Forces in Light Rods and Joints

1 A light rod AB is in equilibrium under the action of forces at its ends A and B only. The force acting on the rod at B has magnitude 45 N and is directed along the rod away from A.
State the magnitude and direction of the force acting on the rod at A, and state whether the rod is in tension or thrust. **[3]**

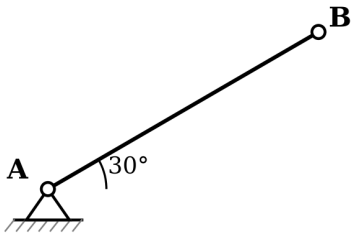
2 A light rod XY is in equilibrium. The rod exerts a force of magnitude 36 N on the pin at X, and this force is directed towards Y.
State the force that the rod exerts on the pin at Y, and state whether the rod is in tension or thrust. **[2]**

3 A particle of weight 60 N is attached at B to the lower end of a light vertical rod AB. The upper end A of the rod is fixed, as shown.
Find the force in the rod AB, stating whether it is a tension or a thrust.



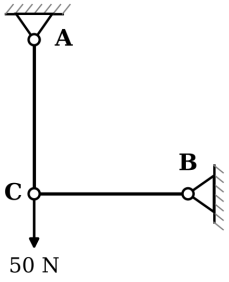
[2]

4 A light rod AB is inclined at 30° to the horizontal, with B above and to the right of A, as shown. The rod is in thrust, and the magnitude of the thrust is 80 N.
Find the horizontal and vertical components of the force that the rod exerts on the pin at B.



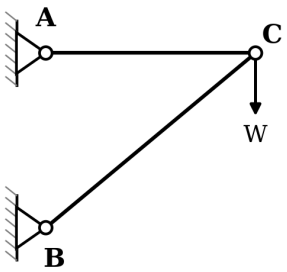
[3]

5 Two light rods, AC (vertical) and BC (horizontal), are freely jointed at C. The other ends A and B are fixed. A load of 50 N is attached at C, as shown.
Find the force in each rod, stating whether it is a tension or a thrust where appropriate.



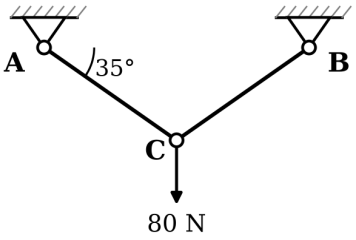
[3]

6 A light framework consists of rods AC and BC, freely jointed at C. The ends A and B are hinged to a vertical wall, with AC horizontal, and a weight W is hung from C, as shown.
State which rod is a tie and which is a strut, giving a reason for each.



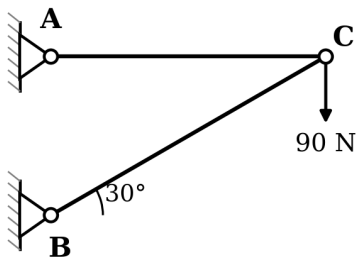
[3]

7 A load of 80 N is hung from the joint C of two light rods AC and BC. The ends A and B are fixed at the same level and each rod makes an angle of 35° with the horizontal, as shown.
Find the force in each rod, stating whether it is in tension or thrust.



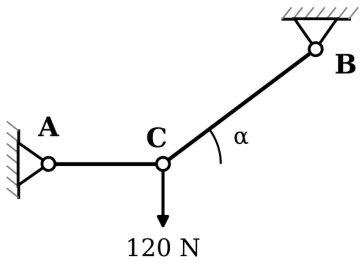
[5]

8 Light rods AC and BC are freely jointed at C. The rod AC is horizontal and the rod BC is inclined at 30° to the horizontal. A and B are hinged to a vertical wall and a load of 90 N hangs from C, as shown.
Find the force in each rod, stating whether each is in tension or thrust.



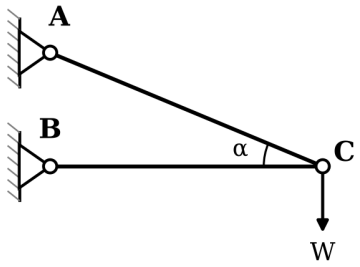
[5]

9 A load of 120 N is hung from the joint C of two light rods AC and BC. The rod AC is horizontal and the rod BC makes an angle α with the horizontal, where $\tan\alpha = \frac{3}{4}$, as shown.
Find the force in each rod, stating whether it is in tension or thrust.



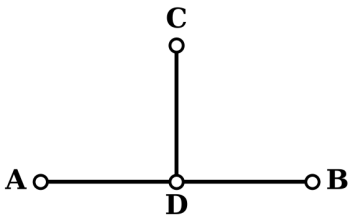
[5]

10 A weight W is hung from the joint C of two light rods. The rod BC is horizontal and the rod AC makes an angle α with the horizontal, where $\tan\alpha = \frac{5}{12}$. The rods are hinged to a vertical wall at A and B, as shown. The force in BC is a thrust of 60 N.
Find the force in AC and the value of W.



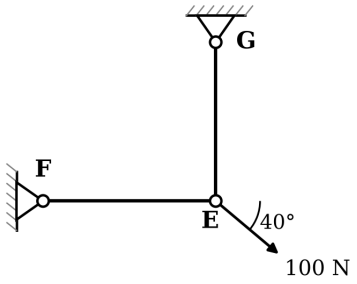
[4]

11 Part of a framework is shown. Three light rods AD, DB and DC meet at the joint D, where AD and DB are in a straight line and DC is perpendicular to them. No external force acts at D.
The force in AD is a tension of 40 N.
Find the force in DB and the force in DC.



[3]

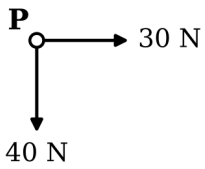
12 Two light rods EF (horizontal) and EG (vertical) are freely jointed at E. A force of magnitude 100 N acts at E, directed at 40° below the horizontal away from F, as shown. The system is in equilibrium.
Find the force in each rod, stating whether it is in tension or thrust.



[5]

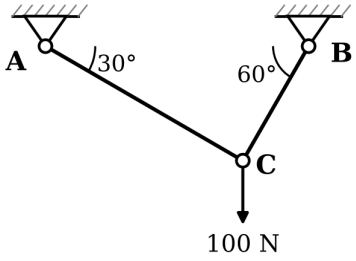
13 In an analysis of a framework a student defines the force in the rod BC to be a tension of T N. After resolving at joint B the student finds $T = -40$.
State the magnitude of the force in BC and whether the rod is in tension or thrust. Explain your answer. **[4]**

14 A light rod PQ is freely jointed at P to a string, and the end Q of the rod is fixed. The forces acting on the pin at P, other than the force from the rod, are a horizontal pull of 30 N from the string and a weight of 40 N, as shown. The system is in equilibrium and the rod lies in the vertical plane of the forces.
Find the magnitude of the force in PQ, state whether it is a tension or a thrust, and find the angle that PQ makes with the horizontal.



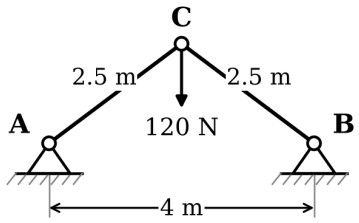
[6]

15 A load of 100 N is hung from the joint C of two light rods AC and BC. The rods are inclined at 30° and 60° to the horizontal, as shown, and the ends A and B are fixed at the same level.
Find the force in each rod, stating whether it is in tension or thrust.



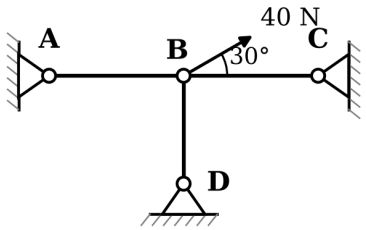
[6]

16 A load of 120 N is supported at C by two light rods AC and BC, each of length 2.5 m. The ends A and B rest on a horizontal surface with AB = 4 m, as shown.
Find the force in each rod, stating whether it is in tension or thrust.



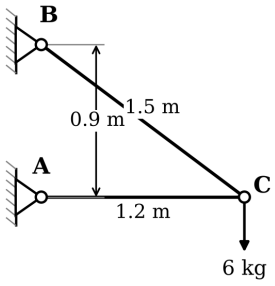
[6]

17 Three light rods AB, BC and BD are freely jointed at B. The rods AB and BC are horizontal and BD is vertical, with D below B. A force of 40 N acts at B at 30° above the horizontal, directed away from A, as shown. The force in AB is a tension of 50 N and the system is in equilibrium.
Find the force in BC and the force in BD, stating whether each is a tension or a thrust.



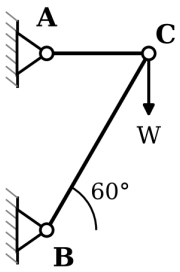
[6]

18 A lamp of mass 6 kg hangs from the end C of a light horizontal rod AC of length 1.2 m. The rod AC is smoothly hinged at A to a vertical wall and is held by a light rod BC of length 1.5 m, where B is on the wall 0.9 m vertically above A, as shown. Take $g = 9.8$ m s^{-2}.
Find the force in each rod, stating whether it is in tension or thrust.



[6]

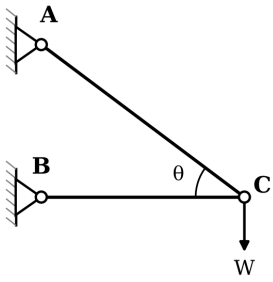
19 Light rods AC and BC are freely jointed at C. AC is horizontal and BC is inclined at 60° to the horizontal. The ends A and B are hinged to a vertical wall and a weight W hangs from C, as shown.



(a) Show that the force in BC is a thrust of magnitude $\frac{2W}{\sqrt{3}}$. **[3]**

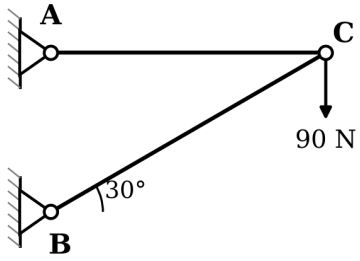
(b) Find, in terms of W, the force in AC. **[2]**

20 A weight W is hung from the joint C of two light rods AC and BC. The rod BC is horizontal and the rod AC makes an angle θ with the horizontal. Both rods are hinged to a vertical wall, as shown. The force in AC is a tension of magnitude 3W.
Find θ and find, in terms of W, the force in BC.



