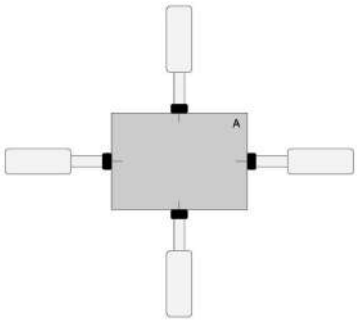
Investigations A&B Key

Part 1: Data Collection / Observations

1. For each investigation, place the 4 spring scales provided to your group so they are pushing on the foam at the locations indicated by the arrows.
2. For each condition, increase or decrease the magnitude of the forces pushing on the foam, and record the force measurements when the system is stable (when the foam is not moving and nobody is touching it).

Investigation	Results for each condition you tested
A 	For both investigations, look for students to record different force combinations acting on the object. **What to do:** Make sure students are following the calibration protocols. If the recorded forces acting on the same axis are not similar, ask students to show you how they are calibrating their setup. Provide suggestions for how to improve data accuracy.
B 	

Part 2: Data Analysis (Complete only *after* you have finished Part 1.)

1. How do the forces pushing on an object compare when it remains "stable"?

These are some possible answers students can provide to this question, and possible instructional moves to support their sensemaking:

- The forces are all different.

What to do: Suggest that students revise their calibration protocol and collect additional data.

- The forces are exactly the same.

What to do: Suggest that students compare their results with the results from other group(s).

- The forces are close in magnitude.

What to do: Encourage students to consider the factors causing variation in their data, and to think about the results they would obtain if these factors were removed.

2. How did you decide that you had tested enough conditions for either investigation (A or B)?

These are some possible answers students can provide to this question, based on their level of sophistication:

- We carried out three measurements, because three is enough.

What to do: This suggests that students are merely following a rule of thumb, rather than assessing the variability in their data. Encourage them to assess whether there is variation in their results, and to consider the factors that might be causing it. Ask them what they could do to reduce any large variation observed in the results.

- We did three measurements, because having more data provides more accurate results.

What to do: Although this answer suggests that students are making connections between data collection and data accuracy, they are not actually assessing the accuracy based on their actual results. Use the following prompts to encourage them to go a step further:

  - **To reflect on variation:** *Think about the differences you observed in your measurements. Why might these variations have occurred?*
  - **To consider factors affecting accuracy:** *What factors could contribute to the variability in your data? Are there any variables that might affect the force measurements you are getting?*
  - **To explore sources of error:** *Can you identify any sources of error that might have influenced the differences in your measurements? How might these errors affect your overall findings?*

- We saw that the results were not exactly the same, but the forces we obtained were very close every time.

What to do: This answer suggests students are looking at the variation in their data to inform their data collection. Suggest that they compare and contrast their results with their peers by saying: *Compare your results with those of your classmates. Are there differences between your data? What could explain these differences? If not, what does our data suggest about the magnitude of the forces acting on a stationary object?*

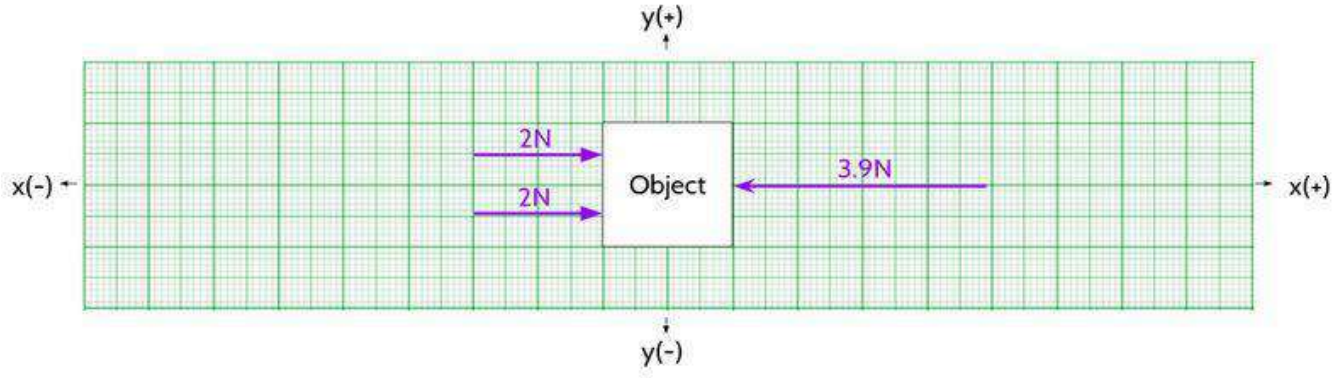
Part 3: Use a Model

Create a free-body diagram to represent a stationary object with 3 contact forces acting on it in the horizontal direction (along the *x-axis*).

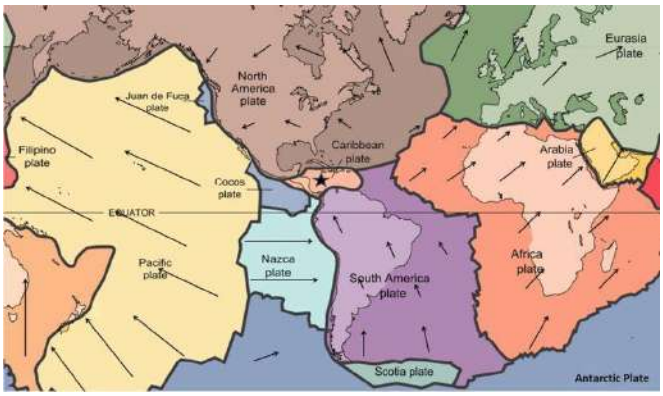
Answers to this question will vary. If the forces acting on the object are not balanced, ask students some of the following prompts:

- *Can you tell me more about why you think the forces acting on this object will not make it move?*
- *What would be the net force acting on this object? Does that mean it would remain stable, or change its motion?*

This is a sample response. Look for students to record the results they actually observe. Given the accuracy of the spring scales they use, it is very likely that the recorded net force will be slightly different from zero.



Then review the *GPS Plate Map*. Evaluate whether your free-body diagram is a reasonable model for explaining why the Caribbean plate (marked with a ★) might appear to be stable (not moving) relative to other plates. Why or why not?



These are some possible answers:

- No, the free-body diagram does not help explain why the Caribbean plate is not moving. The object does not move because the forces acting on it are balanced, but the map shows that other plates, like the South American plate, are actually pushing the Caribbean plate, so it should be moving north.
- No, the Caribbean plate is not moving, because the GPS map does not show any velocity arrows on it.

What to do: For students to understand that Earth systems are dynamic and interacting, it is important that they consider how one component of the system interacts with other components. If students suggest that the Caribbean plate is not moving because there are no GPS motion arrows drawn on it, suggest that they consider whether other plates are exerting forces on it, and whether those forces seem to be balanced or unbalanced.