Nucleic Acids

- Carries and stores genetic information of species
- Chemically stable
- Very long

	base pairs (kb)	length (μm)
SV40	5.1	1.7
lambda phage	48.6	17
T2 phage	166	56
Mycoplasma	760	260
E.coli	4,000	1,360
Yeast	13,500	4,600
Drosophila	165,000	56,000
Human	2,900,000	990,000

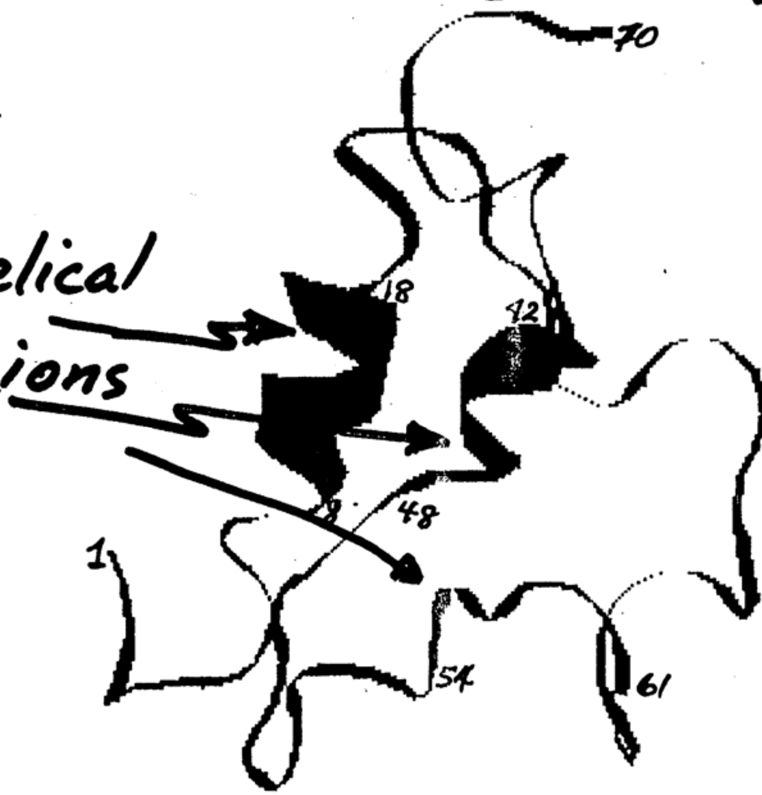
Two slides removed due to copyright restrictions.

- Diagrams of hydrophilic amino acids removed due to copyright restrictions. (From Lodish et al)
- Chemical structure of adenosine triphosphate (ATP). Fig. 2.9 in Alberts et al., *Molecular Biology of the Cell*.
- Diagrams of aggrecan (proteoglycan) – referencing work by Dick Heinegard (1989) – and chondroitin sulfate.

IGF-I

Insulin-Like Growth Factor-I

α-helical regions



"Folds" like Insulin in Aqueous Solution

- M.W. ~ 7,600 Da
- pI ~ 8.4 (basic)

PROTEIN: (70 amino acids)

(⊕ at pH ~ 7)

Exception : Migratory Birds (pigeons)

Image removed due to copyright restrictions.

Figure 1 in Mora, Cordula V. "Magnetoreception and its Trigeminal Mediation in the Homing Pigeon." *Nature* 432 (2004): 508-511.

Collection of bacteria using Dielectrophoretic force

Figures 3 and 4 removed due to copyright restrictions.

See B. H. Lapizco-Encinas, B. A. Simmons, E. B. Cummings, Y. Fintschenko
Anal. Chem.2004, 76,1571-1579

