

# FPP: BaBar Physics Examples

Solutions for assessment should be delivered to Roger Barlow by any reasonable means by 6 January 2010, at which time model answers will be put on the web.

**Example 1** Why does the  $t$  quark decay so quickly. Give 3 reasons.

**Example 2** The cross section for  $e^+e^- \rightarrow \mu^+\mu^-$  at 10 GeV is 0.94 nb. How many muon pairs will be produced every second at a B factory with a luminosity of  $1.4 \cdot 10^{34}/\text{cm}^2/\text{s}$ ?

**Example 3** In the decay  $D^{*0}(2010) \rightarrow D^+\pi^-$  calculate the momentum of the pion in the  $D^*$  rest frame

**Example 4** In the decay  $\Upsilon(4S) \rightarrow B^+B^-$  calculate the speed of the  $B$  mesons in the  $\Upsilon$  rest frame.

**Example 5** : From Richard Feynman, "Six easy pieces". He is hypothesising that we have been communicating with intelligent aliens:

"What would happen when [...] we each have taught the other to make space ships and we meet halfway in empty space? We have instructed each other on our traditions, and so forth, and the two of us come rushing out to shake hands. Well, if he puts out his left hand, watch out!"

Why? Explain how the confusion would have arisen.

**Example 6** Suppose a neutral  $B$  meson is produced. If one of the decay products is a high energy  $\mu^+$ , is this meson more likely to be a  $B^0$  or a  $\overline{B}^0$ ?

**Example 7** Why is this implication less reliable for a low energy  $\mu^+$ ?

**Example 8** In measuring  $B_s^0$  oscillations you have to determine (i) the time of the decay of the B meson (2) whether it is a  $B_s^0$  or a  $\overline{B}_s^0$  and (3) Whether it started out as a  $B_s^0$  or a  $\overline{B}_s^0$ . Explain briefly how one can achieve the first two of these.

**Example 9** The 3rd step is the hardest. Explain how this can be done by observing (1) a fast charged lepton on the opposite side of the event and (2) a charged Kaon in a nearby same-side jet.

**Example 10** Give 2 reasons why the above technique (2) cannot be done at BaBar. (It is done at CDF. Google will give you all the details.)

**Example 11** Draw Feynman diagrams for the following decays and give any CKM factors in the amplitude. (Give all distinct lowest-order diagrams)

(i)  $\Upsilon(4S) \rightarrow \mu^+\mu^-$

(ii)  $B^+ \rightarrow \tau^+\nu_\tau$

(iii)  $K^- \rightarrow \pi^0 e^- \overline{\nu}_e$

(iv)  $B^0 \rightarrow D^+\pi^-$

(v)  $K^0 \rightarrow \overline{K}^0$

(vi)  $B^0 \rightarrow \pi^+\pi^-$

**Example 12** If there were 4 generations of quarks and leptons, how many rotation angles and phases would be needed to parametrise the equivalent of the 4 by 4 mixing matrix?