqrt{2}} \times \frac{1}{\sqrt{2}}$$

$$F_{AC} = \frac{Pl}{2}$$

At joint C

$$F_{CA} = F_{CD} = \frac{Pl}{2} \qquad [\because F_{CE} = 0]$$

1.4 (a)



$\Sigma F_H = 0$ & $\Sigma F_V = 0$

At joint "L"

$$\therefore \quad F_{LK} - F_{LM} = 0 \quad (\Sigma F_H = 0)$$

$$F_{LN} = 0 \quad (\Sigma F_V = 0)$$

Hence no force is acting on the truss number LN.

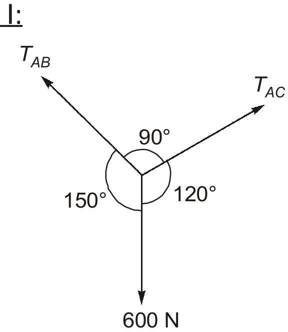
1.5 (b)

In equilibrium, potential energy is minimum.

If any system is in equilibrium and subjected to many independent variables, partial derivatives of its total potential energy with respect to each of the independent variable must be zero.

1.6 (a)

<u>Method I:</u>



By Lami's theorem

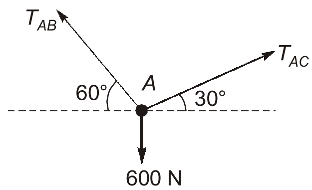
$$\frac{T_{AB}}{\sin 120°} = \frac{T_{AC}}{\sin 150°} = \frac{600}{\sin 90°}$$

$\therefore \quad T_{AB} = 600 \sin 120° = 519.61 \approx 520$ N

and $\quad T_{AC} = 600 \sin 150° =$ **300 N**

<u>Method II:</u>

In equilibrium,



Horizontal forces,

$$\Sigma F_x = 0,$$

$$T_{AC} \cos 30° - T_{AB} \cos 60° = 0$$

$$T_{AC} = T_{AB} \frac{\cos 60°}{\cos 30°} = \frac{T_{AB}}{\sqrt{3}} \quad ...(i)$$

Vertical forces,

$$\Sigma F_y = 0,$$

$$T_{AC} \sin 30° + T_{AB} \sin 60° - 600 = 0$$

$$T_{AC} \sin 30° + T_{AB} \sin 60° = 600$$

$$T_{AC} + \sqrt{3}\ T_{AB} = 1200 \quad ...(ii)$$

From equation (i) and (ii)

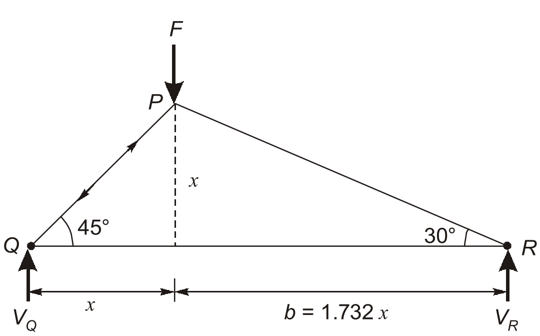
$$\frac{T_{AB}}{\sqrt{3}} + \sqrt{3} T_{AB} = 1200$$

$$4T_{AB} = 1200\sqrt{3}$$

$$T_{AB} = 300\sqrt{3} = 519.61 \text{ N} = 520 \text{ N}$$

and $\quad T_{AC} = \dfrac{T_{AB}}{\sqrt{3}} = \dfrac{300\sqrt{3}}{\sqrt{3}} = 300$ N

1.7 (b)



$$\tan 30° = \frac{x}{b}$$

$$b = \frac{x}{\tan 30°} = 1.732\, x$$

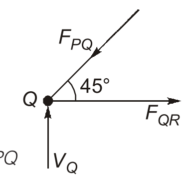
Taking moment about Q

$$F \times x = V_R \times 2.732\, x$$

$$V_R = 0.366\, F$$

$$V_Q = F - 0.366\, F$$

$$= 0.634\, F$$



FBD of joint Q

Let force in the member PQ is F_{PQ}

$\therefore F_{PQ} \sin 45° = V_Q$

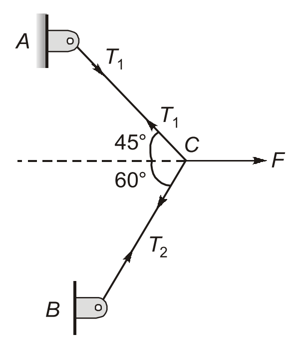
$\Rightarrow F_{PQ} \sin 45° = 0.634$ F

Force in member QR

$F_{QR} = F_{PQ} \cos 45° =$ **0.634*F***

1.8 (a)