Dielectrophoretic Manipulation of Cells

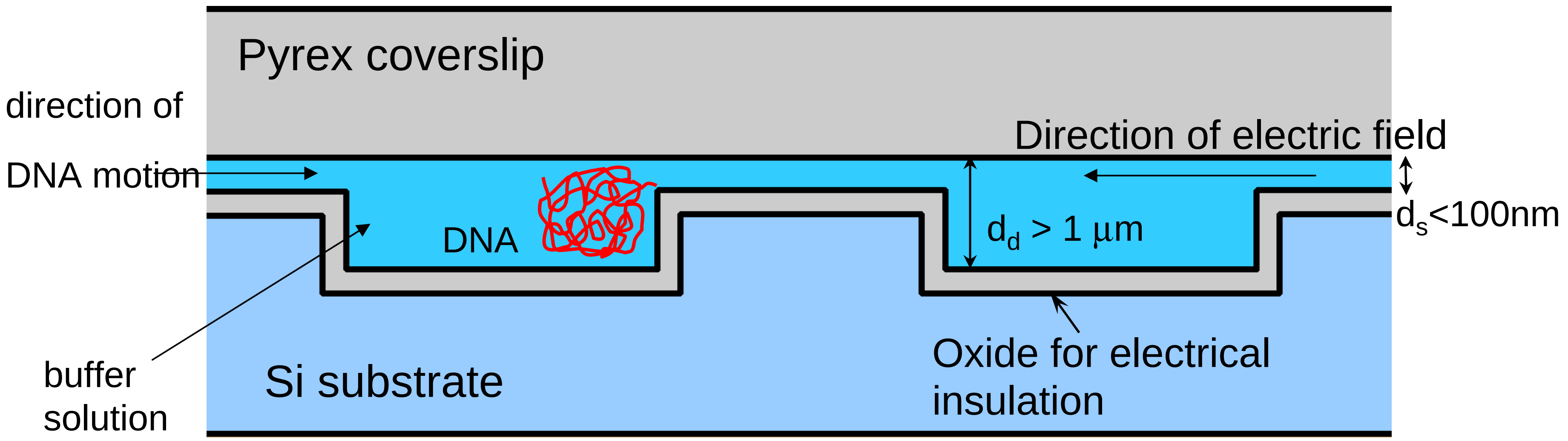
See Grey et al. “Cells trapped by dielectrophoresis.”
Biosensors and Bioelectronics 19 (2004) 1765–1774

