ROTATIONAL EQUILIBRIUM

Force, lever arm, torque, and balance

Name: _____	Period: _____	Date: _____

INVESTIGATION QUESTION **How do mass and distance from a pivot determine rotational equilibrium?**

TIME 30 minutes	SIMULATION BuildPhysics > Rotational equilibrium	UNIT 5 Torque & Rotational Dynamics

Learning targets

- Calculate clockwise and counterclockwise torques about a pivot.
- Determine the balancing position for different masses.
- Distinguish zero net torque from zero individual torque.

Model before you measure

Choose the pivot as the torque axis. The riders' weights act downward at different lever arms.	$\tau = rF\sin\theta$ $\quad \Sigma\tau = 0$ $\quad m_1gr_1 = m_2gr_2$

Important: Use $g = 9.8\ m/s^2$. Measure each horizontal distance from the pivot to the rider's center of mass.

Pre-lab prediction | 4 minutes

1. If one rider moves twice as far from the pivot, how must that rider's mass change to keep balance?

2. Can the beam be balanced while both riders exert nonzero torques? Explain.

3. Predict the rotation direction if clockwise torque is greater than counterclockwise torque.

PART A Find the balancing position

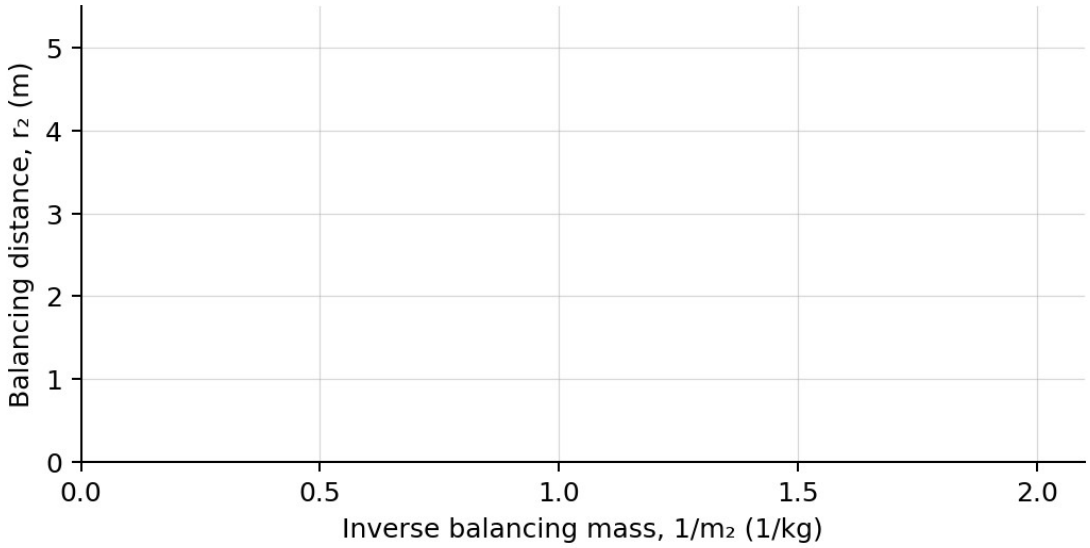
Setup | 3 minutes

- ☐ Load Rotational equilibrium. Pause the simulation and record the left rider's mass and distance from the pivot.
- ☐ Keep the left rider fixed. Change the right rider's mass to each listed value.
- ☐ Move the right rider until the beam remains level with negligible angular acceleration.
- ☐ Record the balancing distance and calculate both torque magnitudes using g = 9.8 m/s².

Balance criterion: The beam is in rotational equilibrium when it remains level and the clockwise and counterclockwise torque magnitudes are equal.

Data table | 10 minutes

Right mass m_2 (kg)	$1/m_2$ (1/kg)	Balance distance r_2 (m)	Left torque (N·m)	Right torque (N·m)	Net torque (N·m)
0.50					
0.75					
1.00					
1.50					
2.00					



4. Plot balancing distance r_2 versus $1/m_2$. Draw a best-fit line.

PART B Create controlled torque imbalances

Torque-direction test | 7 minutes

Procedure: Begin from one balanced trial. Move only the right rider by the listed amount, reset, and record the initial angular acceleration.

Right-rider position	Net torque direction	Initial α (rad/s²)	Observed rotation
0.50 m closer			
0.25 m closer			
Balanced position			
0.25 m farther			
0.50 m farther			

Analysis | 7 minutes

5. What physical quantity should the slope of the r_2-versus-$1/m_2$ graph represent?

6. How closely did the two torque magnitudes agree in balanced trials?

7. How did the sign of net torque relate to the sign of angular acceleration?

8. Explain why equal downward forces do not necessarily produce equal torques.

Claim-Evidence-Reasoning conclusion

Evaluate this claim: A beam is balanced whenever the forces on the two sides are equal.

CLAIM	Accept, reject, or revise the statement.
EVIDENCE	Cite at least two measured trials or graph features.
REASONING	Use lever arms, torque direction, and the rotational-equilibrium condition.

Exit ticket

A 60 kg rider sits 2.0 m left of a pivot. Where should a 40 kg rider sit on the right to balance the beam?