Contemporary physics for students and teachers with limited mathematics skills

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Kansas State University
Physics Education Research

Supported by the National Science Foundation

KSU Physics Education Research Group

- 2 faculty
- 2 post-docs
- 8 graduate students
- 5 undergraduates

- Looking for a post-doc who can start as soon as possible.

Here

Sytil Murphy

Liz Gire

Nassar Juma

Collaborators

- Sytil Murphy
- Dyan McBride
- Ebone Pierce
- Josh Gross
- Brandon Sargent
- N. Sanjay Rebello
- Wally Axmann
- Lei Bao
- Chandima Cumaranatunge
- Abby Dimtrova
- Larry Escalada
- Bob Grabhorn
- Kastro Hamed
- Bob Hower
- Seunghee Lee
- Heidi Mauk
- Gabi Mihalcea
- Kirsten Hogg
- Mike Thoresen

In Germany

- Manfred Euler (Kiel)
- Hartmut Wiesner (Munich)
- Rainer Müller (Brunswich)
- Hannes Hoff (Munich)
- Monica Ring (Munich)
- Christine Waltner (Munich)

Instructional materials for different types of students

- Secondary school
- Non-science university students
- Science & Engineering students
  - Modern Physics course
- Pre- & In-service Teachers
- Premedical & biology students
- Web surfing public
  - unintentional

Goals

- Make contemporary physics accessible to as many people as possible
  - Students at all levels
  - Anyone else who is interested
- Help students understand *why* & how we learn about nature
- Increase contemporary physics literacy *at the conceptual level*
  - Use appropriate math and physics prerequisites
- Show the relevance to contemporary life
  - Particular medical diagnosis and imaging

Method

Integrate

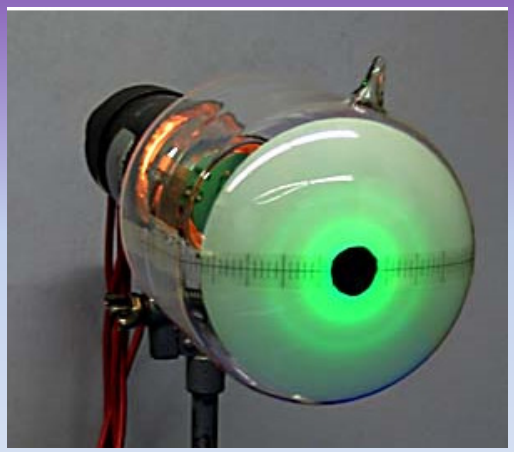
- hands-on activities
  - with inexpensive devices or
  - advanced pedagogical apparatus
- interactive computer visualizations & analogs
- written documents

in an activity-based environment.

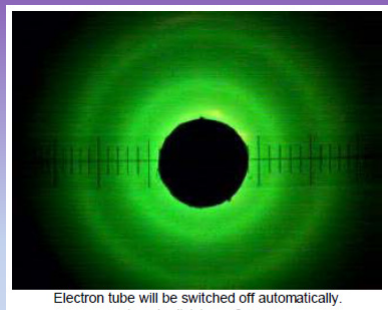
Hands-on + Visualization

- Helps students build models of complex phenomena
- Provides experience with the way physicists build knowledge
- Offers conceptual understanding
  - With or without mathematics

Electron diffraction experiment



Remote controlled experiment



Electron tube will be switched off automatically.
1 scale division ≡ 2 mm.