See Prof. Joel Voldman’s group website: http://www.rle.mit.edu/biomicro/dep.htm

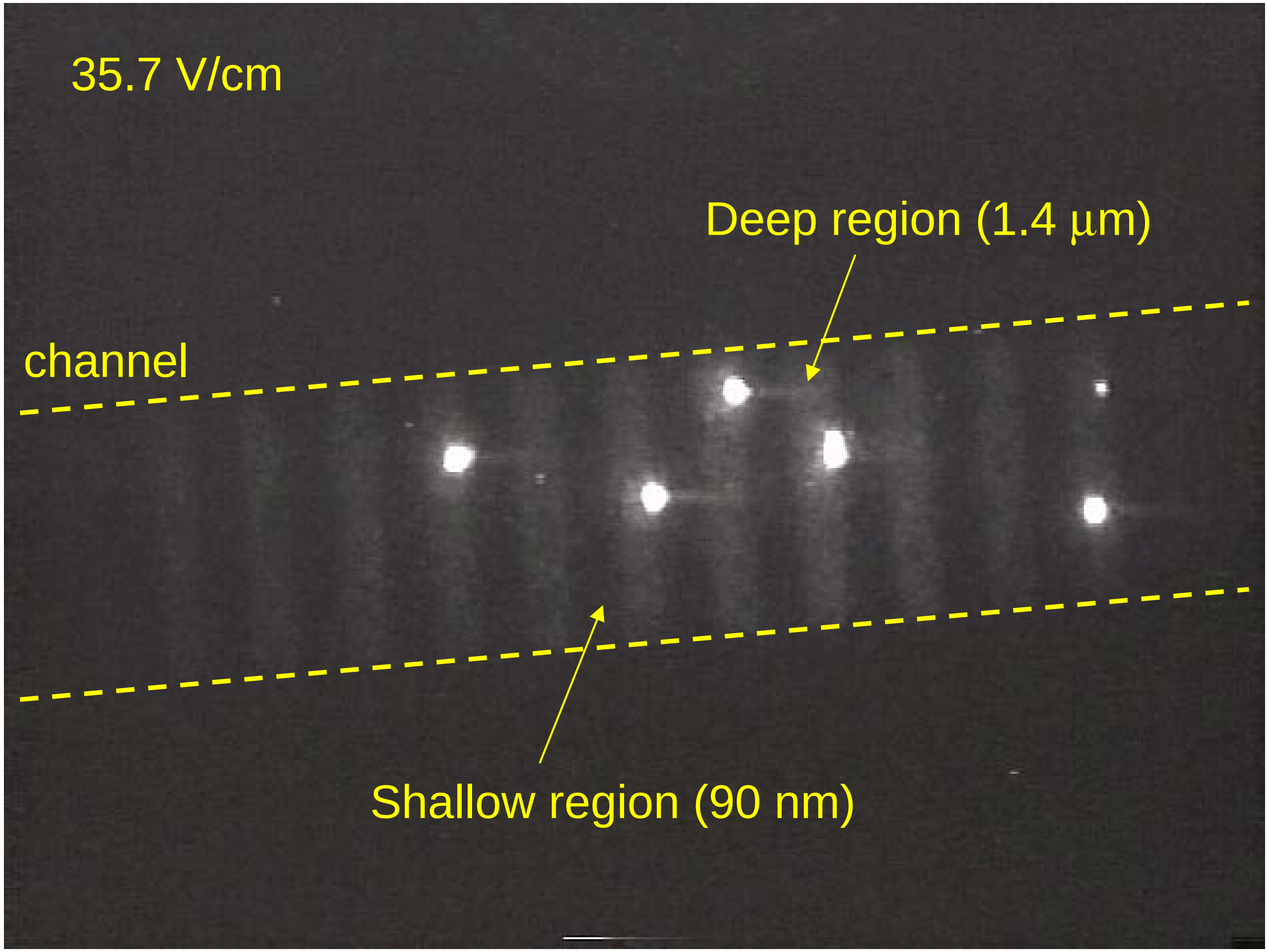
Design of nanofluidic channel

- Constriction much smaller than R_g (the radius of gyration of DNA)
- Open (deep) region where DNA can relax into equilibrium spherical shape
- Entropic hindrance for DNA from entering the shallow region
- Trapping affects DNA motion driven by an electric field

Cross sectional diagram of the channel



Motion of DNA in Channels



From Prof. Han's Ph.D thesis

Key Concepts for this section

1: Lorentz force law, Field, Maxwell’s equation

2: Ion Transport, Nernst-Planck equatioin

3: (Quasi)electrostatics, potential function,

4: Laplace’s equation, Uniqueness

5: Debye layer, electroneutrality

Goals of Part II:

(1) Understand when and why electromagnetic (E and B) interaction is relevant (or not relevant) in biological systems.

(2) Be able to analyze quasistatic electric fields in 2D and 3D.

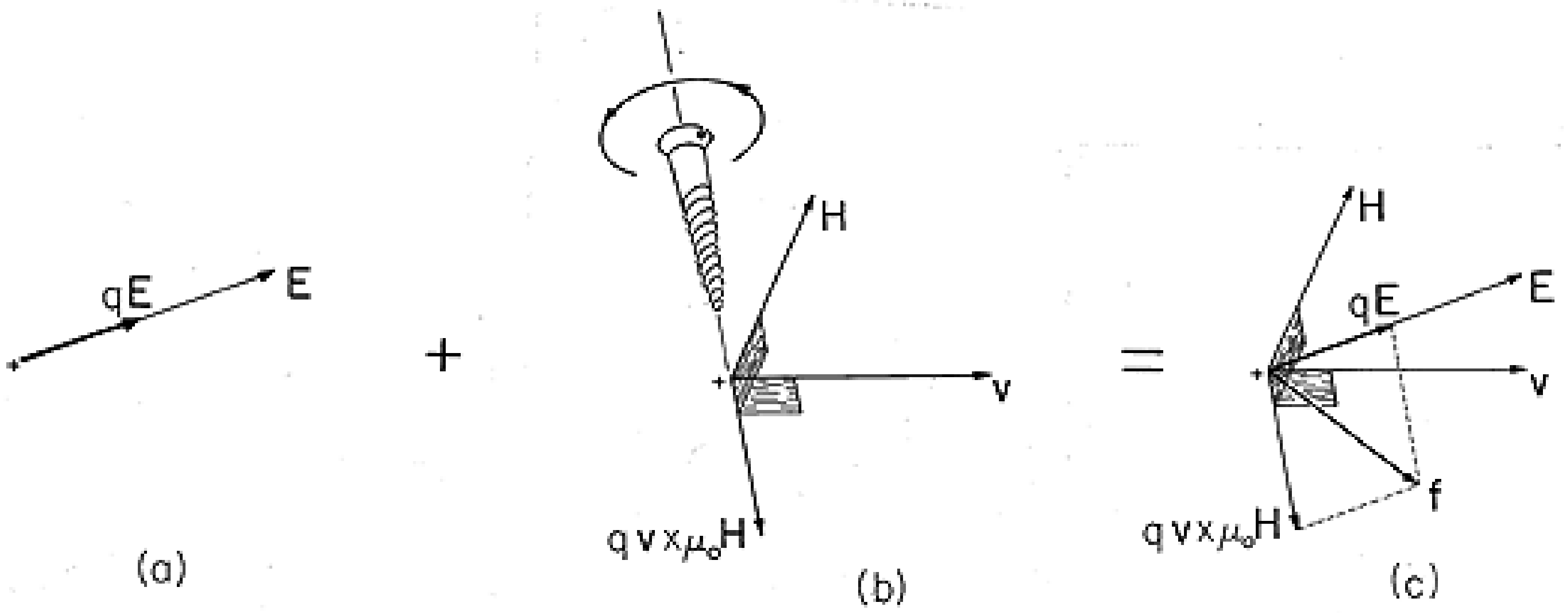
The "field" theory of electromagnetic forces

