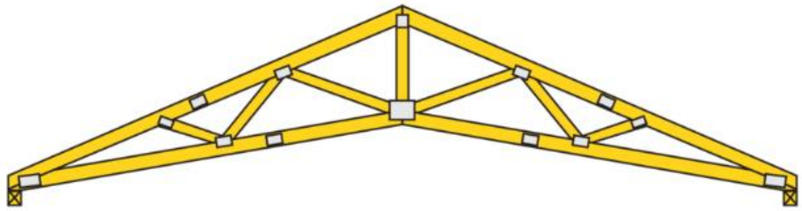
How Scissor Trusses Work:



Scissor trusses are used when a vaulted ceiling is required

Consider the 24’ wide Modified Queen scissor truss with top chord at a 7/12 pitch and bottom chord at a 3/12 pitch.

The outer members are named top and bottom chords and the inner members are named the web.

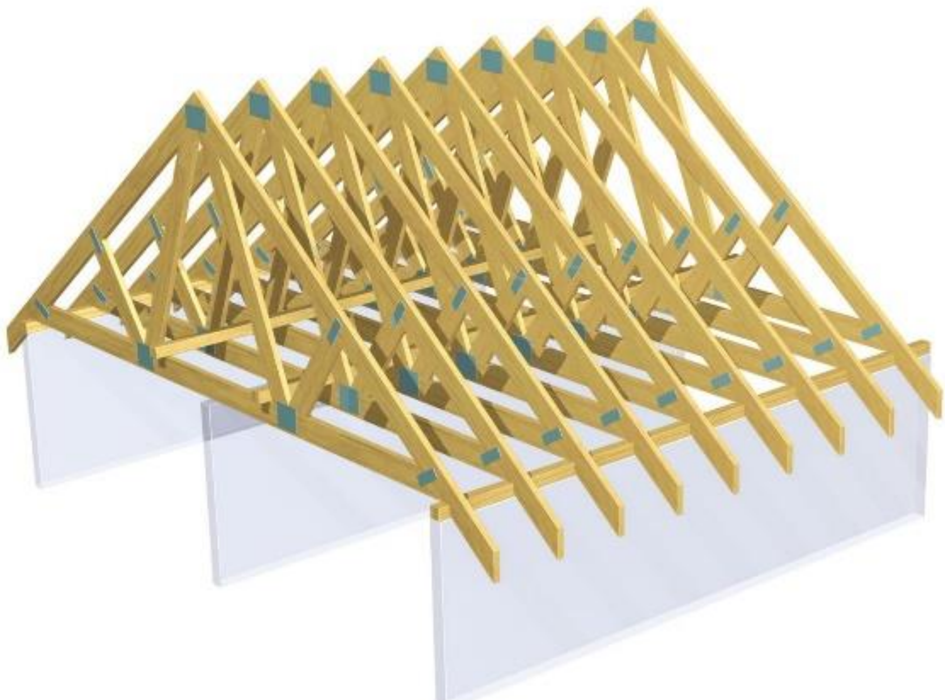
Note: *top and bottom chords are divided into equal lengths.*

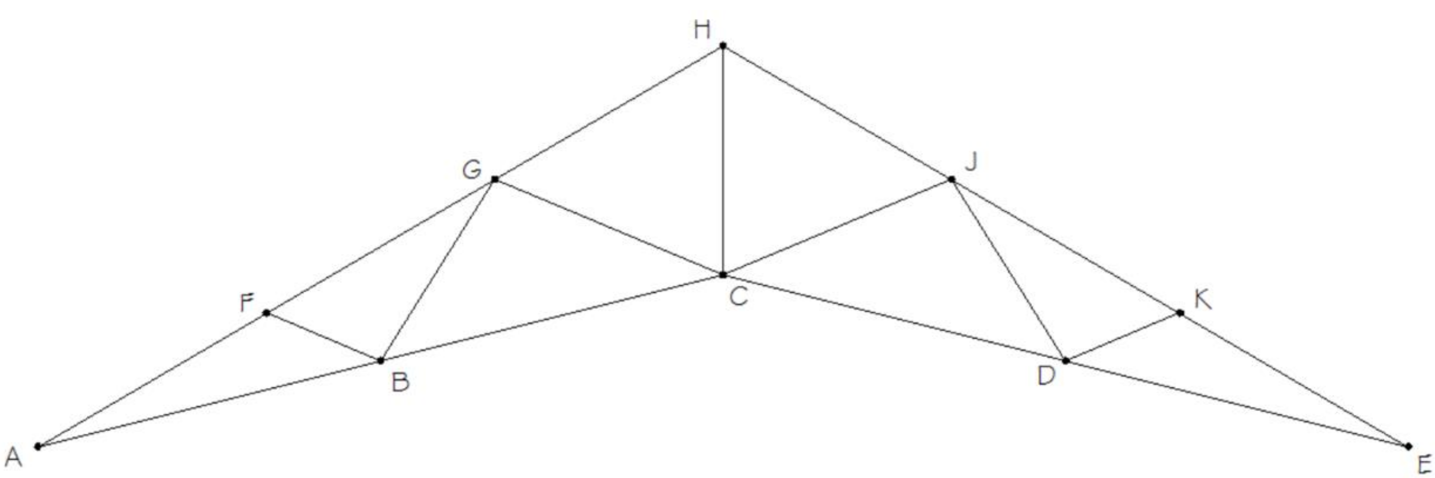
1. Calculate all angles and lengths necessary to build the truss.
2. Each truss is responsible for a 2 foot section through the roof as trusses are typically placed 24” apart and thus must carry 12” on either side.
   Calculate the tension and compression forces on each member given the load requirements below.