[5]

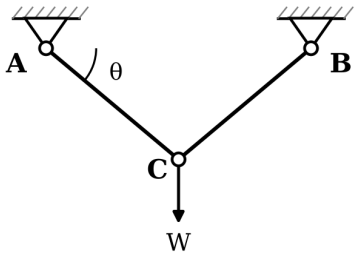
21 A light horizontal rod AC and a light rod BC inclined at 30° to the horizontal are freely jointed at C and hinged to a vertical wall at A and B, as shown. A load of 90 N hangs from C. A student's solution to find the forces is:
"Let the force in BC be P. Resolving vertically: P cos 30° = 90, so P = 103.9 N. Resolving horizontally: T = P sin 30° = 52.0 N."



(a) Identify the error in the student's working. **[2]**

(b) Find the correct forces in the two rods, stating whether each is in tension or thrust. **[6]**

22 A weight W hangs from the joint C of two identical light rods AC and BC. The ends A and B are fixed at the same level and each rod makes an angle θ with the horizontal, as shown.



(a) Show that the tension in each rod is $\frac{W}{(2 \sin \theta)}$. **[4]**

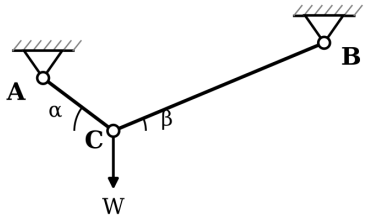
(b) Find the value of θ for which the tension in each rod equals W. **[2]**

(c) Explain why, however large the tension the rods can bear, it is impossible for the rods to be exactly horizontal when supporting W. **[2]**

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23 A weight W is hung from the joint C of two light rods AC and BC. The rod AC makes an angle α with the horizontal, where $\tan \alpha = \frac{3}{4}$, and the rod BC makes an angle β with the horizontal, where $\tan \beta = \frac{5}{12}$. A and B are fixed points above C, as shown.

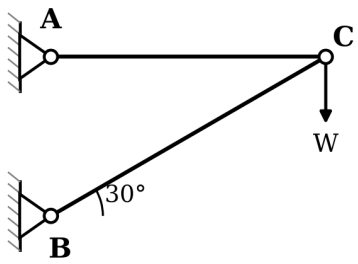
Find, in terms of W, the force in each rod.



[8]

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24 A load of weight W hangs from the joint C of two light rods, AC horizontal and BC inclined at 30° to the horizontal, hinged to a vertical wall at A and B, as shown. The rod AC will break if the tension in it exceeds 1200 N. The rod BC will buckle if the thrust in it exceeds 800 N. Find the greatest value of W for which neither rod fails.

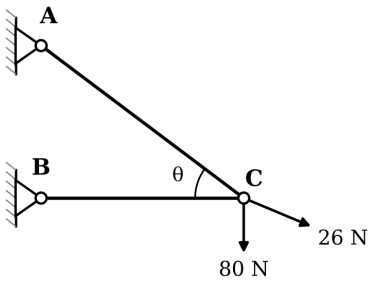


[7]

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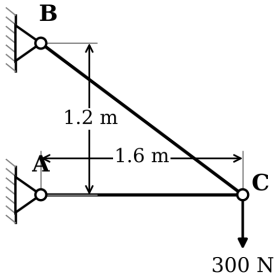
25 The rod BC is horizontal and the rod AC makes an angle θ with the horizontal, where $\tan\theta = \frac{3}{4}$. The light rods are freely jointed at C and hinged to a vertical wall at A and B. A load of 80 N hangs from C and a second force of 26 N acts at C, directed away from the wall and downwards at an angle φ below the horizontal, where $\tan\varphi = \frac{5}{12}$, as shown.

Find the force in each rod, stating whether it is a tension or a thrust.



[8]

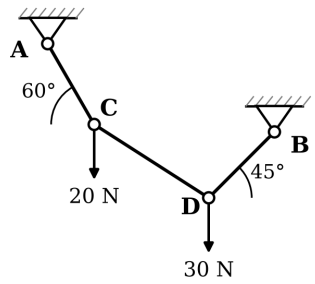
26 A sign of weight 300 N hangs from C. It is supported by a light horizontal rod AC of length 1.6 m and a light rod BC, where A and B are on a vertical wall with B 1.2 m above A, as shown. The rods are pin-jointed at C and hinged to the wall.



(a) Explain why the force in a light rod with a smooth pin joint at each end acts along the rod. **[2]**

(b) Find the force in BC and the force in AC, stating tension or thrust. **[5]**

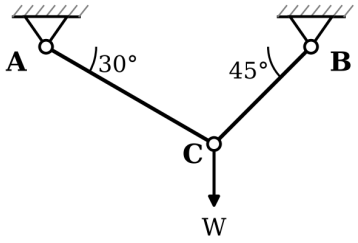
27 Three light rods AC, CD and DB are freely jointed at C and D, and the ends A and B are fixed. Weights of 20 N and 30 N hang from C and D respectively. The rod AC makes an angle of 60° with the horizontal at C and the rod DB makes an angle of 45° with the horizontal at D, as shown, with A and B above the level of C and D. The system is in equilibrium.



(a) Consider the whole system of rods as a single body subject to the two weights and the forces from AC and DB. Find the tension in AC and the tension in DB. **[6]**

(b) Find the force in CD, stating whether it is a tension or a thrust, and find the angle that CD makes with the horizontal, stating whether D is above or below C. **[6]**

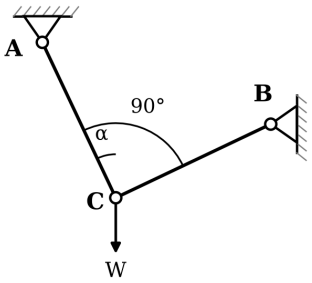
28 A weight W hangs from the joint C of two light rods AC and BC. The rods are inclined at 30° and 45° to the horizontal, as shown, and A and B are fixed at the same level.



(a) Show that the tension in AC is $(\sqrt{3} - 1)$W. **[6]**

(b) Find the tension in BC in the form kW, giving k in exact form. **[3]**

29 A weight W hangs from the joint C of two light rods CA and CB with angle ACB = 90°. The rod CA makes an angle α with the upward vertical and A and B are fixed, as shown. The system is in equilibrium.

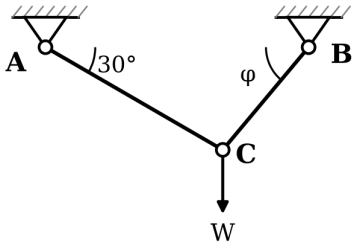


(a) By resolving in suitable directions, show that the tension in CA is W cos α and find the tension in CB in terms of W and α. **[5]**

(b) Given that the tension in CA is twice the tension in CB, find α and find, in terms of W, the tension in each rod. **[5]**

(c) Explain why the sum of the two tensions exceeds W. **[2]**

30 A weight W hangs from the joint C of two light rods AC and BC. The rod AC is inclined at 30° to the horizontal. The point B can be placed so that the rod BC makes any chosen angle φ with the horizontal, where $0 < \varphi < 90°$, with A and B above C on opposite sides of C, as shown. The system is in equilibrium.

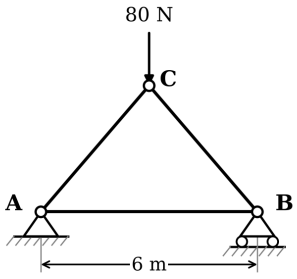


(a) Show that the tension in BC is $\dfrac{W \cos 30°}{\sin(\varphi + 30°)}$. **[6]**

(b) Find the value of φ for which the tension in BC is as small as possible, and find this least tension. **[4]**

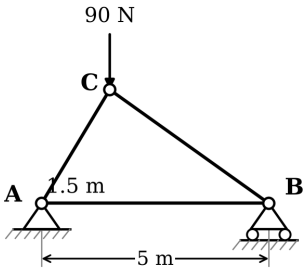
Frameworks and Support Reactions

1 A light framework ABC is in the form of a triangle with AB = 6 m, with C vertically above the midpoint of AB. The framework is smoothly hinged to a fixed support at A and rests on a smooth horizontal surface at B. A load of 80 N is attached at C, as shown.
Find the vertical reaction at each support.



[3]

2 A light triangular framework ABC rests with a pin at A and a roller at B on a horizontal surface, where AB = 5 m. The joint C is vertically above a point 1.5 m from A. A load of 90 N hangs from C, as shown.
Find the reactions at A and B.

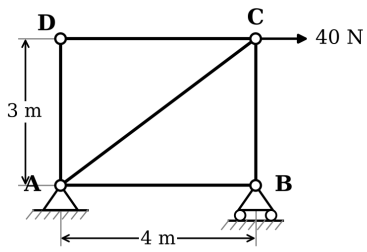


[3]

3 A light framework is smoothly hinged to a fixed support at A and rests on a smooth horizontal surface at B.
(a) State the direction of the reaction at B. **[1]**
(b) State the number of unknown components of reaction at A, and say how many independent equations of equilibrium are available for the whole framework in a plane. **[2]**

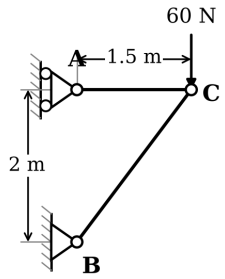
4 The horizontal and vertical components of the reaction at a hinge are 24 N and 7 N respectively. The horizontal component acts to the right and the vertical component acts upwards.
Find the magnitude of the reaction and its angle with the horizontal. **[3]**

5 A light rectangular framework ABCD with a diagonal AC is hinged to a fixed support at A and rests on a smooth horizontal surface at B, where AB = 4 m and BC = 3 m. A horizontal force of 40 N acts at C, as shown.
Find the vertical reaction at B.



