# More Physics with Less Equipment

Single Apparatus for Multiple Magnetic Concepts

Vince Kuo

K. Heller, C. Henderson, M. Myhrom,

and the Physics Education Research Group

University of Minnesota

http://www.physics.umn.edu/groups/physed/

T. Hodapp

Hamline University

NSF Grant # ILI-9651339

# Outline

- Design Criteria
- Uses of the apparatus in each of the magnetic concepts
  - fields, forces, flux, induction
- Special features on the design of the apparatus

# Pedagogical Reasons

- Issues
  - problem solving
  - basics of physics principles, not on details of apparatus
    - avoid association of specific apparatus with specific principles
- Design implications
  - a single piece of apparatus for multiple tasks
  - simple measurements in agreement with simple calculations

# Practical Reasons

- Issues
  - 3 laboratory rooms, each containing 5 identical experimental stations
  - ~ 800 students
  - 5 days a week, 8 hours a day
  - one lab attendant

- Design implications
  - apparatus set-up must be efficient and robust
    - a single piece of apparatus for multiple tasks
    - less equipment to maintain

# Results

- This particular apparatus is used for the entire unit on magnetism
  - "context rich" laboratory problems
    - 8 on fields and forces
    - 6 on flux and induction
  - ~ 5 out of 15 weeks of course time
  - in conjunction with 3 chapters from the textbook
    - magnetic fields
    - magnetic fields due to current
    - induction and inductance

# Sample laboratory problem

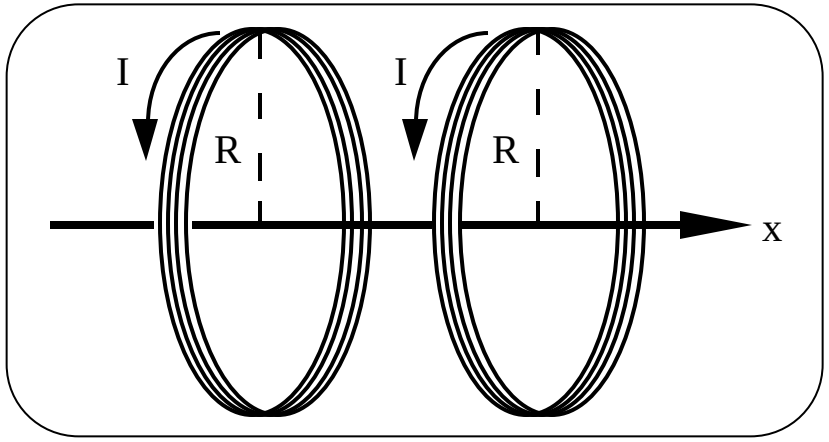
**Problem Statement:**

You have a part time job working in a laboratory developing large liquid crystal displays that could be used for very thin TV screens and computer monitors. The alignment of the liquid crystals is very sensitive to magnetic fields. It is important that the material sample be in a fairly uniform magnetic field for some crystal alignment tests. The laboratory has two nearly identical large coils of wire mounted so that the distance between them equals their radii. You have been asked to determine the magnetic field between them to see if it is suitable for the test.