Design loads:

a. Roof Live load = 25 lb/ft^2
b. Roof Dead load= 15 lb/ft^2
c. Ceiling Dead load = 10 lb/ft^2

Note: *Live load on the roof is snow load and dead loads are roofing on the top chord and drywall on the ceiling.*





Solution for How Scissor Trusses Work:

1. Angle and Length Solutions:

Given: AE = 24 feet = 288 inches

(1) $\theta = \tan^{-1}\left(\frac{3}{12}\right) \approx 14.04^o$… since the slope of the bottom chord is 3/12 and considering right ΔALC

(2) AC ≈ 148.4" … $cos(14.04^o) = \frac{144}{AC}$

(3) AB = BC ≈ 74.2" … as AC is divided into equal lengths based on the design of the truss

(4) $\Phi = \tan^{-1}\left(\frac{7}{12}\right) \approx 30.26^o$… since the slope of the top chord is 7/12 and considering right ΔALH

(5) AH ≈ 166.7" … $cos(30.26^o) = \frac{144}{AH}$

(6) AF = FG = GH ≈ 55.6" … as AH is divided into equal lengths based on the design of the truss

(7) <FAB ≈ 16.2° … Φ - θ

(8) FB ≈ 26" … law of cosines ΔAFB

(9) <FBA ≈ 36.7° … law of sines ΔAFB

(10)<AFB ≈ 127.1° … law of sines ΔAFB

(11)<GFB ≈ 52.9° … supplementary angles

(12)GB ≈ 44.9" … law of cosines ΔFGB

(13) <FGB ≈ 27.5° … law of sines ΔFGB

(14) <FGB ≈ 99.7° … law of sines ΔFGB

(15) <GBC ≈ 43.7° … supplementary angles

(16)GC ≈ 52" … law of cosines ΔGBC

(17) <BCG ≈ 36.7° … law of sines ΔGBC

(18) <BGC ≈ 99.7° … law of sines ΔGBC

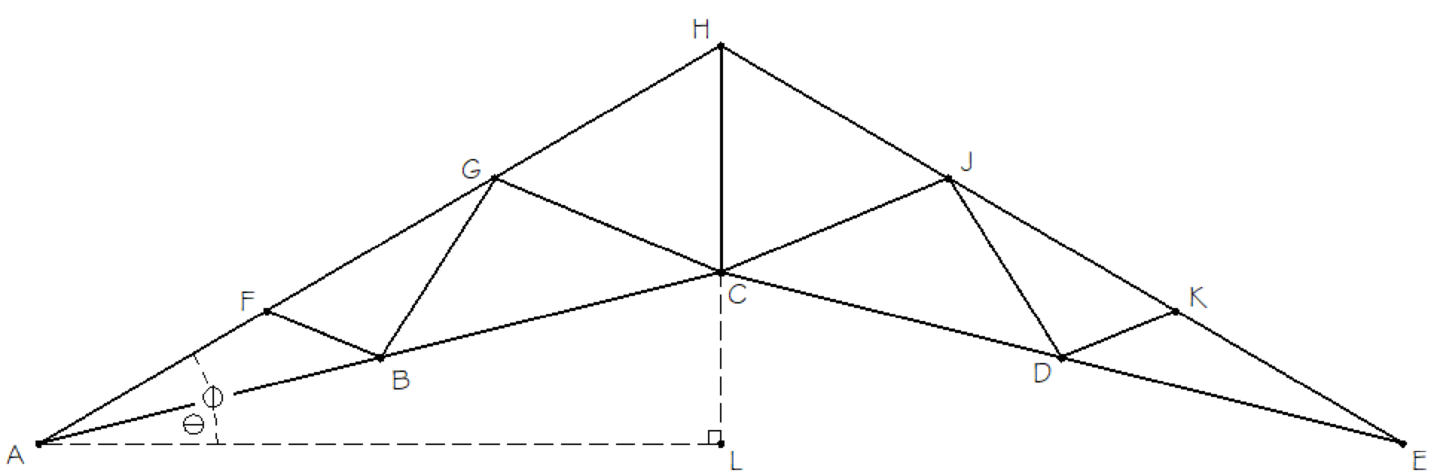
(19) <HGC ≈ 52.9° … supplementary angles