Source (charge, current) → E and B field → Lorentz force

- Lorentz Force Law

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

- Electric Force on a charge q : q**E**
- Magnetic Force on a charge q : q **v × B**

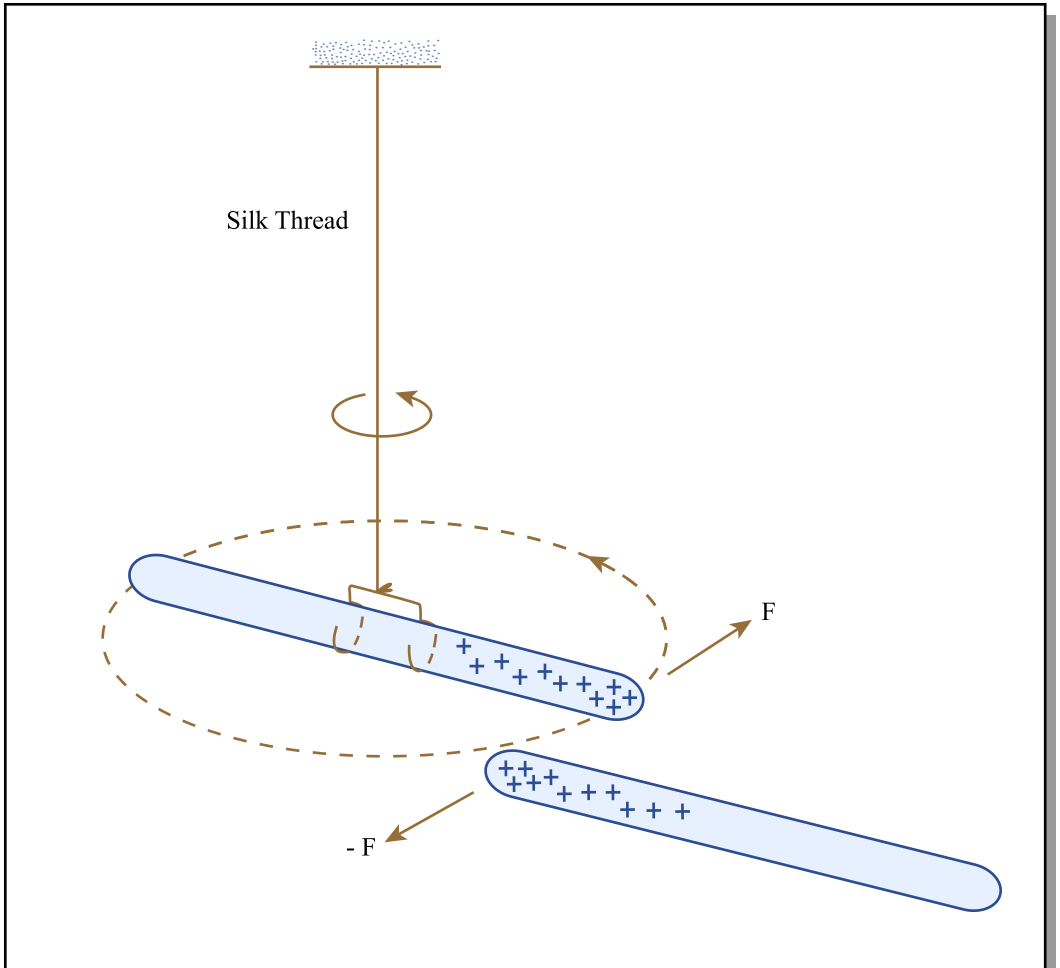


H&M Figure 1.1.1

Coulomb's law

$$F_{Coulomb} = \frac{1}{4\pi\varepsilon_o}\frac{Q_1 Q_2}{r^2}$$

$$\varepsilon_o = 8.85\times10^{-12}\,(F/m)$$



Two positively charged glass rods repel each other.

Figure by MIT OCW.