<u>Method I:</u>



Using Lami's theorem

$$\frac{T_1}{\sin 120°} = \frac{T_2}{\sin 135°} = \frac{F}{\sin 105°}$$

$T_1 = 0.8965F$

$T_2 = 0.732F$

Vertical reaction at B,

$R_B = T_2 \cos 30° = 0.732 \cos 30°$

$R_B =$ **0.634 kN**

Method II:

$$\Sigma F_x = 0,$$

$$(F_{AC})_x + (F_{BC})_x = F \quad ...(i)$$

$$\Rightarrow F_{AC} \cos 45° + F_{BC} \cos 60° = F$$

$$\Sigma F_y = 0,$$

$$F_{AC} \sin 45° = F_{BC} \sin 60°$$

$$F_{AC} = \frac{F_{BC} \sin 60°}{\sin 45°} = 1.224\, F_{BC}$$

$$\Rightarrow \quad 1 = 0.865\,F_{BC} + 0.5\,F_{BC}$$

$$\therefore \quad F_{BC} = \frac{1}{1.365} = 0.732 \text{ kN}$$

Vertical force at B, $(R_B)_V = F_{BC}\sin 60°$

$$= 0.732 \sin 60° = 0.634 \text{ kN}$$

1.9 (b)

Method I:

Maximum force = 0.8965F

$$\therefore \text{ Max stress } \frac{0.8965F}{100} \le 100 \text{ MPa}$$

$$\therefore\ 100 \ge \frac{0.8965 \times F}{100}$$

$\therefore$ $F \le$ **11.154 kN**

Method II:

As, $F_{AC} = 0.895$ kN

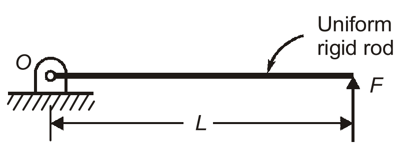
then

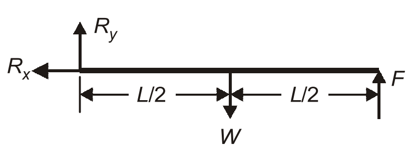
$$\frac{F \times F_{AC}}{A} = 100$$

$$\frac{F \times 0.895}{100} = 100$$

$$F = 11173.18 \text{ N} = 11.173 \text{ kN}$$

1.10 (b)





$\Sigma R_x = 0 \Rightarrow R_x = 0$

$\Sigma R_y = 0 \Rightarrow R_y + F = W$

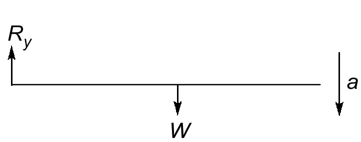
$R_y = (W - F)$ ...(i)

If force F removes, then rod will rotate about O, then

$$T_{(\text{torque})} = I\alpha$$

$$W \times \frac{L}{2} = \left(\frac{W}{g}\right)\frac{L^3}{3} \times \alpha \quad \text{...(ii)}$$

$$W - R_y = \left(\frac{W}{g}\right)a_{cg} \quad \text{...(iii)}$$



$$a_{cg} = \left(\frac{L}{2}\right)\alpha \quad \text{...(iv)}$$

Equations (ii), (iii), (iv)

$$W \times \frac{L}{2} = \left(\frac{W}{g}\right)\frac{L^2}{3} \times \frac{a_{c.m}}{\left(\frac{L}{2}\right)}$$

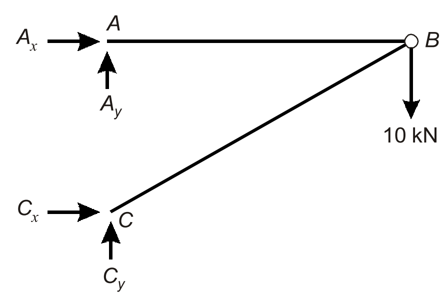
$$W \times \frac{L}{2} = \left(\frac{W}{g}\right) \times \frac{L^2}{3} \times \left(\frac{2}{L}\right) \times \frac{(W - R_y)}{\left(\frac{W}{g}\right)}$$

$$\frac{3W}{4} = W - R_y$$

$$R_y = \frac{W}{4}$$

1.11 Sol.

Method I:



$AB = 1$ m

$AC = 0.5$ m

$BC = \sqrt{1^2 + 0.5^2} = \sqrt{1.25} = 1.118$ m

$A_x + C_x = 0$

$A_y + C_y = 10$

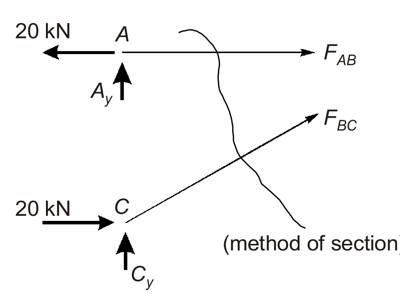
(from force equilibrium)

