

1.6 Structures – trusses and frames

Name: _____ Class: _____ Date: _____ Total: 25 marks

KEY WORDS truss • tension • compression • method of joints
• method of sections • zero-force member

Objective

Solve trusses by the method of joints and the method of sections, identify zero-force members by inspection, and extend the same dismembering discipline to frames and machines. Every member force is checked through a second joint or an unused section.

1 Key knowledge and worked examples

■ **A truss is a collection of two-force members**

A **truss** is straight members joined at frictionless pins, loaded only at the joints – so every member is a **two-force member** carrying pure **tension** or **compression** along its axis. Solve the support reactions first, then work joint by joint.

Method of joints : at each joint, two force equations solve two unknown member forces. Start where only two members meet.

Worked example. A joint at the wall carries a 3.6 kN hanging load, held by a horizontal member and an inclined member rising on 3-4-5 geometry. Vertically: $F_{inclined} \times (3/5) = 3.6 \rightarrow F_{inclined} = 6kN$ (tension). Horizontally: the horizontal member takes $6 \times (4/5) = 4.8kN$ compression. Every joint is this step.

■ **Method of sections: cut for the member you want**

Method of sections slices through at most three members and takes moments or forces on one piece – ideal for one member deep inside a long truss. Choose the moment centre where two cut members cross, and the third solves alone.

■ **Zero-force members and the frame extension**

Zero-force members : at an unloaded joint with exactly two non-collinear members, both carry zero; at an unloaded three-member joint where two are collinear, the third carries zero. Finding them first shrinks the arithmetic – they are not wasted metal; they stabilise the truss during construction.

Frames and machines have multi-force members: dismember, draw each member’s FBD with joint forces equal and opposite on the neighbour, and solve piece by piece – the same discipline, one more layer.

2 Practice

2.1 At a truss joint, a 4.5 kN load hangs and one member rises at 3-4-5 geometry (3 vertical, 4 horizontal) while a horizontal member completes the joint. Find both member forces, stating tension or compression. [4]

2.2 An unloaded joint has exactly two non-collinear members and no external load. State both member forces and the reasoning in one sentence. [2]

2.3 A simply supported roof truss carries 10 kN at its apex through symmetric members at 45°. Find the force in each apex member by the method of joints, and state tension or compression. [4]

3 Exam-style questions

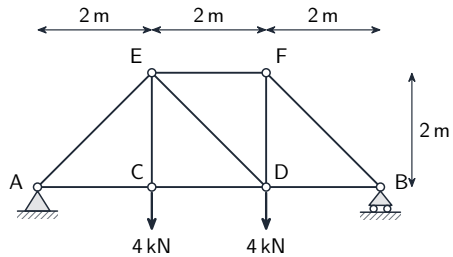
3.1 The Pratt truss shown has a span of 6 m in three 2 m panels and a height of 2 m. It rests on a pin at A and a roller at B. The bottom joints are A, C, D and B; the top joints E and F sit above C and D. The members are AC, CD, DB, EF, CE, DF, AE, FB and the interior diagonal ED. A load of 4 kN hangs at C and another at D.

(a) Find the support reactions at A and B. [2]

(b) Use the method of joints, at A and then at C, to find the forces in members AE, AC and CE. State tension or compression for each. [4]

(c) Cut the truss through EF, ED and CD and keep the left piece. Use moments about suitable points to find the forces in CD and EF, stating tension or compression. [3]

(d) Explain, without solving any joint, why member ED carries no force. [1]



3.2 A frame consists of a two-force strut and a multi-force horizontal member. Explain, in two or three sentences each, (a) why the method of joints cannot solve the frame as if it were a truss, and (b) how the dismembering procedure recovers the solution, naming where the equal-and-opposite pairs act. [5]

Solutions

2.1

- Vertical: $F_{\text{inclined}} \times (3/5) = 4.5 \rightarrow F_{\text{inclined}} = 7.5 \text{ kN}$.
- Tension – the joint hangs from it.
- Horizontal: $F_{\text{horizontal}} = 7.5 \times (4/5) = 6 \text{ kN}$.
- Compression – it pushes back against the inclined member's horizontal pull.

2.2

- Both are zero.
- Two non-collinear forces can only sum to zero if both are zero – the components cannot cancel in both directions otherwise.

2.3

- Joint at the apex: two symmetric members at 45° , 10 kN down.
- Vertical: $2F \sin 45^\circ = 10$, so $F = 7.07 \text{ kN}$.
- Both members are in compression (they prop the apex from below the load's line).

3.1

(a)

- Moments about A: $R_B \times 6 = 4 \times 2 + 4 \times 4$, so $R_B = 4 \text{ kN}$. Vertically $R_A = 8 - 4 = 4 \text{ kN}$, and $A_x = 0$ because no load is horizontal.
- Check: the truss and its loads are symmetric, so equal reactions are expected.

(b)

- Take tension as positive (a member in tension pulls on the joint). Joint A: vertically $4 + F_{AE} \sin 45^\circ = 0$, so $F_{AE} = -5.66 \text{ kN}$: **5.66 kN compression**.
- Horizontally at A: $F_{AC} + F_{AE} \cos 45^\circ = 0$, so $F_{AC} = +4 \text{ kN}$: **4 kN tension**.
- Joint C: the only vertical member is CE, so $F_{CE} - 4 = 0$ and $F_{CE} = 4 \text{ kN}$: **4 kN tension** – the vertical hangs C's load from the top chord.

(c)

- Moments about E remove EF and ED, which both pass through E. On the left piece, R_A turns clockwise with arm 2 m, the load at C acts along E's vertical line, and F_{CD} acts 2 m below E: $-4 \times 2 + 2F_{CD} = 0$, so $F_{CD} = 4 \text{ kN}$ **tension**.
- Moments about D remove ED and CD: $-4 \times 4 + 4 \times 2 - 2F_{EF} = 0$, so $F_{EF} = -4 \text{ kN}$: **4 kN compression**. The sagging truss stretches its bottom chord and squeezes its top chord, as expected.

(d)

- On the left piece, $R_A = 4 \text{ kN}$ up and the 4 kN load at C already balance, and EF and CD are horizontal, so the vertical component of ED must be zero. The middle panel carries no shear.

3.2

- (a) Truss methods assume every member is a two-force member; a multi-force member carries loads along its length, so its joint forces are NOT directed along the member and the joint equations have the wrong unknowns.
- (b) Dismember the frame: each member gets its own FBD; at each shared pin, the force on member 1 is equal and opposite to the force on member 2 (Newton's third law at the pin).
- Solve the two-force member first (direction known), then the multi-force member with its three equations.