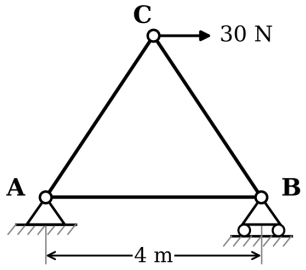
[3]

6 A light framework ABC is attached to a vertical wall at A and B, where B is 2 m vertically below A. The joint at A is attached to the wall so that the reaction at A is horizontal, and the framework is hinged at B. A load of 60 N hangs from C, which is 1.5 m horizontally from A and level with A, as shown.
Find the magnitude of the horizontal reaction at A.



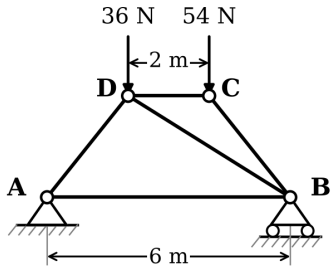
[3]

7 A light triangular framework ABC has AB = 4 m, with C at a height of 3 m above the midpoint of AB. It is hinged to a fixed support at A and rests on a smooth horizontal surface at B. A horizontal force of 30 N acts at C, as shown.
Find the reaction at B and the magnitude and direction of the reaction at A.



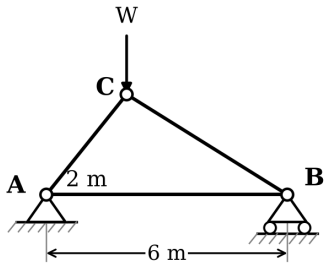
[5]

8 A light framework ABCD has AB = 6 m and DC = 2 m, with DC parallel to AB. D is vertically above a point 2 m from A and C is vertically above a point 2 m from B. The framework is hinged at A and rests on a smooth horizontal surface at B. Loads of 36 N at D and 54 N at C are attached, as shown.
Find the vertical reaction at each support.



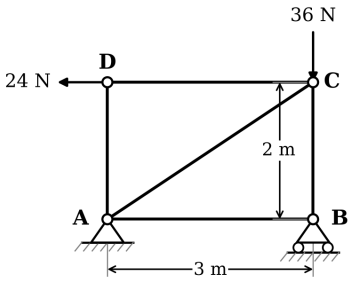
[5]

9 A light triangular framework ABC rests in a vertical plane with a hinge at A and a roller at B on a horizontal surface, where AB = 6 m. The joint C is vertically above a point 2 m from A, and a load of W newtons hangs from C. The reaction at B has magnitude 45 N.
Find the value of W and the vertical reaction at A.



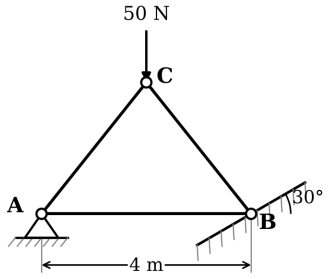
[5]

10 A light rectangular framework ABCD with a diagonal AC is hinged to a fixed support at A and rests on a smooth horizontal surface at B, where AB = 3 m and BC = 2 m. A load of 36 N acts vertically downwards at C and a horizontal force of 24 N acts at D, directed away from C, as shown.
Find the magnitude and direction of the reaction at A.



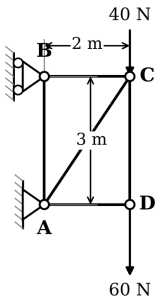
[5]

11 A light triangular framework ABC with AB = 4 m (horizontal) is hinged at A and rests with B on a smooth plane inclined at 30° to the horizontal. C is vertically above the midpoint of AB and a load of 50 N hangs from C, as shown.
Find the magnitude of the reaction at B and the vertical component of the reaction at A.



[5]

12 A light rectangular framework ABCD with a diagonal AC is attached to a vertical wall at A and B, where B is 3 m above A and BC = 2 m. The framework is hinged at A, and at B the connection to the wall allows only a horizontal reaction. Loads of 40 N and 60 N hang from C and D respectively, as shown.
Find the reaction at B and the magnitude and direction of the reaction at A.



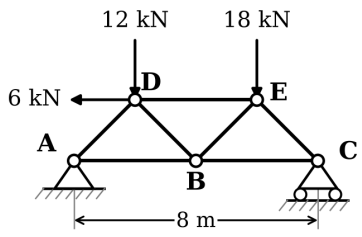
[5]

13 A plane framework is made of light rods smoothly pin-jointed together. A simple rigid (minimally rigid) framework with j joints needs exactly $2j - 3$ rods.

(a) A framework has 7 joints and 11 rods. Show that it is a simple rigid framework. **[2]**

(b) A different framework has 6 joints and 8 rods. Explain whether it is rigid. **[2]**

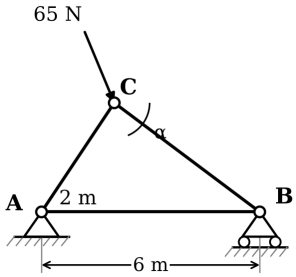
14 A light bridge framework ABCDE is hinged at A and rests on a roller at C on a smooth horizontal surface. The joints A, B and C are in a horizontal line with AB = BC = 4 m, and D and E are 2 m above AB and BC, vertically above the midpoints of AB and BC respectively. Loads of 12 kN and 18 kN act vertically downwards at D and E, and a horizontal force of 6 kN acts at D, directed away from E, as shown.
Find the reaction at C and the magnitude and direction of the reaction at A.



[6]

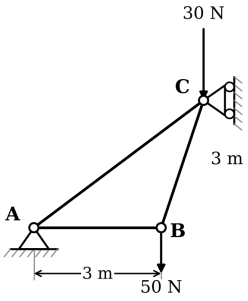
15 A light triangular framework ABC is hinged at A and rests on a roller at B on a smooth horizontal surface, where AB = 6 m. The joint C is 3 m above AB and vertically above a point 2 m from A. A force of 65 N acts at C, directed downwards and to the right at an angle α below the horizontal, where $\tan\alpha = \frac{12}{5}$, as shown.

Find the reaction at B and the magnitude and direction of the reaction at A.



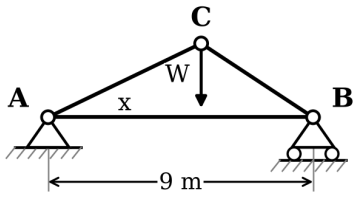
[7]

16 A light triangular framework ABC lies in a vertical plane. It is hinged to the ground at A and the joint C rests against a smooth vertical wall. The joint B is on the horizontal ground level with A, with AB = 3 m, and C is 3 m above the level of AB and 4 m horizontally from A. Loads of 50 N and 30 N act vertically downwards at B and C respectively, as shown.
Find the reaction at C and the magnitude and direction of the reaction at A.



[7]

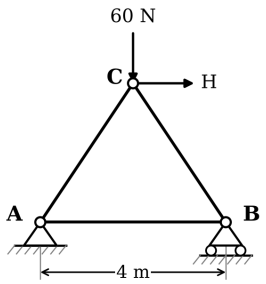
17 A light triangular framework ABC, with AB = 9 m, rests in a vertical plane with a hinge at A and a roller at B on a smooth horizontal surface. A load of W newtons hangs from C, which is vertically above a point at a distance x metres from A, as shown (not drawn to scale).



(a) Find, in terms of W and x, the reactions at A and B. **[4]**

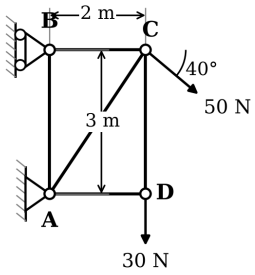
(b) Find the value of x for which the reaction at A is $\frac{5}{4}$ of the reaction at B. **[2]**

18 A light triangular framework ABC is hinged at A and rests on a roller at B on a smooth horizontal surface, where AB = 4 m. The joint C is 3 m above the midpoint of AB. A vertical load of 60 N and a horizontal force of H newtons both act at C, as shown. The reaction at A acts at 45° to the horizontal and has an upward vertical component.
Find the value of H.



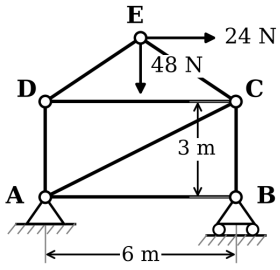
[6]

19 A light rectangular framework ABCD with a diagonal AC is attached to a vertical wall at A and B, where AB = 3 m and BC = 2 m. The framework is hinged at A, and at B the connection allows only a horizontal reaction. A force of 50 N acts at C, directed away from the wall at 40° below the horizontal, and a load of 30 N hangs from D, as shown.
Find the reaction at B, stating its direction, and the magnitude of the reaction at A.



[6]

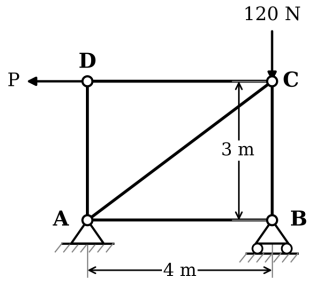
20 A light framework ABCDE has ABCD as a rectangle with AB = 6 m and BC = 3 m, and E is 2 m above the midpoint of DC. There are seven rods: AB, BC, CD, DA, DE, EC and AC. It is hinged at A and rests on a roller at B on a smooth horizontal surface. A vertical load of 48 N and a horizontal force of 24 N act at E, as shown.



(a) Show that the framework is a simple rigid framework. **[2]**

(b) Find the reaction at B and the magnitude and direction of the reaction at A. **[5]**

21 A light rectangular framework ABCD with a diagonal AC is hinged at A and rests on a roller at B on a smooth horizontal surface, where AB = 4 m and BC = 3 m. A load of 120 N acts vertically downwards at C and a horizontal force of P newtons acts at D, directed away from C, as shown.

