

# FLAVOUR PHYSICS ASSESSMENT

To be returned to Tim Gershon ([T.J.Gershon@warwick.ac.uk](mailto:T.J.Gershon@warwick.ac.uk)) by April 29<sup>th</sup> 2011

You may use any reference material that you wish, but you are not intended to expend great effort in answering the questions.

Answer the following, each in 100 words or less (10 marks each).

1. Explain how the GIM mechanism predicts the existence of the charm quark.
2. How does the existence of three families of quarks allow CP violation within the Standard Model?
3. Imagine that there is a fourth family of quarks ( $t', b'$ ) with  $m(t') > m(b')$ , that is decoupled from the three SM families since  $V_{t'b'} = 1$ . Describe how the  $b'$  quark might be detected. If a strongly bound  $b'b'$  state exists, would it decay and if so, how?
4. Describe which combinations of the charm mixing parameters  $x_D = \Delta m_D/\Gamma_D$  and  $y_D = \Delta\Gamma_D/2\Gamma_D$  can be measured in the following final states: (i)  $K^+K^-$ , (ii)  $K^+\pi^-$ , (iii)  $K^+\mu^-$ .
5. Extrapolating from the existing limit, estimate how much data LHCb would need to observe the rare decay  $B_s \rightarrow \mu\mu$  with  $5\sigma$  significance if its branching fraction is 3 times larger than the SM prediction.

Give brief answers to the following (5 marks each). Use diagrams and calculations as appropriate.

6. Draw a Feynman diagram for the leptonic decay  $D_s^+ \rightarrow \mu^+\nu$ . What property of the CKM matrix can be determined from the measurement of its branching fraction?
7. Draw a Feynman diagram for the rare decay  $K_L \rightarrow \pi^0\nu\bar{\nu}$ . What property of the Unitarity Triangle can be determined from the measurement of its branching fraction?
8. Estimate the maximum size of direct CP violation in  $B^0 \rightarrow DK^{*0}$  within the Standard Model.
9. The mass differences in the  $B_d$  and  $B_s$  systems are measured to be  $\Delta m_d = (0.511 \pm 0.005 \pm 0.006) \text{ ps}^{-1}$  and  $\Delta m_s = (17.77 \pm 0.10 \pm 0.07) \text{ ps}^{-1}$  respectively. Estimate the ratio of CKM matrix elements  $|V_{td}/V_{ts}|$ .
10. The golden mode for studying CP violation in  $B_s$  oscillations is  $J/\psi\phi$ . Describe the relative advantages and disadvantages of equivalent measurements in the decay channels (i)  $J/\psi\eta'$ ; (ii)  $D_s^+D_s^-$ ; (iii)  $\phi\phi$ .

Finally, in as many words as you like (25 marks)

11. Describe existing constraints on a possible fourth generation of quarks, and discuss how such new particles might reveal themselves in flavour observables?