(20)HC ≈ 48" … law of cosines ΔGHC

(21) <GHC ≈ 59.7° … law of sines ΔGHC

(22) <GCH ≈ 67.4° … law of sines ΔGHC

Note: *this is a gross oversimplification as the members are actually not lines. The bottom chord is a trapezoid, the top chord is a parallelogram, and the webs are a pentagon and hexagon. A real truss involves calculating all the lengths and angles in each of these polygons.*



2. Compression and Tension Solutions:

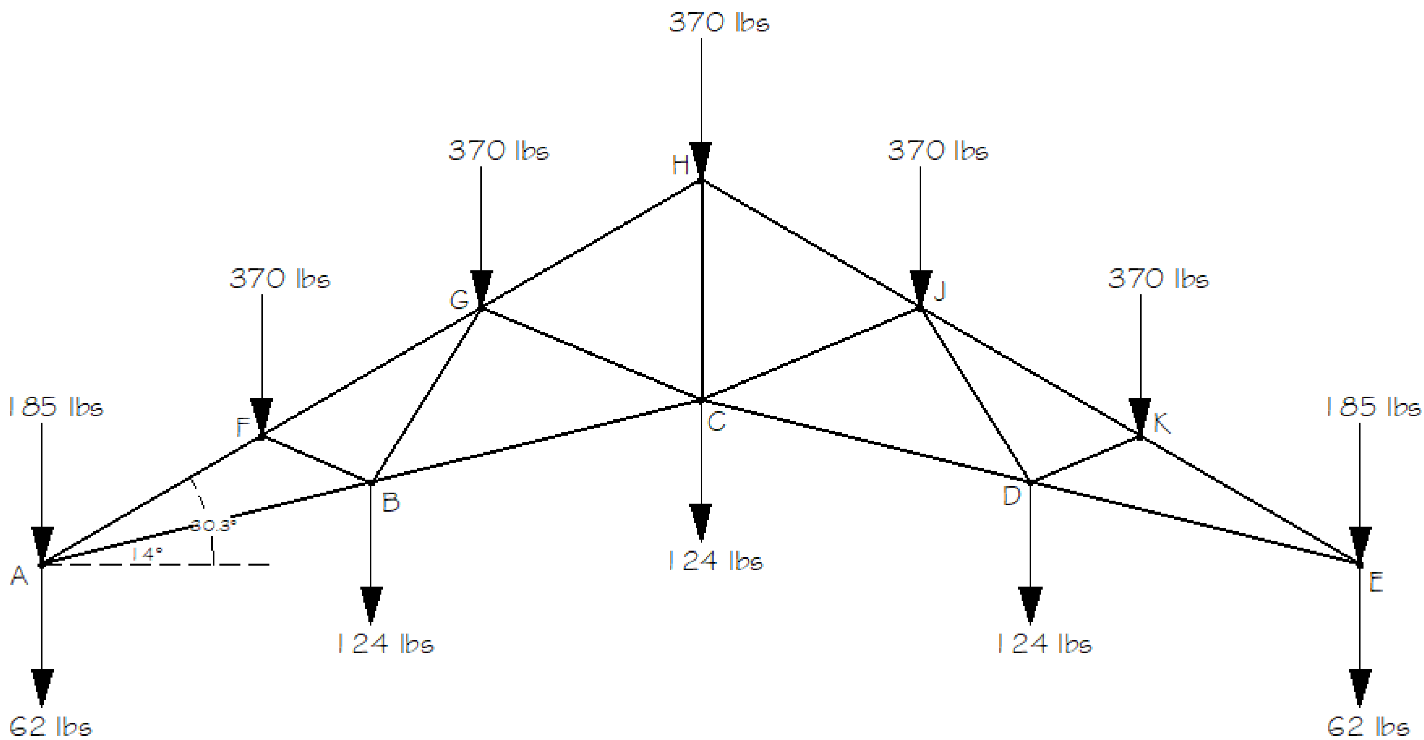
Loading the Truss:

