**Unit 4 - Activity 4**

**Pairs of Forces Stations**

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In the set of activities that follows, you will be asked to think about situations in which two objects interact. You should, in each case, think about the magnitude (amount) and direction of the forces that each object exerts on the other. You will be asked to make a prediction about the relative magnitudes of the forces each object exerts or experiences. For instance, if the situation involves two cars colliding, you might say that the force exerted on the small car by the large car is greater than the force exerted on the large car by the small car. Alternative possibilities are that the force on the small car by the large car is less than the force on large car by the small car. A third possibility is that the large car exerts the same force on the small car as the small car exerts on the large car. A convenient way to express such ideas is in the form of an inequality or an equation, using the agent-object notation that we have been using in our force diagrams. If the symbol L represents the large car and the symbol S represents the small car, the three possible predictions listed above could be represented as follows: FA by S on L > FA by L on S, FA by S on L < FA by L on S, or FA by S on L = FA by L on S. It is also possible that your answer depends on some condition. Predict what you think in each case, stating any required conditions for your prediction. For each station record a table of values for the forces measured by the spring scales.

At each station, it is important that you understand that each of the objects involved in the interaction is a system. Each object will have a spring scale connected to it. The spring scale will indicate the force experienced by the object to which it is connected. If the spring scale is connected to object A, and a force is exerted on object A by object B, the reading of that spring scale is the force on object A by object B. Remember, the systems are the objects to which the spring scales are connected, not the spring scales themselves.

Another important experimental note is that the spring scales are only able to read forces in one dimension. Make sure that the spring scales are pulling on one another in a straight line along the axis of the spring scale. It is also important to check the calibration of the spring scales often.

For a selected interaction at each station, you will draw a physical diagram of the situation. You should also draw two force diagrams; one for each object involved in the interaction. It is critical that you draw the arrows in your two force diagrams with the same spring scale in mind. It is equally important that you properly label each force diagram using the agent-object notation.

While you are performing each of the activities, you should be looking for an underlying “Big Idea” that ties the various activities together.

**Station 1 - Students Pulling on Each Other**

At this station, you and your partner will each hold a spring scale. For each situation described below, predict how the force student A exerts on student B will compare to the force student B exerts on student A. You will then perform the action described and compare the actual result to your prediction. Apply several different magnitudes of force for each situation and collect a table of values for the forces measured by each spring scale. Assume that the spring scale held by student A indicates the force exerted on student A by student B and the spring scale held by student B indicates the force exerted on student B by student A.

Student B

Student A

Force Diagrams

Physical Diagram

Your predictions can take the form of

FA on B > FB on A, FA on B < FB on A, FA on B = FB on A,

or some other description if you prefer.

Explain the reasoning behind your prediction and any conditions which are necessary for your prediction.

Include a physical diagram and a force diagram for situation **3** in the space to the right.

|  |  |
| --- | --- |
| FA on B (N) | FB on A (N) |
|  |  |

1. With a rubber band connecting the hooks on the spring scales, student A should pull on student B while student B passively holds the spring scale.

**Prediction:**

**Result:**

2. Using the same setup, student B should pull on student A while student A passively holds the spring scale.

**Prediction:**

|  |  |
| --- | --- |
| FA on B (N) | FB on A (N) |
|  |  |

**Result:**

**3.** Both students should pull on each other.

**Prediction:**

|  |  |
| --- | --- |
| FA on B (N) | FB on A (N) |
|  |  |

**Result:**

**Station 2 - Cars Towing Each Other on a Level Road**

Consider two cars, one of which is three times as massive as the other. In each situation, one of the cars should be thought of as being in neutral with the engine off. The second car should be considered to have the engine running and will tow the first. This situation will be modeled by having wooden blocks with different masses, and your hand will be the engine for the car that is doing the towing. For each situation described below, predict how you think the force the large car exerts on the small car will compare to the force the small car exerts on the large car. You will then perform the action described and compare the actual result to your prediction. Apply several different magnitudes of force for each situation and collect a table of values for the forces measured by each spring scale. Assume that the force attached to the large car indicates the force experienced by the large car, and the spring scale connected to the small car indicated the force experienced by the small car.

Your predictions can take the form of

FL on S > FS on L, FL on S < FS on L, FL on S = FS on L,

Large Car

Small Car

Force Diagrams

Physical Diagram

or some other description if you prefer.

Explain the reasoning behind your prediction and any conditions which are necessary for your prediction.

Include a physical diagram and a force diagram for situation **1** in the space to the right.

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**1.** Large car tows small car at constant speed.