Gauss's Law : Electric vs Magnetic field

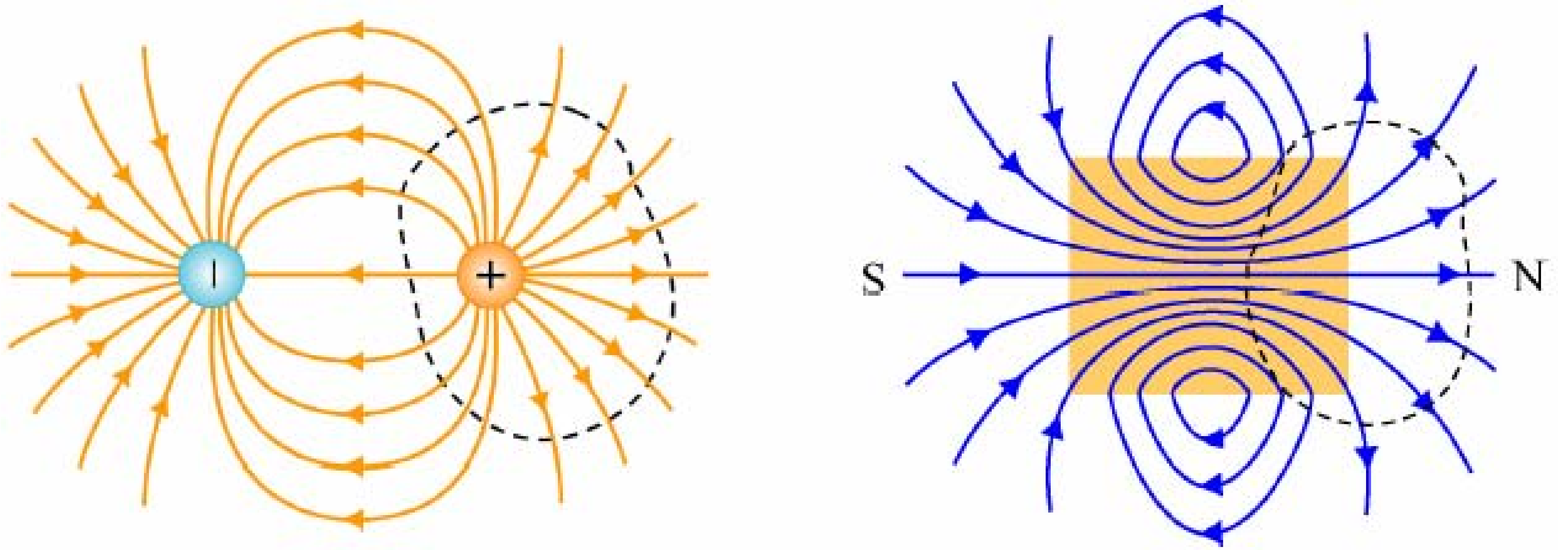


Figure 13.2.1 Gauss's law for (a) electrostatics, and (b) magnetism.

Image source: MIT 8.02 class notes.
Courtesy of Dr. Sen-ben Liao, Dr. Peter Dourmashkin, and
Professor John W. Belcher. Used with permission.

Oerstead (1820)

