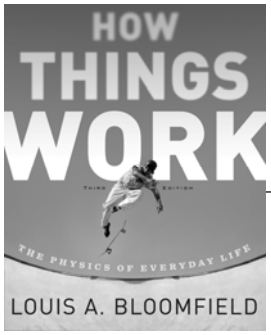

Demystifying Physics

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What is *How Things Work*?

- It's Physics in the Context of Objects
  - It puts objects before physics concepts
  - It puts physics concepts before formulas
  - It's "backwards"
- It's the "Case Study" Method
- It's how Scientists actually Discover Science
- It's what Makes Science Fun

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Overview of this Presentation

- Motivation for *How Things Work*
- Structure of *How Things Work*
  - An Example: Music Boxes
- Choosing the Objects
- Some Illustrations:
  - Roller Coasters
  - Bicycles
  - Clocks
  - Microwave Ovens
- Assignments and Assessment
- Observations about *How Things Work*

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Why *How Things Work*?

- "Oh, I'm a physicist" … *(end of conversation)*
- Conventional physics outreach is often:
  - magic & mysteries *(no explanation).*
  - factoids *(what, where, when, but never why or how).*
  - names *(memorization of random information).*
  - recipes *(mindless plugging and chugging).*
  - formalized "scientific method" *(canned experiments).*

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Why *How Things Work*? (con't)

- In contrast, *How Things Work*
  - grows naturally from the everyday world.
  - explains rather than obscures.
  - emphasizes thought and understanding.
  - builds confidence rather than destroying it.
  - is useful in everyday life.
- The audience for *How Things Work* is
  - anyone who is curious about the world around them.
  - absolutely enormous and largely untapped.

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Structure of *How Things Work*

- A hierarchy with three levels
  - Level 1: Areas of Physics – for instructor
  - Level 2: Objects of Everyday Life – for students
  - Level 3: Concepts of Physics – for both

7. Heat and Phase Transitions
   - 7.1 Woodstoves
     (thermal energy, heat, temperature, chemical bonds and reactions, conduction, thermal conductivity, convection, radiation, heat capacity)
   - 7.2 Water, Steam, and Ice
     (phases of matter, phase transitions, melting, freezing, condensation, evaporation, boiling, relative humidity, latent heats of melting and vaporization)
   - 7.3 Incandescent Lightbulbs
     (electromagnetic spectrum, light, black body spectrum, emissivity, Stefan-Boltzmann law, thermal expansion)

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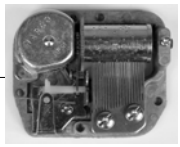
Example: Music Boxes



- Introduces New Concepts
  - 9. Resonance and Mechanical Waves
    - 9.1 Music Boxes

    (natural resonance, harmonic oscillators, simple harmonic motion, frequency, pitch, sound, music, harmonic and non-harmonic overtones, sympathetic vibration, standing and traveling waves, transverse and longitudinal waves, velocity, frequency, and wavelength in mechanical waves, superposition)
- Reinforces Old Concepts
  - Energy and Work (Chapter 1)
  - Springs and Stable Equilibria (Chapter 3)
  - Aerodynamics (Chapter 6)

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Questions about Music Boxes

- *What* are vibration, pitch, sound, and music?
- *Why* does a tine vibrate?
- *Why* do different tines have different pitches?
- *Why* is a tine's pitch independent of its volume?
- *How* does sound from the music box reach us?
- *How* does the music box produce sound?
- *Why* does a music box sound like a music box?

These *why* and *how* questions are full of physics!