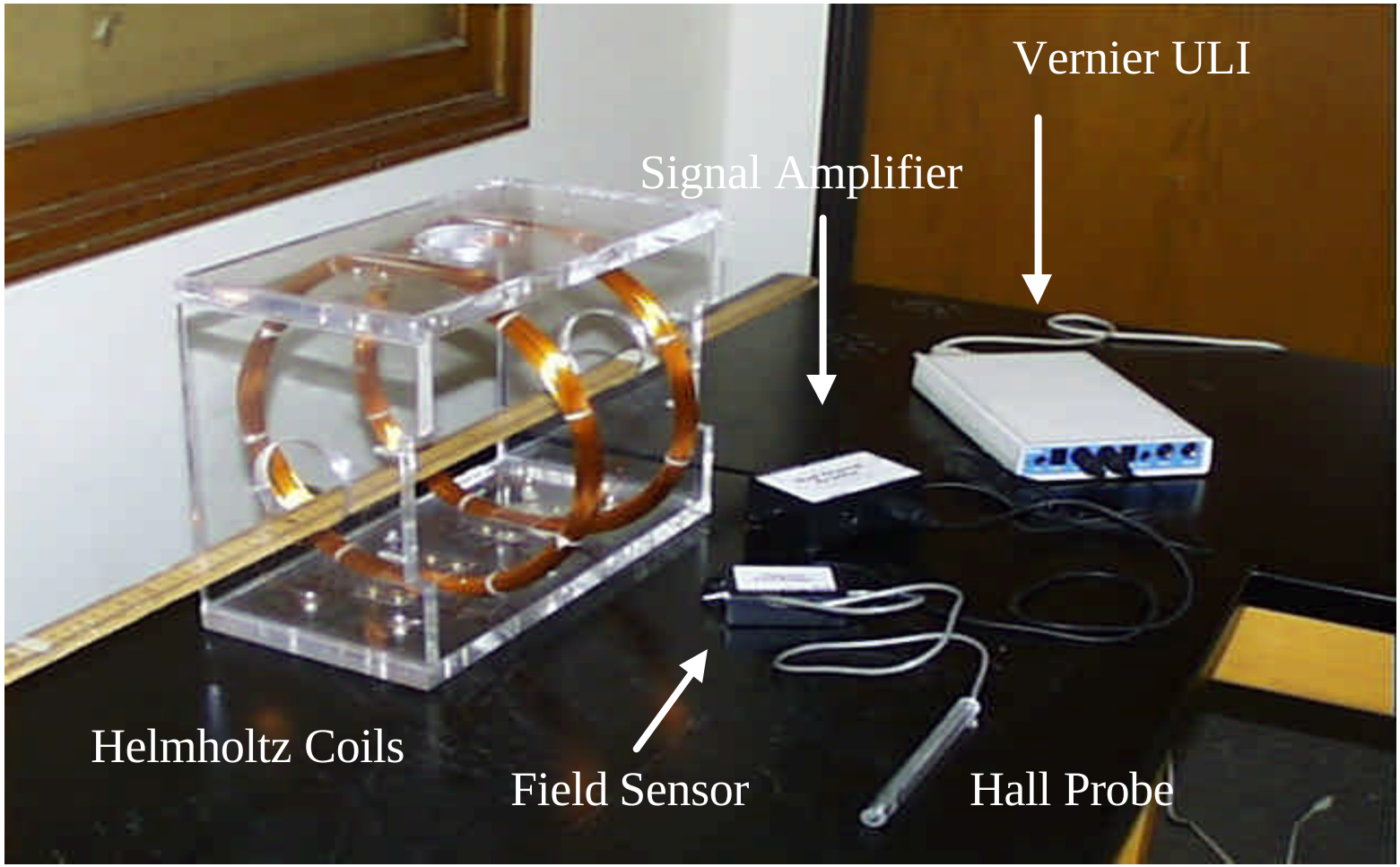
**Equipment:**

Connect two large coils to a power supply so that each coil has the same current. (Each coil has 150 turns)

You will have a digital Multimeter (DMM), a compass, a meter stick, and a Hall probe. A computer is used for data acquisition.

