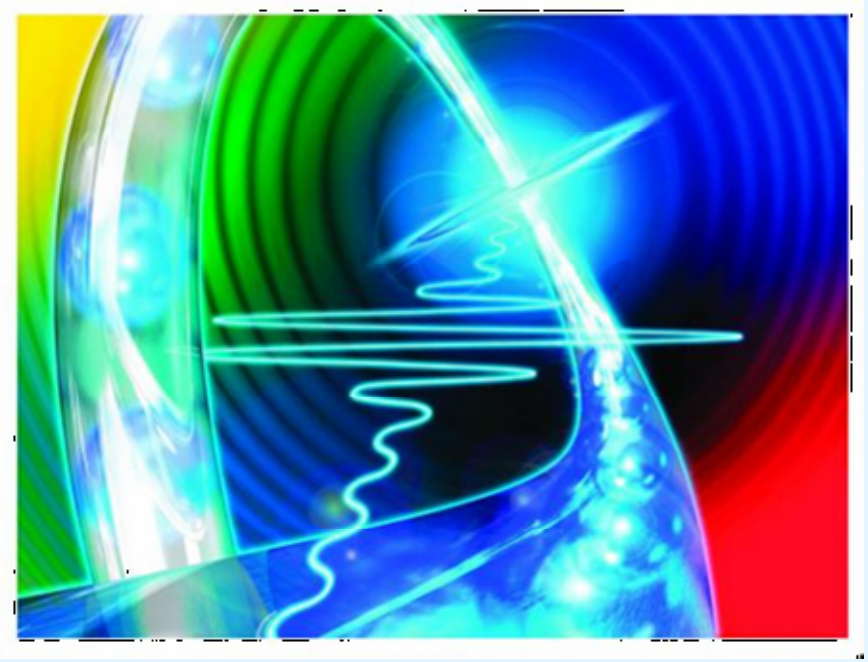


Physics 1B: Electricity and Magnetism

Prerequisites

Eric L. Michelsen

emichels at physics etc.

Goals

"Now in the further development of science, we want more than just a formula. First we have an observation, then we have numbers that we measure, then we have a law which summarizes all the numbers. But the real *glory* of science is that *we can find a way of thinking* such that the law is *evident*."

- Richard Feynman,
Feynmann Lectures on Physics, Volume 1.

Physics 1B

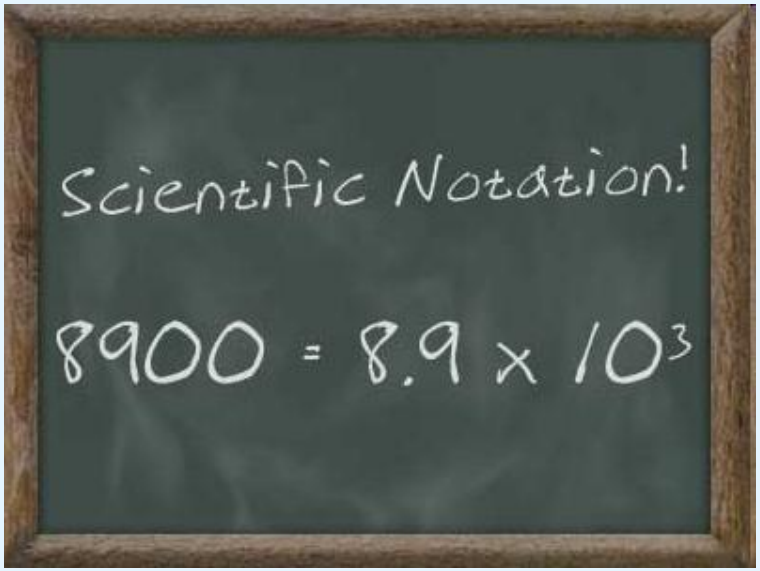
- Physics includes math.
  - And we're not shy about it.
- But we don't hide behind it
  - without a conceptual understanding, math is gibberish.