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Choosing the Objects

- Set the physics agenda first, then choose the objects
- A typical object has one central physics issue
- Play up that central issue whenever possible
- Caveats *(learned from painful experience)*
  - Some objects present physics better than others
  - Some objects aren't of general interest
  - Less is more; you can't do everything
- *HTW*'s Table of Contents follows this approach

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How Things Work Table of Contents (Part 1)

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How Things Work Table of Contents (Part 2)

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Goals for *How Things Work*

- *How Things Work* should help students:
  - begin to see science in everyday life
  - learn that science isn't frightening
  - learn to think logically in order to solve problems
  - develop and expand their physical intuition
  - learn how things work
  - see the universe as predictable rather than magical
  - see the history of science and technology

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How Things Work is a Flexible Concept

- While the objects provide a common ground,
  - different instructors teach differently
  - different students learn and think differently
- To be successful with *HTW*, an instructor should
  - employ any of the best classroom techniques
  - respect the students and listen to them
- *HTW* sets the stage for exceptional productivity

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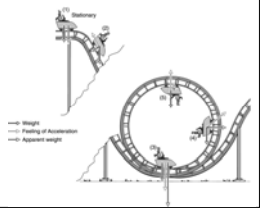
Roller Coasters

- How do loop-the-loops work?
- Physics concepts involved:
  - Inertia
  - Acceleration and forces
  - Centripetal accelerations
  - Weight and "weightlessness"



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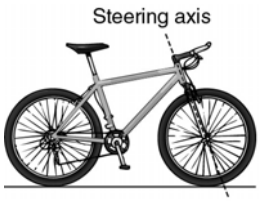
Bicycles

- Why are bicycles so stable?
- Physics concepts involved:
  - Equilibrium
  - Energy and acceleration
  - Stable and unstable equilibriums
  - Static stability
  - Gyroscopic precession
  - Dynamic stability



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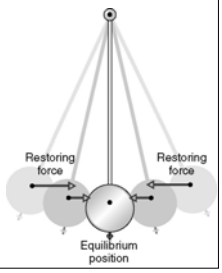
Clocks

- How do clocks keep time?
- Physics concepts involved:
  - Time and Space
  - Forces and Acceleration
  - Harmonic Oscillators



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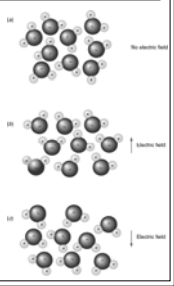
Microwave Ovens

- How do microwave ovens cook?
- Physics concepts involved:
  - Electric fields
  - Polar molecules and free charges
  - Electrostatic forces and torques
  - Electromagnetic waves
  - Wavelength and frequency



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Demonstrations and Laboratories

- Demonstrations are key in a *HTW* course
  - They connect real objects and physics concepts
  - They help students apply and generalize concepts
- Demonstrations are best when they are familiar
  - Use the object under discussion
  - Use objects similar to those under discussion
- Laboratories are Do-It-Yourself Demonstrations
  - The students themselves examine the objects
  - They use the objects, build them, disassemble them

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Homework Exercises

- Focus on concepts, familiarity, relevance
- Ideal exercises make students think hard about familiar objects to understand their physics
- For example: (last exercise of a sequence)
  - Why does gum thrown out the front window of a car often fly back in the rear window?

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Research Papers

- Students explain the physics of their own object
- Requires the student to
  - identify physics issues in a new situation
  - apply physics concepts to that situation
  - use the language of science meaningfully
  - develop a logical discussion of physics in context
  - understand how their object works
- Done well, it's the capstone project for *HTW*

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Exams

- Questions
  - are primarily conceptual
  - are based on familiar, relevant observations
  - require understanding and thought to answer
  - are multiple choice or short answer
  - resemble those in the *Force Concept Inventory*

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Philosophy of *How Things Work*

- It's an outreach course, not a recruiting course
- It aims to inform bright, eager non-scientists
  - who don't know what physics is
  - who don't know why physics matters
  - who respond to relevance, value, and respect
- *How Things Work* is about *them*, not about *us*
- If you build it, they will come

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Observations about *How Things Work*

- The impact of *How Things Work*
  - Many non-science students are now learning physics
  - These students find physics useful
  - There is less fear of physics – a cultural change
  - Physics has become a valued part of the curriculum
  - Other physics courses are flourishing

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Observations about *How Things Work* (con't)

- My own experiences
  - I'm enjoying teaching more than ever
  - I feel as though I make a difference
  - I get to explain physics widely
  - I've learned a great deal of science

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The End

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