

Wheels 1

# Wheels

Turn off all electronic devices

Wheels 2

## Observations about Wheels

- Friction makes wheel-less objects skid to a stop
- Friction can waste energy and cause wear
- Wheels mitigate the effects of friction
- Wheels can also propel vehicles

Wheels 3

## 6 Questions about Wheels

1. Why does a wagon need wheels?
2. Why is sliding a box across the floor usually hardest at the start?
3. How is energy wasted as a box skids to a stop?
4. How do wheels help a wagon coast?
5. How do powered wheels propel a bicycle or car forward?
6. How is energy present in a wheel?

Wheels 4

## Question 1

Q: Why does a wagon need wheels?

A: Friction opposes a wheel-less wagon's motion

Frictional forces

- oppose relative sliding motion of two surfaces
- act along the surfaces to bring them to one velocity
- come in Newton's third law pairs

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## Question 2

Q: Why is sliding a box across the floor usually hardest at the start?

A: Static friction is usually stronger than sliding friction.

Static friction opposes the start of sliding

- varies in amount from zero to a maximum value

Sliding friction opposes ongoing sliding

- has a constant value proportional to support force

Static friction's maximum usually exceeds sliding friction

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## Question 3

Q: How is energy wasted as a box skids to a stop?

A: That energy becomes thermal energy.

Only sliding friction wastes energy

- The two surfaces travel different distances
- The missing work becomes thermal energy
- The surfaces also experience wear

## The Many Forms of Energy

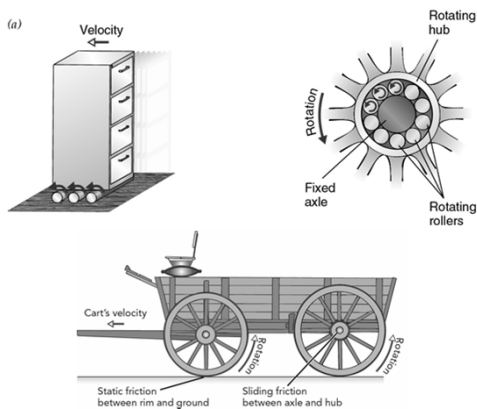
- Kinetic: energy of motion
- Potential: stored in forces between objects
  - Gravitational
  - Elastic
  - Magnetic
  - Electric
  - Electrochemical
  - Chemical
  - Nuclear
- Thermal energy: disorder into tiny fragments
  - Reassembling thermal energy is statistical impossible

## Question 4

Q: How do wheels help a wagon coast?

A: Wheels can eliminate sliding friction.

- Wheels & roller bearings eliminate sliding friction
  - rollers eliminate sliding friction, but don't recycle
  - simple wheels have sliding friction at their hub/axle
  - combining roller bearings with wheels is ideal



## Question 5

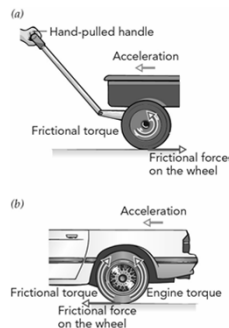
Q: How do powered wheels propel a bicycle or car forward?

A: They use static friction to obtain a forward force from the ground.

- As you or an engine exert torque on a powered wheel
  - static friction from the ground produces an opposing torque
  - The two torques partially cancel, reducing the wheel's angular acceleration
  - The ground's static frictional force pushes the vehicle forward

## Practical Wheels

- Free wheels are turned by the vehicle's motion
- Powered wheels propel the vehicle as they turn.



## Question 6

Q: How is energy present in a wheel?

A: Kinetic energy, both translation and rotational.

For a translating wheel:

$$\text{kinetic energy} = \frac{1}{2} \cdot \text{mass} \cdot \text{speed}^2$$

For a rotating wheel:

$$\text{kinetic energy} = \frac{1}{2} \cdot \text{rotational mass} \cdot \text{angular speed}^2$$

The wheel of a moving vehicle has both forms of kinetic energy!

## Summary about Wheels

- Sliding friction wastes energy
  - Wheels eliminate sliding friction
  - A vehicle with wheels coasts well
- Free wheels are turned by static friction
- Powered wheels use static friction to propel car