Magnetism

I. Magnetic Field
- units, poles
- effect on charge

II. Magnetic Force on Current
- parallel currents, motors

III. Sources of Magnetic Fields
- Ampere's Law
- magnetism in matter

IV. Magnetic Induction
- Faraday's Law
- Lenz's Law

	The student will be able to:	HW:
1	Define and illustrate the basic properties of magnetic fields and permanent magnets: field lines, north and south poles, magnetic compasses, Earth's magnetic field.	✓ 1 – 4
2	Solve problems relating magnetic force to the motion of a charged particle through a magnetic field, such as that found in a mass spectrometer.	✓ 5 – 11
3	Solve problems involving forces on a current carrying wire in a magnetic field and torque on a current carrying loop of wire in a magnetic field.	✓ 12 – 18
4	State and apply relation between magnetic field and position for a long current carrying wire and solve related problems.	✓ 19 – 25
5	Qualitatively describe and apply properties of magnetic dipole fields generated by loops of current and model behavior of magnetic materials using domains, ferromagnetism, paramagnetism, and diamagnetism.	✓ 26 – 30
6	State and apply Faraday's Law and Lenz's Law and solve problems involving induced emf and magnetic flux.	31 – 38

Induction

- Just as an electric field can induce an electrostatic charge, a magnetic field can induce a current.
- However, it is observed that only a *changing* magnetic field can result in a current – presence of a *static* magnetic field will <u>not</u> induce a current.
- If current exists, it follows that there must be voltage, which in this case is called emf ("electromagnetic force").

