What Do We Know about the Fundamental Forces?

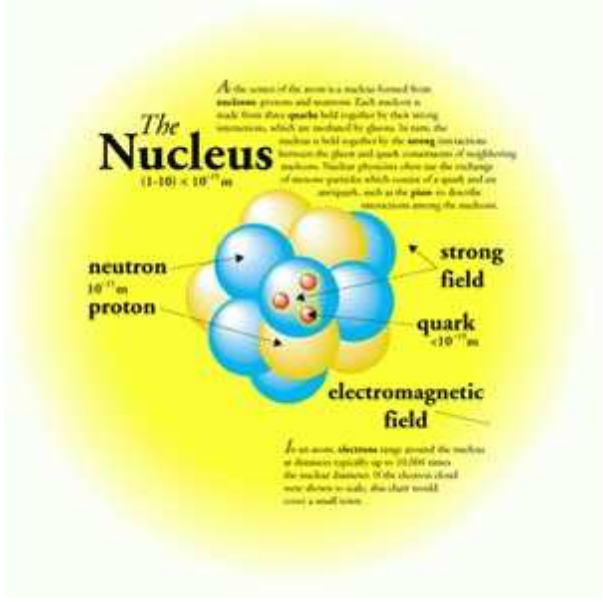
- The Universe is made of quarks, leptons and force carriers.

name	field or force carried by boson	spin	electric charge	mass (MeV/c^2)
photon	electromagnetism *(light)*	1	0	0
W **Z**	weak force *(radioactivity)*	1	+1,-1 0	80400 91200
gluon	strong force *(nuclear force or color force)*	1	0	0
graviton *[predicted]*	gravity	2	0	0

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c^2	Electric charge	Flavor	Approx. Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0	u up	0.003	2/3
e electron	0.000511	−1	d down	0.006	−1/3
ν_μ muon neutrino	<0.0002	0	c charm	1.3	2/3
μ muon	0.106	−1	s strange	0.1	−1/3
ν_τ tau neutrino	<0.02	0	t top	175	2/3
τ tau	1.7771	−1	b bottom	4.3	−1/3

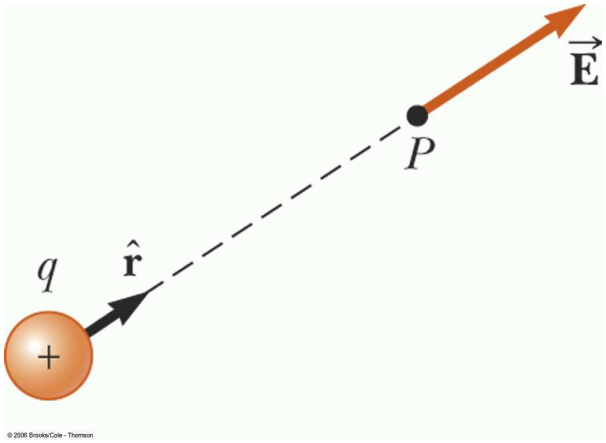
- The atomic nucleus is made of protons and neutrons bound by the strong force.



- The quarks are confined inside the protons and neutrons.
- Protons and neutrons are NOT confined.