**Prediction:**

**Result:**

2. Large car tows small car while speeding up.

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**Prediction:**

**Result:**

3. Small car tows big car at constant speed.

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**Prediction:**

**Result:**

4. Small car tows big car while speeding up.

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**Prediction:**

**Result:**

**Station 3 - Cars Towing Each Other on a Hill**

Consider two cars, one of which is three times as massive as the other. In each situation, one of the cars should be thought of as being in neutral with the engine off. The second car should be considered to have the engine running and will tow the first. This situation will be modeled by having wooden blocks with different masses, and your hand will be the engine for the car that is doing the towing. For each situation described below, predict how you think the force the large car exerts on the small car will compare to the force the small car exerts on the large car. You will then perform the action described and compare the actual result to your prediction. Apply several different magnitudes of force for each situation and collect a table of values for the forces measured by each spring scale. Assume that the force attached to the large car indicates the force experienced by the large car, and the spring scale connected to the small car indicated the force experienced by the small car.

Large Car

Small Car

Force Diagrams

Physical Diagram

Your predictions can take the form of

FL on S > FS on L, FL on S < FS on L, FL on S = FS on L,

or some other description if you prefer.

Explain the reasoning behind your prediction and any conditions which are necessary for your prediction.

Include a physical diagram and a force diagram for situation **3** in the space to the right.

1. Small car tows large car up the hill at constant speed.

**Prediction:**

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**Result:**

2. Large car tows small car up the hill at constant speed.

**Prediction:**

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**Result:**

**3.** Small car tows large car up the hill at increasing speed.

**Prediction:**

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**Result:**

4. Large car tows small car up the hill at increasing speed.

**Prediction:**

|  |  |
| --- | --- |
| FS on L (N) | FL on S (N) |
|  |  |

**Result:**

**Station 4 - Forces on Carts**

Consider two students on low friction carts able to push on each other. Consider the force that each student exerts on the other during the interaction. What motion results in each case? Does the force depend on the mass of the students? Does the motion depend on the mass of the students? For each situation described below, predict how the force student A exerts on student B will compare to the force student B exerts on student A. You will then perform the action described and compare the actual result to your prediction.

Cart B

Cart A

Force Diagrams

Physical Diagram

Your predictions can take the form of

FA on B > FB on A, FA on B < FB on A, FA on B = FB on A,

or some other description if you prefer.

Explain the reasoning behind your prediction and any conditions which are necessary for your prediction.

Include a physical diagram and a force diagram for situation **3** in the space to the right.

1. Student A sits on a cart. Student B sits on a cart. Student A should push on student B while student B sits passively (does not push). How do the forces compare? What motion do you expect for each student? What motion actually occurs?

**Prediction:**

**Result:**

2. Student A sits on a cart. Student B sits on a cart. Student B should push on student A while student A sits passively. How do the forces compare? What motion do you expect for each student? What motion actually occurs?

**Prediction:**

**Result:**

**3.** Both students should push on each other. How does the force exerted on student A by student B compare to the force exerted on student B by student A? Does your answer depend on the mass of each student? What motion do you expect for each student? What motion actually occurs?

**Prediction:**

**Result:**

**Station 5 - Forces on Carts 2**

Consider two students, one on a low friction cart and another standing on the ground. Consider the force that each student exerts on the other during the interaction. Does the force depend on the mass of the students? For each situation described below, predict how the force student A exerts on student B will compare to the force student B exerts on student A. You will then perform the action described and compare the actual result to your prediction.

Cart B

Cart A

Force Diagrams

Physical Diagram

Your predictions can take the form of

FA on B > FB on A, FA on B < FB on A, FA on B = FA on B,

or some other description if you prefer.

Explain the reasoning behind your prediction and any conditions which are necessary for your prediction. Include a force diagram for each of the students in each situation.

Include a physical diagram and a force diagram for situation **3** in the space to the right.

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1. Student A sits on a cart. Student B stands on the ground. Student B should push on student A student A sits passively (does not push). A third student prevents the cart from moving. How do the forces compare?

**Prediction:**

**Result:**

2. Student A sits on a cart. Student B stands on the ground. Student B should push on student A so that the cart moves at a constant speed. How do the forces compare?

**Prediction:**

**Result:**

**3.** Student A sits on a cart. Student B stands on the ground. Student B should push on student A so that the cart moves at an increasing speed. How do the forces compare?

**Prediction:**

**Result:**

4. Student A sits on a moving cart. Student B stands on the ground. Student B should push on student A so that the cart moves at a decreasing speed. How do the forces compare?

**Prediction:**

**Result:**