Faraday’ s Law

$$e = -\frac{DF_M}{Dt}$$

where: ε = induced emf

Φ_M = magnetic flux

t = time

Magnetic Flux

$$\Phi_M = \vec{B} \cdot \vec{A}$$

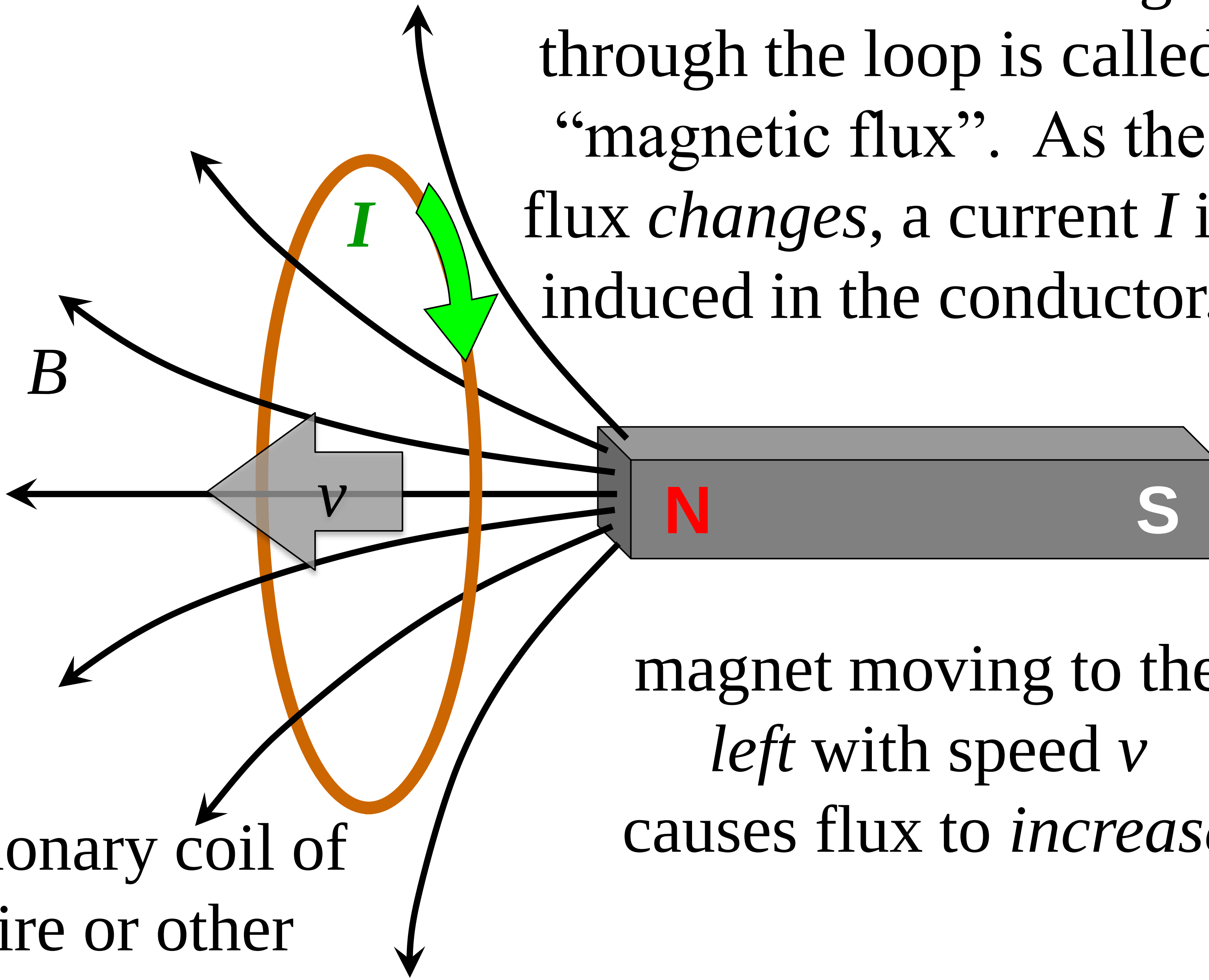
$$\Phi_M = B_{||} A = B A_{||}$$

$$\Phi_M = BA\cos\theta$$

where: Φ_M = magnetic flux
B = magnetic field
A = area vector (normal)

SI unit: 1 weber = 1 tesla·1 meter^2
Wb = T·m^2

The field *B* extending through the loop is called “magnetic flux”. As the flux *changes*, a current *I* is induced in the conductor.



