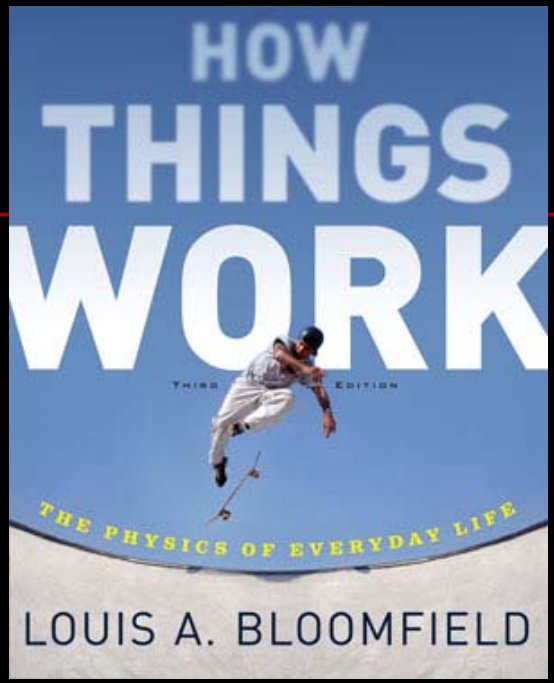
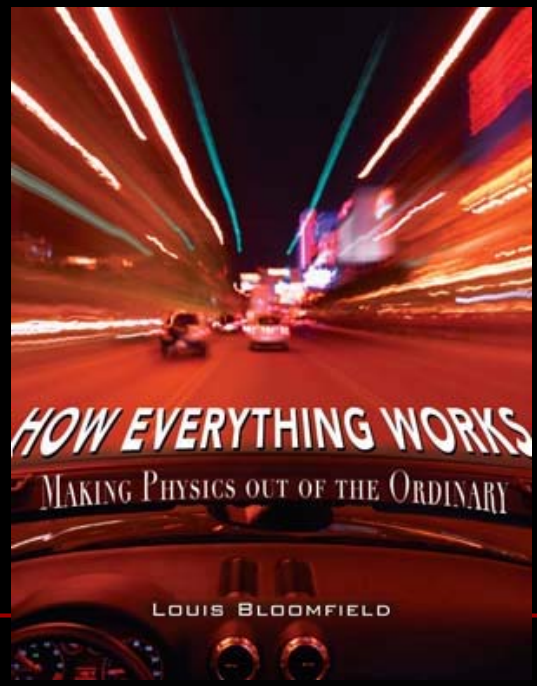
How Things Work

Teaching Science in Context





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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

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
- Observations about *How Things Work*

Why *How Things Work*?