Review

- Scientific notation, significant digits
- Metric prefixes
- Radians
- Trigonometry
- Rectangular, cylindrical, and spherical polar coordinates
- Fundamental measurable quantities
  - SI units: MKSA
  - Metric prefixes: difference ‘tween mJ and MJ
- Vectors
- Calculus: there will be some
- The Greek alphabet: learn it (there’s a song)

Scientific Notation

- Computer scientific notation:
  - 3.14e7 (or 3.14E7, or 3.14e+7, etc.)
    - Equivalent to 3.14×10^{7}
  - 1.745e-2 = $1.745 \times10^{-2} = 0.01745$
- Significant digits: use them
  - 10. has 2 significant digits
  - 10.0 has 3
  - 100 has 1
  - If in doubt, use scientific notation
    - It's unambiguous: in scientific notation, every digit you write is significant



What is 10e6?

A 10,000,000

B 1,000,000

C 1×10^6

D 1.0×10^6

E 1×10^5

This angle is about how many radians?

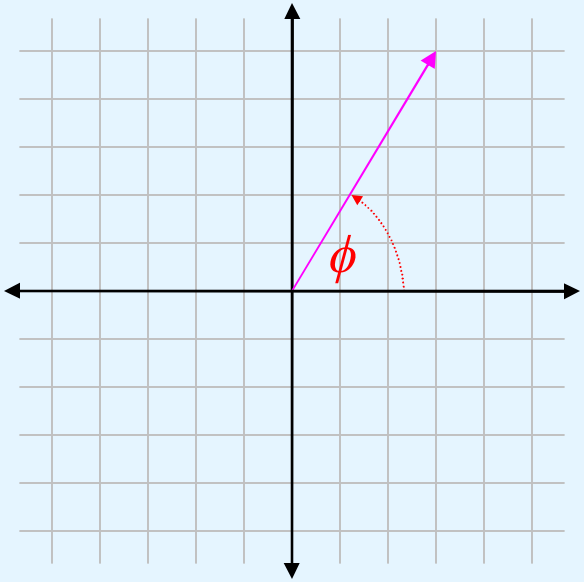
A 0.5

B 1

C 2

D π

E 2π



Simplified Trigonometry

From OAD: 

$\sin = \text{opp} / \text{hyp}$

$\cos = \text{adj} / \text{hyp}$

$\sin^2 + \cos^2 = 1$

From OAB: 

$\tan = \text{opp} / \text{adj}$

$\tan^2 + 1 = \sec^2$

(and with OAD) $\tan = \sin / \cos$

http://physics.ucsd.edu/~emichels/

Funky Mathematical Physics Concepts

Fundamental (macroscopic) measurable quantities

- How many fundamental (macroscopic) measurable quantities are there?
  - What are they?
- How much is a joule?
- What are the units of energy, in fundamental units?

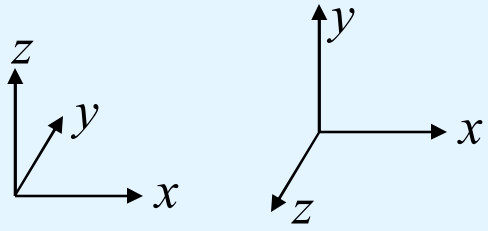
Metric prefixes

- pico p 10^{-12}
- nano n 10^{-9}
- micro μ 10^{-6}
- milli m 10^{-3}
- kilo k 10^{3}
- mega M 10^{6}
- giga G 10^{9}

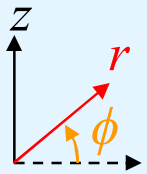
The difference between ‘m’ and ‘M’ is a factor of a billion

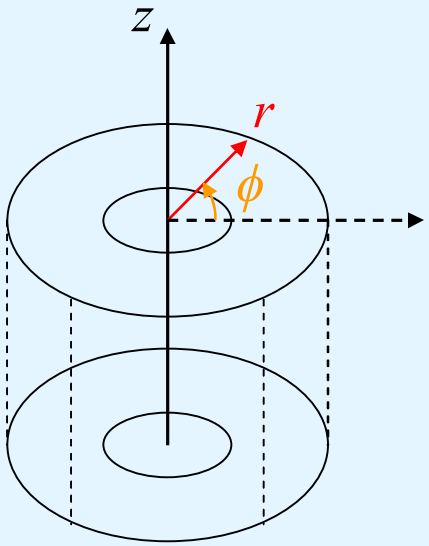
Coordinates (different than math)

