Monday, February 27, 2012
4:24 PM

Discrete Symmetries (in Particle Physics)

$$\left.\begin{array}{l}\left.\begin{array}{l}P\text{ - parity}\\ C\text{ - charge conjugation}\end{array}\right\}CP\\ T\text{ - time reversal}\end{array}\right\}CPT$$

What are they?
Are these symmetries observed?

So g could be C, P, T, CP or CPT

First: All are examples of $\mathbb{Z}_2$: $\{I, g\}$ where $g^2 = I$

a) closure $I\cdot I = I$, $I\cdot g = g\cdot I = g$, $g\cdot g = I$
b) Identity $I\cdot g = g$
c) Inverse $g\cdot g = I \Rightarrow g = g^{-1}$
d) Associativity Can be faithfully represented by $\{1,-1\}$ with multiplication and this is obviously associative.

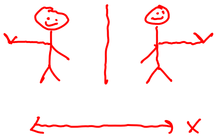
Parity

Recall $O(3) = \overset{\text{rotations on vectors}}{\widetilde{SO(3)}} \times \underbrace{\mathbb{Z}_2}_{\text{Inversions of coordinates }(P)}$

$\Rightarrow$ $O(3): \{M\}$ such that $M^T M = \mathbb{I}$, $\det M = \pm 1$
$SO(3): \{M\}$ such that $M^T M = \mathbb{I}$, $\det M = +1$
$P: \left\{\mathbb{I}, \begin{pmatrix}-1&&\\&-1&\\&&-1\end{pmatrix}\right\}$

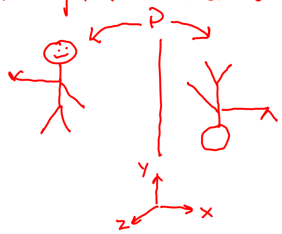
Can get any element of $O(3)$ by combining an $SO(3)$ w/ P.

Some call parity "mirror" symmetry:



This would be true if we defined it as $P_x: \left\{\mathbb{I}, \begin{pmatrix}-1&&\\&1&\\&&1\end{pmatrix}\right\}$, but this treats x preferentially.

Instead we will work with $P: \left\{\mathbb{I}, \begin{pmatrix}-1&&\\&-1&\\&&-1\end{pmatrix}\right\}$ which sends $x\to -x$, $y\to -y$, $z\to -z$ (all on equal footing)
But remember that to get the "other" 2 minus signs we can invert x, then do a 180° in the y-z plane:



Note that you can't get the result of P by rotating alone!

NOTE: In many cases we will just reflect in x to make visualization easier!

Tuesday, February 28, 2012
8:06 AM

Okay so we know that physics over $\overbrace{\text{small length scales}}^{\text{to ignore curvature}}$ is invariant under rotations (actually under the Lorentz group).

Is it invariant under P? For a long time the assumed answer was yes.

2 ways to answer : a) Consider all SM processes and their parity transformed versions. If all quantities (lifetimes, reaction rates, etc.) are the same then P is "good." If any differ then P is "bad."

b) Assign a "parity" label to particles and see if processes "conserve" parity.

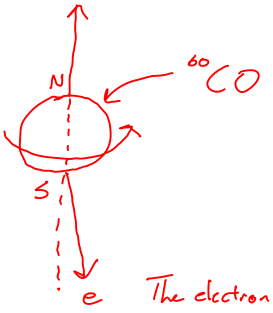
Answer: Nope! The SM violates P.
We will see evidence in both ways.

Tuesday, February 28, 2012
8:21 AM

Experimental test suggested by Lee + Yang and carried out by "dragon lady" Wu.

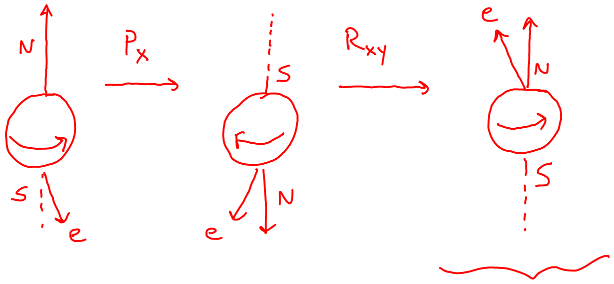
Cobalt 60 decay: $^{60}CO \longrightarrow {}^{60}Ni + e + \bar{\nu}_e$

Nuclear spin picks out a preferred direction (N + S poles of magnetic dipole moment)



The electron <u>always</u> emerges <u>opposite</u> the nuclear spin.

Now let's consider the P transformed version of this:



So in the P transformed version of this process, the electron emerges <u>along</u> the nuclear spin.

This is never observed to happen!!

Okay so maybe P-violation only occurs in this one single interaction. But wait...