$\Sigma M_A = 0$

$C_x \times 0.5 = 10 \times 1$

or $C_x = 20$ kN

and $A_x = -20$ kN

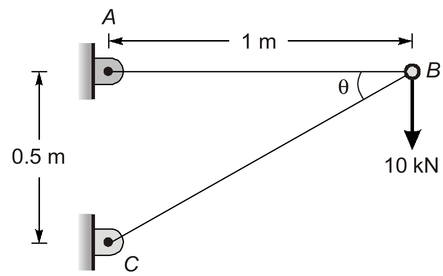


$$\Sigma M_c = 0$$

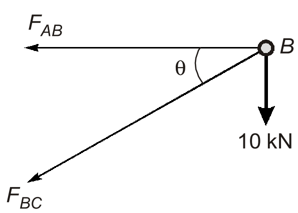
$$\Rightarrow \quad F_{AB} \times 0.5 = 20 \times 0.5$$

$$\therefore \quad F_{AB} = 20 \text{ kN}$$

<u>Method II:</u>



Free body diagram of point B,



Horizontal Reaction:

$$F_{BC} \cos\theta = -F_{AB} \quad \text{...(i)}$$

Vertical Reaction:

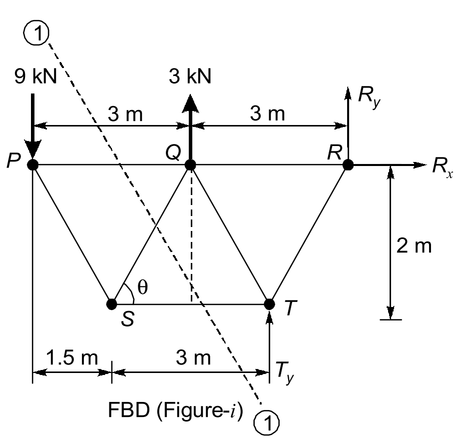
$$F_{BC} \sin\theta = -10 \quad \text{...(ii)}$$

Putting the value of F_{BC} from equation (ii) to equation (i)

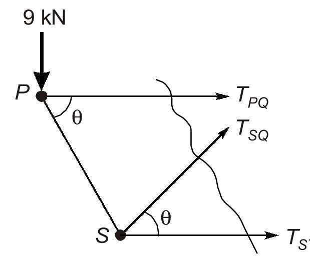
$$\frac{-10}{\sin\theta} \times \cos\theta = -F_{AB}$$

$$\therefore \quad F_{AB} = 10 \times \cot\theta = 10 \times \frac{1}{0.5} = 20 \text{ kN}$$

1.12 (a)



FBD (Figure-*i*)



Section through *PQ*,*QS*, & ST (Figure-*ii*)

$$\tan\theta = \frac{2}{1.5}$$

$$\theta = 53.13°$$

Considering L.H.S. of section (1)......(1)

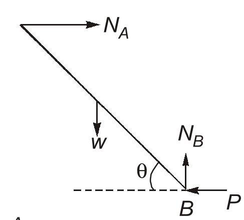
$$\Sigma F_v = 0$$

$$-9 + T_{SQ} \times \sin\theta = 0$$

$$T_{SQ} = \frac{9}{\sin 53.13°} = 11.25 \text{ kN (Tensile)}$$

1.13 Sol.

Drawing FBD of ladder AB



$$\tan\theta = \frac{3}{4}$$

$$(\Sigma F)_y = 0$$

$$\Rightarrow \quad 600 \text{ N} = N_B$$

Taking moment about A

$$-600 \times 2.5 \times \cos\theta + N_B \times 5 \times \cos\theta - P \times 5 \times \sin\theta = 0$$

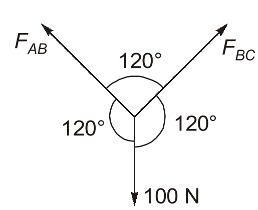
$$\Rightarrow -600 \times 2.5 \times \frac{4}{5} + 600 \times 5 \times \frac{4}{5} - P \times 5 \times \frac{3}{5} = 0$$

$$\Rightarrow P = 400 \text{ N}$$

1.14 (c)

For a joint we can write 2 equilibrium equations, so for j joints we will have $2j$ equations. If there are m members in a truss then we need to calculate m unknowns. Also we need to calculate 3 reactions for a plane truss. So for determinate truss $m + 3 = 2j$.