- Rectangular

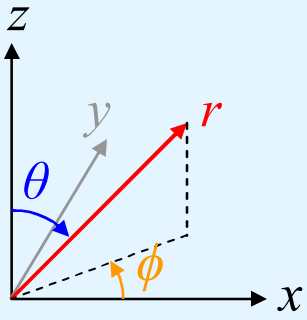


- Cylindrical





- Spherical polar



Review: Four fundamental (macroscopic) quantities

- MKSA
- distance: meter, m
- mass: kilogram, kg
- time: second, s
- charge: ampere => coulomb, C
  - more on this later

What are the units of energy, in fundamental units?

A kg-m/s

B kg-m^2/s

C kg-m/s^2

D kg-m^2/s^2

E N-m

Notation

- $\sim$ and $\propto$
  - $\propto \equiv$ proportional to
  - $\sim \equiv$ "is of the order of magnitude" (in our book, S&J *POP*)
- sometimes I sloppily use $\sim$ when I could use the stronger $\propto$
  - Don't let me get away with this

Greek alphabet (1)

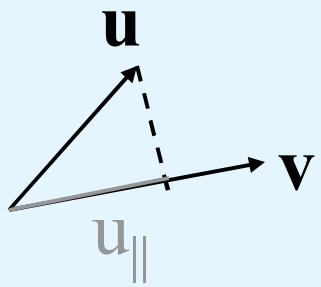
α	alpha (al'fu)	coefficient of linear thermal expansion. (Capital: A, not used)
β	beta (bae'tu)	velocity as a fraction of the speed of light ($\beta = v/c$). (Capital: B, not used)
γ	gamma (gam'u)	the relativistic ratio $1/\sqrt{(1 - \beta^2)}$, aka time-dilation/length-contraction factor
Γ	capital gamma	Christoffel symbols (General Relativity). Generalized factorial function.
δ	delta (del'tu)	the Dirac impulse function, or the Kronecker delta. An inexact differential (calculus)
∂	old-style delta	partial derivative (calculus)
Δ	capital delta	a small change
ε	epsilon (ep'si-	a small error. (Capital: E, not used)
ζ	zeta (zae'tu)	not commonly used. (Capital: Z, not used)
η	eta (ae'tu)	efficiency; flat-space metric tensor. (Capital: H, not used)
θ	theta (thae'tu)	angle
Θ	capital theta	not commonly used. Sometimes angle.
ι	iota (ie-o'tu)	not commonly used. (Capital: I, not used)
κ	kappa (kap'u)	not commonly used. (Capital: K, not used)
λ	lambda (lam'du)	wavelength
Λ	capital lambda	cosmological constant
μ	mu (mew)	micro (10^{-6}). (Capital: M, not used)

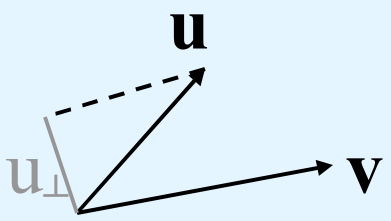
Greek alphabet (2)

ν	nu (noo)	frequency. Not to be confused with an italic v: *ν* vs. nu: ν. (Capital: N, not used)
ξ	xi (zie, sometimes ksee)	damping ratio
Ξ	capital xi	not commonly used
ο	omicron (oe'mi-kron)	not used. (Capital: O, not used)
π	pi (pie)	ratio of a circle's circumference to its diameter, ~ 3.14159...
Π	capital pi	product (multiplication)
ρ	rho (roe)	mass density; charge density; correlation coefficient. (Capital: P, not used)
σ	sigma (sig'mu)	standard deviation; surface charge density.
Σ	capital sigma	sum (addition)
τ	tau (rhyme: cow, or spa)	time; torque. (Capital: T, not used)
υ	upsilon (oops'i-lon)	not commonly used. (Capital: Y, not used)
ϕ	phi (fee or fie)	angle.
φ	old-style phi	angle
Φ	capital phi	electric potential; general potential
χ	chi (kie)	degrees of freedom. (Capital: X, not used)
ψ	psi (sie)	wave-function amplitude
Ψ	capital psi	not commonly used
ω	omega (oe-mae'gu)	angular velocity; angular frequency
Ω	capital omega	angle; solid angle; ohm (unit of electrical resistance)

