Exercices

Exercise 1)

Consider a IIA $Z_2 \times Z_2$ orientifold analogous to the MSSM-like we discusssed but with $D6$-branes wrapping the 3-cycles (hep-th/0203160):

MSSM-2	(n_i^1, m_i^1)	(n_i^2, m_i^2)	(n_i^3, m_i^3)
$N_a = 6 + 2$	$(1, 0)$	$(3, 1)$	$(3, -1/2)$
$N_b = 4$	$(1, 1)$	$(1, 0)$	$(1, -1/2)$
$N_c = 2$	$(0, 1)$	$(0, -1)$	$(2, 0)$

Note that the third torus is tilted and then admits fractional wrapping numbers.

- Find the massless chiral fermion spectrum.
- The model has RR-tadpoles. Show that adding 4 branes with wrapping numbers $(-2, 1)(-3, 1)(-3, 1/2)$ along with 6 branes with wrapping numbers $(1, 0)(1, 0)(2, 0)$ renders the theory tadpole free (use RR-tadpole conditions of transparency in p. 64 with $\beta_1 = \beta_2 = 1$, $\beta_3 = 1/2$).
- Find the conditions that the complex structure moduli $\tau_i = R_y^i / R_x^i$ have to obey so that the configuration is $N = 1$ supersymmetric (use eq. (39) in transparencies).

Exercise 2)

In the same model of previous exercise:

- Obtain the extra chiral matter fields charged under the SM group appearing due to the additional D6-branes introduced to cancel RR tadpoles.
- Show that all the $U(1)$'s in the model except $U(1)_c$ get a mass by combining with RR scalars (this is analogous to the exercise in p. 49,50 in transparencies).
- Show that there is a linear combination of RR pseudoscalar fields which does not combine with any $U(1)$ and hence remain massless. Does it have axion-like couplings to QCD?
- Compute the gauge kinetic function of the MSSM gauge fields. Check whether gauge coupling unification may be achieved (see eq. 47 in Part II of transparencies).

Exercise 3)

Consider stacks of $D3$-branes at a Z_3 singularity. Look for Chan-Paton twist matrices $\gamma_{3,\theta}$ giving rise to a Pati-Salam non-Abelian gauge group $SU(4) \times SU(2)_L \times SU(2)_R$ with three generations. Check tadpole cancellations and if required add $D7_r$-branes in order to cancel them. Compute then the full fermion chiral spectrum and find the $U(1)$ charges of fields under the unique anomaly-free $U(1)$. (Follow the same ideas as in examples in p. 61-71 or 76-79 in part 2 of transparencies)

Exercise 4)

Consider a $N = 1$ supergravity Lagrangian with a Kahler potential and gauge kinetic function depending on a Kahler modulus T like

$$K \;=\; -3log(T+T^*) \;+\; log|W|^2 \;+\; \sum_\alpha \frac{|C_\alpha|^2}{(T+T^*)^{\xi_\alpha}} \;;\; f_a \;=\; T \tag{1}$$

The C_α are chiral fields of the MSSM and the superpotential W includes the Yukawa couplings. Here ξ_α are the 'modular weights' of the chiral fields C_α. Asuming the the only source of SUSY breaking is given by the auxiliary field F_t of the modulus T

- Derive the general expression for the soft terms (scalar masses m_α, A-parameters, B-parameter) in terms of the gaugino mass M and the ξ_α. (Just take general expressions in p. 52 of Part III of transparencies and plug in the expression for gauge kinetic function and Kahler metrics in eq.(59) of Part III of transparencies).

- Find out the structure of soft terms for a model in which chiral MSSM fields all reside at intersecting $D7$-branes.