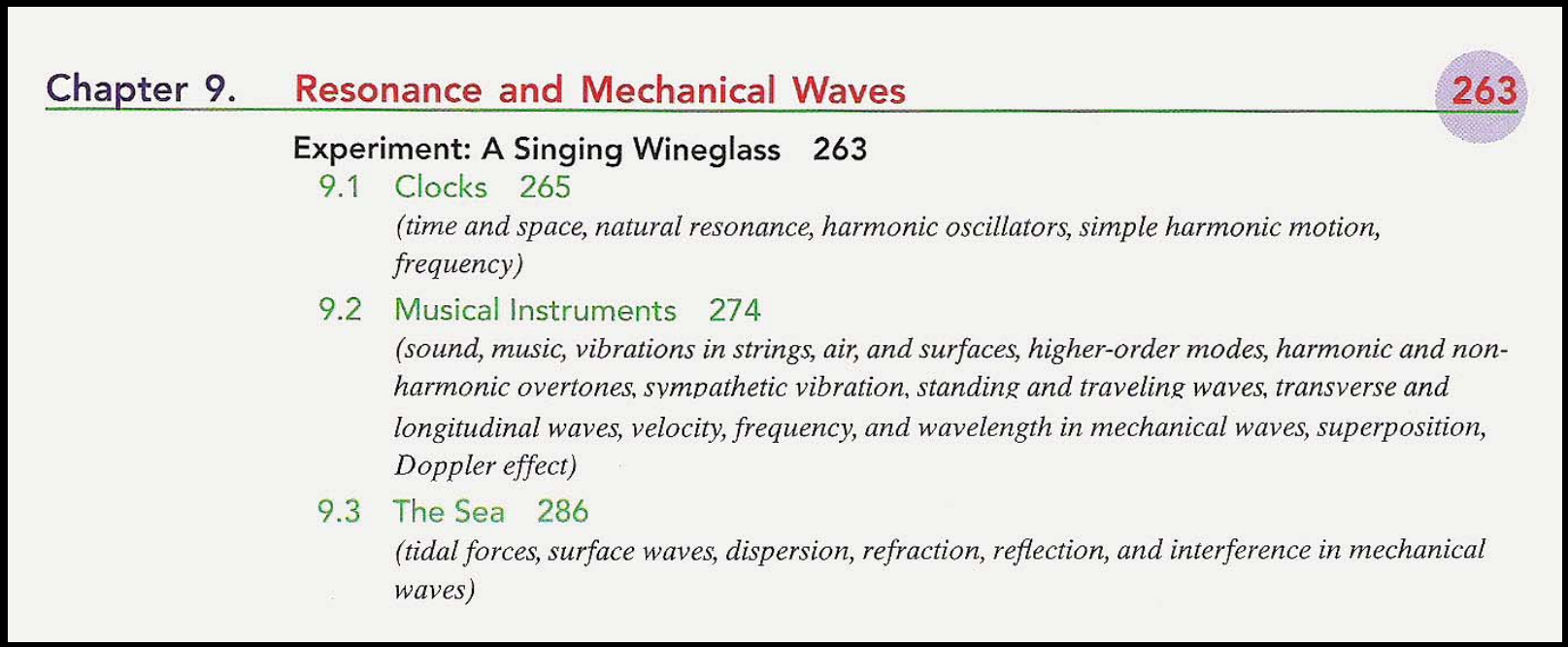
- "Oh, I'm a physicist" … *(end of conversation)*
- Conventional physics outreach is often:
  - magic & mysteries *(no explanation).*
  - factoids *(what, where, when, but never why or how).*
  - names *(memorization of random information).*
  - recipes *(mindless plugging and chugging).*
  - formalized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

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.

Structure of *How Things Work*

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



Chapter 9. Resonance and Mechanical Waves 263

Experiment: A Singing Wineglass 263

9.1 Clocks 265

(time and space, natural resonance, harmonic oscillators, simple harmonic motion, frequency)

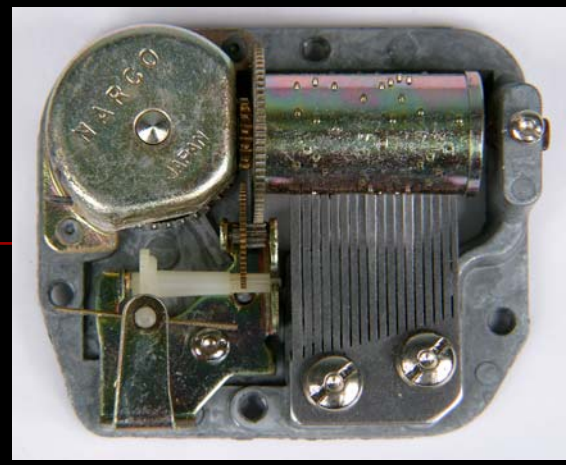
9.2 Musical Instruments 274

(sound, music, vibrations in strings, air, and surfaces, higher-order modes, harmonic and non-harmonic overtones, sympathetic vibration, standing and traveling waves, transverse and longitudinal waves, velocity, frequency, and wavelength in mechanical waves, superposition, Doppler effect)

9.3 The Sea 286

(tidal forces, surface waves, dispersion, refraction, reflection, and interference in mechanical waves)

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)

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 science!