Vectors

- We eat vectors for breakfast
- What is a vector?
- Vectors add: $\mathbf{w} = \mathbf{u} + \mathbf{v}$
- Scalar multiply: $\mathbf{w} = a\mathbf{u}$
- Dot product: $a = \mathbf{u} \cdot \mathbf{v}$
  - Product of parallel components
- Cross product: $\mathbf{w} = \mathbf{u} \times \mathbf{v}$
  - Product of perpendicular components
  - In direction perpendicular to both





Calculus

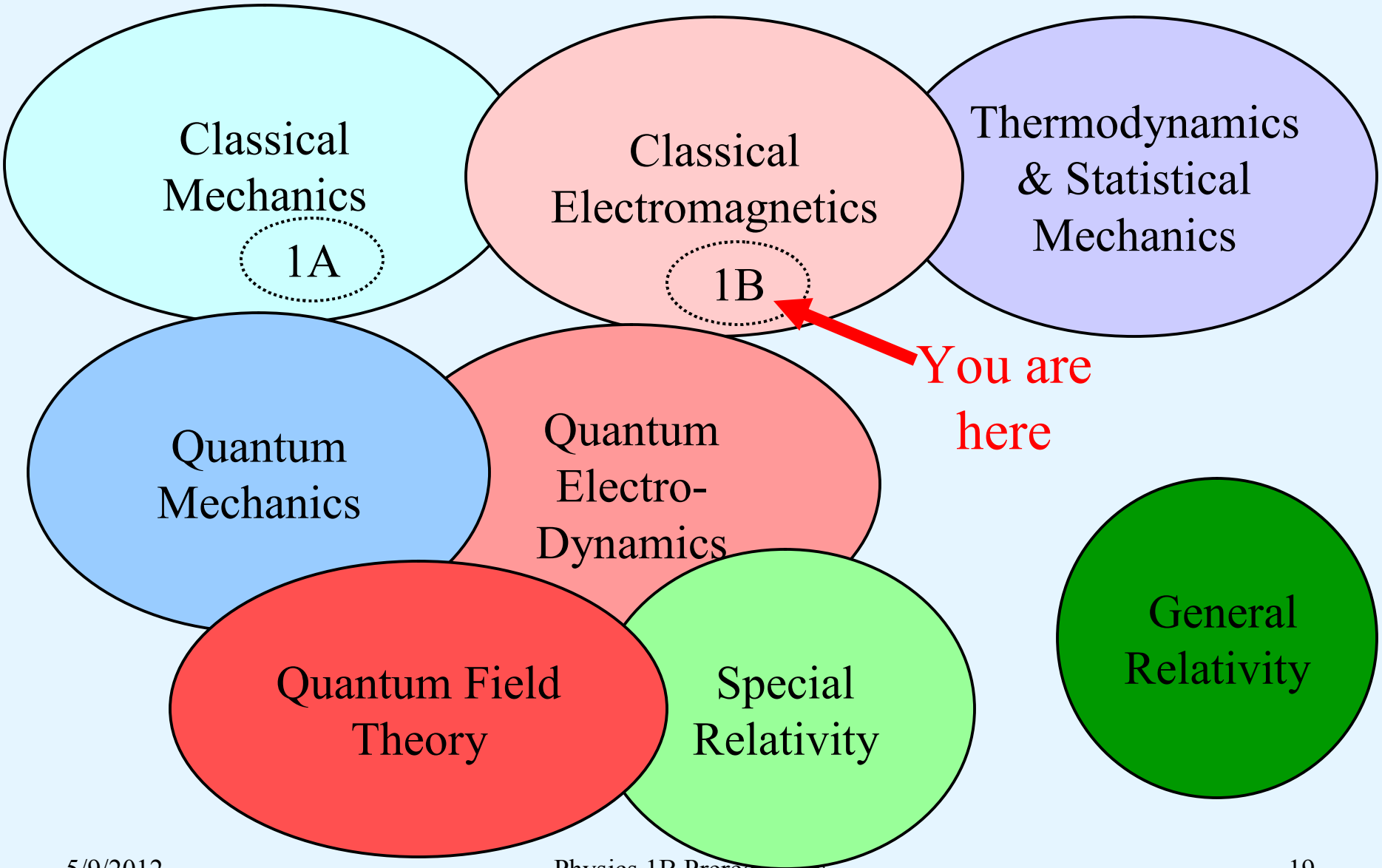
- Basic derivatives and integrals
- Gradients

