

Bicycles

Turn off all electronic devices

Observations about Bicycles

- They are hard to keep upright while stationary
- They stay upright easily while moving forward
- They require leaning during turns
- They can usually be ridden without hands

5 Questions about Bicycles

1. Why is a stationary tricycle so stable?
2. Why is stationary bicycle so unstable?
3. Why does a moving tricycle flip during turns?
4. Why must you lean a bicycle during turns?
5. Why can you ride a bicycle without hands?

Question 1

Q: Why is a stationary tricycle so stable?

A: The tricycle is in a stable equilibrium

- Stable equilibrium has restoring influences
 - that tend to return the tricycle to equilibrium
- If center of gravity is above base of support,
 - its gravitational potential energy increases as it tips,
 - it accelerates in the direction opposite that tip,
 - and it tends to return to the stable equilibrium.

Question 2

Q: Why is stationary bicycle so unstable?

A: The bicycle is in an unstable equilibrium

- Unstable equilibrium has destabilizing influences
 - that tend to tip bicycle away from equilibrium
- If center of gravity is above line of support,
 - its gravitational potential energy decreases as it tips,
 - it accelerates in the direction of that tip,
 - and it tends to tip away from the unstable equilibrium.

Question 3

Q: Why does a moving tricycle flip during turns?

A: Inertial effects overwhelm its static stability

- During a turn, wheels accelerate to the inside
 - but upright rider is almost inertial (coasts forward),
 - so tricycle and rider begin to tip.
 - Restoring influences arise but they're too weak,
 - so tricycle and rider tip over.
- Tricycle drives out from under center of gravity
- Tricycle is dynamically unstable

Question 4

Q: Why must you lean a bicycle during turns?

A: To balance inertial effects with static instability

- During a turn, the wheels accelerate to the inside
 - and leaning rider accelerates to the inside
 - so the rider and bicycle turn together safely.
- Bicycle drives under rider's center of gravity
- Bicycle is dynamically stable

Question 5

Q: Why can you ride a bicycle without hands?

A: It automatically steers under center of gravity

- When bicycle begins to lean, it steers because
 - the fork pivots to reduce total potential energy
 - ground's torque on front wheel causes precession
- A forward-moving bicycle that begins to tip
 - automatically returns to its unstable equilibrium,
 - and thus exhibits wonderful dynamic stability

Summary about Bicycles

- Tricycles
 - have static stability
 - but inertial effects can flip tricycles during turns
- Bicycles
 - are statically unstable
 - can lean during turns to avoid flipping
 - automatically steer back to unstable equilibrium
 - have remarkable dynamic stability