1.15 Sol.



$$\frac{F_{AB}}{\sin 120°} = \frac{100}{\sin 120°} \text{ or } F_{AB} = \mathbf{100\ N}$$

1.16 (a)

Using Lami's theorem,

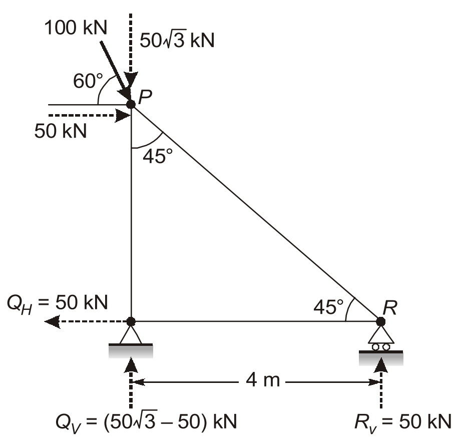
$$\frac{T_1}{\sin 120°} = \frac{500}{\sin 90°}$$

$\therefore$ $T_1 = 500 \sin 120° = 433$ N

$$\frac{T_2}{\sin(360° - (120° + 90°))} = \frac{500}{\sin 90°}$$

$\Rightarrow$ $T_2 = \mathbf{250\ N}$

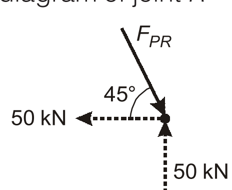
1.17 (c)



$$\Sigma M_Q = 0$$
$$R_v \times 4 - 50 \times 4 = 0$$
$$R_v = 50 \text{ kN}$$

Force in member QR = 50 kN (Tensile)

Free body diagram of joint R



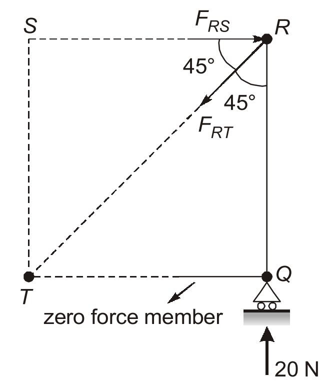
$$F_{PR} \cos 45° = 50$$

$$F_{PR} = \frac{50}{\cos 45°} = \mathbf{70.71\ kN}$$

1.18 (c)

$$R_P + R_Q = 30 \text{ kN}$$
$$\Sigma M_P = 0$$
$$30 \times 2 = R_Q \times 3$$
$$R_Q = 20 \text{ N}$$
$$R_P = 10 \text{ N}$$

Using method of section

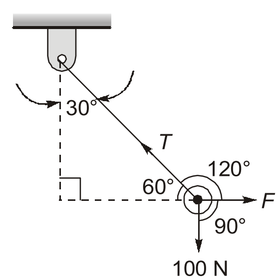


Considering moment about point T, which is zero

$$R_Q \times 1 = F_{RS} \times 1$$
$$F_{RS} = R_Q = \mathbf{20\ N\ compressive}$$

1.19 Sol.

<u>Method I:</u>



Applying Lami's theorem

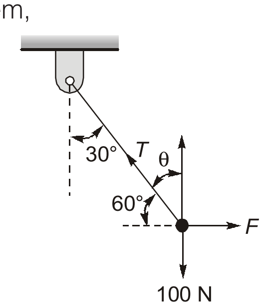
$$\frac{100}{\sin 120°} = \frac{F}{\sin(60° + 90°)} = \frac{T}{\sin 90°}$$

$$F = \frac{100 \sin 150°}{\sin 120°} = \mathbf{57.74\ N}$$

<u>Method II:</u>

This problem can be solved without applying Lami's theorem,

As,



$\therefore$ $\theta = 30°$, then

Vertical reactions,

$$T \cos 30° = 100 \text{ N}$$

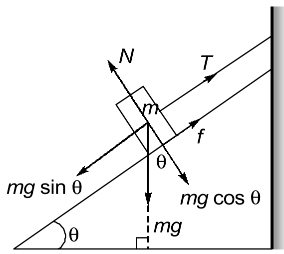
$$T = \frac{100 \times 2}{\sqrt{3}} \text{ N} = \frac{200}{\sqrt{3}}$$

Horizontal reactions,

$$F = T \cos 60° = \frac{200}{\sqrt{3}} \times \frac{1}{2} = \frac{100}{\sqrt{3}} = 57.74 \text{ N}$$

1.20 Sol.

$\mu_s = 0.25, \; T_{max} = 20 \text{ N}$



Balancing forces along the inclined plane

$\Rightarrow \quad T + f = mg \sin\theta$

$f = \mu N$

$N = mg\cos\theta$

(balancing forces perpendicular to the inclined plane)