The Electric and Magnetic Fields

$$d\vec{E} = k_e \frac{dq\hat{r}}{r^2}$$



The Electric and Magnetic Fields

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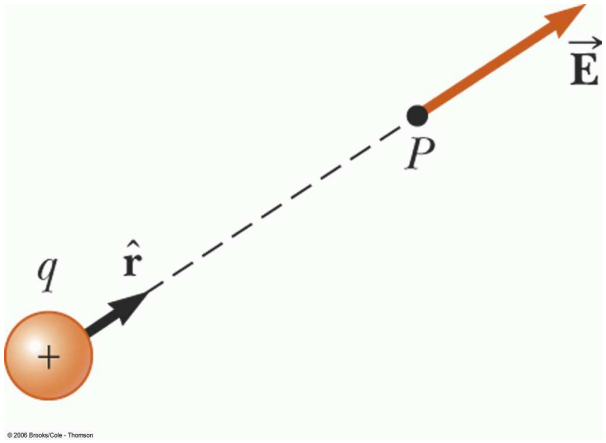
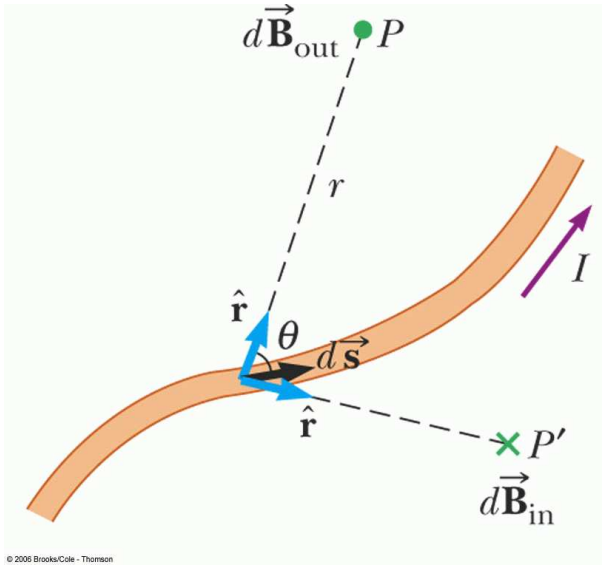
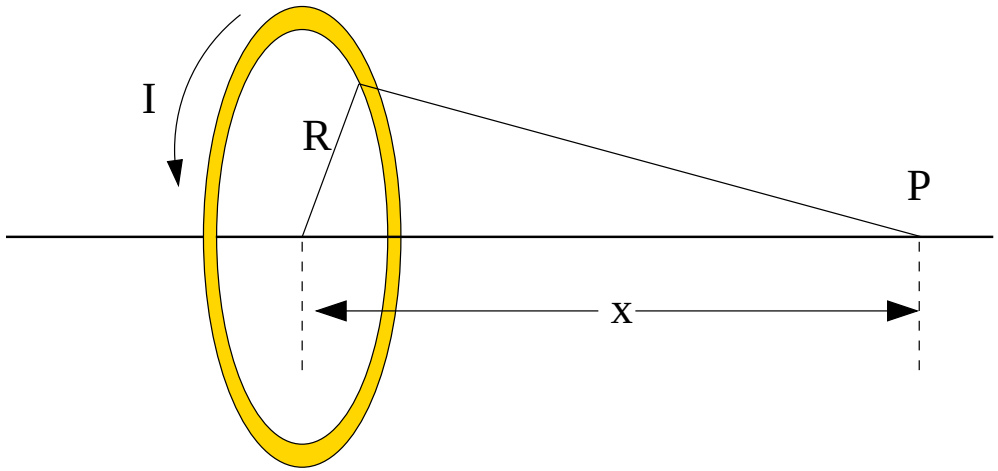