$$E(x) = -\frac{dV(x)}{dx} \qquad V(x) = -\int_A^B E(x)\,dx \qquad \mathbf{E}(\mathbf{r}) = -\nabla V(\mathbf{r})$$

- A few line integrals

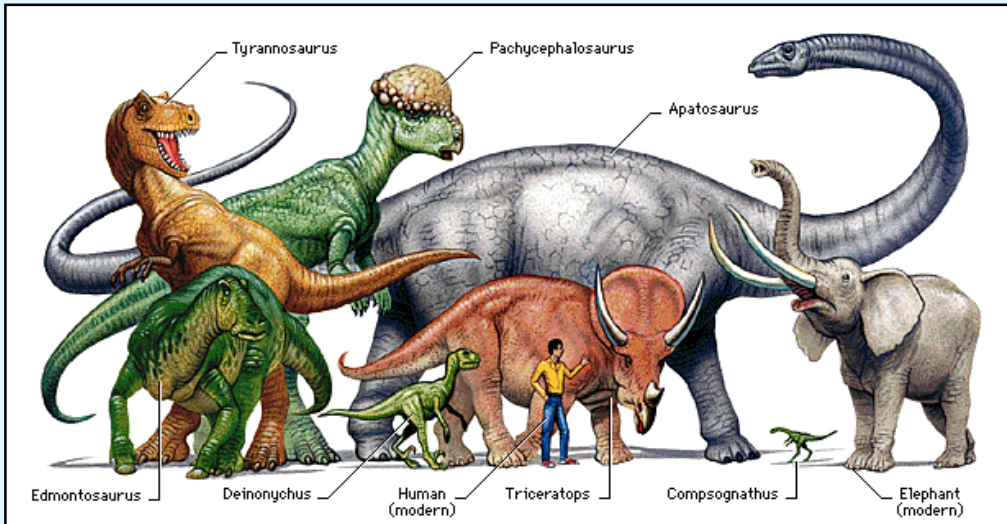
$$V(\mathbf{r}) = -\int_A^B \mathbf{E}(\mathbf{r}) \cdot d\mathbf{r}$$

The pedagogical structure of physics



The language of science (1)

- **Speculation**: a guess
  - Possibly hinted at by evidence, but not well supported
    - The sky is blue because light reflected from the blue ocean illuminates it
    - Some dinosaurs had green skin
  - Every scientific fact and theory started as a speculation



The language of science (2)

- **Fact**: A small piece of information
- Backed by solid evidence
  - In hard science, usually repeatable evidence
    - The sky is blue
    - Copper is a good conductor of electricity
      - Beyond genuine doubt
        - Despite arguments that "nothing can be proved 100%"
      - If someone disputes a fact, it is still a fact
        - I say the sky is red
        - Does that mean there is a "debate" about the sky color?
      - "If a thousand people say a foolish thing, it is still a foolish thing."

The language of science (3)

- **Theory**: The highest level of scientific achievement
  - A *quantitative, predictive, testable* model which unifies and relates a body of facts
  - Every scientific theory was, at one time, *not* generally accepted
  - A theory becomes accepted science *only* after being supported by overwhelming evidence
    - Not a speculation
    - Atomic theory of matter
    - Maxwell's electromagnetic theory
    - Newton's theory of gravity
    - Germ theory of disease