SPH4U: Strings and Composite Objects

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How to strings do their thing? Let's find out!

A: String Theory

You need three identical spring scales. Connect all three spring scales into a chain. Each scale represents a piece of "string material" and the spring connections (hooks) represent the forces that act between the pieces of string material.

1. **Observe.** Hold on to each end of the chain of scales and stretch them horizontally along your table. How do the readings of each scale compare? What happens to the readings when you pull harder?

   When we pull on the ends of the chain, we notice that the readings are about the same. When we pull harder, they all increase by about the same amount.

2. **Reason.** Is it possible to have tension in the string (your chain of scales) by pulling on only one end?

   Yes it is possible to have tension in the spring because when we pulled on one end, there was a reading on the scale.

3. **Reason.** Your hands are pulling on each end of the string and the ends of the string are pulling on your hands (what law was that?). How hard does each end of the string pull on your hands?

   This would be Newton's 3rd law. The end of the string pulls the same amount that your hands pull on the string.

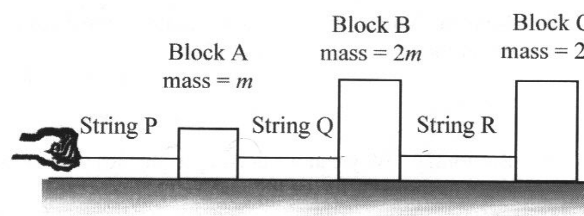
> **Physics String** has a few special properties: (1) it is massless, (2) it does not stretch, and (3) it exerts equal and opposite forces on the objects it connects. Consequently, we can think of a string as producing a single tension interaction, between the two connected objects, an interaction which obeys Newton's 3rd law.

B: Composite Objects

Most objects are made up of millions of smaller parts, all interacting together. With so many interactions, why can we actually do simple physics and not get bogged down? Consider the situation shown below. Three blocks are connected by strings and pulled along a frictionless table by a steady force from your hand. The masses of the blocks are indicated.

1. **Reason.** How does the motion of blocks A, B, and C compare?

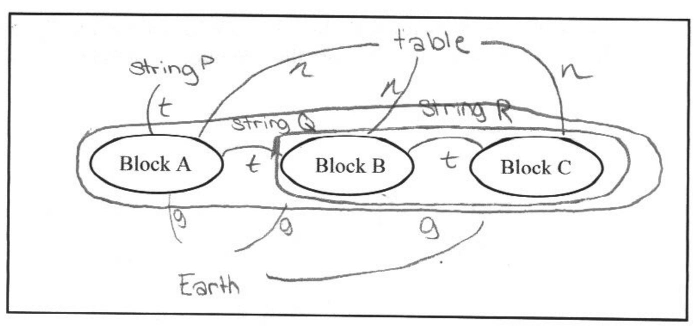
   The motion of blocks A, B, and C would be the same

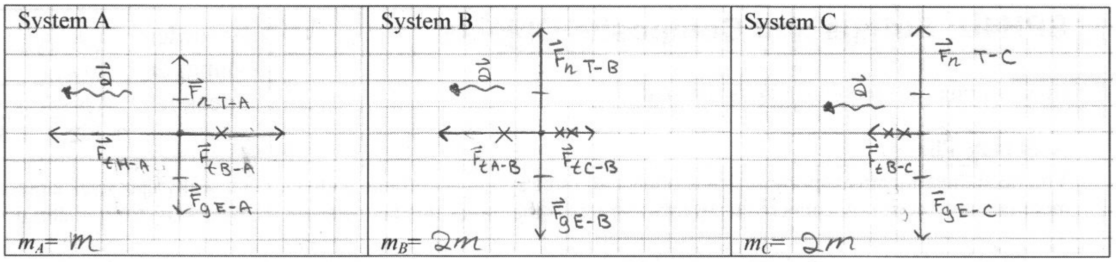


> A *composite object* is any object whose parts all move together with the same acceleration.

2. **Represent.** We will start by considering each block as a separate system (systems A, B and C). Complete the interaction diagram for the three blocks.

3. **Represent.** Draw a separate FD for each of systems A, B, and C. Don't forget to: use the 3rd law notation, draw an acceleration vector, and draw the vector lengths carefully!(next page!)

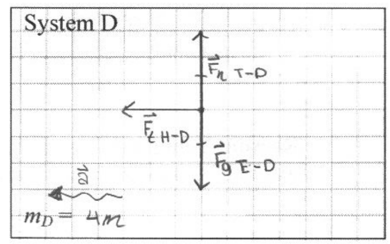




4. **Reason.** Rank in increasing size the magnitudes of the *net forces* on systems A, B, and C. Explain.

The rank is B, C, and A. B and C should have the same net force since they have the same acceleration. A should have a smaller net force since it has a smaller mass

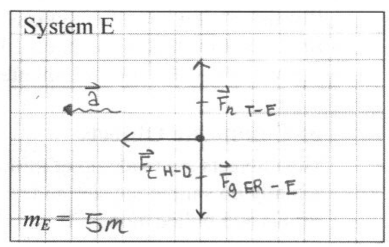
5. **Represent and Explain.** Use a new colour to draw a new system boundary (circle) in the interaction diagram consisting of blocks B and C together. Use the words "internal" and "external" to help explain how to use the interaction diagram to decide which forces should appear on a new force diagram for the new system, which we will call system D.



Internal: String R
↳ F_t B-C
F_t C-B

External: Earth ↳ F_g E-D; table ↳ F_n T-D; String Q ↳ F_t H-D

6. **Represent.** Use another colour to draw another new system in the interaction diagram consisting of blocks A, B and C together. Draw the force diagram for system E. Indicate the mass of the system.



7. **Reason.** How does the acceleration of system D and E compare with that of A, B, and C? Explain.

The acceleration of all these systems would be the same. The difference is that the forces would be different

8. **Reason.** Which system has the simplestforce diagram for the purpose of finding the force of tension in string P? What about for string Q? for string R?

System E has the simplest force diagram for finding the force of tension is string P. System D for string Q & system C for String R

9. **Summary.** Why can we do simple physics with complex objects that are made up of many, many parts? (Why aren't there millions of forces on our FDs?)

It's because we only show the external forces on our FDs. The internal forces are not shown.

10. **Solve.** Consider a situation where m = 1.0 kg and the hand exerts a force of 15 N. Find the magnitude of the other tension forces. (Tip: Always make sure that the mass used in the 2nd law is the mass of the system you are analyzing!)

$F_{net\,x} = ma_x$

$a_x = \frac{F_{net\,x}}{m} = \frac{15}{5\,kg} = 3\,m/s^2$

$F_{net\,x} = ma_x$

$F_{t\,H\text{-}A} - F_{t\,B\text{-}A} = ma_x$

$F_{t\,B\text{-}A} = 15N - 1kg(3m/s^2) = 12N$

$\because F_{t\,B\text{-}A} = F_{t\,A\text{-}B}$,

$F_{t\,A\text{-}B} = 12N$

$F_{t\,A\text{-}B} - F_{t\,C\text{-}B} = ma_x$

$F_{t\,C\text{-}B} = 12N - 2kg(3m/s^2) = 6N$

$\because F_{t\,C\text{-}B} = F_{t\,B\text{-}C}$,

$F_{t\,B\text{-}C} = 6N$