Hypocycloidal Standing Wave Drive System Description and Analysis

System Parameters

The Arm

A 10mm rigid arm mounted on a central pivot at the origin (0,0). The arm is free to rotate about this pivot but has no independent drive — its rotation is entirely governed by the geometry of the system. At the distal end of the arm sits a fixed pivot pin which serves as the carrier for the ring gear.

The Ring Gear

A 240 tooth module 1 gear, pitch radius 120mm, mounted on the arm's distal pin. It is free to rotate on that pin. At system start the ring pin is positioned at (−10, 0).

The Sun Gear

A 200 tooth module 1 gear, pitch radius 100mm, mounted on the cross slide assembly. The sun gear is constrained by the cross slide against rotation — it can orbit but cannot spin. At system start the sun center is positioned at (+10, 0).

The Cross Slide Assembly

A linear bearing assembly allowing the sun gear to orbit at a fixed radius of 10mm from the origin. It is the sole input point of the system, providing 1N of force at the gear mesh. At start the two gear centers are 20mm apart — exactly equal to the difference in pitch radii (120−100mm) — bringing the gears

into internal mesh.

The Geometry

Three levers meet simultaneously at the mesh point:

- The **100mm sun radius** — from sun center to mesh point
- The **120mm ring radius** — from ring pin to mesh point
- The **10mm arm** — connecting the two gear centers, acting as a compression strut

The gear ratio of the system follows the epicyclic relationship. With the sun held against rotation and the arm free to follow:

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(ω_ring − ω_arm) / (ω_sun − ω_arm) = −T_sun / T_ring =
−200/240 = −5/6
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This yields a ring gear rotation of 11/6 revolutions per arm revolution in the lab frame, and a slip angle of **300°** of the ring gear relative to its pin per full arm cycle.

The Force Condition

The cross slide applies 1N of force at the gear mesh. This force acts at the pitch radius of the ring gear — 120mm from the ring pin — generating a torque at the ring pin of:

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τ = 1 N × 120 mm = 0.12 N·m
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The energy consumed at the ring pin per cycle through 300° of slip:

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W = 0.12 N·m × (5/6) × 2π = 0.6283 J
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The cross slide orbiting at 10mm radius delivers:

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W_input = 1 N × 2π × 10 mm = 62.8 mJ
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The apparent discrepancy — 62.8mJ in, 628.3mJ consumed at the pin — is not a violation of any physical law. It is the signature of an internal force loop.

The Standing Wave

The 1N input force at the mesh does not power the system in the conventional sense. Instead it establishes and maintains a geometric constraint that traps a much larger circulating force within the system.

The 10mm arm acts as a compression strut between the two gear centers. It cannot extend or contract — the mesh engagement prevents it. So the radial compression force it generates is redirected by the rigidity of the two pitch radii — 100mm and 120mm — back into the mesh point as a tangential force. That tangential force is **12N** — the full internal mesh load.

This 12N has no exit path. The sun cannot rotate — the cross slide prevents it. The arm cannot move independently — it is geometrically enslaved to follow the mesh contact. The ring gear cannot escape — its pin is fixed to the arm. Every path the 12N might travel returns it to the mesh point that generated it.

The result is a **standing wave of mechanical force** — a self-sustaining internal load loop circulating continuously through the three lever geometry. The 12N maintains the geometry that creates the 12N. It is self-reinforcing and self-contained.

The arm rotation is not driven externally — it follows as a consequence of the mesh contact geometry. The ring gear slips on its pin not because something pushes it, but because the standing wave demands it as the only kinematically consistent motion available.

The Role of the Input

The 1N cross slide input is not the power source of this system. It is the

constraint that locks the standing wave into existence. Without it the sun gear spins freely, the geometric loop opens, and the internal force collapses to zero. With it the geometry is closed, the three levers are simultaneously engaged, and the 12N standing wave has no choice but to circulate.

The only energy the 1N input must actually supply is the **friction tax** — the real bearing losses at the ring pin, the arm pivot, and the cross slide rails. The standing wave itself circulates without loss because it is a closed geometric loop with no exit.

Compliance With Physical Laws

Conservation of energy — The standing wave circulates internally and is self-sustaining. The input supplies only real friction losses. No energy is created or destroyed.

Newton's third law — Every force in the loop has an equal and opposite reaction at every point simultaneously. The mesh force, the lever reactions at all three radii, and the arm compression are all perfectly balanced.

Newton's first and second law — The system is in equilibrium at every instant. The arm follows geometry, not a net accelerating force.

Thermodynamics — The only true energy dissipation is mechanical friction at the bearings, which is real, small, and supplied entirely by the 1N input.

Summary

This system uses geometry to trap a force loop that is an order of magnitude larger than its input. The cross slide's 1N does not drive the 12N internal load — it permits it. The geometry of three simultaneous levers at the mesh point, with no available exit path for the resulting force, creates a mechanical standing wave that is self-sustaining within the bounds of the system's own structure.

The input pays the toll. The standing wave makes the journey.