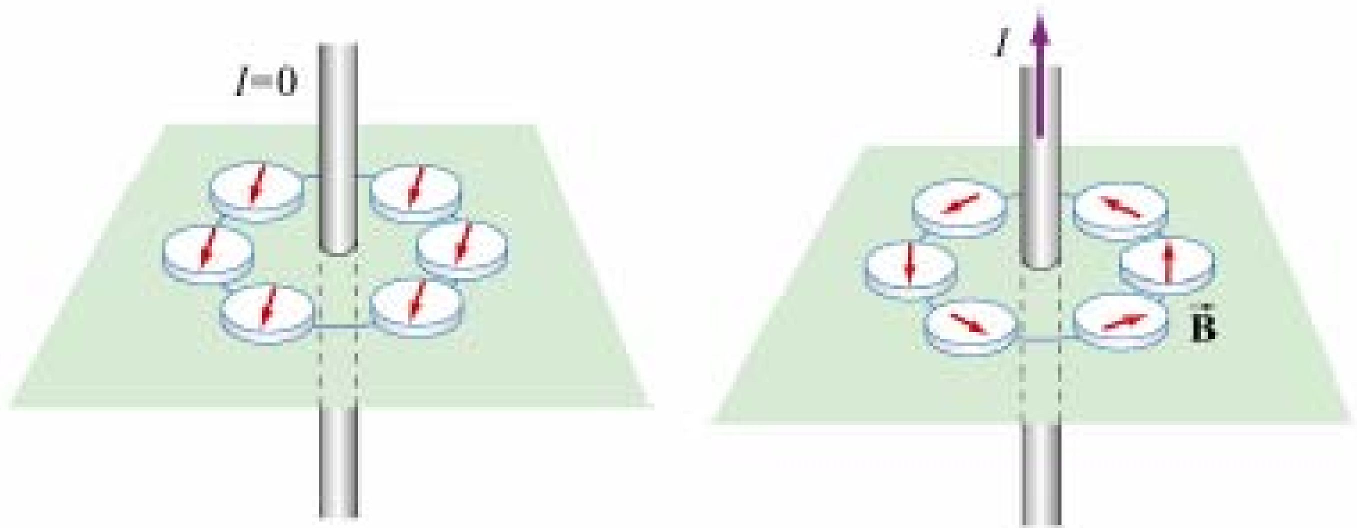


Figure 9.3.1 Deflection of compass needles near a current-carrying wire

Figure 9.8.3 Magnetic field lines due to (a) a current loop, and (b) a small bar magnet.

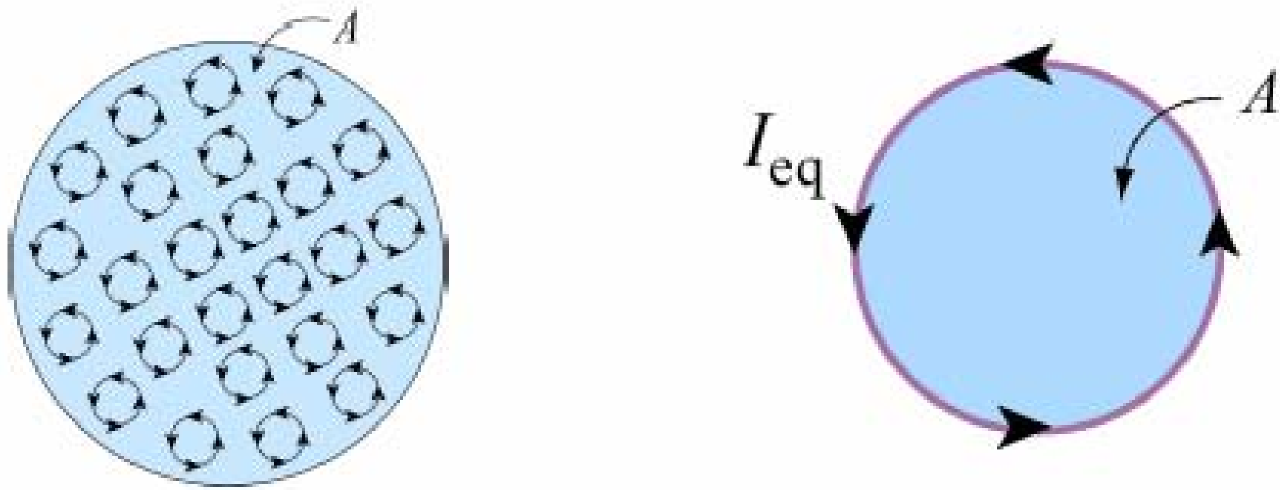


Figure 9.6.2 (a) Top view of the cylinder containing magnetic dipole moments. (b) The equivalent current.

Ampere's law

$$\frac{1}{\mu_o}\oint_C \vec{B}\cdot d\vec{s} = \int_S \vec{J}\cdot d\vec{a} = I$$