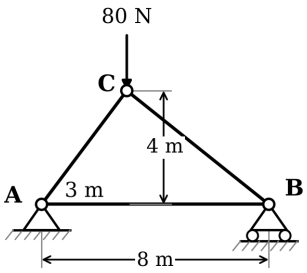


(a) Show that the reaction at B is $(120 - \frac{3P}{4})$ N. **[3]**

(b) Find the greatest value of P for which the framework remains in contact with the surface at B. **[2]**

(c) Given that P = 100, find the magnitude and direction of the reaction at A. **[4]**

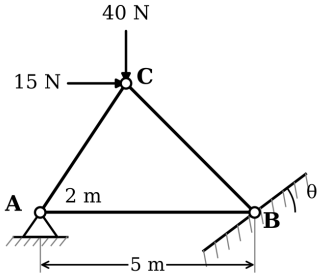
22 A light triangular framework ABC is hinged at A and rests on a roller at B on a smooth horizontal surface, where AB = 8 m. The joint C is 4 m above AB and vertically above a point 3 m from A. A load of 80 N hangs from C, as shown. A student writes: "Moments about A: $8R_B = 80 \times 4$, so $R_B = 40$ N and $R_A = 40$ N."



(a) Identify the error in the student's working. **[2]**

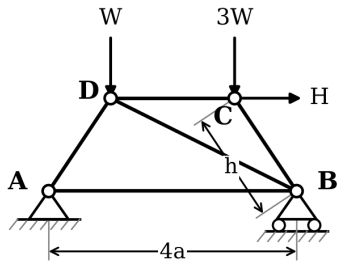
(b) Find the correct reactions at A and B. **[4]**

23 A light triangular framework ABC with AB = 5 m (horizontal) is hinged at A and rests with B against a smooth plane inclined at an angle θ to the horizontal, where $\tan\theta = \frac{3}{4}$. The joint C is 3 m above AB and vertically above a point 2 m from A. A vertical load of 40 N and a horizontal force of 15 N, directed away from A, both act at C, as shown.
Find the magnitude of the reaction at B and the magnitude and direction of the reaction at A.



[9]

24 A light framework ABCD has AB = 4a, with DC parallel to AB at a height h above it. D is vertically above a point at distance a from A and C is vertically above a point at distance a from B. The framework is hinged at A and rests on a roller at B on a smooth horizontal surface. A load of W acts vertically downwards at D, a load of 3W acts vertically downwards at C and a horizontal force H acts at C, directed away from D, as shown.

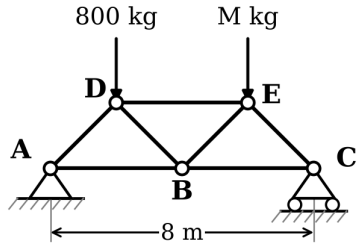


(a) Show that the reaction at B is $\frac{5W}{2} + \frac{Hh}{(4a)}$ and find the vertical component of the reaction at A. **[6]**

(b) Given that $h = \frac{3a}{2}$, find H in terms of W for which the vertical reaction at A is zero, and write down the horizontal reaction at A in this case. **[3]**

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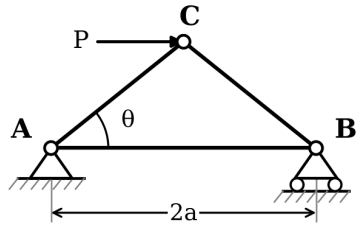
25 A light bridge framework ABCDE has A, B, C in a horizontal line with AB = BC = 4 m, and D and E are 2 m above AB and BC respectively, vertically above their midpoints. It is hinged at A and rests on a roller at C on a smooth horizontal surface. Loads are carried at D and E of masses 800 kg and M kg respectively, as shown. The roller at C can safely bear a reaction of at most 12 kN. Take $g = 9.8$ m s^{-2}.
Find the greatest possible value of M.



[7]

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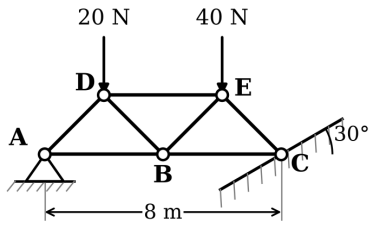
26 A light triangular framework ABC is isosceles with AB = 2a and AC = BC, and angle CAB = θ. It is hinged at A and rests on a roller at B on a smooth horizontal surface. A horizontal force of magnitude P acts at C, pointing away from B, as shown.



(a) Show that the magnitude of the reaction at A is $P\sqrt{1 + \frac{1}{4}\tan^2\theta}$. **[5]**

(b) Given that the magnitude of the reaction at A is $\frac{5P}{4}$, find θ. **[3]**

27 A light bridge framework ABCDE has A, B, C in a horizontal line with AB = BC = 4 m, and D and E are 2 m above AB and BC respectively, vertically above their midpoints. It is hinged at A and the joint C rests on a smooth plane inclined at 30° to the horizontal, as shown. Loads of 20 N and 40 N act vertically downwards at D and E respectively.



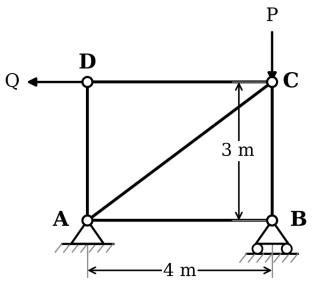
(a) Find the magnitude of the reaction at C. **[5]**

(b) Find the magnitude and direction of the reaction at A. **[5]**

(c) The plane is now replaced by a smooth plane inclined at 30° to the horizontal in the opposite sense (falling to the right). State, with a reason, how the magnitudes of the reactions at C and at A change. **[2]**

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28 A light rectangular framework ABCD with a diagonal AC is hinged at A and rests on a roller at B on a smooth horizontal surface, where AB = 4 m and BC = 3 m. A load of P newtons acts vertically downwards at C and a horizontal force of Q newtons acts at D, directed away from C, as shown. The reaction at B is 60 N and the reaction at A has magnitude 75 N.

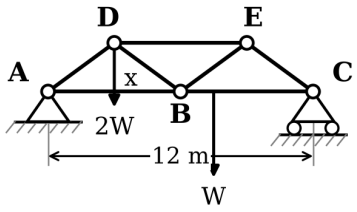


(a) Show that $4P - 3Q = 240$, and write down the components of the reaction at A in terms of P and Q. **[5]**

(b) Find P and Q. **[6]**

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29 A light bridge framework has joints A, B and C in a horizontal line with AB = BC = 6 m. A load of 2W acts vertically downwards at the joint D, which is 3 m horizontally from A. A trolley of weight W can be placed at any point of the horizontal rod AC, at a distance x metres from A, where $0 \leq x \leq 12$, as shown (not drawn to scale). The framework is hinged at A and rests on a roller at C on a smooth horizontal surface. Take the weight of the framework itself to be negligible.



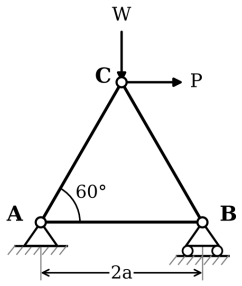
(a) Find, in terms of W and x, the reactions at C and at A. **[5]**

(b) The reaction at C must not exceed 1.1W and the reaction at A must not exceed 2.1W. Find the range of possible values of x. **[5]**

(c) The trolley is fixed at x = 6 and its weight is changed to W'. Find the greatest value of W' (in terms of W) for which the reaction at C does not exceed 1.1W. **[2]**

---

30 A light framework ABC is an equilateral triangle of side 2a. It is hinged at A and rests on a roller at B on a smooth horizontal surface, with AB horizontal and C above AB. A vertical load of weight W and a horizontal force P act at C, with P directed away from B, as shown.

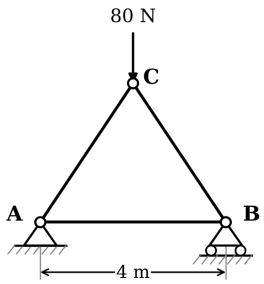


(a) Show that the vertical reaction at B is $\frac{1}{2}(W + \sqrt{3}P)$, and find the horizontal and vertical components of the reaction at A. **[5]**

(b) Show that the square of the magnitude of the reaction at A is $\frac{7}{4}P^2 - \frac{\sqrt{3}}{2}WP + \frac{1}{4}W^2$.
Hence find the value of P, in terms of W, for which the magnitude of the reaction at A is least, and find this least magnitude. **[6]**

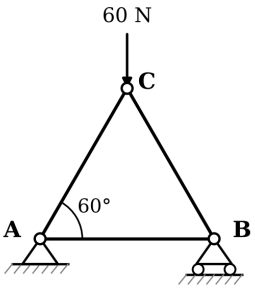
Method of Joints

1 A light framework ABC is hinged at A and rests on a roller at B. A load of 80 N hangs from C, as shown. The reactions at A and B are each 40 N upwards.
By considering the equilibrium of joint A, find the force in each of the rods AB and AC, stating whether each is in tension or thrust.



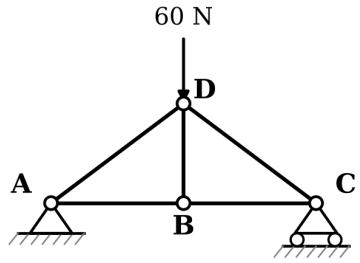
[3]

2 A light framework ABC is an equilateral triangle. It carries a load of 60 N at C, as shown.
By considering the equilibrium of joint C, find the force in each of the rods AC and BC, stating whether each is in tension or thrust.



[3]

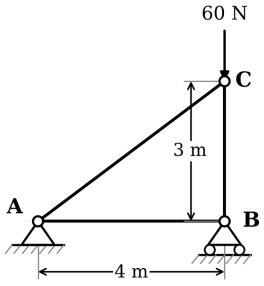
3 A light framework ABCD is supported at A and C and carries a load of 60 N at D, as shown. The joint B is not loaded and the rods AB and BC are in a straight line.
Identify the rod that carries no force, giving a reason.



