1. Physics 13: Radiation Measures and Particles

Physics 13: Radiation Measures and Particles

Physical quantity	Units	Definition	Remarks
source activity	Curie	$3.7X10^{10}$ disintegrations/sec	radioactivity of 1 gram of radium
	Becquerel	1 disintegration/s	newer Standard Int'l unit
amount of radiation	Roentgen	produces ~$2X10^9$ ion pairs in 1 cm^3 air	radiologist's units; amount produced by 1 Ci at 1m in 1hr
dose	rad	produces 1/100 J/Kg in biological tissue	human exposure
	Gray	1 J/Kg or 100 rads	new S.I. unit
biological dose	rem	biological effect of 1 rad of gamma rays	approximate measure of biological effect for any radiation
	Sievert	100 rems	New S.I. units

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 1
(c) 2006, Gary R. Goldstein, Ph.D.

2. Relations among measures

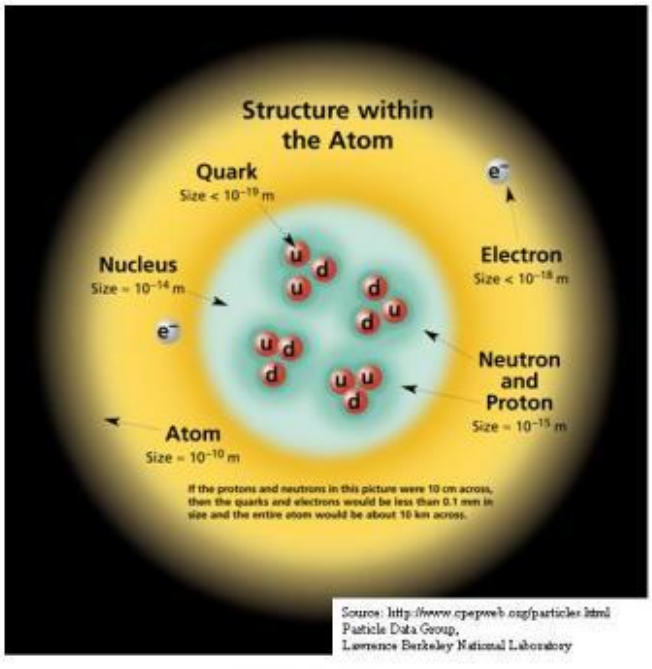
Relations among measures

Order of magnitude estimates or "Rules of thumb"

a. 1 gram of Ra or a 1 Ci source produces 1 R per hour at 1 meter distance;
b. 1 R (of gammas) gives about 1 rem dose (1 rad is about 1 rem); but 1 R (of alphas) gives about 10 rem dose; other radiation is between these extremes;
c. 1 milliCurie of material dissolved in 1 liter of water produces 8 rem/hour (for gammas);
d. 1 rem dose increases the number of cancer deaths by 200 in a population of 1 million people.

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 2
(c) 2006, Gary R. Goldstein, Ph.D.

3. Lecture 18: Radiation Measures: Slide 3

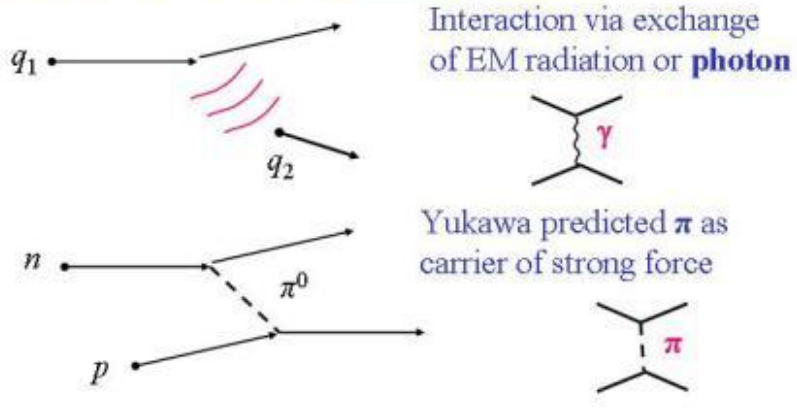


9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 3
(c) 2006, Gary R. Goldstein, Ph.D.

