How to Make a Ball Orbit Itself

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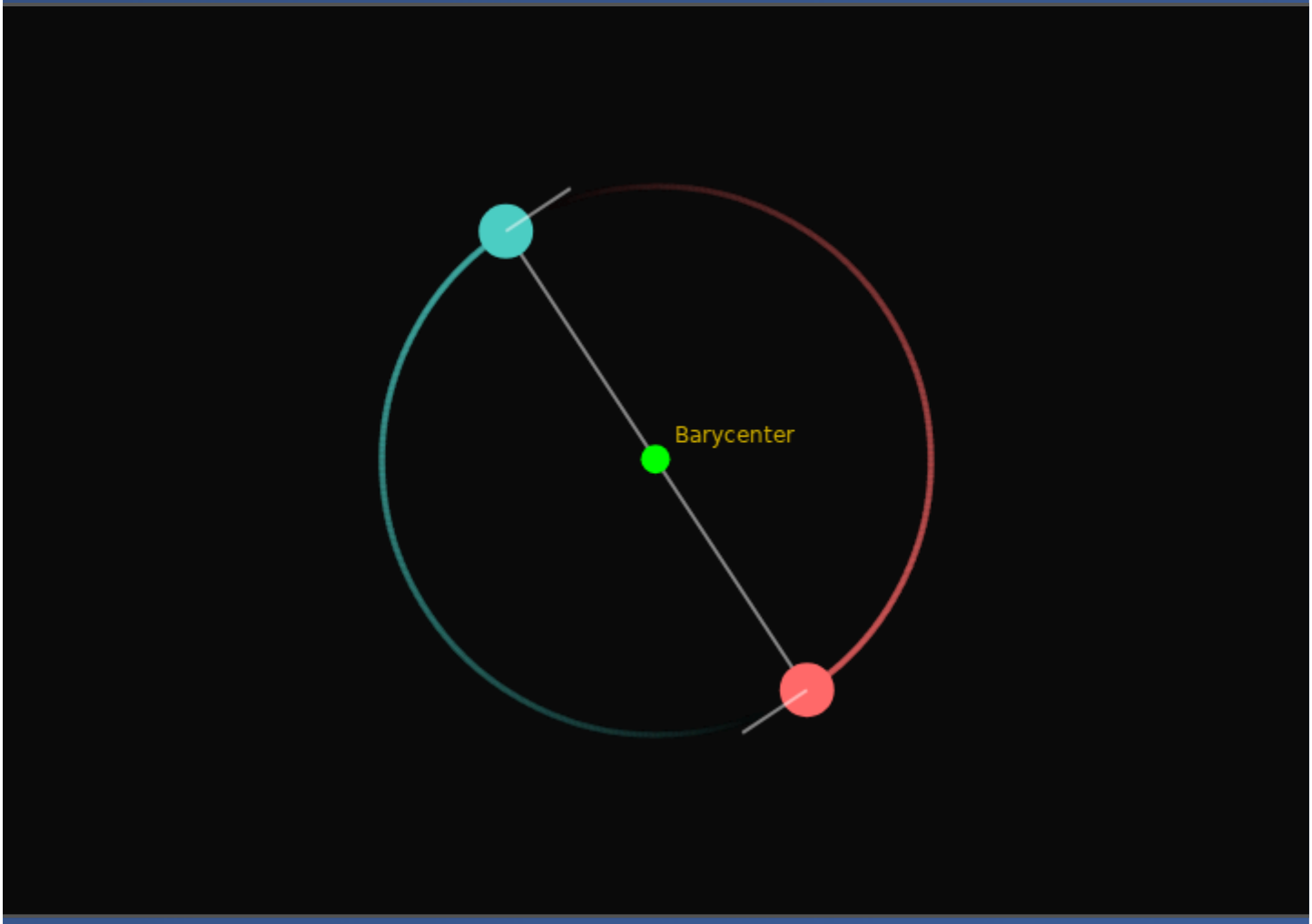
A Force Exchange Theory of Rotation That Unifies Circular and Linear Motion

How to Make a Ball Orbit Itself

A Momentum Exchange Theory of Rotation



Two Balls (Original) | Cut String (Light Pin) | Cut String (Massive Pin)

Cut String (Fixed Pin) | Cut String (Zero Mass Pin) | Three Balls

Cut String (Equal Mass Pin) | Pause/Resume | Reset

Animation Speed: 1x

Tip: Click and drag to pan • Scroll to zoom in/out

Core Concept

Consider a simplified spinning top consisting of:

- A central pin (needle)
- Two balls of mass m at distance R from the pin
- A string of length 2R connecting the balls

The Key Insight: The string provides tension that creates the centripetal force needed for circular motion. We can understand this system by examining how forces are exchanged between the two bodies through the pin, and what happens when we remove one of the balls.