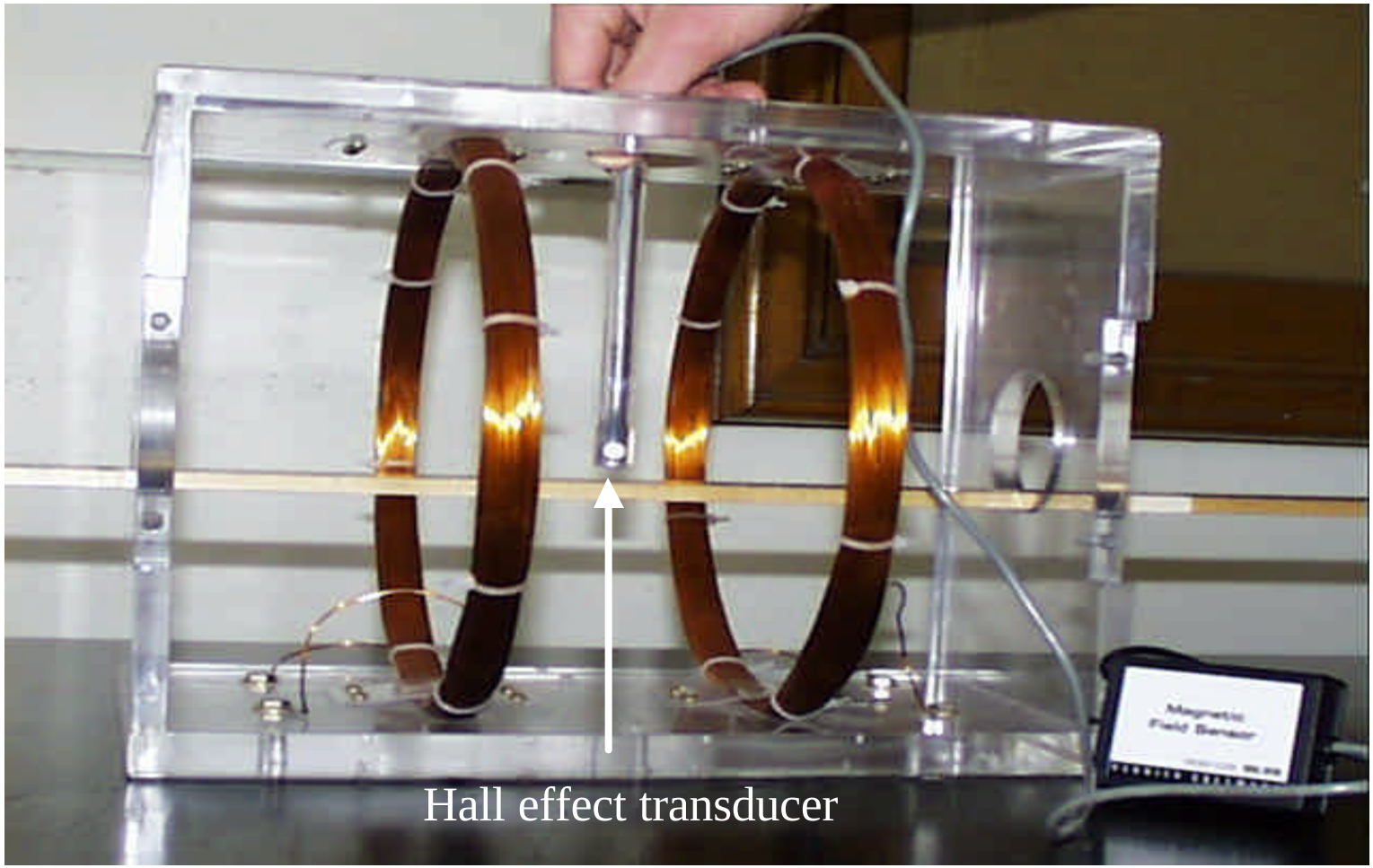


# Uses: Standard Set-up



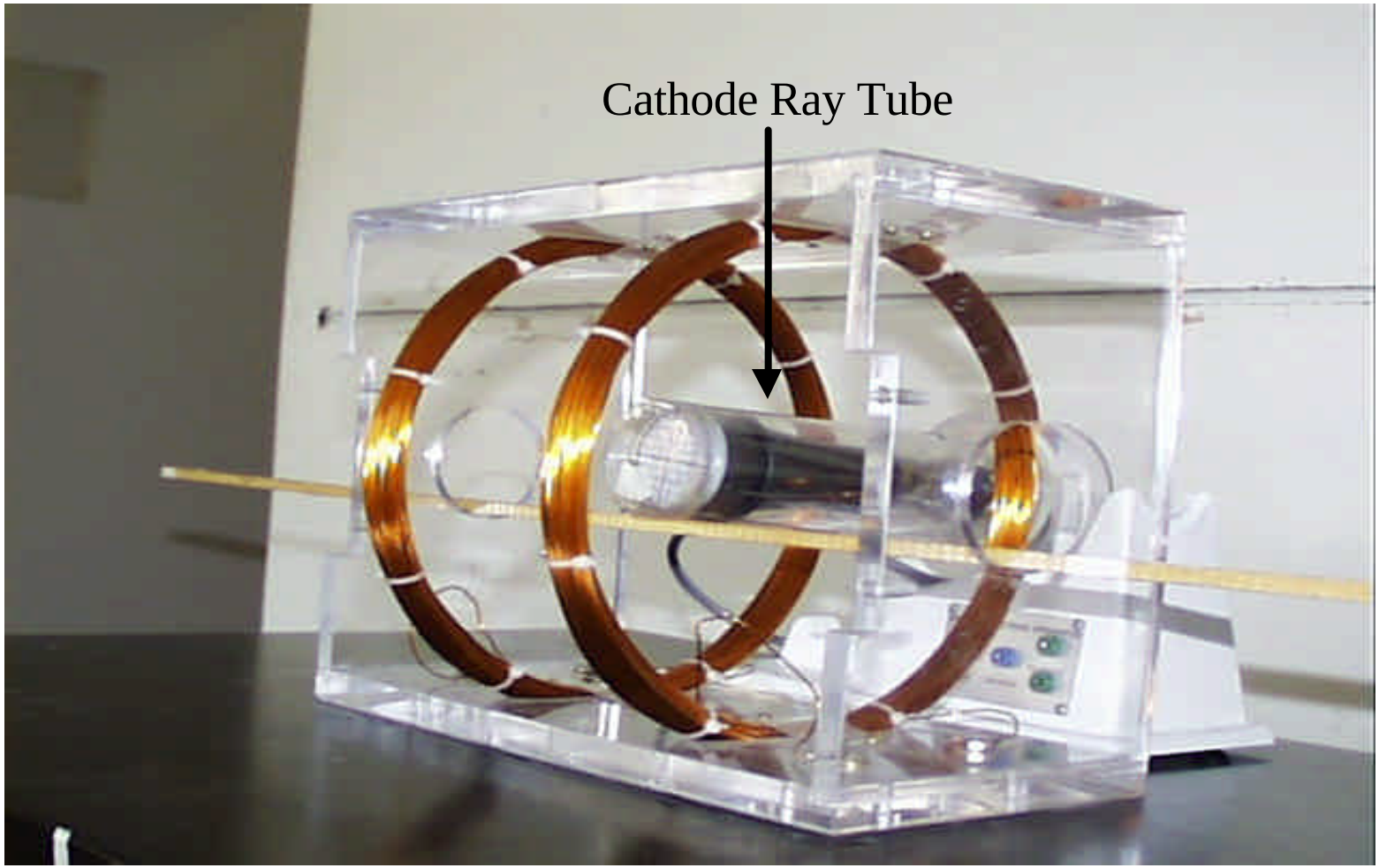
# Uses: Fields

Biot-Savart



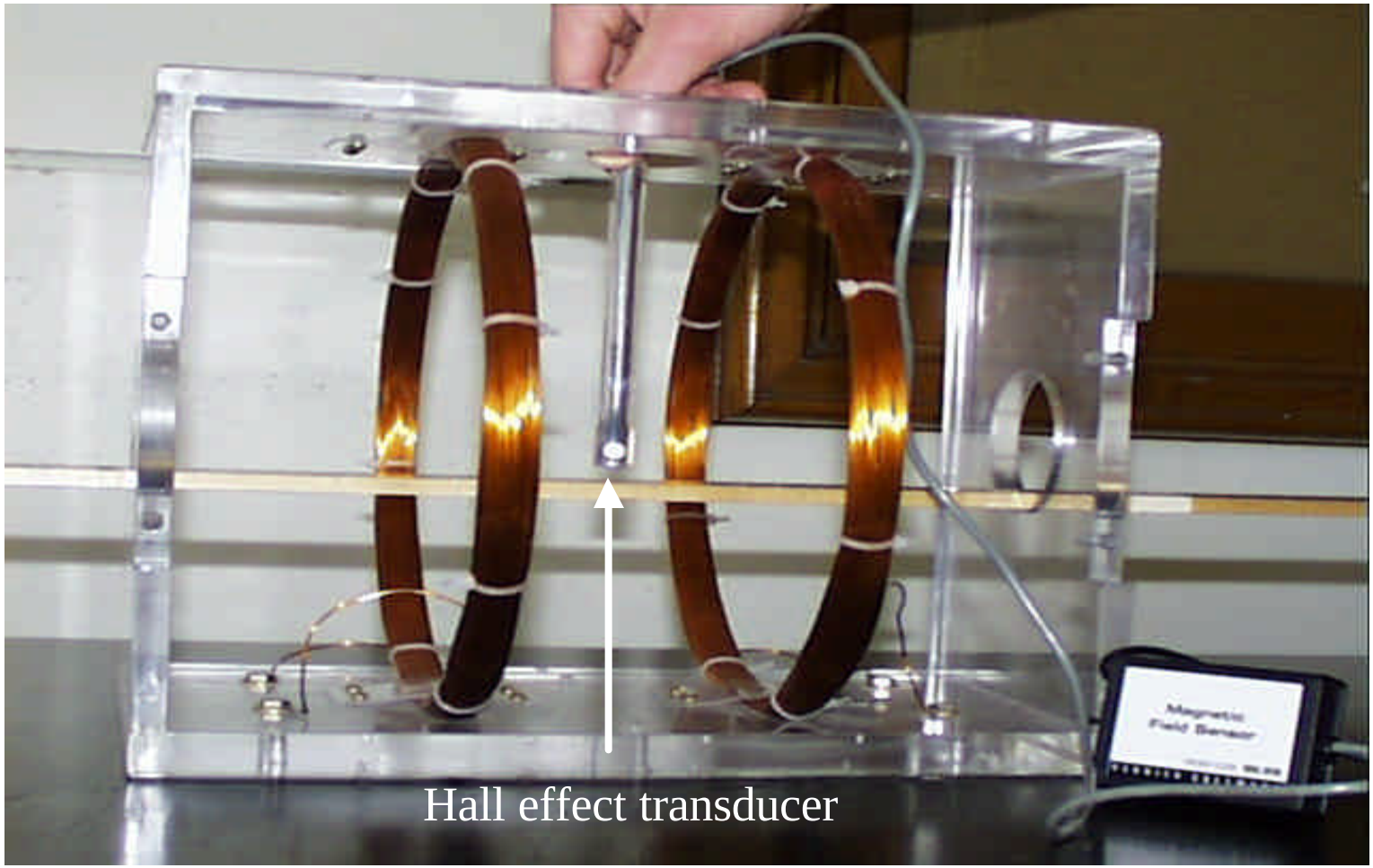