$T + \mu mg\cos\theta = mg\sin\theta$

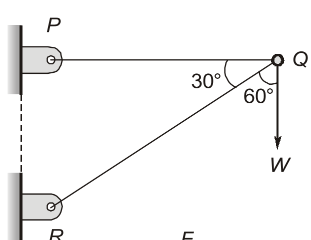
$20 + 0.25 \times mg\cos\theta = mg\sin\theta$

$20 + 0.25 \times m \times 10 \times 0.8 = m \times 10 \times 0.6$

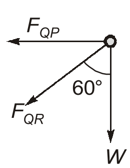
$20 = 4m$

$\therefore \quad m = 5 \text{ kg}$

1.21 (b)



At joint Q



$\Sigma F_V = 0$

$F_{QR}\cos 60° + W = 0$

$$F_{QR} = -\frac{W}{\cos 60} = -2W$$

$= 2W \text{(compressive)}$

$\Sigma F_H = 0$

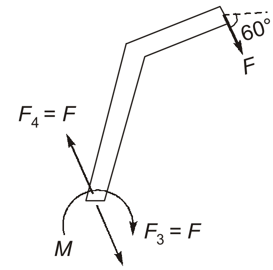
$\therefore F_{QP} + F_{QR}\cos 30° = 0$

$F_{QP} = -F_{QR}\cos 30°$

$= -(-2W)\cos 30°$

$$F_{QP} = +2W \times \frac{\sqrt{3}}{2} = +W\sqrt{3} \quad \text{(tensile)}$$

1.22 (a)



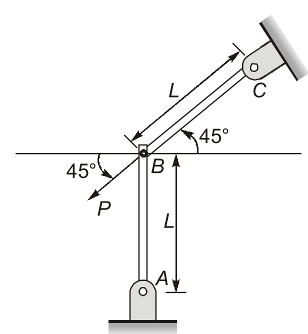
Applying equal, opposite and parallel forces at the base, F_3 and F_4.

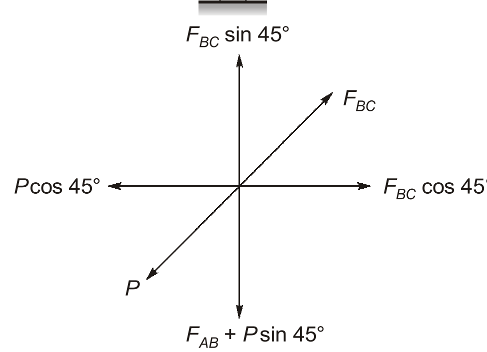
F_4 and F will form a couple at the base whose magnitude will be M and F_3 will be force which will have a horizontal and vertical components, which are displayed by R_H and R_V in the figure of option (a). Hence correct answer will be (a) and not (b) because in figure of option (b) support at the base has not been removed.

POINTS TO REMEMBER

As bar is clamped at one end i.e. acting like fixed support. So as we know in the fixed support horizontal reaction, vertical reaction and moment will act.

1.23 Sol.





At equilibrium,

$\Sigma F_V = 0 \text{ and } \Sigma F_H = 0$

$F_{BC}\sin 45° = F_{AB} + P\sin 45° \quad \text{...(i)}$

$$F_{BC}\cos 45° = P\cos 45° \quad ...(ii)$$

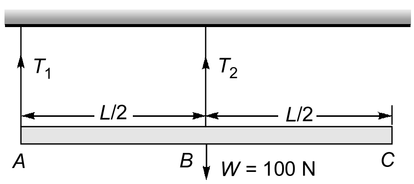
$$\therefore \quad F_{BC} = P$$

$$P\sin 45° = F_{AB} + P\sin 45°$$

$$\therefore \quad F_{AB} = 0$$

$$\sigma_{AB} = 0$$

1.24 (b)



Considering equilibrium of bar,

$$\Sigma\vec{F} = 0$$

$$T_1 + T_2 = 100\text{ N} \quad ...(i)$$

and $\Sigma M_A = 0$

$$T_2 \cdot \frac{L}{2} = 100 \times \frac{L}{2}$$

$$\therefore \quad T_2 = 100\text{ N}$$

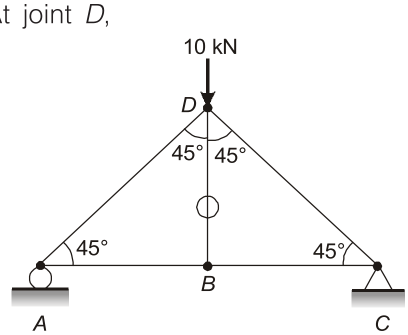
$$T_1 = 0\text{ N}$$

1.25 (5)

