FLAVOUR PHYSICS HOMEWORK

You may use any reference material that you wish, but you are not intended to expend great effort in answering the questions. If you have questions you are welcome to contact me to ask (T.J.Gershon@warwick.ac.uk) … but please be patient if it takes me a little while to reply. Any feedback on the lectures is also welcome – constructive criticism is especially helpful.

1. How does the GIM mechanism suppress flavour-changing neutral currents?

2. Describe the quark content of the three light neutral vector mesons (ρ^0, ω, φ), commenting on relevant symmetries.

3. How does the existence of three generations of quarks allow CP violation within the Standard Model?

4. Give the production and decay processes in which the J/ψ particle was discovered. Explain why the vector J/ψ was observed before its lighter pseudoscalar counterpart, the η_c.

5. Describe how the lifetime difference in the B_s meson system ($\Delta\Gamma_s$) can be measured.

6. Draw a Feynman diagram for the leptonic decay $B^+ \to \mu^+\nu$. What property of the CKM matrix can be determined from the measurement of its branching fraction? What theoretical input is required? Estimate the branching fraction within the Standard Model.

7. What property of the Unitarity Triangle can be measured from the rate of the rare kaon decay $K_L \to \pi^0\nu\nu$?

8. Estimate the maximum size of direct CP violation in $B^0 \to DK^{*0}$ within the Standard Model.

9. The phase of charm oscillations can in principle be measured in $D \to K^+K^-$ decays (in analogy to the measurement of sin(2β) in $B_d \to J/\psi K_S$ decays). Estimate its value within the Standard Model.

10. Sketch the phase space of $B \to X_u l\nu$ decays in the (m_X, q^2) plane (where m_X is the invariant mass of the hadronic system X_u produced from the $b \to u$ transition, and q^2 is the invariant mass squared of the lepton-neutrino system). Denote regions that are uncontaminated by background from $b \to c$ transitions.

11. Estimate the ratio of lifetimes of the B mesons (mass ~ 5 GeV, dominant decays via V_{cb}) to those of the charm mesons (mass ~ 2 GeV, dominant decays via V_{cs}). Compare your answer to the PDG value and comment on any discrepancy.

12. Imagine that the top quark was light enough to form stable hadrons, giving two new flavoured neutral mesons (let's call them T_u and T_c). Estimate the values of the mixing parameters Δm, $\Delta\Gamma$ and $|q/p|$ for these pretend mesons.

13. Give at least four examples of measurements that can be made at hadron colliders that could disprove the minimal flavour violation hypothesis.

14. Assuming that new physics exists at the TeV scale and obeys the minimal flavour violation hypothesis, what new physics effects might be observed in flavour experiments at hadron experiments?

15. Read the “Oops Leon” paper and figure out what's wrong.