how to solve Newton's Second Law problems
with two objects connected by a rope

1. Make a **sketch** of the two objects and their surroundings.
2. Write down **what the question is asking for**. If possible, represent what is asked for with a symbol.
3. Show the two objects' directions of motion by **adding velocity vectors to your sketch**.
4. Check that all given units are **SI units**.
5. For symbolic problems, write down **the "given" symbols**.
FREE-BODY DIAGRAMS
6. Identify the two **objects** that you will apply Newton's Second Law to. These will be the objects connected by the rope, and are usually the objects whose mass is mentioned in the problem. Identify the **instant or interval of time** for which you are applying Newton's Second Law to the objects.
7. Start two, separate **Free-Body Diagrams** for the two objects from step 6 by drawing vectors for the two objects' **weights**.
8. Complete the **Free-Body Diagram** for each object by drawing a force vector exerted **by each thing that is *touching* the object**. Each Free-body Diagram should include only the forces exerted *on*, not *by*, the object that you are focusing on for that diagram. A surface may exert *both* a normal force *and* a frictional force.
FORCE TABLES
9. Write down **axes** with **positive directions**. It is OK to choose different axes for the two objects. For each object, it is usually best to choose an axis that points in the object's direction of motion.
10. Start two **Force Tables** for the two objects. For each force from your Free Body Diagrams, write down a number, symbol, or expression to represent **the magnitude of the overall vector**. For a massless rope stretched over a massless, frictionless pulley, *the magnitude of the tension force is the same at both ends of the* rope, although the direction of the tension force may be different at the two ends of the rope.
11. Complete the **Force Table** by breaking each force into **components**. Always include a "+" or "-" sign on each nonzero component.
NEWTON'S SECOND LAW EQUATIONS
12. Write the **Newton's Second Law equations** for the two objects at the top of adjacent columns. Keep your later versions of the Newton's Second Law equations organized in these columns. If an object experiences no forces in a component, it is usually not necessary to write the Newton's Second Law equation for that component for that object.
13. On the left sides of the Newton's Second Law equations, **add all the individual force components,** including any negative signs, using the components from the Force Table. On the right sides of the Newton's Second Law equations, when possible, substitute specific values or symbols for the objects' **masses** and for the objects' **acceleration components**. *The magnitude of the acceleration will be the same* for two objects connected by an unstretchable rope, although the directions of the accelerations may be different for the two objects. If an object is motionless in a component, or if an object moves with constant velocity in a component, then that component of the object's acceleration is 0.
14. **Use algebra to solve** the Newton's Second Law equations for the unknowns.
15. **Check** that you answered the right question, and that you answered all parts of the question. **Check** that your answer makes sense. For numerical answers, **check** that you included units. For symbolic answers, **check** that your answer includes only the "given" symbols.

how to solve Newton’s Second Law problems
with two objects in contact with each other

1. Make a **sketch** of the two objects and their surroundings.
2. Write down **what the question is asking for**. If possible, represent what is asked for with a symbol.
3. Show the objects’ direction of motion by **adding a velocity vector to your sketch**.
4. Check that all given units are **SI units**.
5. For symbolic problems, write down **the “given” symbols**.
FREE-BODY DIAGRAMS
6. Identify the **objects** that you will apply Newton’s Second Law to. The usual candidates are the two “individual” objects whose mass is mentioned in the problem, and a “combined” object that consists of *both* of those objects. Usually the best approach is to focus on the combined object, and *one* of the individual objects. Identify the **instant or interval of time** for which you are applying Newton’s Second Law to the objects.
7. Start a separate **Free-Body Diagram** for each of the objects you chose to focus on in step 6 by drawing a vector for each object’s **weight**.
8. Complete the **Free-Body Diagram** for each object by drawing a force vector exerted **by each thing that is *touching* the object**. Each Free-body Diagram should include only the forces exerted *on*, not *by*, the object that you are focusing on for that diagram. A surface may exert *both* a normal force *and* a frictional force. Usually, we will treat the boundary between the two individual objects as a “surface”. If so, each individual object will exert a normal force, and, possibly, a friction force, on the other individual object. Because of Newton’s Third Law, these two normal forces will point opposite to each other, as will the two friction forces if they exist.
FORCE TABLES
9. Write down **axes** with **positive directions**. It is usually best to choose an axis that points in the objects’ direction of motion.
10. Complete a **Force Table** for each object you chose to focus on in step 6. Because of Newton’s Third Law, the normal forces exerted by each individual object on the other individual object will have the same magnitudes, as will the friction forces between the two individual objects if they exist. Always include a “+” or “-” sign on each nonzero component.
NEWTON’S SECOND LAW EQUATIONS
11. Write the **Newton’s Second Law equations** for the objects you chose to focus on in step 6, at the top of adjacent columns. Substitute appropriately into the equations. If the two individual objects remain in contact with each other, while moving in a straight line without sliding relative to each other, then *the two individual objects, and the combined object, will all have the same magnitude and direction of acceleration*. If an object is motionless in a component, or if an object moves with constant velocity in a component, then that component of the object’s acceleration is 0.
12. **Use algebra to solve** the Newton’s Second Law equations for the unknowns.
13. **Check** that you answered the right question, and that you answered all parts of the question. **Check** that your answer makes sense. For numerical answers, **check** that you included units. For symbolic answers, **check** that your answer includes only the “given” symbols.