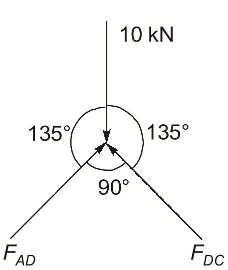
By symmetry, force in member *AB* and *CD* will be same

By symmetry, $R_A = R_C = 5$ kN

At joint *D*,

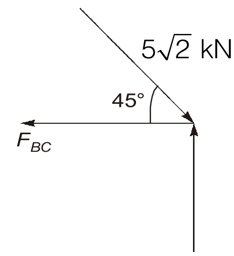


Joint *D*,



$$\frac{F_{AD}}{\sin 135°} = \frac{10}{1} = \frac{F_{DC}}{\sin 135°}$$

$$F_{DC} = 10\sin 135° = 5\sqrt{2}\text{ kN (Compressive)}$$

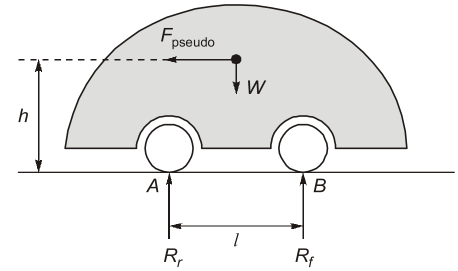


Joint *C*,

$$5\sqrt{2}\cos 45° = F_{BC}$$

$$F_{BC} = 5\text{ kN (Tensile)}$$

1.26 (d)



Pseudo force, $F_{\text{pseudo}} = ma$ in opposite direction of motion of car.

$$\Sigma F_V = 0$$

$$R_r + R_f = W \quad ...(1)$$

Taking moment about *A*

$$(F_{\text{pseudo}})h + (R_f)l = \frac{Wl}{2}$$

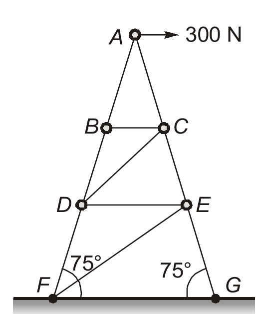
$$m_a h + R_f l = \frac{Wl}{2}$$

$$R_f = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a \quad ...(2)$$

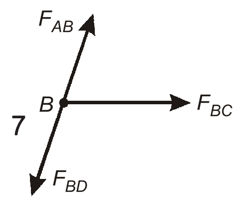
From (1) and (2)

$$R_r = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a$$

1.27 (0)

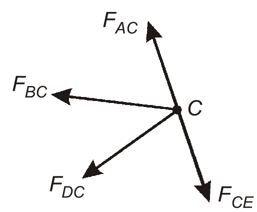


Considering joint B,



$\Rightarrow F_{BC} = 0$ (for equilibrium)

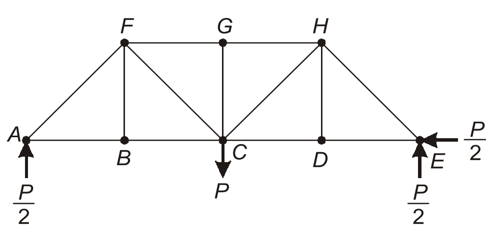
Now considering joint C,



For equilibrium, $F_{DC} = 0$

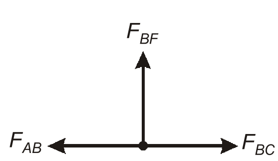
(As $F_{BC} = 0$)

1.28 (b)



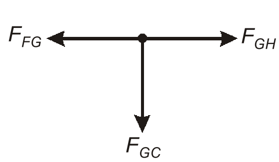
For equilibrium, vertical component of reaction at E is equal to $\frac{P}{2}$. Since the angle make by reaction at E is 45°, so both R_{HE} and R_{VE} are equal.

At joint B,



For equilibrium, $F_{BF} = 0$

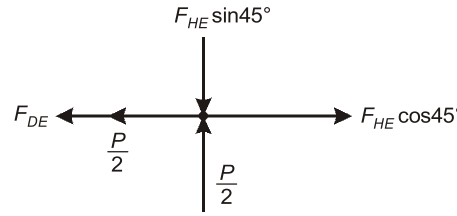
At joint G



For equilibrium, $F_{GC} = 0$

Similarly, $F_{DH} = 0$

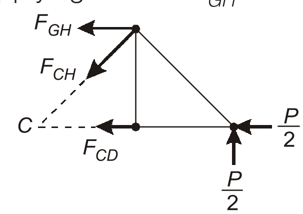
At joint E,



For equilibrium, $F_{DE} = 0$

$\therefore F_{CD} = 0$

Now, applying MOS for F_{GH}



Taking moment about C,

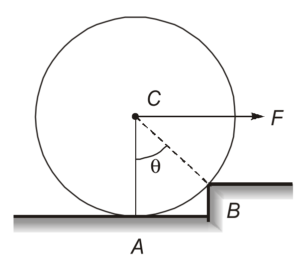
$$F_{GH} \times 1 + \frac{P}{2} \times 2 = 0$$

$$F_{GH} = -P$$

$$\therefore \quad F_{GH} \neq 0$$

$$F_{GF} \neq 0$$

1.29 (b)