$$d\vec{B} = k_m \frac{Id\vec{s}\times\hat{r}}{r^2}$$

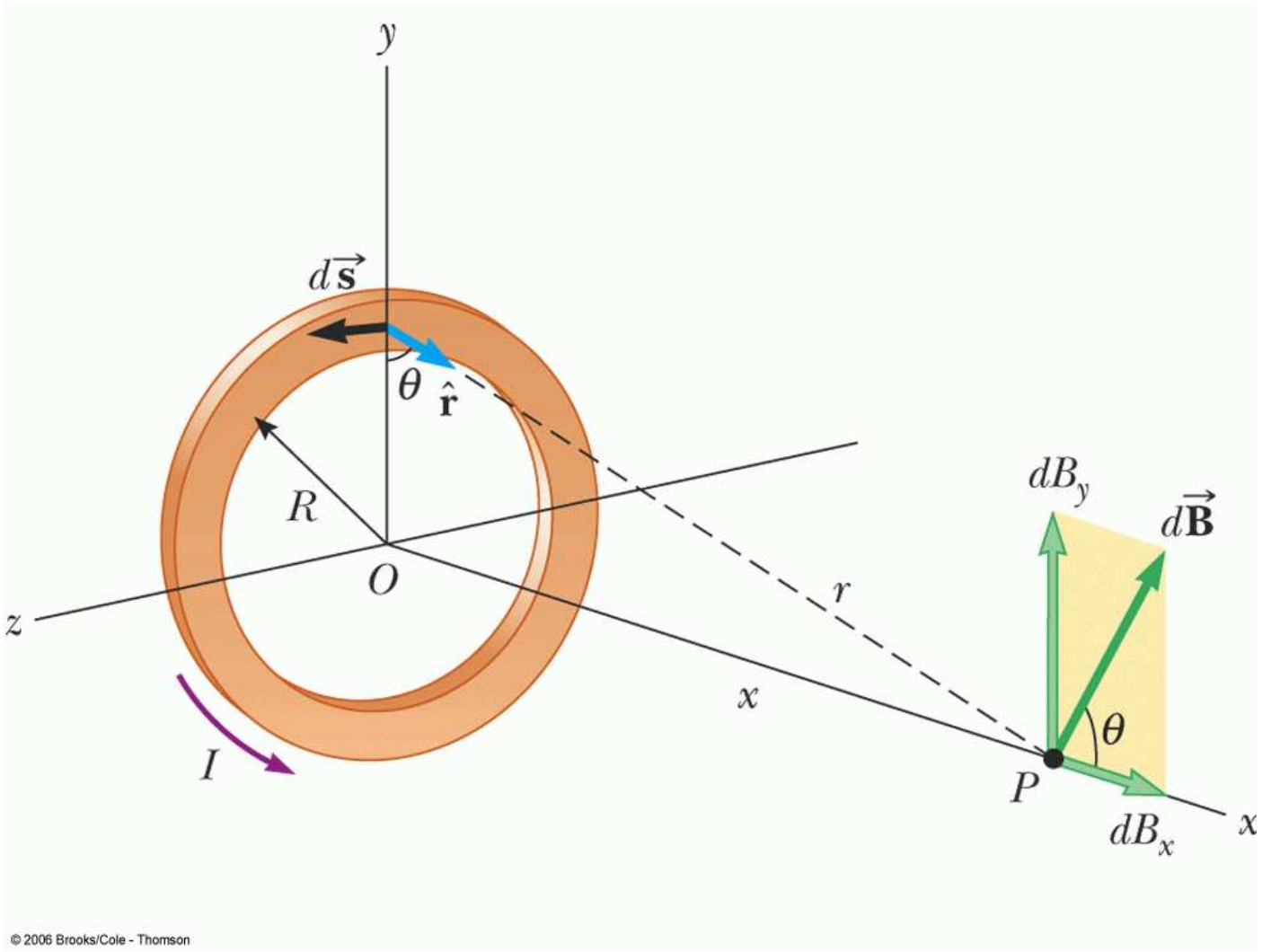


The Magnetic Field of a Current Loop

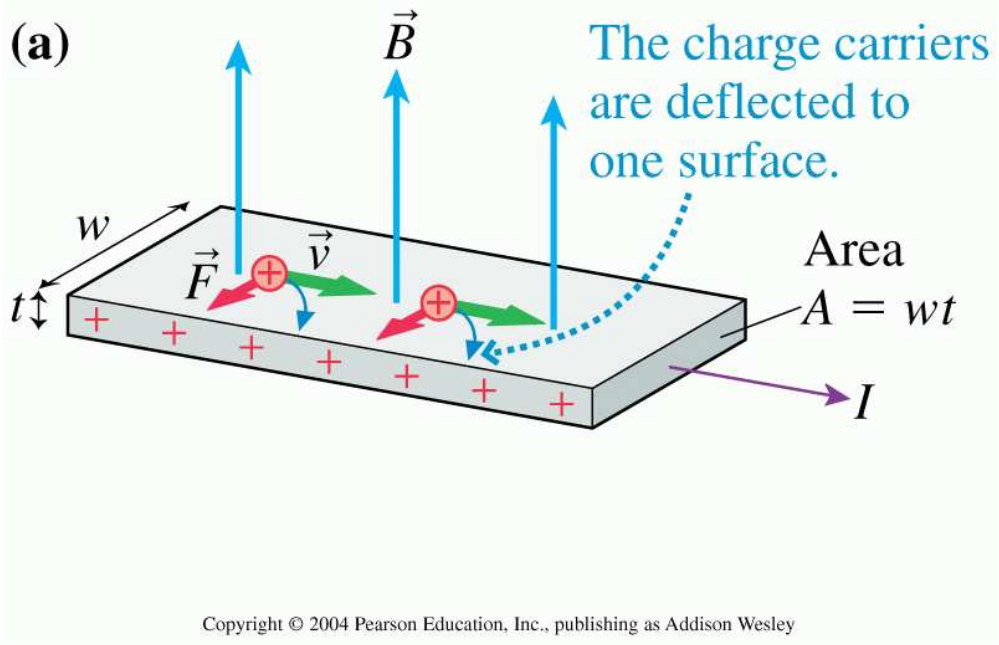
Consider a circular loop of radius R located in the $y-z$ plane and carrying a steady current I. What is the magnetic field at an axial point P a distance x from the center of the loop in terms of I, R, x, and any other constants?