magnet moving to the *left* with speed *v* causes flux to *increase*

stationary coil of wire or other conducting loop

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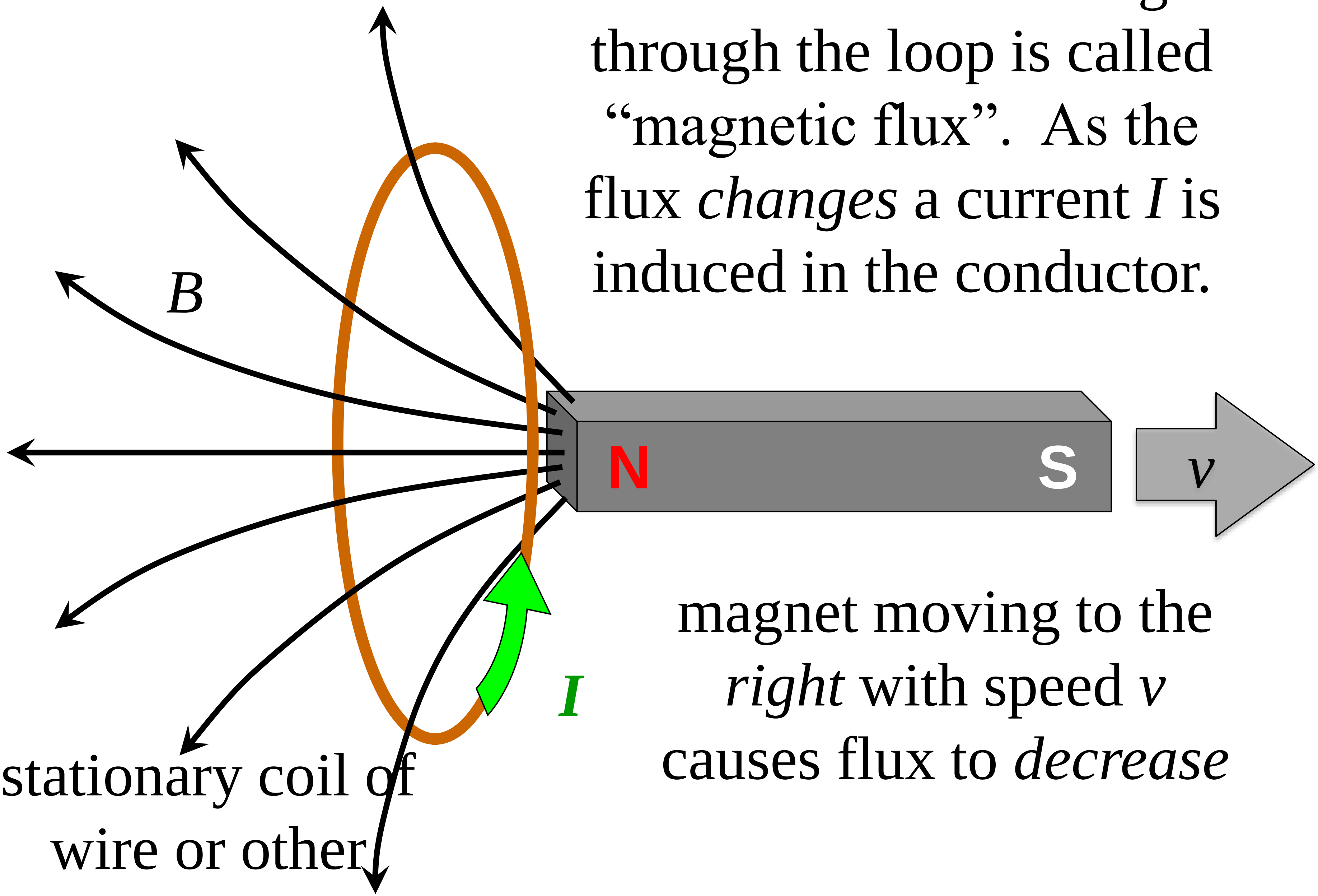
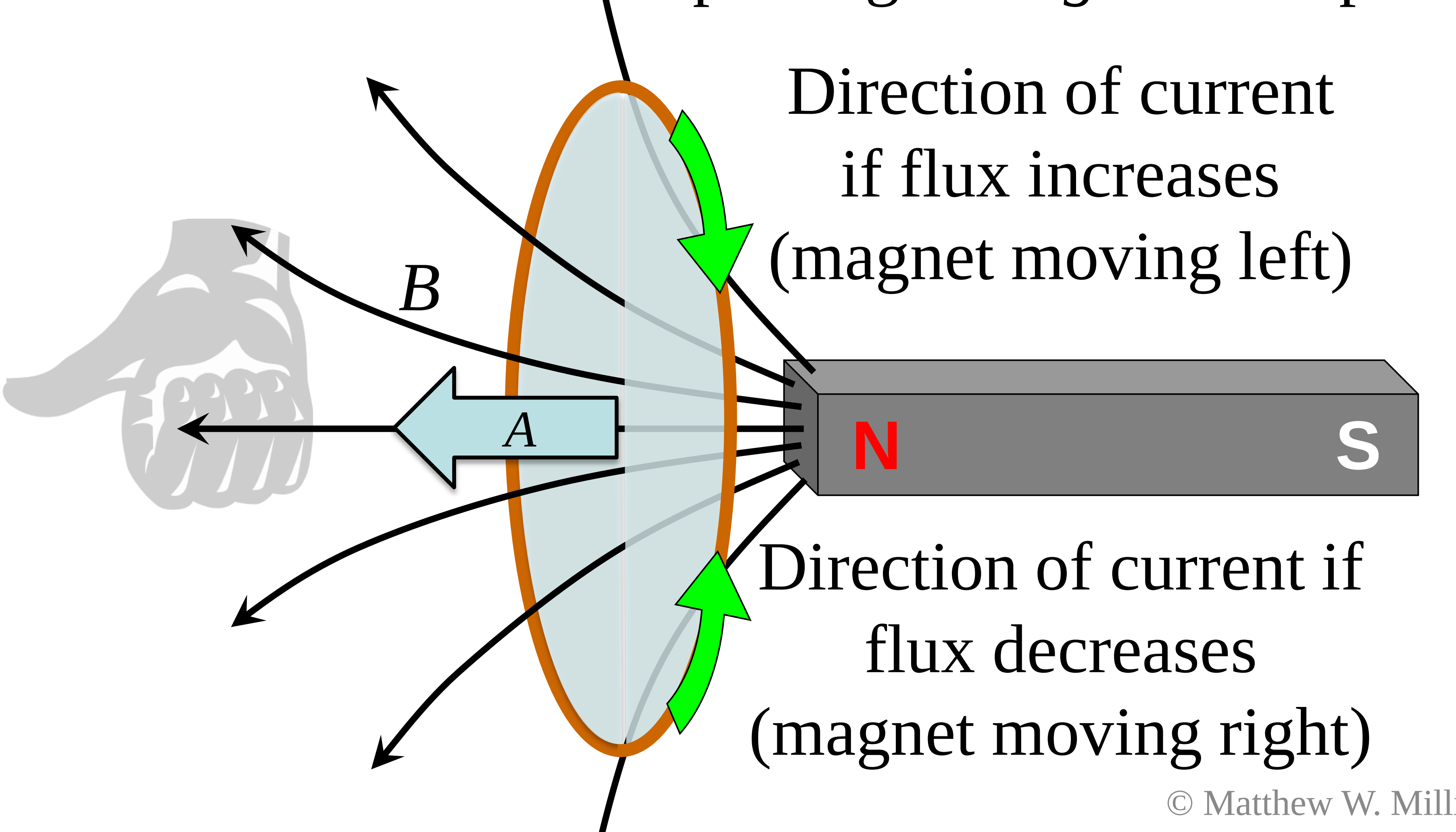


