Physics 225A Second Problem Set

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1. In B. Richter's summary talk of LP99, he recommends that Bill Gates fund *which* experiment?

2. Refer to the notes on 2-state systems that were handed out, and describe how the mixing of pairs of states causes their energy eigenvalues to *repel*.

3. The mixing of fundamental particles usually is described by a matrix of mass *squared* (M^2), not M. The main reason is that the wave equation for particles usually involves M^2. We discussed in class how the mixing of more fundamental particles leads to the observed Z^0 and the γ. (The precise *mechanism* of that mixing defines the frontier of research right now... it could be the 'Higgs Mechanism'). The more 'fundamental' particles are usually referred to as the A and the B; the mass of the A is the same as that of the $W^{\pm}$, or $M_A = M_W = 80.4\,\mathrm{GeV}$. The mass of the B is a more elusive concept... that is what this problem is, in part, about.

   (a) The M^2 mixing matrix, μ, for the A and the B is

   $$\mu = \begin{bmatrix} M_A^2 & x \\ x & M_B^2 \end{bmatrix}$$

   Use the assumption that one state has zero mass to solve for the real-valued unknown x.

   (b) Use the measured value of $M_Z = 91.2\,\mathrm{GeV}$ to determine the numerical value of M_B.

   (c) Solve for the cosine of the mixing angle, $|\cos\theta_W|$, in terms of M_W and M_Z.

   (d) **Warning:** this problem is an illustrative example; the mixing matrix introduced was *ad hoc*. The actual Higgs Mechanism is just a little more subtle. However, the flavor of the Mechanism, that it results in the relationship between the W mass, the Z^0 mass, and the mixing angle, is nicely (and correctly) described. It is higher-order quantum corrections to that relationship (computed using the techniques introduced by Veltman and 't Hooft) that enable one to estimate the mass of the Higgs particle, the H^0, from precise measurements of the W, Z^0, and t-quark masses, and from precise measurements of the mixing angle $\sin\theta_W$. As the Nobel Web-page notes (a link is on our course Web-page), similar computations successfully predicted the t-quark mass.