The bottom chord AC is 12.4 feet long and carries a 2 foot wide section of the ceiling weighing 10 lbs/ft^2. So it must carry 248 lbs, evenly distributed along its length which results in the forces shown at joints A, B, C, D and E.

The top chord AH is 13.89 feet long and carries a 2 foot wide section of the roof weighing 40 lbs/ft^2. So it must carry 1111 lbs, evenly distributed along its length which results in the forces shown at joints A, F, G, H, J, K and E.

The entire truss then must carry 2718 lbs and thus the walls at A and E must each push up at 1359 lbs. This will result in A being forced up at 1112 lbs.

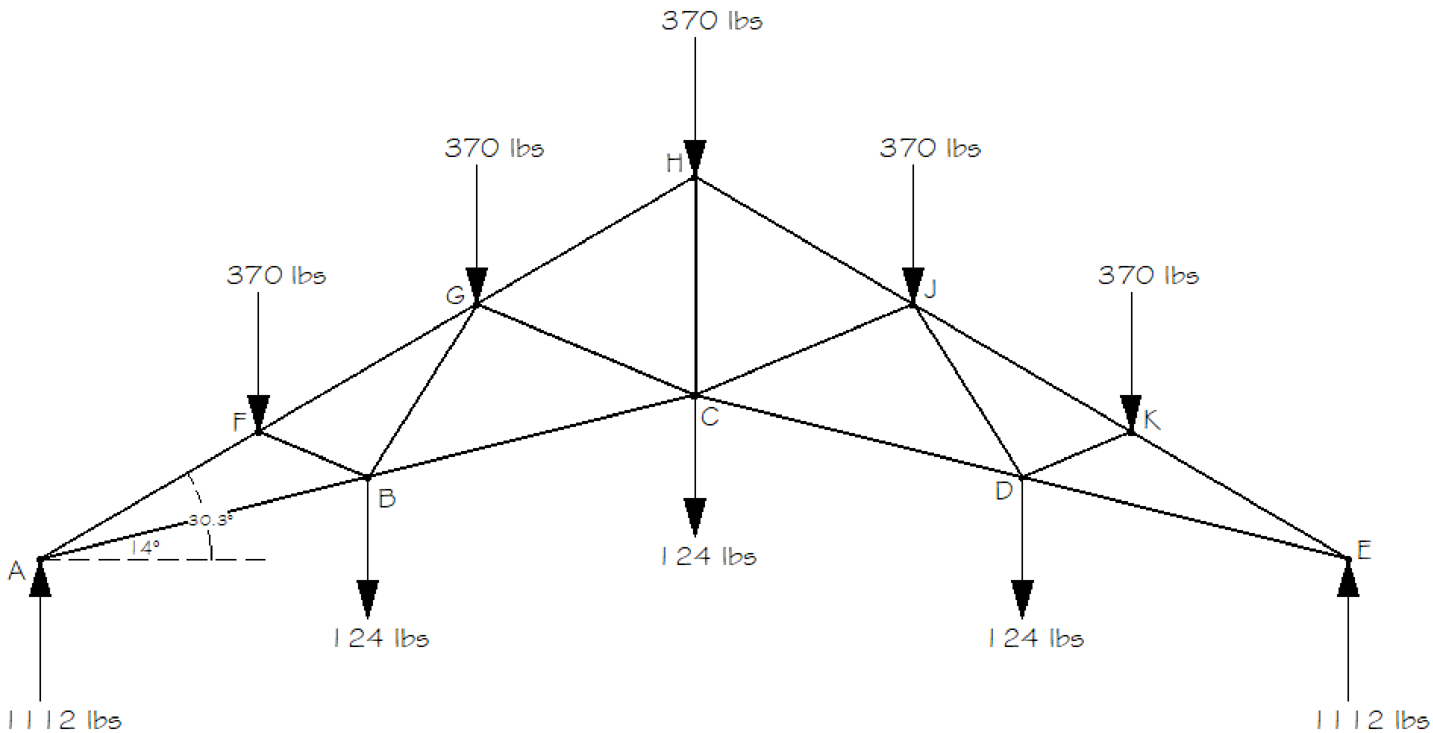
Trusses are then analyzed by looking at each joint and finding the force that each associated member must endure to ensure the joint does not move. The angular nature of the members can be resolved into horizontal and vertical components to simplify the calculations.



