

Wheels 1

Wheels

Wheels 2

Observations about Wheels

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

Wheels 3

5 Questions about Wheels

- Why does a wagon need wheels?
- Why do sleds seem to “break free” and then slide easily when you shove them hard enough?
- What happens to energy as a sled skids to rest?
- How do wheels help a wagon coast?
- What energy does a wheel have?

Wheels 4

Question 1

- Why does a wagon need wheels?
- Why do sleds work well only on snow or ice?

Wheels 5

Frictional Forces

- A frictional force
 - opposes relative sliding motion of two surfaces
 - points along the surfaces
 - acts to bring the two surfaces to one velocity
- Frictional forces always come in 3rd law pairs:
 - Pavement’s frictional force pushes cart backward
 - Cart’s frictional force pushes pavement forward

Wheels 6

The Two Types of Friction

- Static Friction
 - Acts to prevent objects from starting to slide
 - Forces can range from zero to an upper limit
- Sliding Friction
 - Acts to stop objects that are already sliding
 - Forces have a fixed magnitude

Wheels 7

Question 2

- Why do sleds seem to “break free” and then slide easily when you shove them hard enough?

Wheels 8

Frictional Forces

- Frictional forces increase when you:
 - push the surfaces more tightly together
 - roughen the surfaces
- Peak static force is greater than sliding force
 - Surface features can interpenetrate better
 - Friction force drops when sliding begins

Wheels 9

Sleds and Friction

- A stationary sled
 - experiences static friction
 - won't start moving until you pull very hard
- A moving sled
 - experiences sliding friction
 - needs to be pulled or it will slow down and stop
 - experiences wear as it skids along the pavement

Wheels 10

Question 3

- What happens to energy as a sled skids to rest?

Wheels 11

Friction, Energy, and Wear

- Static friction
 - Both surfaces travel the same distance (often zero)
 - No work “disappears” and there is no wear
- Sliding friction
 - The two surfaces travel different distances
 - Some work “disappears” and becomes thermal energy
 - The surfaces experience wear
- A sliding box turns energy into thermal energy

Wheels 12

The Many Forms of Energy

- Kinetic: energy of motion
- Potential: stored in forces between objects
 - Gravitational
 - Elastic
 - Magnetic
 - Electric
 - Electrochemical
 - Chemical
 - Nuclear
- Thermal energy: the same forms of energy, but divided up into countless tiny fragments

Energy and Order

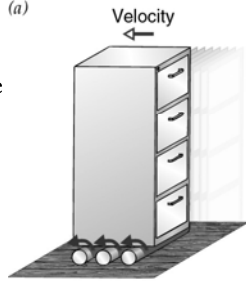
- A portion of energy can be
 - Organized – ordered energy (e.g. work)
 - Fragmented – disordered energy (e.g. thermal energy)
- Turning ordered energy into disordered energy
 - is easy to do
 - is statistically likely
- Turning disordered energy into ordered energy
 - is hard to do
 - is statistically unlikely (it's effectively impossible)

Question 4

- How do wheels help a wagon coast?

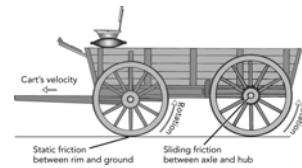
Rollers

- Eliminate sliding friction ^(a) at roadway
- Are inconvenient because they keep popping out from under the object



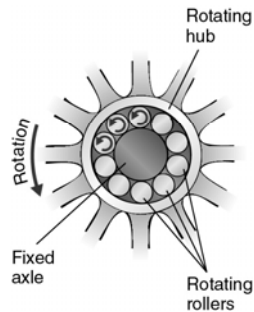
Wheels

- Eliminate sliding friction at roadway
- Convenient because they don't pop out
- Allow static friction to exert torques on wheels and forces on vehicle
- Wheel hubs still have sliding friction



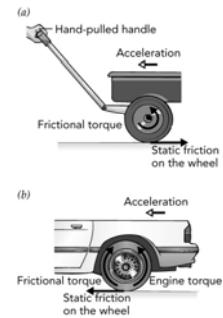
Bearings

- Eliminate sliding friction in wheel hub
- Behave like automatically recycling rollers



Practical Wheels

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



Question 5

- What energy does a wheel have?

Wheels and Kinetic Energy

- A moving wheel has kinetic energy:
kinetic energy = $\frac{1}{2} \cdot \text{mass} \cdot \text{speed}^2$
- A spinning wheel has kinetic energy:
kinetic energy = $\frac{1}{2} \cdot \text{rotational mass} \cdot \text{ang. speed}^2$
- A moving and spinning wheel has both
- Both kinetic energies are transferred via work

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