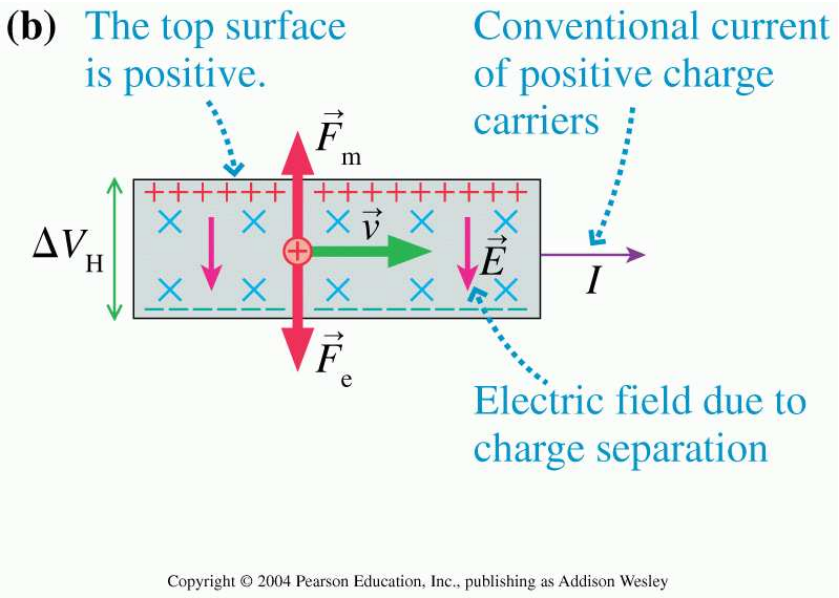


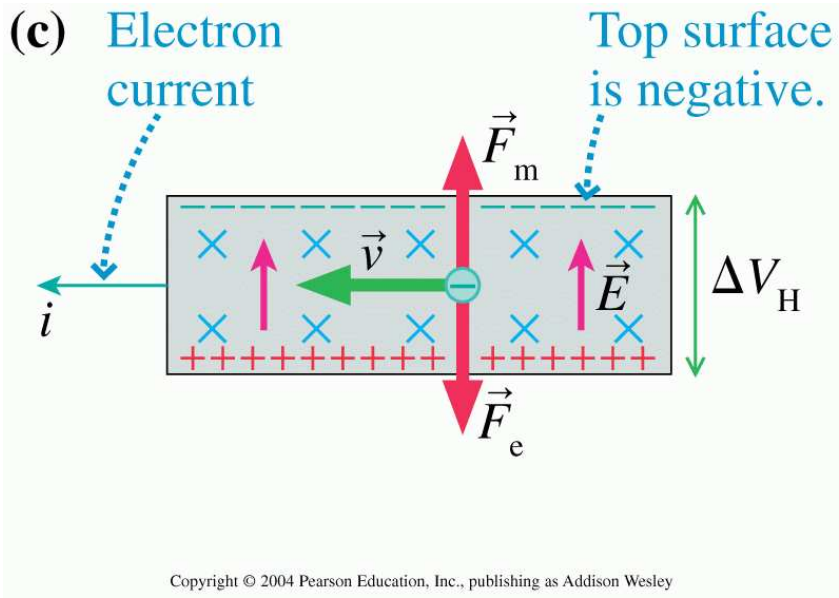
The Magnetic Field of a Current Loop



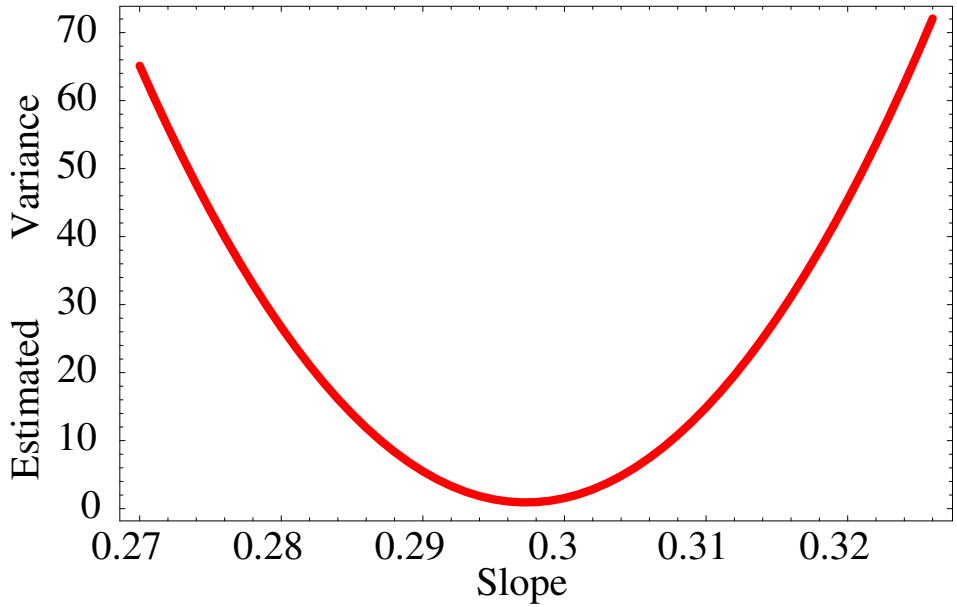
How the Sensor Works - The Hall Effect







Fitting the Data



In the plot above the value of the y-intercept is kept at its best fit value and the slope is varied. The estimated variance is the following.