4. Origin of Nuclear or Strong Force?

Origin of Nuclear or Strong Force?

- Larger than EM repulsion for Z>1, but doesn't act beyond
- Short range ~ 10^{-15}m=1fm
- Compare to EM or QED **exchange** fields



9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 4
(c) 2006, Gary R. Goldstein, Ph.D.

5. Exchanges and forces

Exchanges and forces

- $p \rightarrow \pi + p$ violates E conservation

But $\Delta E \geq m_\pi c^2$ then $\Delta t \geq \frac{\hbar}{2m_\pi c^2}$ or $c\Delta t \geq \frac{\hbar}{2m_\pi c}$

range of strong force is $\sim c\Delta t \sim 10^{-15}\text{m} \sim \frac{\hbar}{2m_\pi c}$

Get $m_\pi c^2 \sim 100$ MeV (actually 140 MeV)

- Exchanged quanta related to strength and range of forces

EM	WI	SI	G
γ	$W^{\pm}$	π?	Graviton
	Z^0	gluon	

- Quantum Field Theory (QED, EW, QCD, Standard Model)

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 5

(c) 2006, Gary R. Goldstein, Ph.D.

6. Particle Physics

Particle Physics

- Atoms ⊃ electrons, nuclei, emit & absorb photons
- What is elementary?
- Nuclei ⊃ n & p, emit & absorb π^+, π^-, π^0
- Collisions (HiE)→ strange particles ⊃ $\Lambda^0, \Sigma^+, \Sigma^-, \Sigma^0$ & $K^{+,-,0}$
  - Strangeness & other (~conserved) quantum numbers - charm, b, t

Hadrons (no) ⊃ Baryons (n,p, Λ, Σ, Λ_C, …) - fermions

Mesons (π,K,D,…) - bosons

Leptons ⊃ $e^{+,-}, \mu^{+,-}, \tau^{+,-}, \upsilon$&anti-$\upsilon$ - fermions (antiparticles)

Intermediate bosons (forces) ⊃ γ ,$W^{+,-}$,Z^0,Graviton, gluons (colors) -Quantum Field Theory - QM&Sp.Rel.

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 6

(c) 2006, Gary R. Goldstein, Ph.D.

7. Conservation and quarks

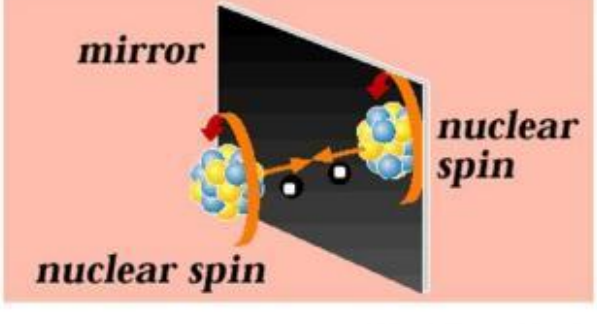
Conservation and quarks

- Conservation laws beyond E,p,J
  - **Symmetry**
    - Discrete intrinsic q.no.s: charge, lepton no., baryon no., strangeness, c, b, t ("flavors" broken by WI)
    - Parity, charge conjugation, time reversal
- Quarks are constituents of hadrons
- uuu & anti-u's, ddd & anti-d's, … COLOR
- (u,d),(c,s),(t,b) ~ $(e,\upsilon_e),(\mu,\upsilon_\mu),(\tau,\upsilon_\tau)$ 3 gen.s
  - p ⊃ u u d , n ⊃ u d d , Λ ⊃ u d s , π^+ ⊃ u anti-d, …
- Color and confinement - QCD

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 7

8. Parity violation

Parity violation



$^{60}Co \rightarrow {}^{60}Ni + e^- + anti\text{-}\nu$ e^- more likely emitted opposite μ

c.f. billiards in mirror

Source: http://www.lbl.gov/abc/wallchart/chapters/03/2.html
Lawrence Berkeley National Laboratory

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 8

9. Lecture 18: Radiation Measures: Slide 9

PROPERTIES OF THE INTERACTIONS

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong: Fundamental	Strong: Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at: 10^{-18} m	10^{-41}	0.8	1	25	Not applicable to quarks
Strength relative to electromag for two u quarks at: 3×10^{-17} m	10^{-41}	10^{-4}	1	60	
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

Source: http://www.cpepweb.org/particles.html
Particle Data Group,
Lawrence Berkeley National Laboratory

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 9
(c) 2006, Gary R. Goldstein, Ph.D.

