Static equilibrium problem – a step by step approach:

What are the tensions in each rope $T_1$ and $T_2$

**Step 1:** make a drawing

**Step 2:** mark drawing with symbols for knowns and unknowns and introduce coordinate system *(everything in blue is added to the drawing above at this stage)*
Step 3: Classify the problem

Here you should recognize:
- Nothing moves – means it’s a static problem
- Question is about forces
→ This is a static equilibrium problem

You should know that this means:
- the vector sum of all forces at all points is zero
- therefore the sum of all x- and all y-components of all forces is zero everywhere

The general strategy for such problems is then:

Step 4: Identify the critical points where the forces in the problem act

Typically all the masses (all forces acting on a mass are treated together, even if its multiple strings/rods/etc) and any connection/branching points. Choose only as much points as you need to figure out the asked for forces from the known ones (here, for example, the connection points with the ceiling would tell you about the force of the ceiling but as you don’t know neither that force nor the tension this obviously does not help).
So these are here: (with some justification why one would pick those)
1. Mass m (this is given and obviously determines the tension)
2. The branchpoint A (lets you connect information about mass with $T_1$ and $T_2$)
Step 5: For each critical point
1. Draw a force diagram (critical point is a point)
2. Take advantage of symmetries (sometimes forces are obviously the same so you will have to deal with fewer unknowns)
3. Decompose all forces in x- and y-components
4. Setup the two equations for static equilibrium (no net force):
\[
F_{x1} + F_{x2} + \ldots = 0 \\
F_{y1} + F_{y2} + \ldots = 0
\]
(idea: once you have done this for all the critical points you have enough equations to solve for your unknowns from the known quantities)

So here for mass m:

\[
mg \quad \text{All in y-direction so no decomposition necessary}
\]

Equations
\[
\text{in x: } 0=0 \\
\text{in y: } -mg + T_3=0 \rightarrow T_3=mg \quad \text{Eq 1}
\]
And for point A:

- first realize that due to symmetry $T_1 = T_2$ (if you don’t this will come out of the calculation) so just call the tension in the string $T$
- $T_3$ is already in y-direction, but $T$ must be decomposed into an x and an y component $T_x, T_y$

  to do this find angle in triangle of decomposition and use sin/cos/tan

$$T_y = T \cos(45^0); \quad T_x = T \sin(45^0) \quad \text{Eq 2}$$

- then setup x- and y- equation (use magnitudes and sign according to coordinate system):

  x-components: $T_x - T_x = 0$ \quad Doesn’t help as its always true

  y-components: $T_y + T_y - T_3 = 0 \implies 2T_y = T_3 \quad \text{Eq 3}$
Step 6: Figure out how to combine all the useful equations (here Eq 1-3) to get the unknown from the known – develop a strategy

• Here we got 3 equations.
• Equations 1 and 3 form 2 equations for 2 unknowns $T_y$ and $T_3$ – so this can be solved
• once one has $T_y$ equation 2 gives $T$ which is what we want to figure out

Step 7: Execute the algebra

Combine Eq 1,3 \[ 2T_y = T_3 \Rightarrow 2T_y = mg \Rightarrow T_y = \frac{mg}{2} \]

Then use Eq 2 \[ T = \frac{T_y}{\cos(45^0)} = \frac{mg}{2\cos(45^0)} = \frac{1\text{kg} \times 9.81\text{kg/m/s}^2}{2\cos(45^0)} = 6.9\text{N} \]

Note that this is NOT half the weight but more. The strings not only support the weight but they also pull on each other in x-direction.