Physikalisches Institut | Exercise 6
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Exercises on Elementary Particle Physics II

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1. *F-term SUSY breaking in the O'Raifeartaigh model*

   Consider the (left) chiral superfields X, Y and Z. The component fields are denoted by (for example) (x, Ψ_x, F_x). Their kinetic energies arise from the following D-terms:

   $$\mathcal{L}_D = (XX^\dagger)_D + (YY^\dagger)_D + (ZZ^\dagger)_D$$

   Remember that the D-terms additionally give quadratic terms in the auxiliary fields (i.e. $|F_x|^2$). Furthermore, we assume the following superpotential:

   $$\mathcal{L}_F = \lambda X(Z^2 - M^2) + gYZ$$

   with λ, g and M real.

   (a) Derive the scalar potential first by using

   $$F_x^* = -\frac{\partial W(x,y,z)}{\partial x} \quad \text{and} \quad V(x,y,z) = \sum_i |F_i|^2$$

   and then explicitly by solving the equations of motions for the auxiliary fields and inserting the result into the Lagrangian.

   (b) Show that the vevs of F_x, F_y and F_z cannot vanish simultaneously. Hence SUSY is spontaneously broken.

   (c) Check that the scalar potential $V(x,y,z)$ has a minimum at $z = y = 0$ when

   $$M^2 < \frac{g^2}{2\lambda^2}.$$

   (d) Compute the scalar masses.

   Hint: Insert shifted fields (e.g. $z \to <z> + z$) into the potential and look for quadratic terms in the fields. In order to diagonalize the mass of the z field, choose the ansatz:

   $$z = \frac{1}{\sqrt{2}}(a + ib)$$

(e) Compute the masses of the fermions.
Hint: Combine Ψ_y and Ψ_z to a Dirac fermion Ψ_D:

$$\Psi_D = \begin{pmatrix} \Psi_y \\ \bar{\Psi}_z \end{pmatrix}$$

The vev of x is undetermined, so the term $x\Psi_z\Psi_z$ does not contribute to the mass.