On the ramp

When a cart rolls down a ramp, it
begins at rest, but starts moving downward upon release
covers more distance each second

When a cart rolls up a ramp, it
rises to a certain height
comes briefly to a stop
descends much like the cart rolling down the ramp
Contact Forces

Objects in contact can push on each other.

Consider a block resting on a ramp.

Support force
prevents the block from penetrating the ramp’s surface
points directly away (perpendicular) from the ramp’s surface

Frictional force
Prevents the block from sliding down the ramp
Pushes along the direction (parallel) of the ramp’s surface

Net Force

The net force on the block is
the sum of all forces on the block
responsible for the block’s acceleration
Horizontal Ramp

Consider a cart resting on a horizontal surface. It experiences,
   It’s downward weight
   A support force from the table

Since the cart is not accelerating,
   The sum of all forces (the net force) on the cart is zero
   The support force must balance the cart’s weight

Action and Reaction

Are both the cart and the ramp pushing on each other?

If you push on a friend, will that friend push back on you?

Newton’s third law: For every force that one object exerts on a second object, there is an equal but oppositely directed force that the second object exerts on the first object.
Question

If you push on a friend who is moving away from you, how will the force you exert on your friend compare to the force your friend exerts on you?

A. You push harder
B. Your friend pushes harder
C. The forces are equal in magnitude

Forces

Consider a cart on a horizontal ramp and the following four forces:
   1. On earth due to gravity from the ball
   2. On the ball due to gravity from the earth
   3. On the ball due to support from the table
   4. On the table due to support from the ball

Forces 1 and 2 are a third law pair
Forces 3 and 4 are a third law pair

Forces 2 and 3 are the only force acting on the ball. They are not a third law pair.

When 2 and 3 are equal in magnitude, the ball doesn’t accelerate.

When 2 and 3 are not equal in magnitude, the ball accelerates.
Energy and Work

Energy - a conserved quantity
  - can’t be created or destroyed
  - can be transformed or transferred between objects
  - is the capacity to do work

Work - Mechanical means of transferring energy
  
  Work = Force \times Distance

  (when force and distance are in the same direction)

Work Done Lifting a Cart

Going straight up:

  \text{Work} = \text{Force} \times \text{Distance}

Going up a ramp:

  \text{Work} = \text{Force} \times \text{Distance}

The work done is the same in either case!
Mechanical Advantage

Doing the same amount of work, but redistributing force and distance

Ramps and pulleys provide mechanical advantage

You can raise a heavy cart with a modest force
You must push that cart a long distance
Your work is independent of the ramp’s steepness
Work done in lifting an object depends only on its change in height

The transfer of Energy

Energy can take many forms
- Kinetic energy – energy associated with moving objects
- Potential energy – energy stored in the forces between objects

Pushing a cart up a ramp – energy is transferred from you to the cart
- You do work on the cart
- Your chemical potential energy decreases
- The cart’s gravitational potential energy increases
Energy

Kinetic energy – energy associated with moving objects

\[ \text{Kinetic energy} = \frac{1}{2} \cdot \text{mass} \cdot \text{speed squared} \]
\[ K = \frac{1}{2} mv^2 \]

Potential energy – energy stored in the forces between objects

Gravitational potential energy = mass \cdot acceleration due to gravity \cdot height
\[ U_g = mgh \]

Summary of Ramps

A horizontal ramp supports all of the carts weight
An inclined ramp supports most of the carts weight
The steeper the ramp the less weight the ramp supports
You can push on the cart (up the ramp) to balance the remaining ramp force
You do work pushing a cart up a ramp
The work you do is independent of the ramps slope – it depends only on the carts change in height
The ramp provides mechanical advantage
It allows you to push less hard, but you must push for a longer distance