Wheels

Turn off all electronic devices

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

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?

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 parallel (along) the surfaces to bring them to one velocity
- come in Newton's third law pairs

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
- has a variable value ranging from zero to a maximum

Sliding friction opposes ongoing sliding
- has a constant value that doesn't depend on relative velocity

Peak frictional force is usually proportional to support force
- Number of contact points is usually proportional to support force
- Soft surfaces that mold to each other don't obey this rule

Static friction's maximum force usually exceeds sliding friction's force

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
  - Magnetic
  - Electrochemical
  - Nuclear
  - Elastic
  - Electric
  - Chemical
- Thermal energy: disorder into tiny fragments
  - Reassembling thermal energy is statistical impossible

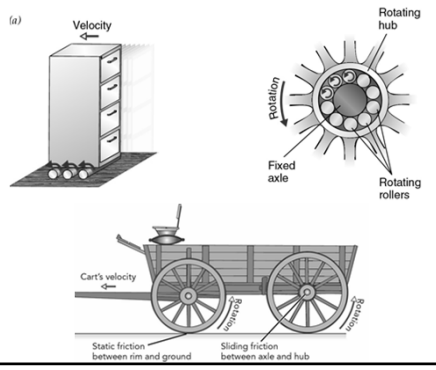
Question 4

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?

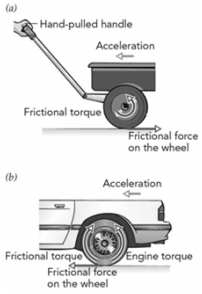
A: They use static friction to obtain a forward force from the ground.

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