$$\sigma^2 = \frac{\sum_{i=1}^{N}(y_i - (mx_i + b))^2}{N - d.o.f} \tag{1}$$

where N is the number of data points and $d.o.f$ is the number of degrees of freedom (*i.e.* free parameters) in the fit.

Using the Reduced χ^2

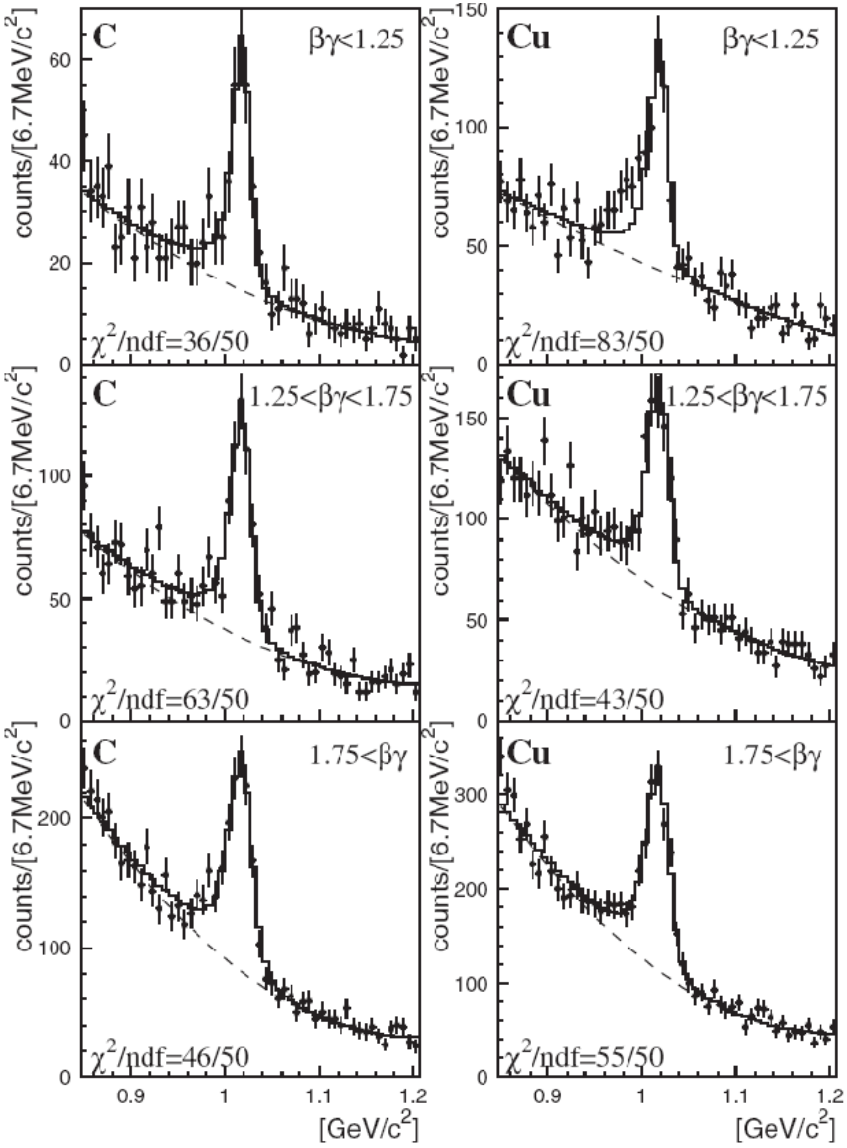
The χ^2 and reduced χ^2 are defined as

$$\chi^2 = \sum_{i=1}^{N} \frac{((y_i - f(x_i))^2}{\sigma_i^2}$$

and

$$reduced\,\chi^2 = \frac{\chi^2}{N - d.o.f}$$

where N is the number of data points.



R. Muto, *et al.*, Phys. Rev. Lett., **98**, 042501 (2007).