magnet moving to the *right* with speed *v* causes flux to *decrease*

stationary coil of wire or other conducting loop

Magnetic flux is a product of magnetic field and the area bound by the loop. When the field is stronger the flux is greater. The magnetic flux is proportional to the number of field lines passing *through* the loop.



About the Induced EMF

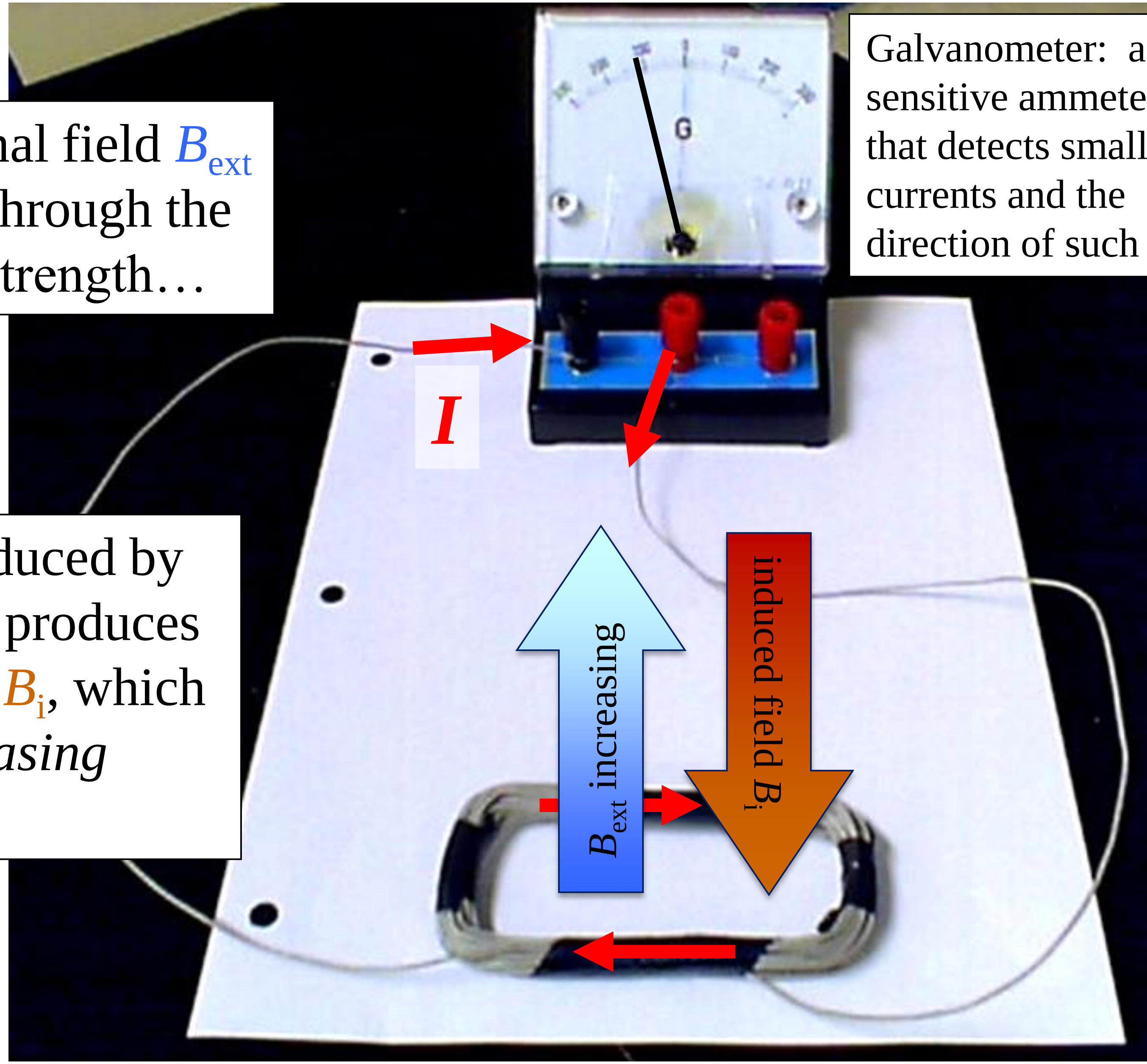
- The negative sign in Faraday's Law indicates the sense of the induced emf.
- The direction in which this emf drives current is referred to as the "sense" of the emf.
- Unlike other voltage sources, an induced emf is not the potential difference between two points (like the terminals of a battery).
- Rather, the induced emf represents "work or energy per charge" "around and along a path".

Lenz's Law

- When a changing magnetic flux induces a current, the induced current *itself* will create an *additional* magnetic field.
- The induced current will always produce a magnetic field that opposes the *change* in magnetic flux.
- If magnetic flux is increasing then the induced magnetic field will point opposite the original.
- This is an easier method for finding the sense of the emf than using the RHR and negative sign in Faraday's Law.

Magnetic Induction Illustrations…

Suppose an external field B_{ext} pointing *upward* through the coil *increases* in strength…