10. Lecture 18: Radiation Measures: Slide 10

BOSONS force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1		
Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	–1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1		
Name	Mass GeV/c^2	Electric charge
g gluon	0	0

Source: http://www.cpepweb.org/particles.html
Particle Data Group,
Lawrence Berkeley National Laboratory

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 10
(c) 2006, Gary R. Goldstein, Ph.D.

11. Lecture 18: Radiation Measures: Slide 11

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

Leptons spin = 1/2

Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	–1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	–1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	–1

Quarks spin = 1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	175	2/3
b bottom	4.3	–1/3

Source: http://www.cpepweb.org/particles.html
Particle Data Group, Lawrence Berkeley National Laboratory

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 11
(c) 2006, Gary R. Goldstein, Ph.D.

12. Lecture 18: Radiation Measures: Slide 12

Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$

Baryons are fermionic hadrons.
There are about 120 types of baryons.

Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
p	proton	uud	1	0.938	1/2
$\bar{p}$	anti-proton	$\bar{u}\bar{u}\bar{d}$	–1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	–1	1.672	3/2

Source: http://www.cpepweb.org/particles.html
Particle Data Group, Lawrence Berkeley National Laboratory

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 12
(c) 2006, Gary R. Goldstein, Ph.D.

13. Lecture 18: Radiation Measures: Slide 13

Mesons $q\bar{q}$

Mesons are bosonic hadrons.
There are about 140 types of mesons.

Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	−1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2 .980	0

Source: , Particle Data Group, Lawrence Berkeley National Laboratory

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 13

14. Unification pre-history

Unification pre-history

- Newton: Astronomy & Physics (Universal gravitation - one coupling strength for all masses - G)
- Maxwell: **E** & **M** (Maxwell's Equations and EM rad'n - one coupling strength - e)
- Dirac, et al.: EM & Relativity (Quantum Theory of Fields)
- Fermi: Weak Interactions (one coupling strength - G_F)
- Yukawa, et al.: Strong Interactions (meson exchanges - coupling strengths became unified via internal symmetries)

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 14

15. Unification - current history

Unification - current history

- Feynman, Schwinger, Tomonagwa: (finite) combination of QM & EM -- QED (m_γ=0, charges)
- Salam, Weinberg, 'tHooft: QED & WI --ElectroWeak Theory (EW) ($M_{W,Z}$~100 GeV, quarks & leptons)
- Gell-Mann, et al.: Q.F.Th. of quarks & gluons -- SI Quantum Chromodynamics (QCD)
- Standard Model: EW X QCD (not G)
  - quarks: 6 flavors, 3 colors & anti-quarks →36
  - leptons: 3 charged, 3 neutral & anti-leptons→12
  - Intermediate bosons: 8 colored gluons, 1 γ, $W^{+/-}$,Z →12
    Total →60

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 15
(c) 2006, Gary R. Goldstein, Ph.D.

16. Beyond Standard Model

Beyond Standard Model

- GUT (M_X~10^{15} GeV) ⊃ EW x QCD
  - Leptons & quarks in same family (3 gen.s)
  - Protons decay
  - All couplings → one
- Supersymmetry (fermions&bosons)
- Supergravity (Quantum Gravity ⊃ more particles and SUSY)
- Superstrings: GUT & Quantum theory of gravity
  - (M_{Planck}~10^{19} GeV) multidimensional space-time (10d, 11d, 26d)
- Theory of Everything? Branes, M-Theory

9/13/2006 Physics 13 - Fall 2001 - GoldsteinPhysics 13 - Fall 04 - G.R. Goldstein 16
(c) 2006, Gary R. Goldstein, Ph.D.