[2]

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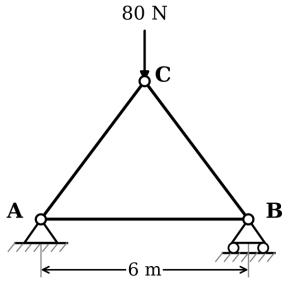
4 A light framework ABC is right-angled at B, with AB horizontal and BC vertical. It carries a load of 60 N at C, as shown.
By considering joint C, find the force in each of the rods BC and AC, stating whether each is in tension or thrust where appropriate.



[3]

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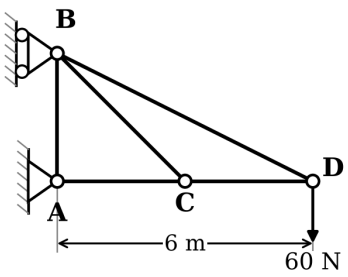
5 A light framework ABC has AB = 6 m, and C is 4 m vertically above the midpoint of AB. A load of 80 N hangs from C, as shown.
Explain why the forces in AC and BC are equal in magnitude, and find this force, stating tension or thrust.



[3]

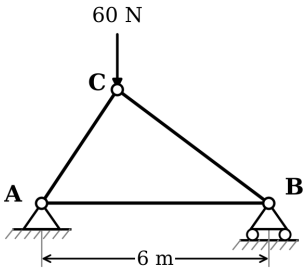
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6 A light bracket ABCD is attached to a vertical wall at A and B, where B is 3 m above A. The joints C and D are on the horizontal line through A, with AC = CD = 3 m, and the rods are AB, AC, BC, BD and CD. A load of 60 N hangs from D, as shown.
By considering the equilibrium of joint D, find the force in each of the rods BD and CD, stating whether each is in tension or thrust.



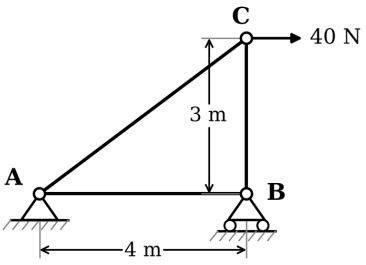
[3]

7 A light framework ABC is hinged at A and rests on a roller at B, where AB = 6 m and C is 3 m above AB and 2 m horizontally from A. A load of 60 N hangs from C, as shown. The reactions at A and B are 40 N and 20 N upwards respectively.
Find the force in each rod, stating whether it is in tension or thrust.



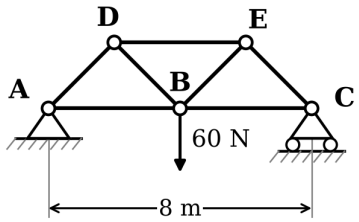
[5]

8 A light framework ABC is right-angled at B, with AB = 4 m horizontal and BC = 3 m vertical. It is hinged at A and rests on a roller at B. A horizontal force of 40 N acts at C, as shown. The reaction at B is 30 N upwards.
Find the force in each rod, stating whether it is in tension or thrust.



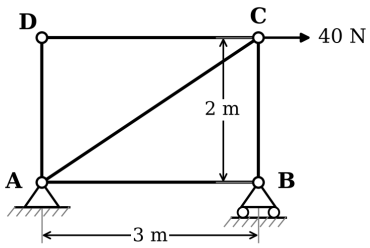
[5]

9 A light Warren framework ABCDE is hinged at A and rests on a roller at C. A, B and C are in a horizontal line with AB = BC = 4 m and D and E are 2 m above the midpoints of AB and BC. A load of 60 N hangs from B, as shown. The reactions at A and C are each 30 N upwards.
By considering joint A, find the force in each of the rods AB and AD, stating tension or thrust.



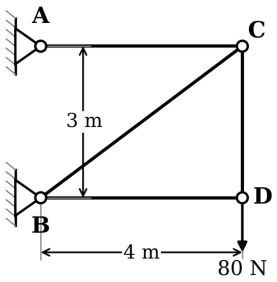
[3]

10 A light rectangular framework ABCD with a diagonal AC is hinged at A and rests on a roller at B, where AB = 3 m and BC = 2 m. A horizontal force of 40 N acts at C, as shown.
Explain why DA and DC carry no force, and find the forces in CA and CB, stating tension or thrust.



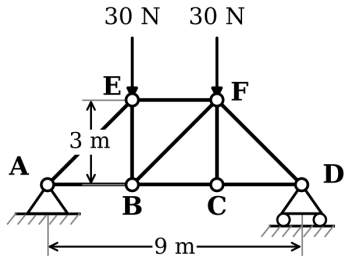
[5]

11 A light cantilever framework ABCD is attached to a vertical wall at A and B, where A is 3 m above B. The joints C and D are 4 m from the wall, with C vertically above D, and the rods are AC, BC, CD and DB. A load of 80 N hangs from D, as shown.
By considering joint D find the forces in DC and DB, and then by considering joint C find the force in BC, stating whether each is in tension or thrust.



[5]

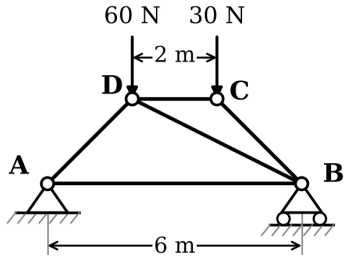
12 The light Howe framework shown has rods AB, BC, CD, AE, EF, FD, BE, CF and BF, with E and F each 3 m above the line ABCD and AB = BC = CD = 3 m. It is hinged at A and rests on a roller at D, and carries loads of 30 N at E and at F. By symmetry the reactions at A and D are each 30 N upwards.



(a) In the method of joints, state which joints could be used first, and explain why joint B could not be used first. **[2]**

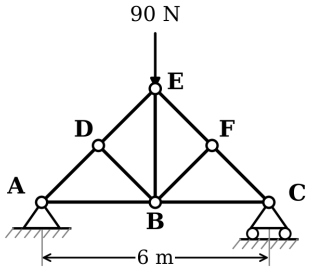
(b) By considering joint A, find the force in each of the rods AB and AE, stating whether each is in tension or thrust. **[3]**

13 A light trapezium framework ABCD has AB = 6 m horizontal and DC = 2 m, parallel to AB and 2 m above it, with D and C each 2 m horizontally from A and B respectively. The rods are AB, BC, CD, DA and DB. The framework is hinged at A and rests on a roller at B, and carries vertical loads of 60 N at D and 30 N at C, as shown.
By considering joints C and D in turn, find the forces in the rods CB, CD, DA and DB, stating whether each is in tension or thrust.



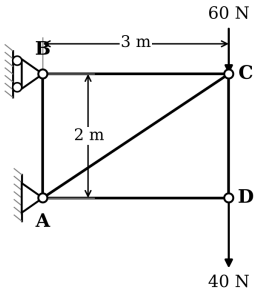
[6]

14 A light roof framework ABCDEF has joints A, B and C in a horizontal line with AB = BC = 3 m, and D, E and F are at heights of 1.5 m, 3 m and 1.5 m above the line, vertically above the midpoint of AB, B and the midpoint of BC respectively, as shown. It is hinged at A and rests on a roller at C, and carries a load of 90 N at E. By symmetry the reactions at A and C are each 45 N upwards.
Find the forces in the rods AB, AD, DE and DB, stating tension or thrust.



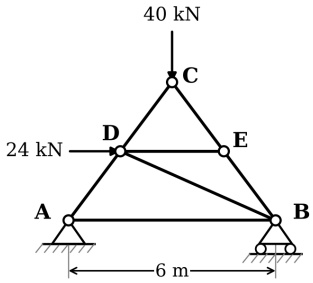
[6]

15 A light rectangular framework ABCD with a diagonal AC is attached to a vertical wall at A and B, with AB = 2 m and BC = 3 m. A load of 60 N hangs from C and a load of 40 N hangs from D, as shown. At A the framework is hinged and at B the connection allows only a horizontal reaction.
Find the force in each of the rods DA, DC, CB and CA, stating whether it is in tension or thrust.



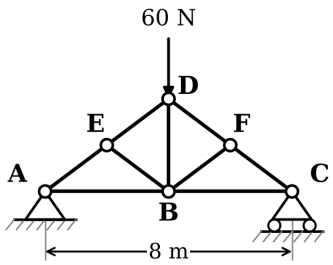
[6]

16 A light A-frame ABCDE has AB = 6 m horizontal, C is 4 m vertically above the midpoint of AB, and D and E are the midpoints of AC and BC. The rods are AB, AD, DC, CE, EB, DE and DB. The frame is hinged at A and rests on a roller at B, and carries a horizontal load of 24 kN at D and a vertical load of 40 kN at C, as shown. The reaction at A has components 24 kN to the left and 12 kN upwards, and the reaction at B is 28 kN upwards.
By considering joints A and B in turn, find the forces in AB, AD, BE and BD, stating whether each is in tension or thrust.



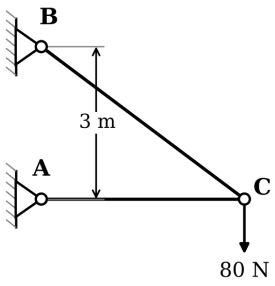
[6]

17 A light framework has joints A, B and C in a horizontal line with AB = BC = 4 m, D is 3 m vertically above B, and E and F are the midpoints of AD and CD, as shown. The framework is hinged at A and rests on a roller at C and carries a load of 60 N at D. By symmetry the reactions at A and C are each 30 N upwards.



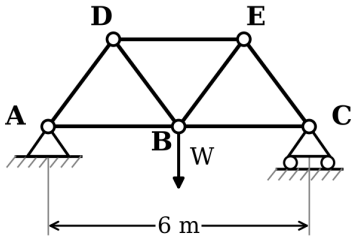
(a) Identify three zero-force rods, giving a reason in each case. **[3]**
(b) Find the forces in the rods AE and AB, stating tension or thrust. **[4]**

18 A light framework ABC is attached to a vertical wall at A and B, where B is 3 m above A, and C is 4 m horizontally from A and level with A. The framework is hinged to the wall at both A and B. A load of 80 N hangs from C, as shown.
Find the force in each of the rods AC and BC, stating whether it is in tension or thrust, and find the vertical component of the reaction at B.