Choosing the Objects

- Set the science agenda first, then choose the objects
- A typical object has one central science issue
- Play up that central issue whenever possible
- Caveats *(learned from painful experience)*
  - Some objects present science 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

How Things Work
Table of Contents (Part 1)

How Things Work
Table of Contents (Part 2)

Goals for *How Things Work*

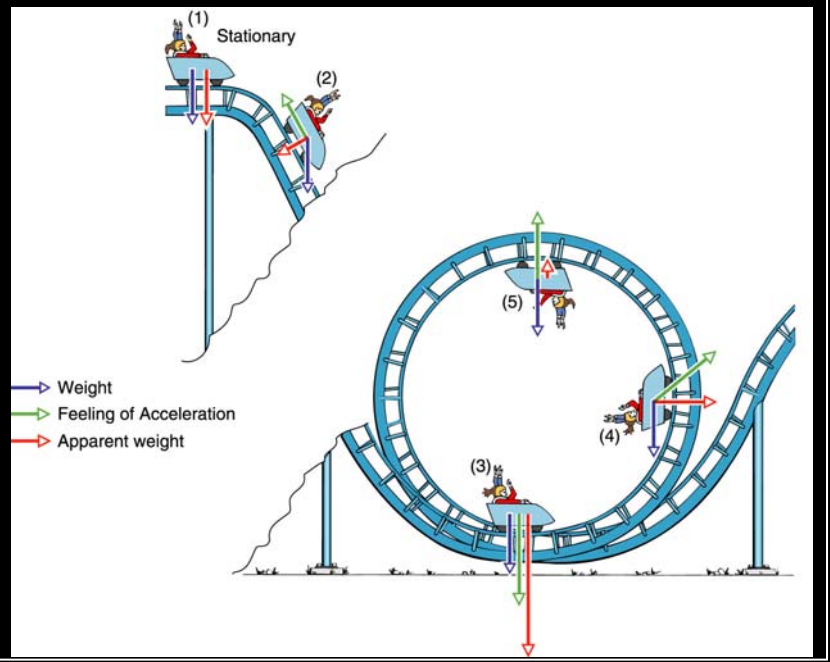
- *How Things Work* should help students:
  - begin to see science in everyday life
  - learn that science isn't frightening
  - learn to think logically in order to solve problems
  - develop and expand their scientific intuition
  - learn how things work
  - see the universe as predictable rather than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

