

### Question:

Raising the height of a small pickup truck may make it unstable during turns. How would uniformly doubling the truck's weight affect its tendency to tip over?

1. Make it less likely to tip over.
2. Make it more likely to tip over.
3. Have no overall effect on its stability.

### Static Stability

- At rest, an object is stable if its center of gravity is above its base.
- A minimum of 3 non-collinear contact points form a base.
- Tricycles are statically stable.
- Bicycles are statically unstable.

### Dynamic Stability

- In motion, an object is stable if it tends to shift its base of support under its center of gravity.
- Bicycles are dynamically stable.
  - Fork shape causes automatic steering.
  - Gyroscopic precession does, too.

### Torques

- During accelerations, vehicles experience torques about their centers of mass.
  - Friction acts at wheels, so torque.
  - Support forces act at wheels, so torque.
  - Weight acts at center of gravity, so no torque.
- If frictional torque doesn't cancel support torque, vehicle will tip over.

### Leaning

- Frictional torques are unavoidable when a vehicle turns.
- Support force torques only occur when a vehicle is leaning.
- Bicycles can lean and thus avoid flipping.
- Tricycles can't lean and flip during turns.

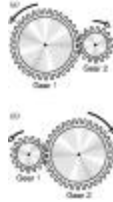
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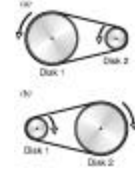
## Gears

- If you push teeth of Gear 1 forward, you do work on it.
- Gear 1 pushes equally hard on teeth of Gear 2, doing work on it.
- Force on Gear 2 is exerted (a) nearer (b) farther from pivot.
- Gear 2 turns (a) faster, with less torque (b) slower, with more torque.



## Chains

- If you push the edge of Disk 1 forward, you do work on it.
- Disk 1 pulls on the chain, which pulls on Disk 2, doing work on it.
- Force on Disk 2 is exerted (a) nearer (b) farther from pivot.
- Disk 2 turns (a) faster, with less torque (b) slower, with more torque.



## Mechanical Advantage

- Gears allow you to exchange force for distance or distance for force in doing work.
- On steep hills, you use a gear that trades large distance with your feet for large force on the rear wheel.
- On flat surfaces, you use a gear that trades large force from your feet for large distance on the rear wheel.

## Rolling and Energy

- A moving bicycle has kinetic energy.
- A kilogram in the wheel rim has twice the kinetic energy of a kilogram in the frame.
- To start the bicycle moving, you must provide its energy.
- Massive bicycles, particularly with massive wheels, are hard to start (and stop).

## Rolling Resistance

- As a wheel rolls, its surface dents inward.
- Denting a surface requires work.
- An underinflated tire with a low coefficient of restitution does not return this work well.
- An underinflated tire wastes energy as it rolls.

## Braking

- Sliding friction converts bicycle's and rider's kinetic energies into thermal energy.
- Rate of conversion is proportional to:
  - frictional force between brake pads and rim.
  - support force on brake pads
  - tension of brake cable
  - force on brake levers.

## Braking problems

- Brake too hard, then wheels begin to skid.
  - Wheels stop rotating.
  - Sliding friction appears between wheels and ground.
- Slowing force exerts a torque on bicycle
  - Rider and bicycle can flip over head first.
  - Rear wheel loses traction and may “fishtail.”
  - Front wheel has improved traction.