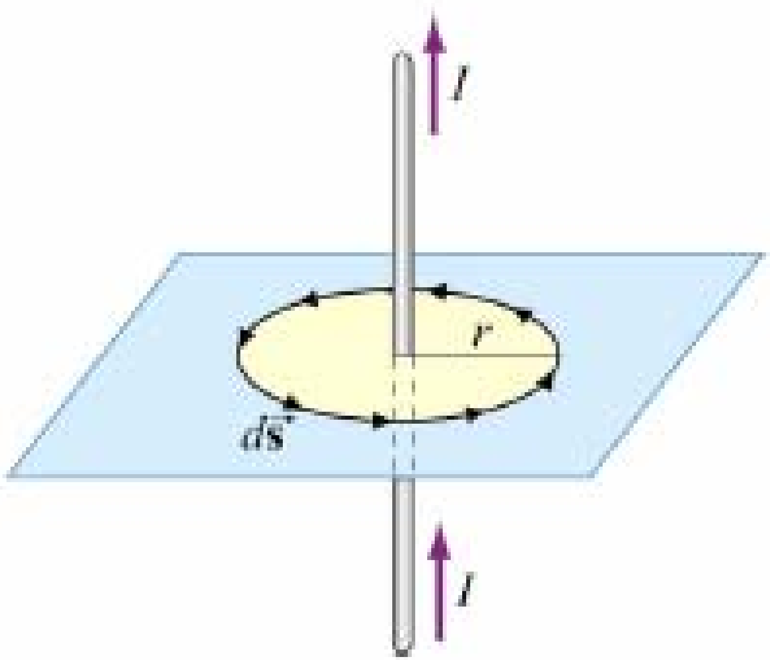


Figure 9.3.2 Amperian loop

Image source: MIT 8.02 class notes.
Courtesy of Dr. Sen-ben Liao, Dr. Peter Dourmashkin, and Professor John W. Belcher. Used with permission.

Maxwell displacement current

$$\frac{1}{\mu_o}\oint_C \vec{B}\cdot d\vec{s} = \int_S \vec{J}\cdot d\vec{a} + \frac{d}{dt}\int_S \varepsilon_o \vec{E}\cdot d\vec{a}$$

(Current) (Displacement current)

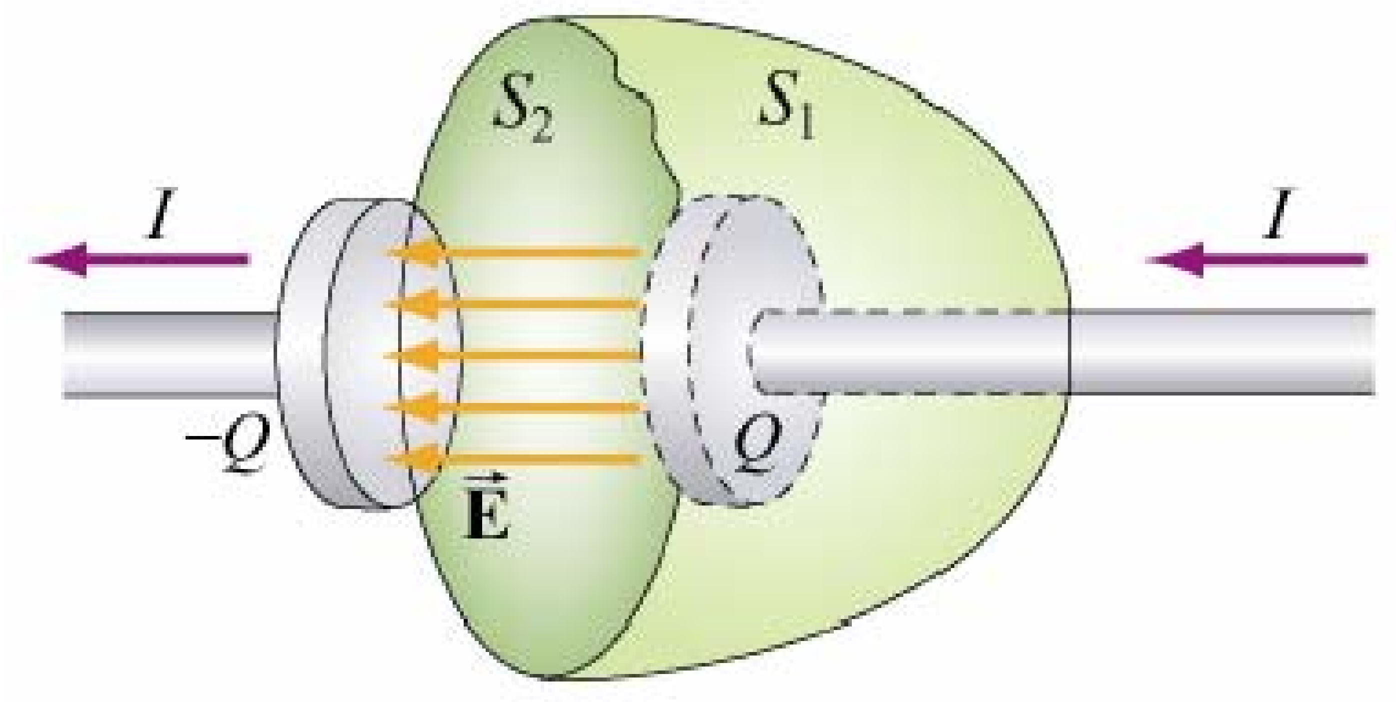


Figure 13.1.2 Displacement through S_2

Image source: MIT 8.02 class notes.
Courtesy of Dr. Sen-ben Liao, Dr. Peter Dourmashkin, and Professor John W. Belcher. Used with permission.