Screenshot

Electron Diffraction
Laboratory

Remaining time to perform experiment: 35 s

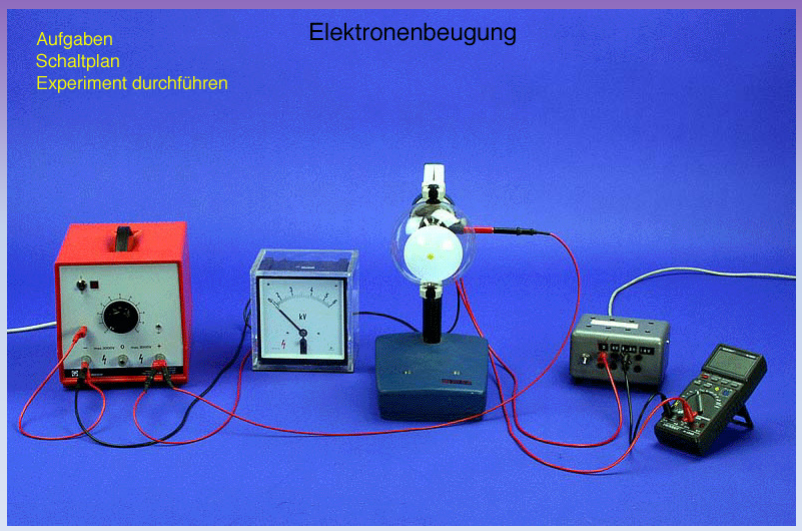
Switch electron tube on

Acceleration voltage:
(0 - 4.3 kV, Format X.XX, ENTER) kV

Actual acceleration voltage: 4.2

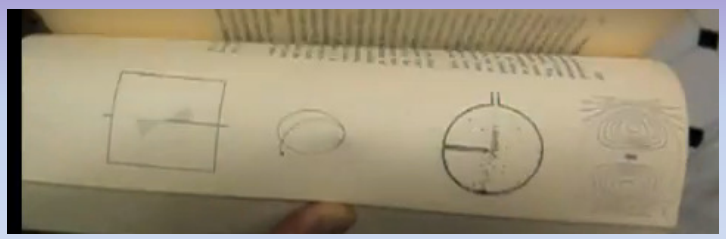
http://rcl.physik.uni-kl.de/

Interactive Screen Experiment

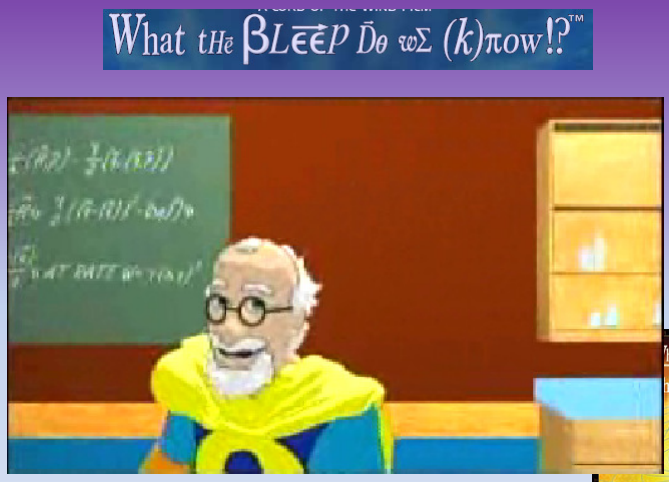


Visualization

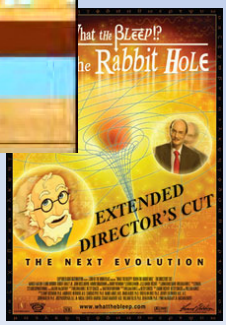
- From Max Born



to …

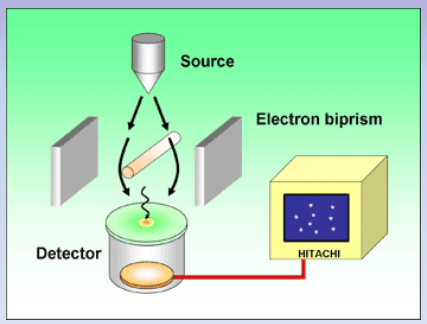


http://www.whatthebleep.com



Example Learning Cycle
(continued)

- Watch video of one electron diffraction
- http://www.hitachi.com/rd/research/em/doubleslit.html



Learning – Modeling Cycle

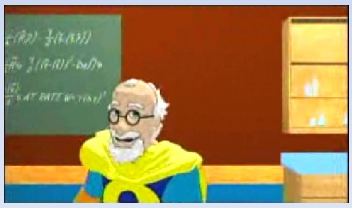
- Hands-on activities
- Explorations precede new concepts
- Applications follow new concepts
- Small group activities
  - Simple equipment
    - & sometimes not-so-simple
  - Visualizations
- Build models based on observations
  - How do we know about things we cannot see?

Example Learning Cycle

- Observe wave interference
- Observe electron diffraction (real)
  - Hands-on
  - Remote control labs (http://rcl.physik.uni-kl.de/)
- Compare changes in patterns of electrons and waves (visualizations)
- Develop a relationship between energy wavelength of electrons

Example Learning Cycle
(continued)

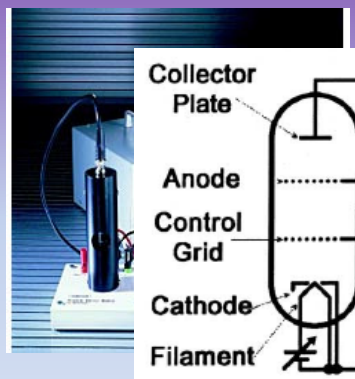
- Watch Dr. Quantum (What the bleep …)
  - As a summary
  - Find errors
  - Collect questions to be answered later