Calculating the Forces on the Truss:

Note: (T) = tension force … a force that would stretch a member, thus a member in tension will pull away from a joint, resisting the stretch it is experiencing.

(C) = compression force … a force that would compress a member, thus a member in compression will push into a joint, resisting the compression it is experiencing.



The wall at A exerts a force of 1112 lbs vertically, and a force of 0 lbs horizontally at A, which members AF and AB must work together to counter. Let's assume members AF and AB are pulling away from A in tension.

Vertically:

AF*sin(30.3°) + AB*sin(14°) + 1112 = 0

Horizontally:

AF*cos(30.3°) + AB*cos(14°) = 0

Note: AF ≈ -3844 & AB ≈ 3421 … solving the system of horizontal and vertical linear equations (the negative indicate my assumption of tension in AF was incorrect)

(1) **AF ≈ 3844 lbs (C)**
(2) **AB ≈ 3421 lbs (T)**

AF exerts a force of 1939 lbs vertically, and a force of 3319 lbs horizontally at F, which members FG and FB must work together to counter. Let's assume members FG and FB are pulling away from A in tension.

Vertically:

FG*sin(30.3°) - FB*sin(22.6°) + 1939 – 370 = 0 … 22.6° = 52.9° – 30.3°

Horizontally:

FG*cos(30.3°) + FB*cos(22.6°) + 3319 = 0

Note: FG ≈ -3415 & FB ≈ -401 … solving the system of horizontal and vertical linear equations (the negatives indicate my assumption of tension in AF and FB was incorrect)

(3) **FG ≈ 3415 lbs (C)**
(4) **FB ≈ 401 lbs (C)**

FB exerts a force of -154 lbs vertically, and a force of 370 lbs horizontally at B. AB exerts a force of -828 lbs vertically, and a force of -3319 lbs horizontally at B. Members BG and BC must work together to counter these forces. Let's assume members BG and BC are pulling away from B in tension.

Vertically:

BG*sin(57.7°) + BC*sin(14°) – 154 – 828 – 124 = 0 … 57.7° = 43.7° + 14°

Horizontally:

BG*cos(57.7°) + BC*cos(14°) + 370 - 3319 = 0

Note: BG ≈ 520 & BC ≈ 2753 … solving the system of horizontal and vertical linear equations

(5) **BG ≈ 520 lbs (T)**
(6) **BC ≈ 2753 lbs (T)**

FG exerts a force of 1723 lbs vertically, and a force of 2948 lbs horizontally at G. BG exerts a force of -440 lbs vertically, and a force of -278 lbs horizontally at G. Members GH and GC must work together to counter these forces. Let's assume members GH and GC are pulling away from G in tension.

Vertically:

GH*sin(30.3°) - GC*sin(22.6°) + 1723 – 440 – 370 = 0

Horizontally:

GH*cos(30.3°) + GC*cos(22.6°) + 2948 - 278 = 0

Note: GH ≈ -2343 & GC ≈ -701 … solving the system of horizontal and vertical linear equations (the negatives indicate my assumption of tension in AF and FB was incorrect)

(7) **GH ≈ 2343 lbs (C)**
(8) **GC ≈ 701 lbs (C)**

GH (and thus JH as well based on symmetry) exert forces of 1182 lbs vertically at H. Member HC must counter these forces. Let's assume members HC is pulling away from H in tension.

Vertically:

$2 * 1182 - HC - 370 = 0$

(9) **HC ≈ 1994 lbs (T)**

Note: symmetry of the truss makes the right side unnecessary to calculate

Note: good as a check to ensure the vertical force at C is also zero: $1994 - 2*701*\sin(22.6^{o}) - 2*2753*\sin(14^{o}) - 124 \approx 0$