# Uses: Forces

$\mathbf{F} = qn \times \mathbf{B}$



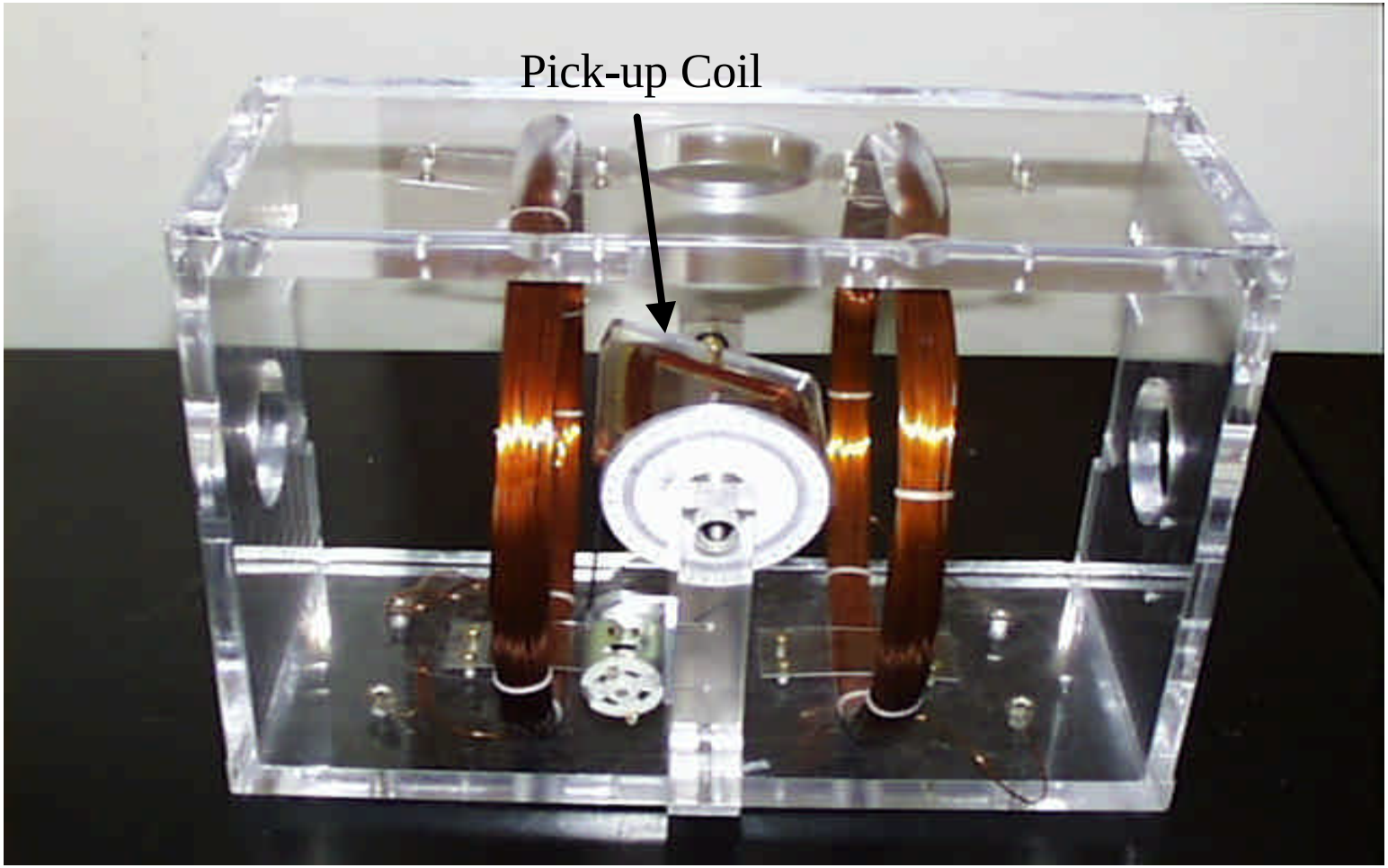
# Uses: Flux

$$\Phi = \int \mathbf{B} \bullet d\mathbf{A}$$

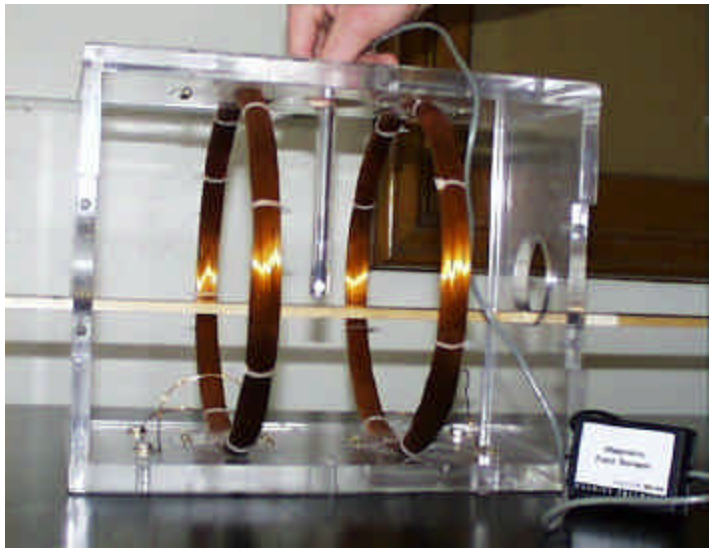


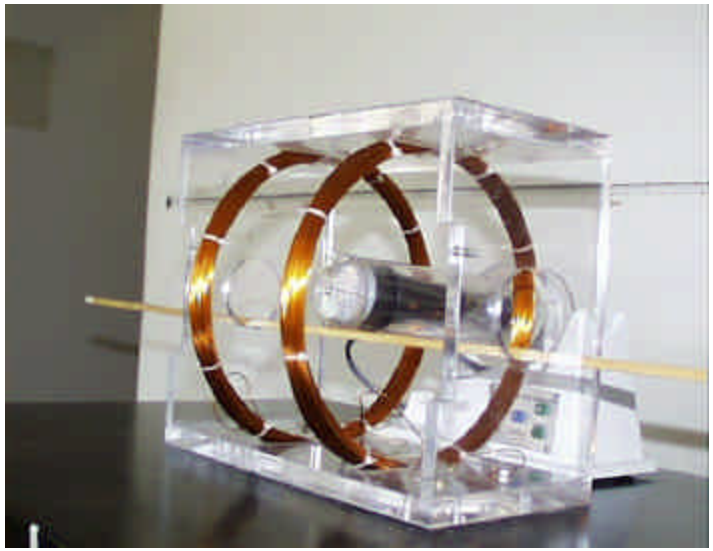