Two examples

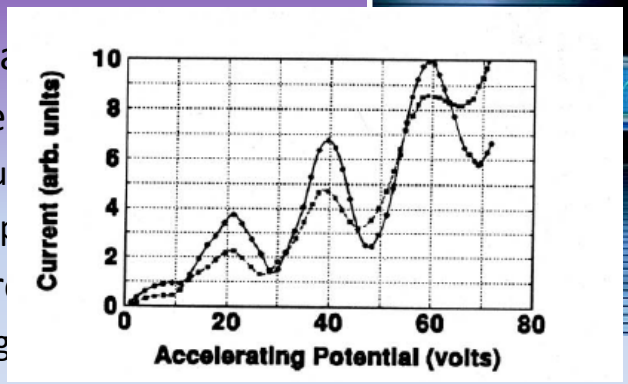
- Franck-Hertz Experiment
  - Sophisticated (and expensive) apparatus
  - Visualization imitates the apparatus
  - Connects to learning of energy quantization
- Magnetic Resonance
  - Analogy using classical apparatus
  - Visualization
  - No real experiment (yet)
  - Connects to medical applications

Franck-Hertz Apparatus



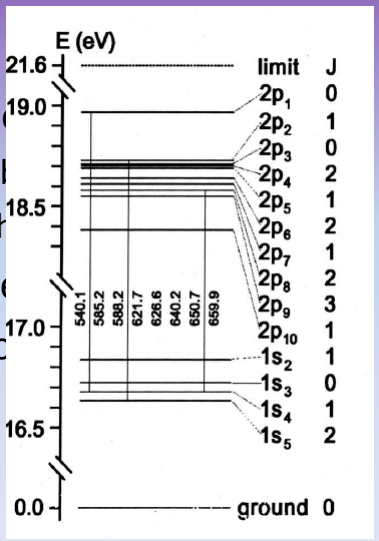
Franck-Hertz Experiment

- Neon ga
- Voltage
  - Manu
  - Sweep
- Visual r
  - Orang
- Graphical results in sweep mode
- Tube labeled in German; Power source in English

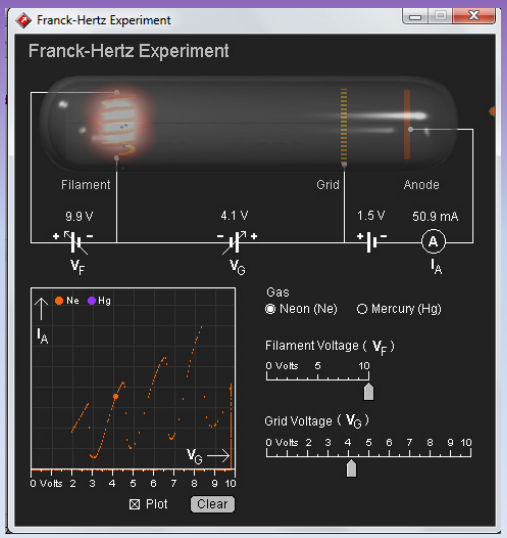


Franck-Hertz Visualization

- Research based
- Students had difficulty d
  - They saw light then dark
  - The voltage-current graph
- Emission OK, but why th
- "If I could see the electr