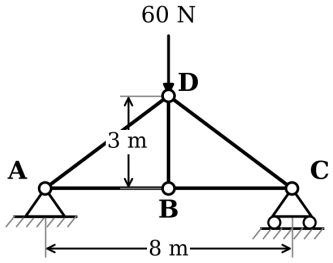
[7]

19 A light Warren framework ABCDE is hinged at A and rests on a roller at C. A, B and C are in a horizontal line with AB = BC = 3 m, and D and E are 2 m above the midpoints of AB and BC. A load of W newtons hangs from B, as shown. The force in the rod AD is a thrust of 50 N.
Find W and the force in AB.



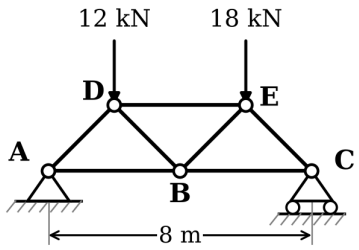
[6]

20 A light framework ABCD is hinged at A and rests on a roller at C. A, B and C are in a horizontal line with AB = BC = 4 m, and D is 3 m vertically above B. A load of 60 N hangs from D, as shown.
Show that the rod BD carries no force, and find the forces in AD, AB and BC, stating tension or thrust.



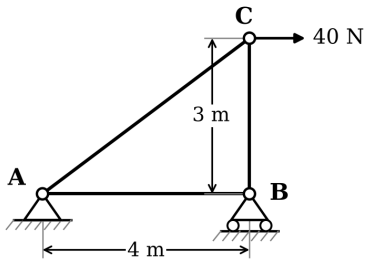
[7]

21 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. A load of 12 kN acts at D and a load of 18 kN at E, as shown.
Find the reactions at A and C, and the forces in the rods AB and AD, stating tension or thrust.



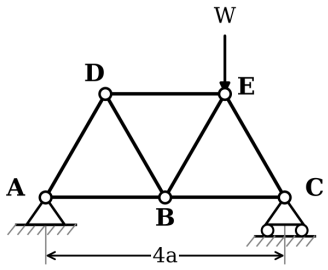
[8]

22 A light framework ABC is right-angled at B, with AB = 4 m horizontal and BC = 3 m vertical, hinged at A and resting on a roller at B. A horizontal force of 40 N acts at C towards the right, as shown. A student analyses joint C by writing: "Horizontally: $40 = T_{CA} \times \frac{4}{5}$, so $T_{CA} = 50$ N (tension). Vertically: $T_{CB} = T_{CA} \times \frac{3}{5} = 30$ N (tension)."



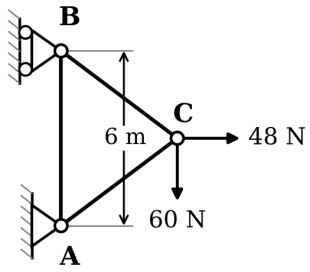
(a) Identify the error in the student's working. **[2]**
(b) Write down the correct forces in CA and CB, and use joint B to find the force in AB. **[3]**
(c) Hence state which of the rods CA and CB is a tie and which is a strut. **[1]**

23 A light framework ABCDE consists of seven rods, each of length 2a, forming three equilateral triangles ABD, BDE and BCE, as shown. It is hinged at A and rests on a roller at C, and a load of weight W acts at E. The reactions at A and C are $\frac{W}{4}$ and $\frac{3W}{4}$ upwards respectively.
Find, in exact form in terms of W, the forces in the rods AD, AB, DB and DE, stating tension or thrust.



[8]

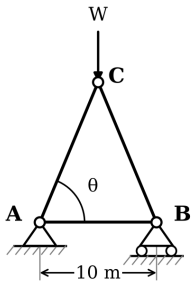
24 A light framework ABC is attached to a vertical wall at A and B, where B is 6 m above A, and C is 4 m from the wall and 3 m above A. The rods are AB, AC and BC. The framework is hinged at A, and at B the connection allows only a horizontal reaction. A vertical load of 60 N and a horizontal force of 48 N, directed away from the wall, both act at C, as shown.



(a) Find the horizontal reaction at B, and the magnitude and direction of the reaction at A. **[3]**

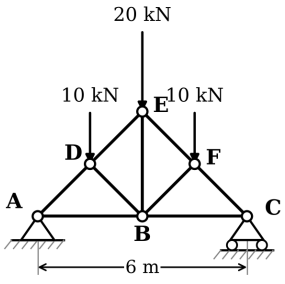
(b) By considering joints C and B, find the force in each rod, stating whether it is in tension or thrust. **[6]**

25 A light framework ABC is isosceles with AC = BC and AB = 10 m horizontal. The joint C is 12 m vertically above the midpoint of AB and carries a load of weight W, as shown. The framework is hinged at A and rests on a roller at B, and the angle CAB = θ.
Find, in terms of W, the force in each rod, stating whether it is in tension or thrust.



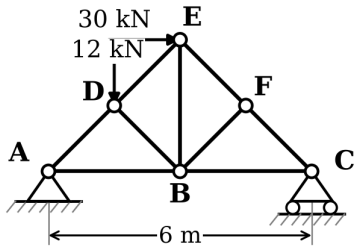
[7]

26 A light roof framework ABCDEF has joints A, B and C in a horizontal line with AB = BC = 3 m, and D, E and F are at heights of 1.5 m, 3 m and 1.5 m above the line, vertically above the midpoint of AB, B and the midpoint of BC respectively. It is hinged at A and rests on a roller at C. Loads of 10 kN, 20 kN and 10 kN act at D, E and F respectively, as shown.
Find the forces in the rods AB, AD, DE and DB, stating tension or thrust.



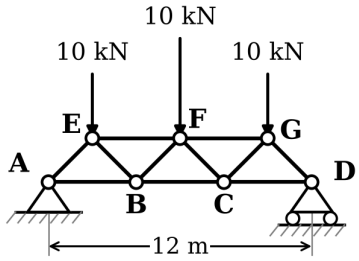
[7]

27 A light roof framework ABCDEF has joints A, B and C in a horizontal line with AB = BC = 3 m, and D, E and F are at heights of 1.5 m, 3 m and 1.5 m above the line, vertically above the midpoint of AB, B and the midpoint of BC respectively. It is hinged at A and rests on a roller at C. A vertical load of 30 kN acts at D and a horizontal load of 12 kN acts at E, directed away from A, as shown.
Find the reactions at A and C and the forces in the rods AB, AD, DB and DE, stating tension or thrust.



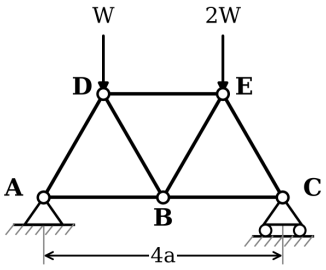
[11]

28 A light framework ABCDEFG has joints A, B, C and D in a horizontal line with AB = BC = CD = 4 m, and E, F and G are 2 m above the midpoints of AB, BC and CD respectively. It is hinged at A and rests on a roller at D, and carries loads of 10 kN at each of E, F and G, as shown.
Find the forces in the rods AB, AE, EB, EF, BF and BC, stating tension or thrust.



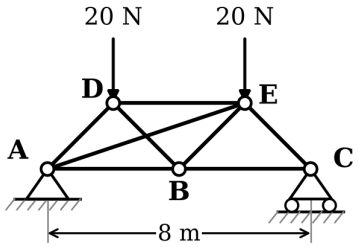
[10]

29 A light framework ABCDE consists of seven rods, each of length 2a, forming three equilateral triangles ABD, BDE and BCE, as shown. It is hinged at A and rests on a roller at C. Loads of weight W and 2W act at D and E respectively.



(a) Find the reactions at A and C. **[4]**
(b) Hence find, in exact form in terms of W, the forces in the rods AD, DB and DE, stating tension or thrust. **[7]**

30 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. Loads of 20 N act at D and E. An extra light rod AE is added, as shown.

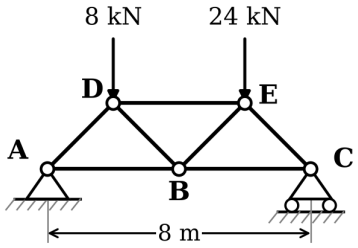


(a) Show that the framework with the extra rod is no longer statically determinate by the method of joints. **[2]**

(b) The rod AE is now removed. Find the forces in all seven rods, stating tension or thrust. **[9]**

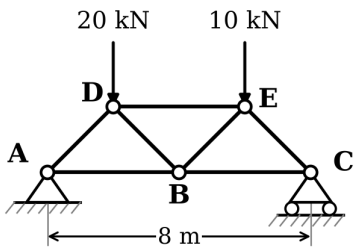
Method of Sections and Harder Frameworks

1 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC respectively. Loads of 8 kN and 24 kN act at D and E, as shown. The reactions at A and C are 12 kN and 20 kN upwards respectively.
By taking a section through AB, DB and DE and taking moments about B for the left-hand part, find the force in DE, stating tension or thrust.



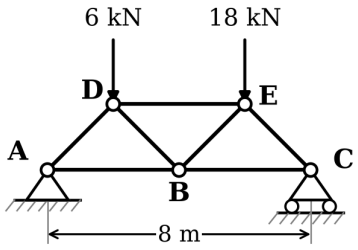
[3]

2 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC respectively. Loads of 20 kN and 10 kN act at D and E, as shown. The reactions at A and C are 17.5 kN and 12.5 kN upwards respectively.
By taking a section through AB, DB and DE and taking moments about D for the left-hand part, find the force in AB, stating tension or thrust.



[3]

3 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC respectively. Loads of 6 kN and 18 kN act at D and E, as shown. The reactions at A and C are 9 kN and 15 kN upwards respectively.
By taking a section through AB, DB and DE and resolving vertically for the left-hand part, find the force in DB, stating tension or thrust.



