Force analysis SiQuENC steps

Neatly and graphically represent **Situation(s)**

1. **Draw** all relevant objects and indicate all requested quantities.
    a. If you would like to watch a video demonstrating what careful reading and drawing looks like, please watch the video near the top of https://davidliao.com.
    b. If you would like to open a guide on your phone that carefully walks you through steps for careful reading (done on occasion as an extremely tedious, slow exercise), you can visit https://davidliao.com/read.php by pointing your phone at the QR code (top-right).
2. **Litmus test:** Step 1 has not been completed until your handmade sketch/notes/tables in combination with any provided illustrations (you can draw directly on a printed illustration in a test) give a complete representation of the problem scenario *so that* were the problem statement text to go missing and had you to redo the problem in 3 weeks, your handmade sketch/notes/tables and any provided illustrations would be enough to allow you to unambiguously understand the problem scenario, including what is requested.

Graphically represent abstracted physical **Quantities**

3. **Bubble:** Draw a dashed bubble enclosing the system.
    a. In problems involving both force analysis and work/energy analysis, it is sometimes helpful to draw different system bubbles for force analysis and work/energy analysis. For example, when there is an object undergoing a height change in a problem scenario, it is often (not a 100% rule) helpful to *exclude* the Earth from the bubble used for force analysis and *include* the Earth in the system for work/energy analysis.
4. **Earth:** Is the Earth nearby?
    a. If the Earth is NOT nearby, skip to step 5 (Touching) below.
    b. If the Earth *is* nearby *and* excluded from the system bubble, then, **for each** massive object in the system other than the Earth, draw a force arrow
        i. Originating from massive object's dot (representing the massive object's center)
        ii. Pointed downward toward the Earth
        iii. Labeled $F_{\mathrm{G,E}\rightarrow\mathrm{OBJECTNAME}}$.
5. **Touching:** Is anything from *outside* the system touching (in contact with) anything *inside* the system. To be extra methodical, you can run your finger along the outline of the dashed bubble to see whether your finger bumps into anything external to the system.
    a. If NOTHING from *outside* the system is touching anything *inside* the system, skip to step 6 (Axis) below.
    b. If at least one object from *outside* the system IS in contact with at least one object *inside* the system, then **for each** contact between an object *outside* the system and an object *inside* the system, draw a force arrow
        i. Consistent with the information in the table of forces in the supplemental handout, "Multiple forces can be applied to an object (AP Physics 1 and 2)."
        ii. Originating from the dot representing the object of interest *inside* the system
        iii. Pointed in the direction of the relevant force applied to the object of interest *inside* the system
        iv. Labeled $F_{\mathrm{TYPE,EXTERNAL\ FORCE\ PROVIDER}\rightarrow\mathrm{OBJECT\ OF\ INTEREST\ IN\ SYSTEM}}$.

6. **Axis:** Draw an axis system.
    a. Technically, you are allowed to draw a Cartesian axis system oriented/tilted however you like, but the algebra and/or analysis tend to be easier when you
        i. Try to orient perpendicular x- and y-axes so that as many forces as possible are parallel with a Cartesian axis (reduces amount of trigonometric functions that appear in the algebra).
        ii. Try to orient the axis system with a positive direction matching the direction of anticipated acceleration (if any) of the system.
        iii. **If the following is unfamiliar, ignore this tip for now:** Try to use, instead of (or in addition to) a Cartesian axis system, a generalized coordinate system (a bendable "snake" axis that hugs a tight string connecting objects in the system).

Identify allowed starting **Equation(s)** and inequalities

7. Set up a force component analysis chart to express Newton's 2nd Law.
    a. In some problems, it is useful to use a column indicating the "snake" component of a force. You can ignore this tip if this tip is unfamiliar. The remainder of this set of steps is written assuming analysis of the "snake" component of a force is not being done.

Table 1: Force-component analysis chart

	Force	F_x	F_y
1			
2			
3			
4			
5			
6			
7	Σ	$\sum F_x = ma_x$ (is $a_x = 0$?)	$\sum F_y = ma_y$ (is $a_y = 0$?)

Analyze

8. In Table 1 above, determine whether either of the acceleration components in row 7 is zero. If so, indicate by slashing through the appropriate acceleration component(s) with an arrow pointing to a label that reads "0".

9. For each force in the free-body diagram drawn using steps 3, 4, 5, and 6 above, fill in a row in Table 1.
    a. The column labeled "Force" is for the algebraic symbol representing the magnitude of each force.
    b. The column labeled "F_x" is for the x-component of each force (format: $\pm$ Variable representing magnitude of force $\text{trig}(\theta)$, where $\text{trig}(\theta)$ is grayed out because sometimes no trigonometric function needs to be explicitly written out). To determine which trigonometric function to use, see the supplemental attachment, "Resolve components for 'slanted' vectors using trigonometry."
10. Write an equation by summing up entries for F_x for the individual forces in Table 1, rows 1-6, and set the sum equal to the ma_x (row 7, possibly already replaced by "0", depending on the problem).
11. Write an equation by summing up entries for F_y for the individual forces in Table 1, rows 1-6, and set the sum equal to the ma_y (row 7, possibly already replaced by "0", depending on the problem).
12. Consider using the table of forces on the supplemental handout, "Multiple forces can be applied to an object (AP Physics 1 and 2)" to replace some of the variables representing magnitudes of forces in the equations written in steps 10 and 11 above with formulas for magnitudes of forces.
13. At this point one or more variables might be possible to solve for by solving one or more equations now written down (it might be necessary to solve a system of simultaneous equations).
14. Make sure to solve for the requested unknowns.

Communicate

15. Express algebraic/numerical answers by boxing statements in the form of Requested variable = expression or maybe Requested variable INEQUALITY expression (please don't just an orphaned algebraic expression or numerical value).
16. Make sure units are included for all numerical results.
17. Make sure every requested quantity is provided.
18. Make sure any question that should be answered in English is answered using standard English.