Wheels

Introductory Question

- The light turns green and you're in a hurry. Will your car accelerate faster if you skid your wheels and "burn rubber" or if you just barely avoid skidding your wheels?

A. Skid your wheels
B. Barely avoid skidding

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

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?

Question 1

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

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

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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

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Question 2

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

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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

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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

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Introductory Question (revisited)

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A. Skid your wheels
B. Barely avoid skidding

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Question 3

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

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Clicker Question

- When a block skids to a stop on a motionless desk, what work is done by those two objects?

A. The desk does negative work on the block.
B. The block does positive work on the desk.
C. Both objects do positive work on one another.
D. Both objects do negative work on one another.
E. The block does positive work on the desk, the desk does negative work on the block.

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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

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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

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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)

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Question 4

- How do wheels help a wagon coast?

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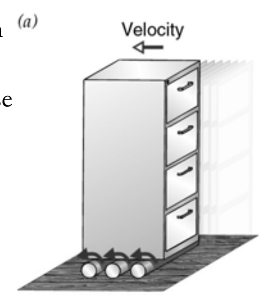
Rollers

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



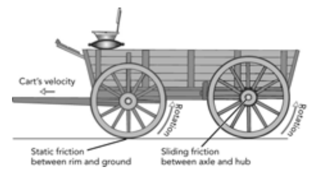
Clicker Question

- When you pull a wheeled cart forward and it is accelerating forward, what frictional force does the ground exert on the wheels as they roll?

A. A sliding frictional force that points backward.
B. A static frictional force that points forward.
C. A static frictional force that points backward.
D. A sliding frictional force that points forward.
E. Zero frictional force.

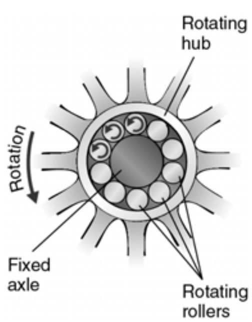
Wheels

- 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



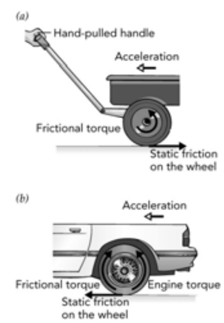
Bearings

- 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 = ½ · mass · speed^2
- A spinning wheel has kinetic energy:
  kinetic energy = ½ · rotational mass · ang. speed^2
- A moving and spinning wheel has both
- Both kinetic energies are transferred via work

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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