Forces / interactions

[we characterized these earlier by their ranges;
also characterized by their strengths, & what they affect]

	Scope	strength
electromagnetic:	all charged particles	weak
weak nuclear:	everything but gluons + gravitons	weak
strong nuclear:	quarks + gluons	strong
gravity.	everything	very weak

electromagnetic:

[dimensionless] $\frac{Ke^2}{\hbar c} \equiv \alpha \approx \frac{1}{137} \sim 10^{-2}$

α ← "fine structure constant"

weak nuclear:

G_F = Fermi constant $\quad \frac{G_F m_p^2}{(\hbar c)^3} \sim 10^{-5}$

strong nuclear:

$\alpha_s \gtrsim 1$ [depends on energy]

gravity:

G_N = Newton's const $\quad \frac{G_N m_p^2}{\hbar c} \sim 10^{-38}$ $[6 \times 10^{-39}]$

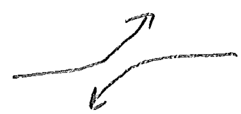
Forces responsible for

1) <u>bound states</u>

solar system (gravity)
atoms (EM)
nuclei, hadrons (strong)

binding energy ↑ w/ strength of interaction [atoms: eV; nuclei: MeV]

2) <u>elastic scattering</u>



[eg electromagnetic repulsion, neutrons scattering from nuclei]

amt of scattering ↑ w/ strength

3) <u>absorption</u> $n + {}^{238}U \longrightarrow {}^{239}U$

probability of absorption ↑ w/ strength
characterized by <u>cross-section</u> σ = <u>effective</u> area of target

[not physical area; eg
n absorption varies w/ speed,
much higher for <u>slow</u> neutrons]

[we'll define σ precisely later]

④ inelastic scattering (transformation) $AB \to ABC$, $AB \to DE$

probability of trans. ~ inelastic cross section ↑ w/ strength of interaction

⑤ decay (into less massive particles) $A \to BC \ldots$

decay constant $\lambda \equiv \frac{\text{prob.}}{\text{time}}$ of decay

λ ↑ w/ strength of interaction

[Phys 3000] If $\lambda = \text{const}$, then exponential decay of particles

$$N(t) = N(0)\, e^{-\lambda t}$$

$N(t) = $ # ptcls remaining at t.

mean life $\tau = \frac{1}{\lambda}$ [problem] $N(t) = N(0)\, e^{-\frac{t}{\tau}}$

$\to \tau$ decreases as strength of interaction increases

half life $T_{\frac{1}{2}}$ defined by $N(t) = N(0) \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

activity $A(t) = -\frac{dN}{dt}$ = # particles that decay per unit time

$= \lambda N(0)\, e^{-\lambda t}$

$= \lambda N(t)$ $\Longrightarrow$ given activity A, # of ptcls $N = \frac{A}{\lambda}$

Also $A(t) = A(0)\, e^{-\lambda t}$

In particle physics, anything that can happen, will.
Conversely: if something doesn't occur, it must be forbidden by conservation laws.

e^- is stable because it is the lightest charged particle so decay into lighter particles violates charge conservation

p is stable because [why not $p \to e^+ \gamma$]
it is the lightest baryon, and baryon # conserved

~~baryon #~~ [Stuckelberg 1938] ~~[illegible]~~
~~by all the forces of the standard model (grav, E-M, weak, strong)~~

Baryon # could be violated by the superweak forces of a GUT, so that p decay could occur very slowly [Diamonds are not forever]

Proton decay expts were begun in 1970's to search for p decay
SuperKamiokande (water) [problem]

So far, none detected

[PPB] $\tau_p > 2E29$ yrs $\tau_{univ} = 13.7E9$ yrs
need a lot of protons

n is not stable (unless inside a nucleus)

$\tau_n = 880\,s \pm 1\,s$ [15 min]

$n \to p e^- \bar{\nu}$

weak interaction decay (because ν involved)
~~small amt of phase space Q = [illegible]~~

→ Long mean life

~~[illegible]~~

Time dilation

τ = mean life of a particle <u>at</u> rest

If particle is moving at speed v then the mean life is increased to $\gamma\tau$ and particle travels a mean distance $v\gamma\tau$ before decaying.