Faraday

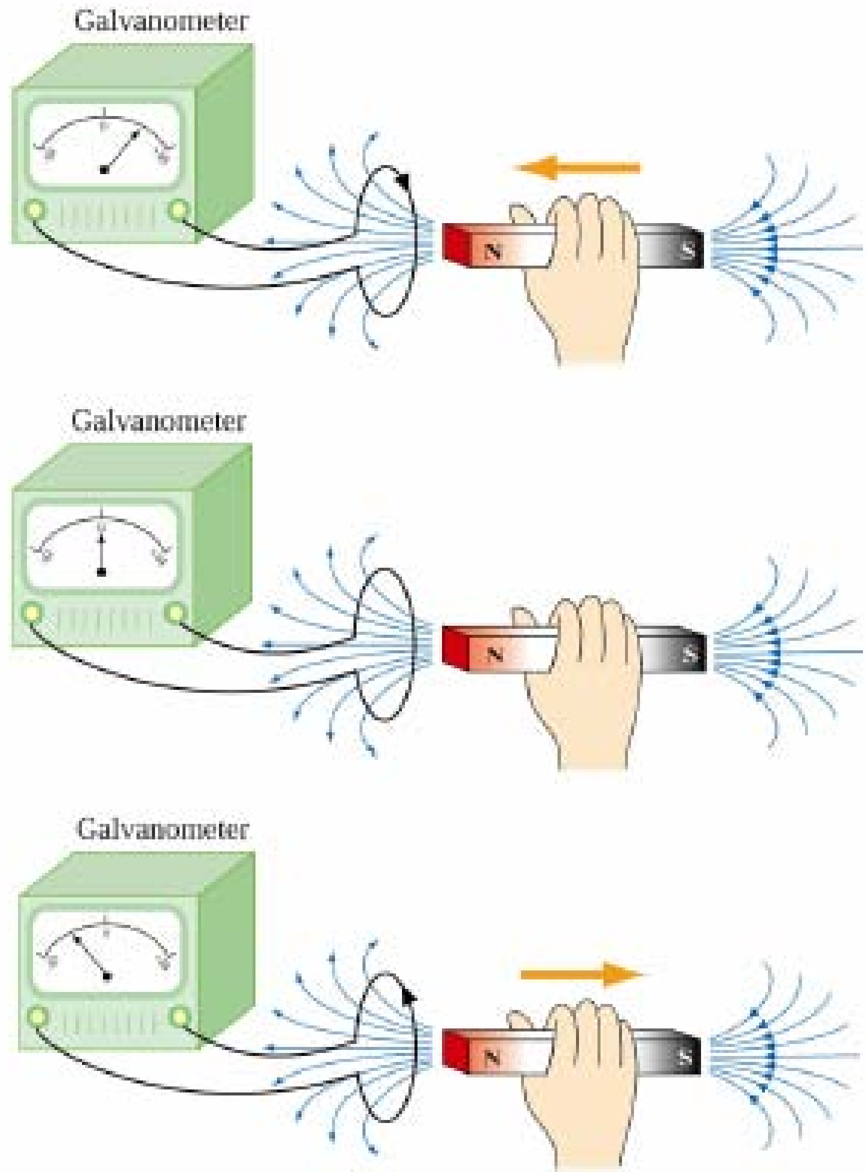


Figure 10.1.1 Electromagnetic induction

Image source: MIT 8.02 class notes. Courtesy of Dr. Sen-ben Liao, Dr. Peter Dourmashkin, and Professor John W. Belcher. Used with permission.

Maxwell's four equations for E

Law	Equation	Physical Interpretation
Gauss's law for $\vec{\mathbf{E}}$	$\oiint_S \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{Q}{\varepsilon_0}$	Electric flux through a closed surface is proportional to the charged enclosed
Faraday's law	$\oint \vec{\mathbf{E}} \cdot d\,\vec{\mathbf{s}} = -\frac{d\Phi_B}{dt}$	Changing magnetic flux produces an electric field
Gauss's law for $\vec{\mathbf{B}}$	$\oiint_S \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$	The total magnetic flux through a closed surface is zero
Ampere – Maxwell law	$\oint \vec{\mathbf{B}} \cdot d\,\vec{\mathbf{s}} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$	Electric current and changing electric flux produces a magnetic field

$$\oint_S \vec{\mathrm{J}} \cdot d\vec{\mathrm{s}} = -\frac{\mathrm{d}}{\mathrm{dt}}\left(\int_V \rho \,\mathrm{dV}\right)$$ Charge Continuity

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$ Lorentz Force Law