Franck-Hertz Visualization

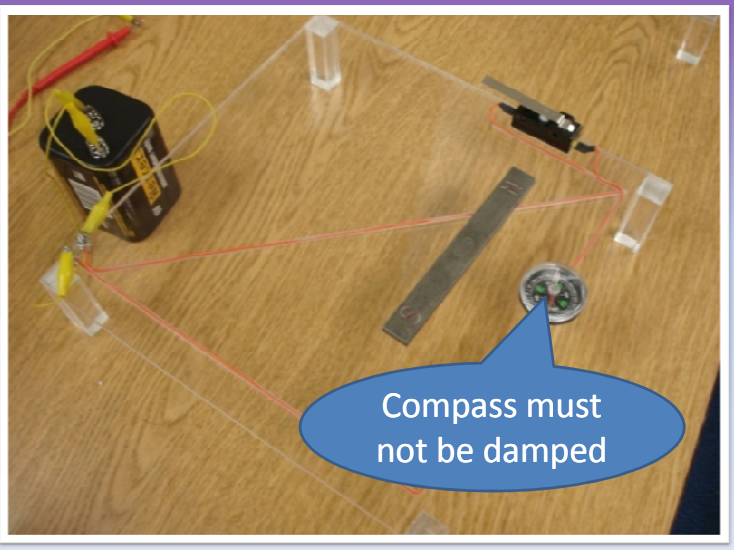


Programmer: Chandima Cumaranatunge

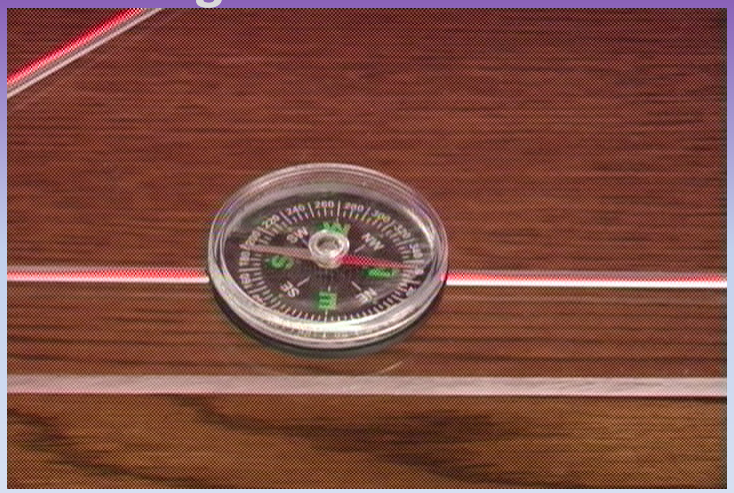
Magnetic Resonance

- Research: Transfer of learning from mechanical system to electromagnetic-mechanical system
- End goal: Teach physics of magnetic resonance imaging
- Primary effort: Sytil Murphy
  - Assisted by Josh Gross

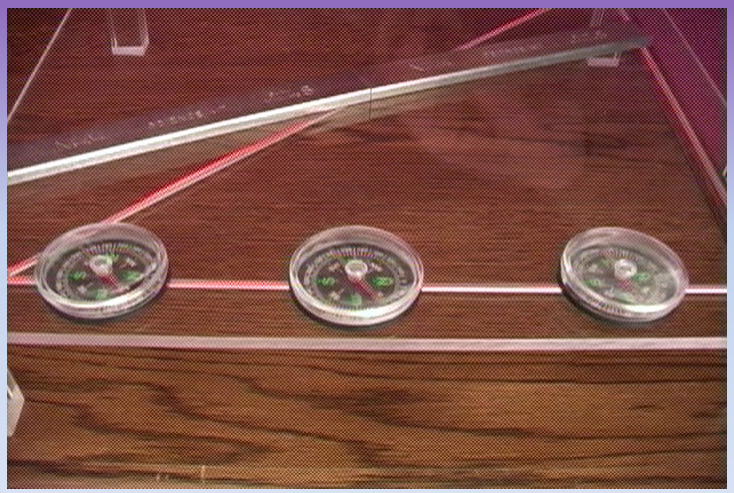
Magnetic Resonance Analog



Magnetic Resonance



With Field Gradient



Sytil Murphy: AAPT Apparatus Competition Prize, 2009

Connections

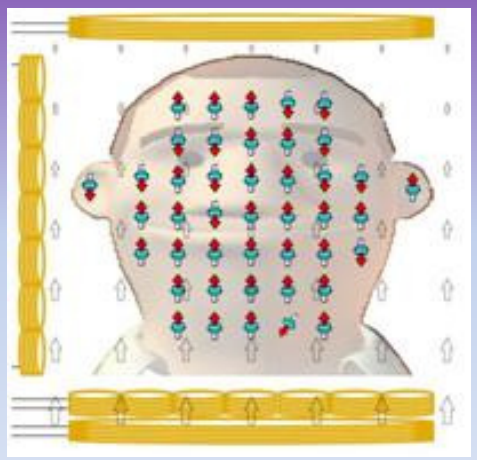
Compass

$$f = \frac{1}{2\pi}\sqrt{\frac{mB}{I}}$$

Atom

$$f = \frac{\gamma}{2\pi}(B)$$

PhET Program



http://phet.colorado.edu/simulations/index.php/
Simplified MRI

Other experiments

Concept	Type of Experiment	Visualization
Rutherford Scattering	Remote	Atomos; PhET
Photoelectric	Hands-on/remote/IBE	PhET
Optical Tomography	Analogy (in development)	CT SIM (LMU & KSU)
STM	??	KSU VQM ($)
Gas Spectra	Hands-on	KSU VQM
Radioactivity	Hands-on/analogy/remote	PhET, others
LED Band Gaps	Hands-on	KSU VQM ($)
MRI	Hands-on analogy	PhET
Wavefront Aberometry	Hands-on Model	KSU MMMM
Various semiconductor	Hands-on	KSU VQM
Energy Diagrams	Hands-on	KSU VQM

Summary

Complex modern physics experiments can help non-science students learn if

- The set-up is understandable and not tedious
- Data collection is straight forward
- Analogies and/or visualizations are available to help the reasoning process.

Resources

http://web.phys.ksu.edu/vqm/

http://web.phys.ksu.edu/mmmm

http://phet.colorado.edu

http://rcl.physik.uni-kl.de

http://www.ztek.com

http://waowen.screaming.net/revision/nuclear/rsanim.htm