

Seesaws 1

# Seesaws

Turn off all electronic devices

Seesaws 2

## Observations about Seesaws

A balanced seesaw rocks back and forth easily  
Equal-weight children sitting on the seats balance a seesaw  
Unequal-weight children don't normally balance the seesaw  
Moving the heavier child toward the pivot restores the balance  
Moving both children closer to the pivot speeds up the motion

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## 6 Questions about Seesaws

1. How does a balanced seesaw move?
2. Why does a seesaw need a pivot?
3. Why does a lone seesaw rider plummet to the ground?
4. Why do the riders' weights and positions affect the seesaw's motion?
5. Why do the riders' distances from the pivot affect the seesaw's responsiveness?
6. How do the seesaw's riders affect one another?

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## Question 1

Q: How does a balanced seesaw move?

A: It moves at a constant rotational speed about a fixed axis in space  
...because the seesaw has rotational inertia!

Three important vector Physical Quantities of Rotational Motion:

1. Angular Position – object's orientation in space  
A vector consisting of an angle and a rotation axis, relative to a reference
2. Angular Velocity – rate at which object's angular position is changing  
A vector consisting of an angular speed and a rotation axis
3. Torque – the amount and direction axis of a twist or spin  
Net torque is the vector sum of all torques on an object

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## Newton's First Law of Rotational Motion

A rigid object that's not wobbling and that is free of outside torques (or is subject to zero net torque) rotates at constant angular velocity.

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## Question 2

Q: Why does a seesaw need a pivot?

A: To prevent translational motion (i.e., falling)

The pivot is placed at the seesaw's natural pivot, its center of mass

The pivot allows rotational motion, but not translation motion

- Translational motion is a change in position
- Rotational motion is a change in angular position

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### Question 3

Q: Why does a lone seesaw rider plummet to the ground?  
A: That rider's weight twists the seesaw and thereby alters its motion

The weight of a lone rider produces a torque on the seesaw

$$\text{torque} = \text{lever arm} \cdot \text{force}_{\text{perp}}$$

(where the lever arm is a vector from the pivot to the location of the force)

That torque causes the seesaw to experience angular acceleration

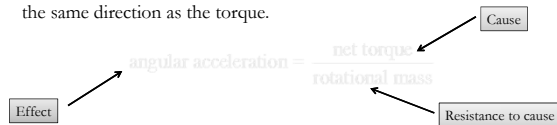
Two more important Physical Quantities of Rotational Motion:

4. Angular Acceleration – rate at which object's angular velocity is changing  
A vector consisting of an rate and a direction axis
5. Rotational Mass – measure of rotational inertia

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### Newton's Second Law of Rotational Motion

An object's angular acceleration is equal to the net torque exerted on it divided by its rotational mass. The angular acceleration is in the same direction as the torque.



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### Question 4

Q: Why do the riders' weights and positions affect the seesaw's motion?

A: To balance the seesaw, their torques on it must sum to zero.

Adding a second rider adds a second torque

- The two torques act in opposite directions
- The seesaw is balanced if it experiences zero net torque due to gravity

Since a rider's torque is their weight times their lever arm,

- a heavier rider should sit closer to the pivot
- a lighter rider should sit farther from the pivot

To cause angular acceleration, a rider leans or touches the ground

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### Question 5

Q: Why do the riders' distances from the pivot affect the seesaw's responsiveness?

A: Moving the riders toward the pivot reduces the seesaw's rotational mass more than it reduces the gravitational torque on the seesaw

Lever arm is a vector from the pivot to the rider

- Gravitation torque is proportional to lever arm
- Rotational mass is proportional to lever arm<sup>2</sup>
- Angular acceleration is proportional to 1/lever arm

Moving the riders toward the pivot increases angular acceleration

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### Question 6

Q: How do the seesaw's riders affect one another?  
A: They exert torques on one another and also exchange energy.

Each rider experiences two torques about pivot:

- A gravitational torque produced by that rider's weight
- A torque exert by the other rider

For a balanced seesaw, the torques on each rider sum to zero

The riders exert equal but opposite torques on one another

Newton's third law of rotational motion

For every torque that one object exerts on a second, there is an equal but oppositely directed torque that the second object exerts on the first.

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### Summary about Seesaws

- A balanced seesaw experiences zero net torque
- A balanced seesaw has a constant angular velocity
- A non-zero net torque causes angular acceleration of the seesaw
- Heavier riders need smaller lever arms
- Lighter riders need larger lever arms