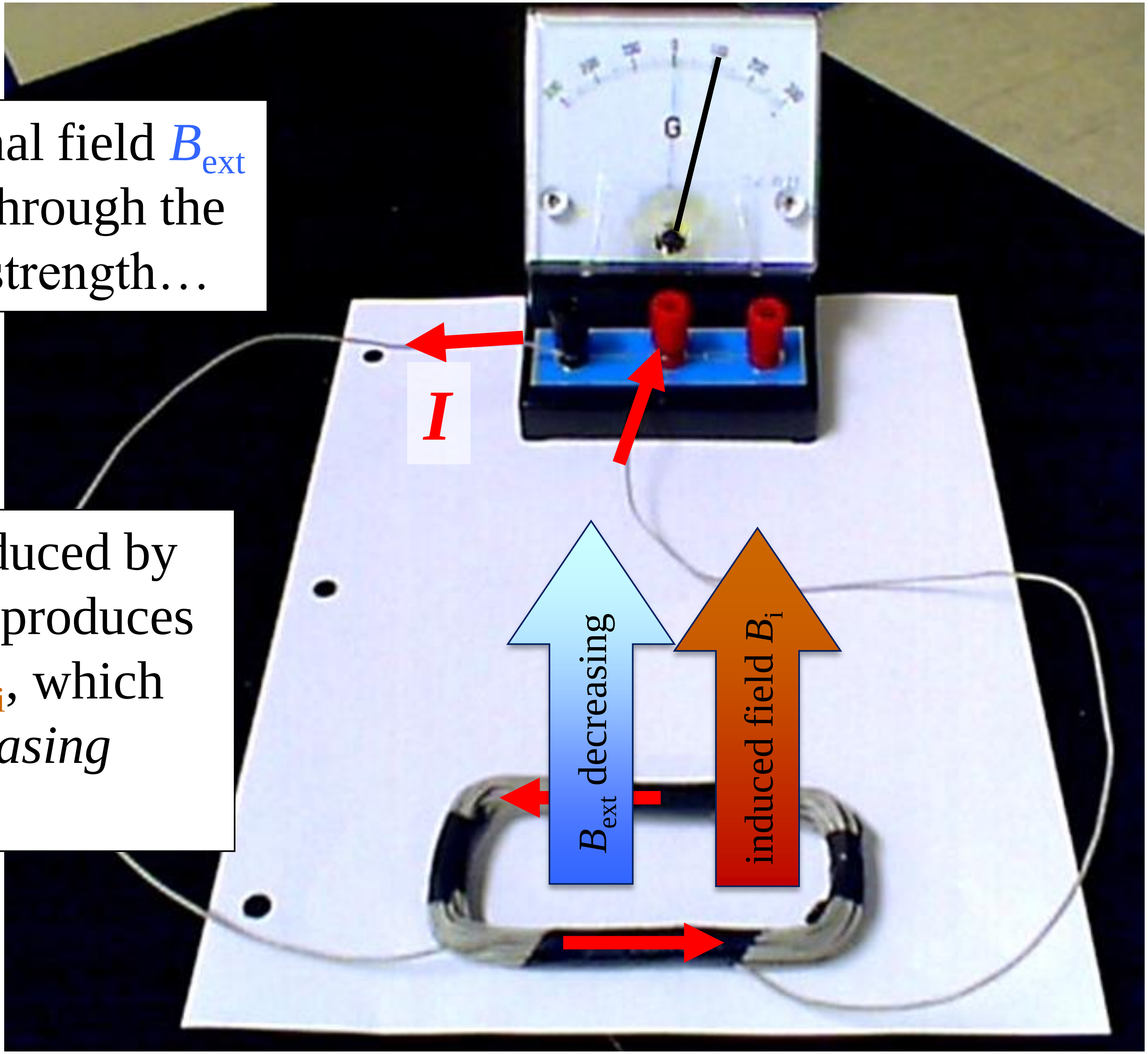


Galvanometer: a sensitive ammeter that detects small currents and the direction of such

…the current I induced by the changing flux produces a *downward* field B_i, which opposes the *increasing* upward flux.

Magnetic Induction Illustrations…

Suppose an external field B_{ext} pointing *upward* through the coil *decreases* in strength…