[3]

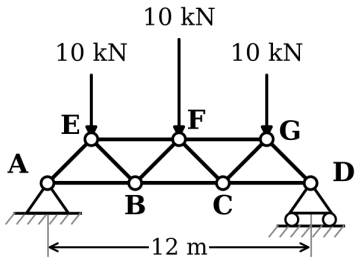
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4 The method of sections is used to find the force in a member of a plane framework.

(a) Explain why a section should not normally cut through more than three members whose forces are unknown. **[2]**

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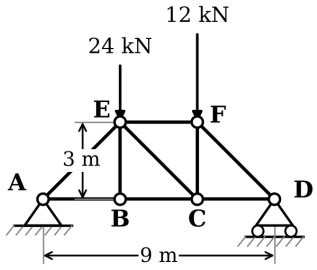
5 A light framework ABCDEFG has joints A, B, C and D in a horizontal line with AB = BC = CD = 4 m, and E, F and G are 2 m above the midpoints of AB, BC and CD respectively. It is hinged at A and rests on a roller at D, and carries loads of 10 kN at each of E, F and G, as shown. The reactions at A and D are each 15 kN upwards.
By taking a section through EF, BF and BC and taking moments about B for the left-hand part, find the force in EF, stating tension or thrust.



[3]

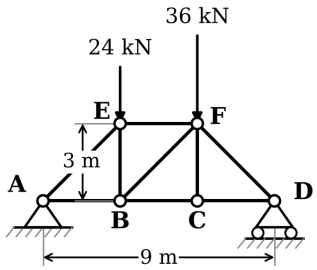
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6 A light Pratt framework has joints A, B, C and D in a horizontal line with AB = BC = CD = 3 m, and E and F are 3 m vertically above B and C respectively. There are nine rods: AB, BC, CD, AE, EF, FD, BE, CF and EC. It is hinged at A and rests on a roller at D, and carries loads of 24 kN at E and 12 kN at F, as shown. The reactions at A and D are 20 kN and 16 kN upwards respectively.
By taking a section through EF, EC and BC and taking moments about C for the left-hand part, find the force in EF, stating tension or thrust.



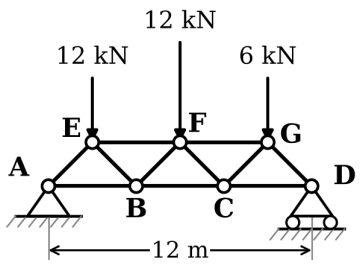
[3]

7 A light Howe framework has joints A, B, C and D in a horizontal line with AB = BC = CD = 3 m, and E and F are 3 m vertically above B and C respectively. There are nine rods: AB, BC, CD, AE, EF, FD, BE, CF and BF. It is hinged at A and rests on a roller at D, and carries vertical loads of 24 kN at E and 36 kN at F, as shown. The reactions at A and D are 28 kN and 32 kN upwards respectively.
Use a section through EF, BF and BC to find the forces in EF and BF, stating tension or thrust.



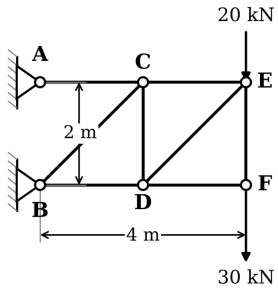
[5]

8 A light framework ABCDEFG has joints A, B, C and D in a horizontal line with AB = BC = CD = 4 m, and E, F and G are 2 m above the midpoints of AB, BC and CD respectively. It is hinged at A and rests on a roller at D. Loads of 12 kN, 12 kN and 6 kN act at E, F and G respectively, as shown. The reactions at A and D are 17 kN and 13 kN upwards respectively.
Use a section through EF, BF and BC to find the forces in BF and BC, stating tension or thrust.



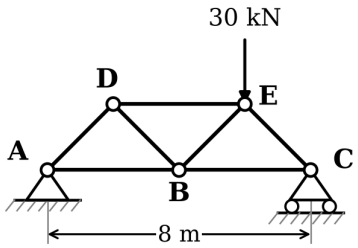
[5]

9 A light cantilever framework is attached to a vertical wall at A and B, where A is 2 m above B. The joints C and E lie on the horizontal through A and D and F on the horizontal through B, with AC = CE = 2 m, so that C is vertically above D and E vertically above F. The rods are AC, CE, BD, DF, CD, EF, BC and DE. Loads of 20 kN and 30 kN hang from E and F respectively, as shown.
Use a section through CE, DE and DF and consider the right-hand part to find the forces in CE and DE, stating tension or thrust.



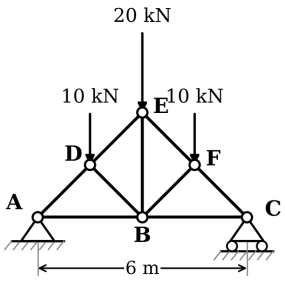
[5]

10 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC respectively. A load of 30 kN acts at E, as shown.
Find the reaction at C, and use a section through AB, DB and DE to find the force in DE, stating tension or thrust.



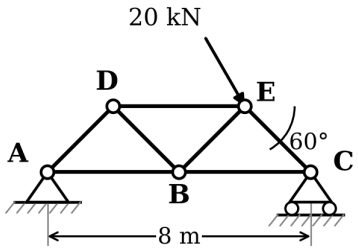
[5]

11 A light roof framework ABCDEF has joints A, B and C in a horizontal line with AB = BC = 3 m, and D, E and F are at heights of 1.5 m, 3 m and 1.5 m above the line, vertically above the midpoint of AB, B and the midpoint of BC respectively. It is hinged at A and rests on a roller at C, and loads of 10 kN, 20 kN and 10 kN act at D, E and F respectively, as shown. The reactions at A and C are each 20 kN upwards.
Use a section through AB, DB and DE to find the forces in DE and AB, stating tension or thrust.



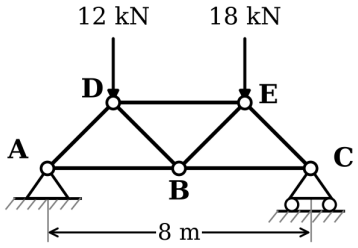
[5]

12 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC respectively. A load of 20 kN acts at E, directed at 60° below the horizontal towards the right, as shown. The reactions at A and C are: at A, a horizontal component 10 kN to the left and a vertical component 1.83 kN upwards; at C, 15.5 kN upwards.
Use a section through AB, DB and DE to find the force in DE, stating tension or thrust.



[3]

13 A section is made through the rods AB, DB and DE of the framework shown, and the left-hand part (containing A and D) is considered. The loads at D and E and the reactions at A and C are known.

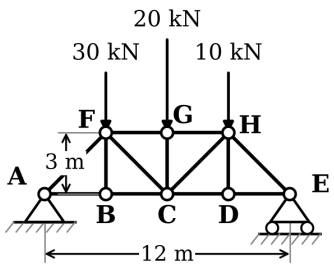


(a) State a point about which moments can be taken so that the equation contains only the force in DE. **[1]**

(b) State a point about which moments can be taken so that the equation contains only the force in AB. **[1]**

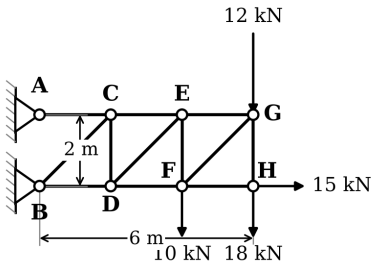
(c) State which equation is used to find the force in DB directly, and why. **[1]**

14 A light Pratt framework has joints A, B, C, D and E in a horizontal line with AB = BC = CD = DE = 3 m, and F, G and H are 3 m vertically above B, C and D respectively. The rods are AB, BC, CD, DE, AF, FG, GH, HE, BF, CG, DH, FC and HC. It is hinged at A and rests on a roller at E, and carries vertical loads of 30 kN at F, 20 kN at G and 10 kN at H, as shown. The reactions at A and E are 35 kN and 25 kN upwards respectively.
Use a section through FG, FC and BC to find the forces in FG and BC, stating tension or thrust.



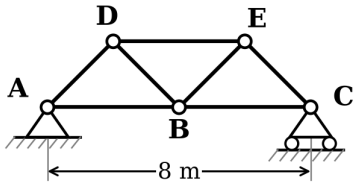
[5]

15 A light cantilever framework is attached to a vertical wall at A and B, where A is 2 m above B. The joints C, E and G lie on the horizontal through A and D, F and H on the horizontal through B, with every bay 2 m wide, so that C is above D, E above F and G above H. The rods are AC, CE, EG, BD, DF, FH, CD, EF, GH, BC, DE and FG. Loads of 12 kN, 10 kN and 18 kN hang from G, F and H respectively, and a horizontal force of 15 kN acts at H, directed away from the wall, as shown.
Use a section through EG, FG and FH and consider the right-hand part to find the forces in EG, FG and FH, stating tension or thrust.



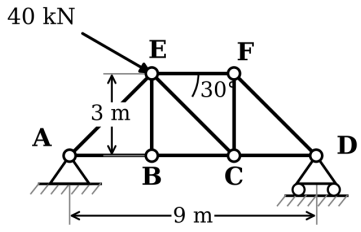
[7]

16 A light Warren framework ABCDE is replaced by one made of seven identical uniform rods each of weight 20 N, joined smoothly as shown, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. It is hinged at A and rests on a roller at C. The weight of each rod may be taken to act as two equal loads, one at each end of the rod.
Find the force in DE, stating tension or thrust.



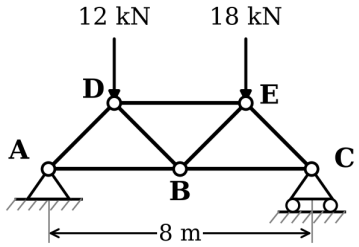
[7]

17 A light Pratt framework has joints A, B, C and D in a horizontal line with AB = BC = CD = 3 m, and E and F are 3 m vertically above B and C respectively. There are nine rods: AB, BC, CD, AE, EF, FD, BE, CF and EC. It is hinged at A and rests on a roller at D. A load of 40 kN acts at E, directed at 30° below the horizontal towards the right, as shown. The reaction at D is 18.2 kN upwards, and at A the reaction has components 34.6 kN to the left and 1.79 kN upwards.
Use a section through EF, EC and BC to find the forces in EF and EC, stating tension or thrust.