The Force Exchange and the Universal Principle

When the system rotates at angular velocity ω:

1. Each ball experiences centripetal acceleration toward the barycenter
2. This acceleration requires a centripetal force
3. **The Beautiful Symmetry of Force Exchange**:
    - Ball 1 pulls on the string with force F_1
    - Ball 2 pulls on the string with equal force F_2 (in opposite direction)
    - The string acts as a conduit for force exchange between the two balls
    - These forces exchange through the pin (action-reaction pairs)
    - Net force on pin: zero (forces perfectly exchanged)

The balancing of forces IS the mechanism of force exchange—each body provides the centripetal force the other needs to orbit the barycenter.

The Universal Principle: In any two-body system, regardless of masses, both bodies orbit their common barycenter (center of mass). The barycenter location is determined by the mass ratio. What changes between configurations is not whether they orbit, but *where* the barycenter is located.

The Critical Test: Cutting One Ball Free

What happens when we cut Ball 2 free mid-rotation?

Case 1: Light Pin (Original Configuration)

- Ball 1 still needs to exchange forces with something to orbit the barycenter
- No Ball 2 to exchange forces with
- Pin cannot exchange sufficient force (too light)
- **Result**: Pin topples over

Case 2: Massive Pin

- Ball 1 now forms a two-body system with the pin

- The massive pin can exchange forces with the ball
- **Barycenter is near the pin** (but not exactly at it)
- **Result**: Both ball and pin orbit their shared barycenter, exchanging forces through the string (like a twin star system)

Case 3: Infinite Mass Pin (Nailed to Desk)

- Pin exchanges force with the ball without moving
- **Barycenter is exactly at the pin's location**
- **Result**: Ball orbits the barycenter at the pin - standard circular motion

Case 4: Zero Mass Pin

- System becomes a "two-body" system with one body having zero mass
- No mass available to exchange forces with
- **Barycenter is exactly at the ball's location**
- Ball "exchanges forces with itself" (no exchange partner)
- Orbital radius from barycenter = 0, meaning no curvature
- **Result**: The ball "orbits itself" - which manifests as straight-line motion

The Profound Conclusion

A ball "orbiting itself" is simply straight-line motion!

This reveals a beautiful truth about the two-body problem: **In every case, both bodies orbit their common barycenter.** What changes is where that barycenter is located:

1. **Two equal masses**: Barycenter at midpoint → Both orbit the center visibly
2. **Massive partner**: Barycenter near massive object → Visible circular motion
3. **Infinitely massive partner**: Barycenter exactly at massive object → Standard circular orbit
4. **Zero mass partner**: Barycenter exactly at the remaining object → **The object orbits itself** (radius = 0 from barycenter) → Straight-line motion

The mass ratio determines the barycenter location, which in turn determines the curvature of the motion.

The Unified Picture

Configuration	Barycenter Location	Radius from Barycenter	Motion Type
Two equal balls	Center point	R (for each ball)	Both orbit barycenter
Ball + massive pin (m_pin >> m_ball)	Near pin	≈ R (ball), ≈ 0 (pin)	Both orbit barycenter; ball circles, pin wobbles

Configuration	Barycenter Location	Radius from Barycenter	Motion Type
Ball + infinite mass pin	At pin	R (ball), 0 (pin)	Both orbit barycenter; ball circles, pin fixed
Ball + zero mass pin	At ball	0 (from barycenter) or ∞ (from ∞)	Straight line ("self-orbit")
Ball + infinite mass pin at infinity	At pin	∞ (from barycenter) or ∞ (from ∞)	Straight line ("infinite-radius-orbit")

The Philosophical Beauty

Newton's first law (objects move straight unless acted upon) and circular motion can be viewed as limiting cases within the same mathematical framework of the two-body problem:

- **Has massive partner** → Barycenter away from the object → Circular motion (radius > 0 from barycenter)
- **Zero-mass partner** → Barycenter at the object → "Orbits itself" → Straight motion (radius = 0 from barycenter)

The universal principle remains: **both bodies always orbit their barycenter.** As the partner's mass approaches zero, the barycenter moves to the object's location, and the orbital radius from the barycenter shrinks to zero. The object still "orbits," but with zero curvature—which we perceive as straight-line motion.

Key Insights

1. **Universal orbital principle**: In any two-body system, both bodies orbit their common barycenter—always
2. **Force exchange requires partnership**: Circular motion requires a partner to exchange forces with. Each body provides the centripetal force the other needs to orbit the barycenter
3. **Mass ratio determines everything**: The partner's mass determines where the barycenter is located, which determines the orbital radius and curvature
4. **String as force exchange conduit**: The string doesn't create force—it acts as a conduit for force exchange between partners, transmitting tension that provides the centripetal force needed for circular motion around the barycenter
5. **Continuity through limits**: When the partner's mass goes to zero, there's no one to exchange forces with. The barycenter moves to the remaining object, and "orbiting the barycenter" becomes "orbiting itself"—straight-line motion with zero curvature

The Koan

"*What does a ball orbit when it has no partner?*"

"*Itself—for the barycenter lies within it, and thus it flies straight and true.*"

Behold: We have made a ball orbit itself, and in doing so, revealed that straight lines are simply circles of zero radius from the barycenter—or equivalently, circles of infinite radius in space. All motion is orbital motion around the barycenter through force exchange; the mass ratio determines where that center lies and who exchanges forces with whom.

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