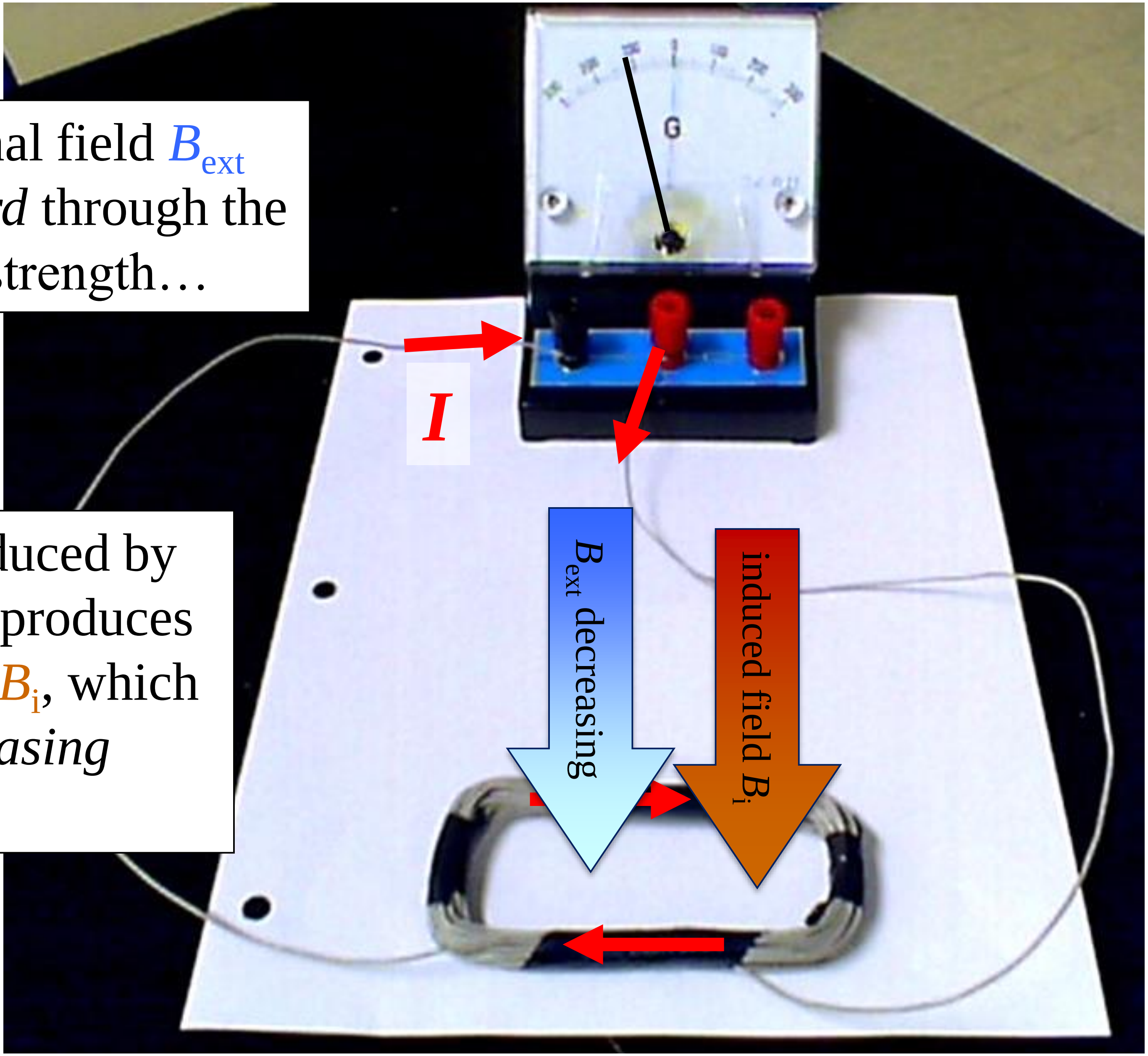


…the current *I* induced by the changing flux produces an *upward* field B_i, which opposes the *decreasing* upward flux.