Weigh = W

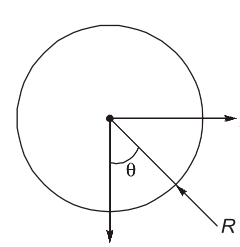
Note:

(i) When the cylinder is about to make out of the curb, it will loose its contact at point A, only contact will be at it B.

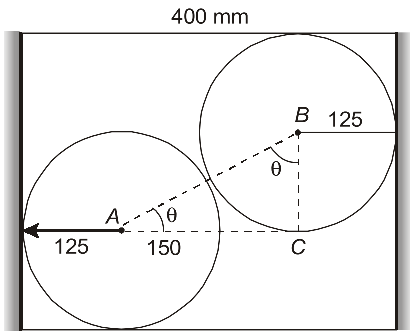
(ii) At verge of moving out of curb, Roller will be in equation under W, F and contact force from B and these three forces has to be concurrent so contact force from B will pass through C.

(iii) Even the surfaces are rough but there will be no friction at B for the said condition.

FBD



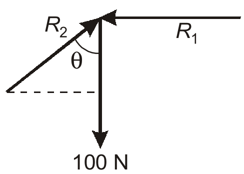
1.30 Sol.



$$BC = 250^2 - 150^2$$

$$\cos\theta = \frac{200}{250}$$

$$\theta = 36.869°$$



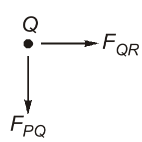
$$R_2 \cos\theta = 100$$

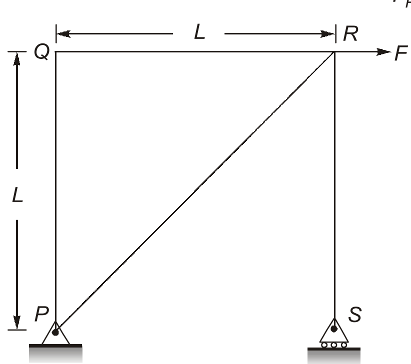
$$R_2 = \frac{100 \times 250}{200} = 125 \text{ N}$$

1.31 (b)

Consider joint Q,

$\Rightarrow \quad F_{QR} = 0$



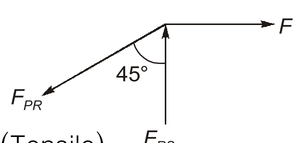


Joint R,

$\Sigma F_H = 0$

$\Rightarrow \quad F_{PR} \sin 45° = F$

$$F_{PR} = \sqrt{2}F \text{(Tensile)}$$



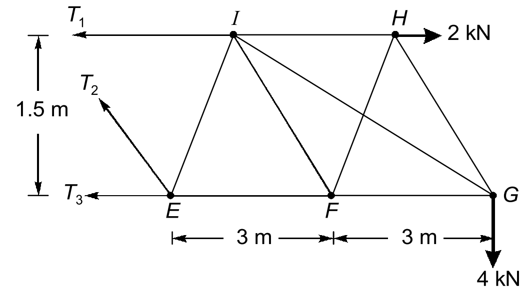
$\Rightarrow \quad F_{PR} \cos 45° = F_{RS}$

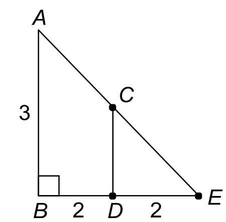
$\Sigma F_V = 0$

$$F_{RS} = \sqrt{2}F \times \frac{1}{\sqrt{2}}$$

$\Rightarrow \quad F_{RS} = F \text{(Comp.)}$

1.33 (18) (18 to 18)





$$\frac{CD}{DE} = \frac{AB}{BE}$$

$$\Rightarrow \quad CD = \frac{2 \times 3}{4} = 1.5 \text{ m}$$

$\Sigma M_E = 0$

$\Rightarrow \quad 2 \times 1.5 - T_1 \times 1.5 + 4 \times 6 = 0$

$$T_1 = \frac{24+3}{1.5} = \frac{27}{1.5} = 18 \text{ kN}$$

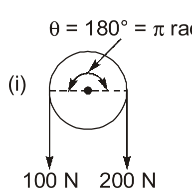
Hence, magnitude of force carried by member CI is 18 kN.