[5]

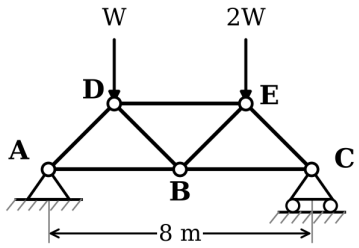
18 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. Loads of 12 kN and 18 kN act at D and E, as shown. The reactions at A and C are 13.5 kN and 16.5 kN upwards respectively.



(a) Use a section through AB, DB and DE to find the force in DE. **[3]**

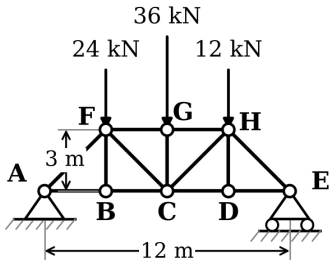
(b) Hence, by considering joint E, find the forces in BE and EC. **[4]**

19 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. Loads of W kN and 2W kN act at D and E respectively, as shown. The force in the rod DE is a thrust of 30 kN.
Find the value of W.



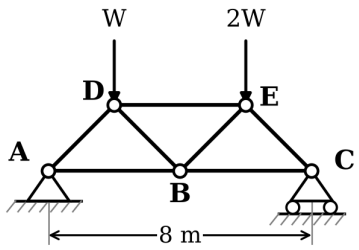
[6]

20 A light Pratt framework has joints A, B, C, D and E in a horizontal line with AB = BC = CD = DE = 3 m, and F, G and H are 3 m vertically above B, C and D respectively. The rods are AB, BC, CD, DE, AF, FG, GH, HE, BF, CG, DH, FC and HC. It is hinged at A and rests on a roller at E, and carries vertical loads of 24 kN at F, 36 kN at G and 12 kN at H, as shown.
Find the reaction at E, and use a section through GH, CH and CD, considering the right-hand part, to find the forces in GH and CD, stating tension or thrust.



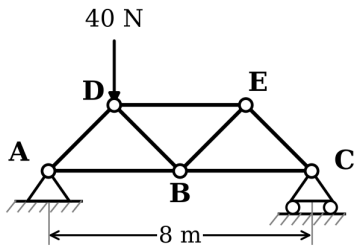
[7]

21 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. Loads of W newtons and 2W newtons act at D and E respectively, as shown. Each rod can withstand a tension of at most 500 N and a thrust of at most 300 N.
Find the greatest value of W for which no rod fails.



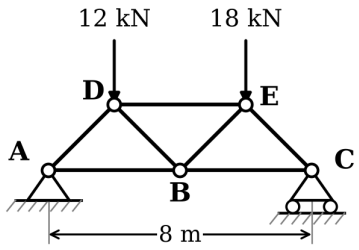
[9]

22 A light Warren framework is made of seven identical uniform rods each of weight 20 N, joined smoothly: ABCDE with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. The weight of each rod may be taken to act as two equal loads, one at each end of the rod. An extra load of 40 N hangs from D. The framework is hinged at A and rests on a roller at C, as shown.
Find the forces in DE and AB, stating tension or thrust.



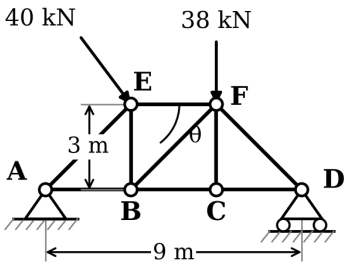
[9]

23 A light Warren framework ABCDE is hinged at A and rests on a roller at C, with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. Loads of 12 kN and 18 kN act at D and E, as shown. The reactions at A and C are 13.5 kN and 16.5 kN upwards. A student cuts through AB, DB and DE and writes: "Moments about B for the left-hand part: $T_{AB} \times 2 = 13.5 \times 4 - 12 \times 2$, so $T_{AB} = 15$ kN (tension)."



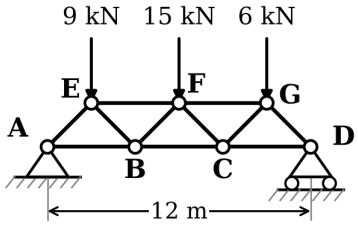
(a) Identify the error in the student's method. **[2]**
(b) Find the correct force in AB, and the force in DE, stating tension or thrust. **[4]**

24 A light Howe framework has joints A, B, C and D in a horizontal line with AB = BC = CD = 3 m, and E and F are 3 m vertically above B and C respectively. There are nine rods: AB, BC, CD, AE, EF, FD, BE, CF and BF. It is hinged at A and rests on a roller at D. A load of 40 kN acts at E, directed at an angle θ below the horizontal away from A, where $\tan\theta = \frac{4}{3}$, and a vertical load of 38 kN acts at F, as shown.
Find the reactions at A and D, and use a section through EF, BF and BC to find the forces in EF and BF, stating tension or thrust.



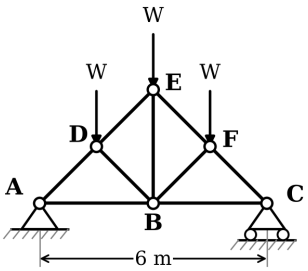
[9]

25 A light framework ABCDEFG has joints A, B, C and D in a horizontal line with AB = BC = CD = 4 m, and E, F and G are 2 m above the midpoints of AB, BC and CD respectively. It is hinged at A and rests on a roller at D. Loads of 9 kN, 15 kN and 6 kN act at E, F and G respectively, as shown.
Find the reactions at A and D, and use a section through FG, CG and CD to find the forces in FG and CD, stating tension or thrust.



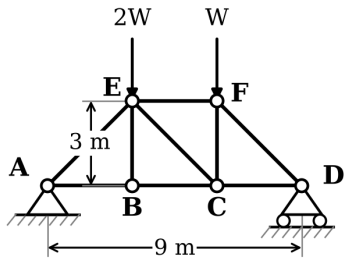
[9]

26 A light roof framework ABCDEF has joints A, B and C in a horizontal line with AB = BC = 3 m, and D, E and F are at heights of 1.5 m, 3 m and 1.5 m above the line, vertically above the midpoint of AB, B and the midpoint of BC respectively. It is hinged at A and rests on a roller at C, and identical loads of W newtons act at each of D, E and F, as shown. Each rod can withstand a tension of at most 600 N and a thrust of at most 400 N.
Find the greatest value of W for which no rod fails.



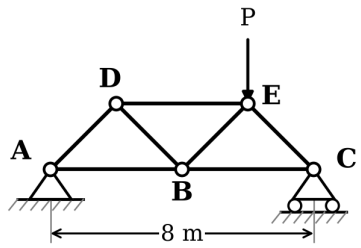
[9]

27 A light Pratt framework has joints A, B, C and D in a horizontal line with AB = BC = CD = 3 m, and E and F are 3 m vertically above B and C respectively, with rods AB, BC, CD, AE, EF, FD, BE, CF and EC. It is hinged at A and rests on a roller at D, and loads of 2W and W newtons act at E and F respectively, as shown. Each rod can withstand a tension of at most 200 N and a thrust of at most 300 N.
Find, with justification, the greatest value of W for which no rod fails, and state which rod or rods fail first.



[12]

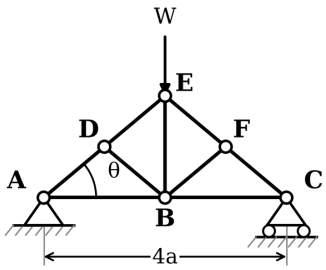
28 A light Warren framework is made of seven identical uniform rods each of weight 30 N, joined smoothly: ABCDE with A, B and C in a horizontal line, AB = BC = 4 m, and D and E 2 m above the midpoints of AB and BC. The weight of each rod may be taken to act as two equal loads, one at each end of the rod. The framework is hinged at A and rests on a roller at C, and a load of P newtons is hung from E, as shown.



(a) Show that the reaction at C is $(105 + \frac{3P}{4})$ N. **[5]**

(b) Given that the reaction at C is twice the reaction at A, find P and find the force in DE, stating tension or thrust. **[7]**

29 A light roof framework ABCDEF has joints A, B and C in a horizontal line with AB = BC = 2a, E vertically above B, and D and F the midpoints of AE and CE respectively. There are nine rods AB, BC, AD, DE, EF, FC, DB, BE and BF. The angle EAB = θ. The framework is hinged at A and rests on a roller at C, and carries a load of weight W at E, as shown.



(a) Show that the reaction at A is $\frac{W}{2}$ and, using a section through AB, DB and DE, show that the force in AB is a tension of $\frac{W}{(2\tan\theta)}$. **[3]**

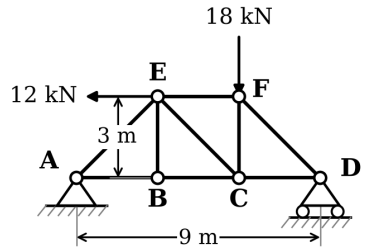
(b) By taking moments about B for the same part, find the force in DE in terms of W and θ, stating whether it is a tension or a thrust. **[4]**

(c) Find the value of θ for which the thrust in DE equals W, and the corresponding force in AB. **[2]**

(d) Explain what happens to the force in AB as θ decreases towards zero, and what this means for a very flat roof. **[2]**

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30 A light Pratt framework has joints A, B, C and D in a horizontal line with AB = BC = CD = 3 m, and E and F are 3 m vertically above B and C respectively, with rods AB, BC, CD, AE, EF, FD, BE, CF and EC. It is hinged at A and rests on a roller at D on a smooth horizontal surface. A horizontal force of 12 kN acts at E, directed away from F, and a vertical load of 18 kN acts at F, as shown.



(a) Find the reaction at D and the magnitude and direction of the reaction at A. **[5]**

(b) Use a section through EF, EC and BC to find the forces in EF and BC, stating tension or thrust. **[7]**