How Things Work is a Flexible Concept

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

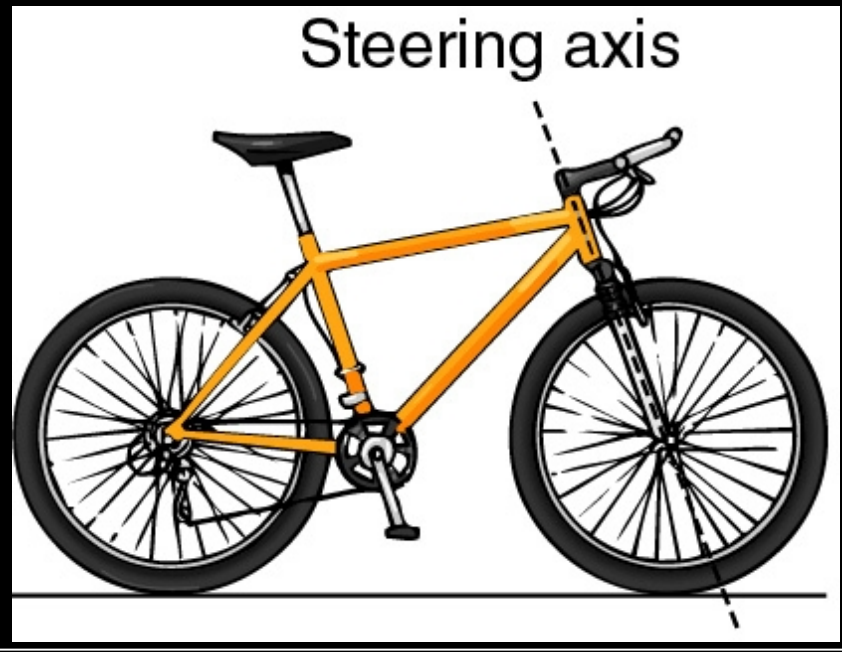
Roller Coasters

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



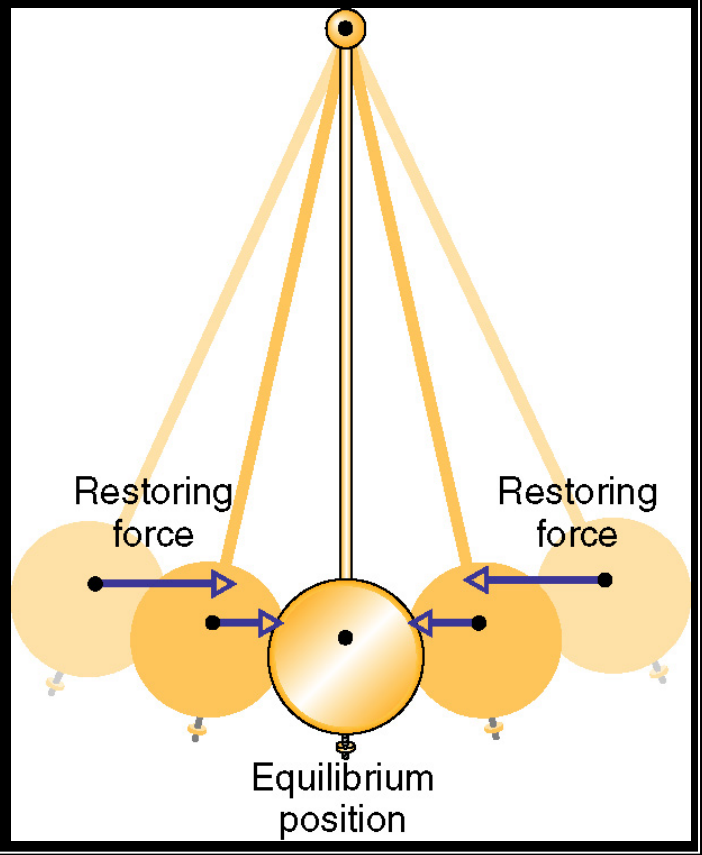
Bicycles

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



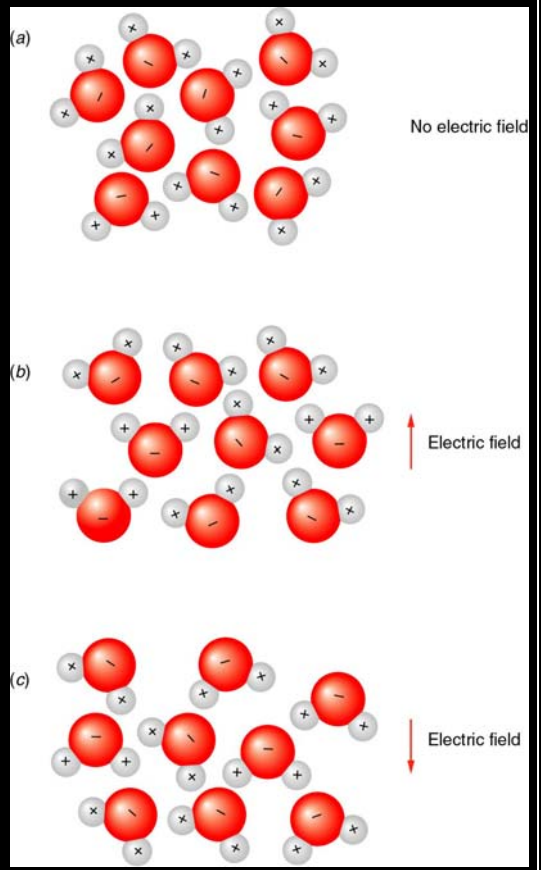
Clocks

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



Microwave Ovens

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



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 science is
  - who don't know why science matters
  - who respond to relevance, value, and respect
- *How Things Work* is about *them*, not about *us*

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

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

The End