How Things Work II
(Lecture #5)

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Can glass really exert a large force on a bullet?

acceleration of bullet = 0
no force on bullet
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no force on bullet

acceleration of bullet is LARGE
force on bullet is LARGE
INTERNAL FORCES
IN GLASS ARE LARGE
Can glass really exert a large force on a bullet?

- Acceleration of bullet = 0
  - No force on bullet

- Acceleration of bullet is LARGE
  - Force on bullet is LARGE
  - Internal forces in glass are LARGE

Once the internal forces in the glass are large enough, the glass is torn apart. Once again the acceleration of bullet = 0
Observations about ramps

• Lifting an object straight up is often difficult.
• Pushing the object up a ramp is usually easier.
• The case depends on the ramp’s steepness.
• Shallow ramps require only gentle pushes.
Physical quantities:
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- Energy
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• Energy
  - A conserved quantity.
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  - One form is the capacity to do work.
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• Work
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• **Work**
  - The mechanical means of transferring energy
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• Work
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  - work = force \cdot distance

(Where the force and distance are in the same direction.)
The different forms of energy
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- Kinetic Energy:
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• Kinetic Energy:
  - The form of energy contained in an object's motion.
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• Potential Energy
The different forms of energy

• **Kinetic Energy:**
  - The form of energy contained in an object's motion.

• **Potential Energy**
  - The form of energy stored in the forces between or within objects.
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The different forms of energy

- **Kinetic Energy:** The form of energy contained in an object's motion.
- **Potential Energy** The form of energy stored in the forces between or within objects.
- **Work** The mechanical means of transferring energy.
  - work = force \cdot distance
Work lifting ball

- Going straight up
  - Force is large
  - Distance is small
Work lifting ball

- Going straight up
  - Force is large
  - Distance is small

\[ \text{Work} = \text{force} \cdot \text{distance} \]
Most of the weight is counteracted by the support force. However, the support force can only be normal to the surface of the ramp. Thus, there is still a small net force that points down along the ramp.
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Work lifting ball

• Going up ramp
  – Force is small
  – Distance is large
Work lifting ball

- Going up ramp
  - Force is small
  - Distance is large

\[ \text{Work} = \text{force} \cdot \text{distance} \]
Work lifting ball

• Going straight up:

\[ \text{Work} = \text{force} \cdot \text{distance} \]

• Going up ramp:

\[ \text{Work} = \text{force} \cdot \text{distance} \]

• The work is the same either way!
Angular motion and seesaws
Question:

You and a child half your height are leaning over the edge of a swimming pool at the same angle. If you both let go simultaneously, who will tip over faster and hit the water first?
Observations about seesaws

• A balanced seesaw can remain horizontal.
• A balanced seesaw rocks back and forth easily.
• Two equal-weight children balance a seesaw.
• Two unequal-weight children don't balance.
• But moving the heavy child inwards helps.
Physics Concept

• Rotational Inertia
  - A body at rest tends to remain at rest.
  - A body that’s rotating tends to remain rotating.
Physical quantities

• Angular position - an object’s orientation.
• Angular velocity - the change in angular position with time.
• Torque - a twist or spin.
Newton's First Law of Rotational Motion
Newton’s First Law of Rotational Motion

A rigid body that is not wobbling and that is free of outside torques rotates at a constant angular velocity.
Center of Mass

- The point about which an object’s mass balances.
- A free object rotates about its center of mass while its center of mass follows the path of a falling object.
Physical quantities

- Angular position - an object’s orientation.
- Angular velocity - the change in angular position with time.
- Torque - a twist or spin.
- Angular acceleration - the change in angular velocity with time.
- Moment of inertia - measure of its rotational inertia.
Newton’s Second Law of Rotational Motion

The torque exerted on an object is equal to the product of that object’s moment of inertia times its angular acceleration. The angular acceleration is in the same direction as the torque.
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The torque exerted on an object is equal to the product of that object’s moment of inertia times its angular acceleration. The angular acceleration is in the same direction as the torque.

Torque = Moment of Inertia \cdot \text{Angular Acceleration}