1.34 (3) (3 to 3)

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

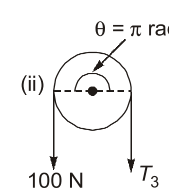
$$\frac{200}{100} = e^{\mu\theta}$$

$$\Rightarrow \quad \mu = 0.22$$



Now, $\quad \dfrac{200}{T_3} = e^{0.22\pi}$

$$\Rightarrow \quad T_3 = \frac{100}{2} = 50 \text{ N}$$

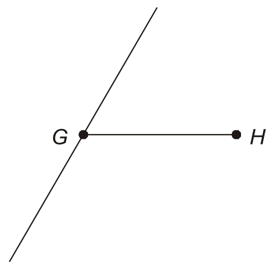


So, for a force of 50 N, number of discs required

$$= \frac{50}{20} = 2.5$$

So, minimum number of discs required are 3.

1.35 (b, d)



If at a joint 3 members are meeting and two are collinear then in 3rd member force will be zero.

$F_{GH} = 0$

1.37 (d)

For the body to be in equilibrium, the three forces can be coplanar, parallel or concurrent.

1.38 (a, b)

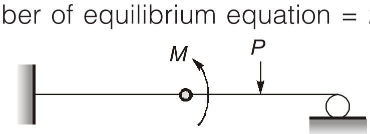
Statically indeterminate structures are those structures that cannot be analyzed using statics or equations of equilibrium. In such cases, the number unknowns exceed the number of equilibrium equations available.

Checking each option:

For option (a),

Number of unknown = 3

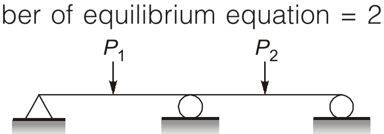
Number of equilibrium equation = 2



For option (b),

Number of unknown = 3

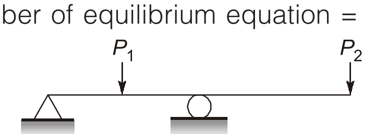
Number of equilibrium equation = 2



For option (c),

Number of unknown = 2

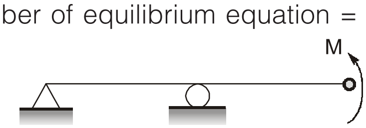
Number of equilibrium equation = 2



For option (d),

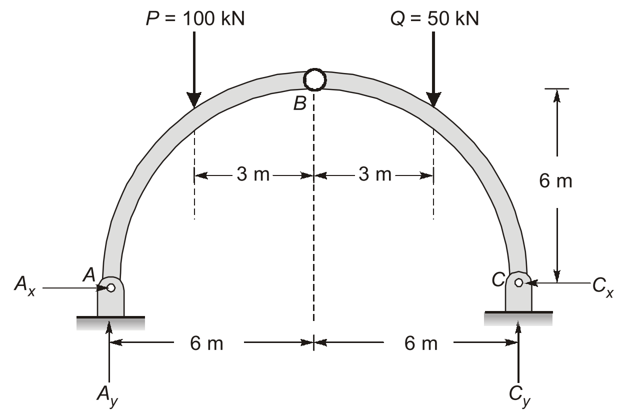
Number of unknown = 2

Number of equilibrium equation = 2



So, (a) and (b) are statically indeterminate structure.

1.39 (37.5) (37.0 to 38.0)



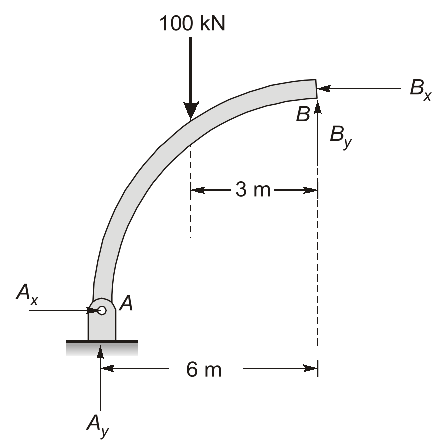
Initially, taking moment about hinged point C,

$\Sigma M_C = 0$

$A_y \times 12 - 100 \times 9 - 50 \times 3 = 0$

$\Rightarrow \quad A_y = 87.5$ kN

FBD for left half section:



Now taking moment about point B.

$\Sigma M_B = 0$

$A_x \times 6 - 87.5 \times 6 + 100 \times 3 = 0$

$\Rightarrow \quad A_x = 37.5$ kN

$\Sigma F_x = 0$

$A_x - B_x = 0$

$\Rightarrow \quad B_x = A_x = 37.5$ kN

■■■■