Magnetic Induction Illustrations…

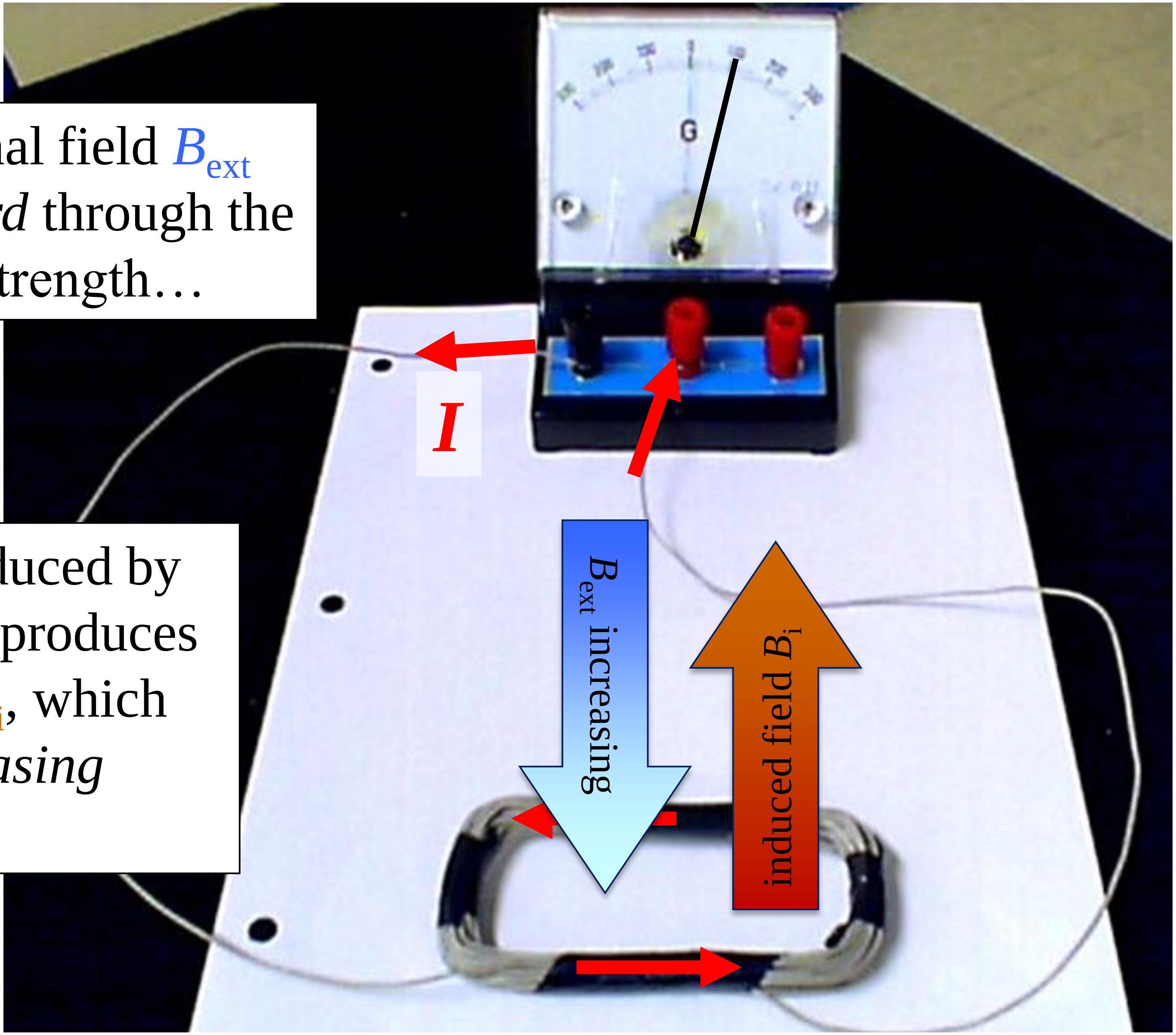
Suppose an external field B_{ext} pointing *downward* through the coil *decreases* in strength…

…the current *I* induced by the changing flux produces a *downward* field B_i, which opposes the *decreasing* downward flux.



Magnetic Induction Illustrations…

Suppose an external field B_{ext} pointing *downward* through the coil *increases* in strength…



…the current I induced by the changing flux produces an *upward* field B_i, which opposes the *increasing* downward flux.

nice simulation of this: search PhET Faraday's Law or use https://phet.colorado.edu/sims/html/faradays-law/latest/faradays-law_en.html