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.
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. 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 Tables. On the right sides of the equations, substitute for the objects' **masses** and **acceleration components**. For two objects moving in straight lines and connected by an unstretchable rope, *if you choose a positive direction for each object that points in the direction of motion for that object*, then the acceleration component in the component of motion for one object will equal the acceleration component in the component of motion for the other object. 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 results 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 "individual" objects are usually the two objects whose mass is mentioned in the problem. If the two individual objects remain in contact, without sliding relative to each other, then it's useful to apply Newton's Second Law to a "combined" object that consists of *both* of the individual objects. In that case, it's usually best to focus on the combined object, and on *one* of the individual 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. The Free-body diagram for the "combined" object should include only the "external" forces exerted on the combined object; this diagram should not include any "internal" force exerted by one *part* of the combined object on another *part* of the combined object. A surface may exert *both* a normal force *and* a frictional force. Usually, 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**. 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. If you are drawing Force Tables for *both* of the "*individual*" objects, you will need to use 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 individual objects remain in contact with each other, while moving in a straight line without sliding relative to each other, then *the 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 results makes sense. For numerical answers, **check** that you included units. For symbolic answers, **check** that your answer includes only the "given" symbols.