# Uses: Induction

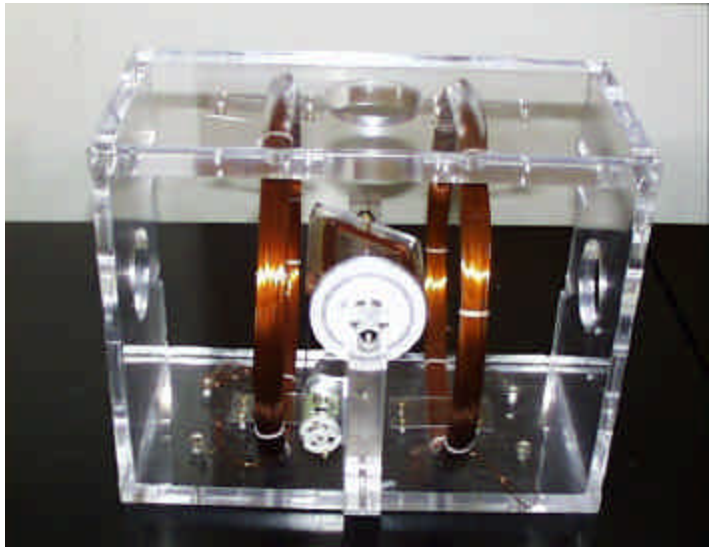
$$\varepsilon = -\frac{d\Phi}{dt}$$



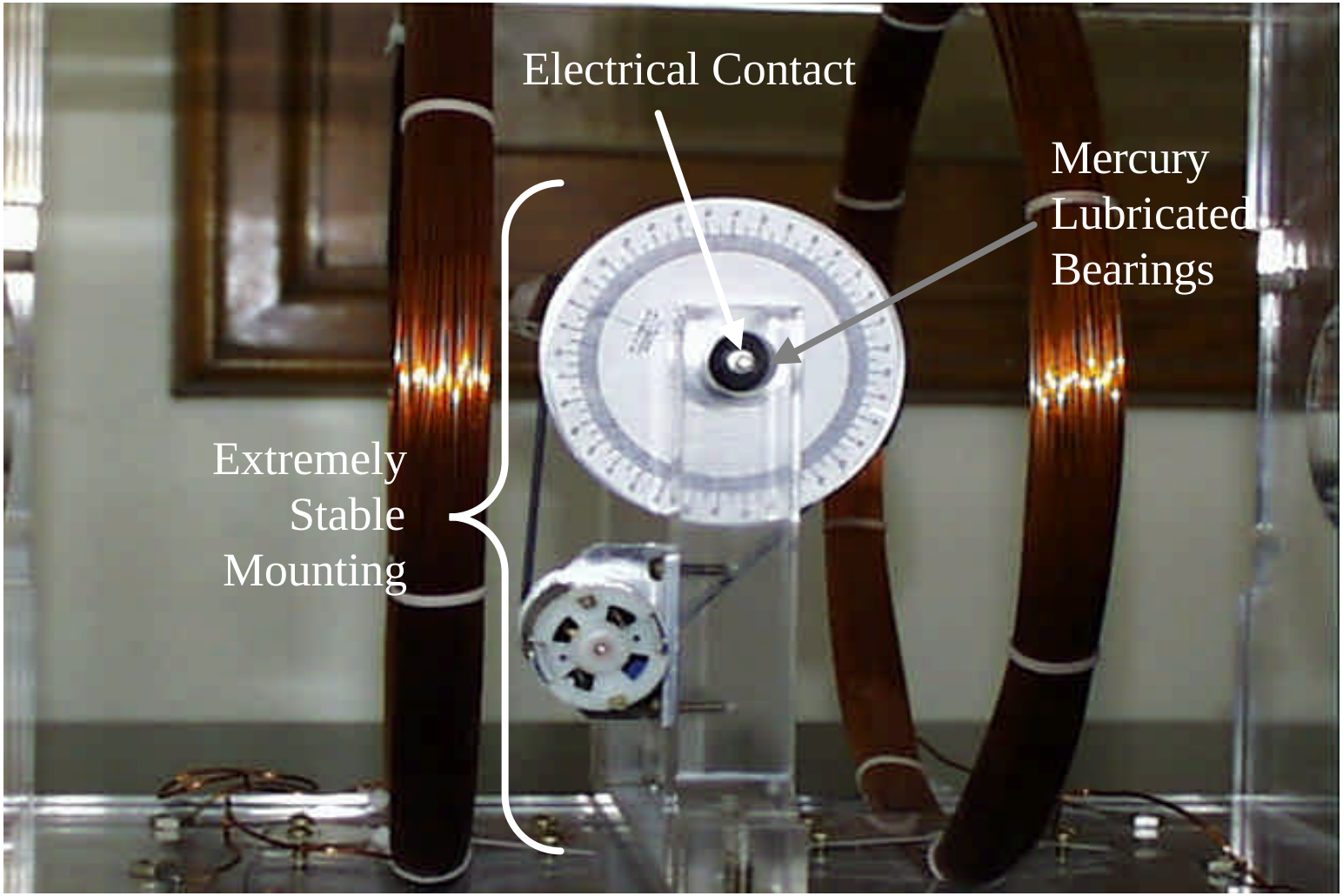
# Design Features







# Design Features



# Summary

- Reasons for the design
  - Practical
    - extensive usage
    - lack of maintenance time
  - Pedagogical
    - problem solving
    - physics principles
- Resultant apparatus
  - Practical
    - efficient and robust
  - Pedagogical
    - generic, yet multipurpose

# Summary

- Uses for the apparatus
  - Magnetic fields of current carrying wires
    - single coil
    - two parallel coils
  - Magnetic forces on a moving charge

    deflection of electron beam in constant field
  - Magnetic flux

    angular dependence
  - Magnetic induction
    - rotating coil in constant field
    - stationary coil in time-varying field