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
- Thermal: 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:

\[ \text{kinetic energy} = \frac{1}{2} \text{mass} \times \text{speed}^2 \]

For a rotating wheel:

\[ \text{kinetic energy} = \frac{1}{2} \text{rotational mass} \times \text{angular speed}^2 \]

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