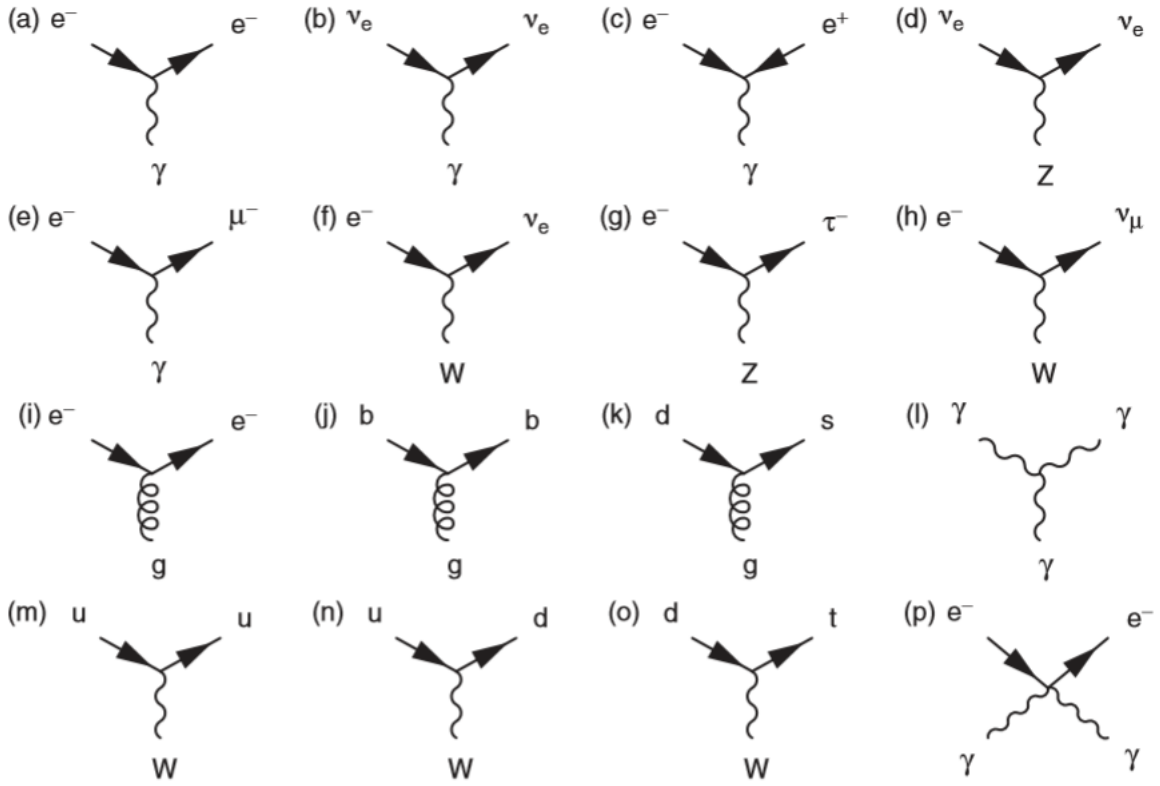
1.1 Feynman diagrams are constructed out of the Standard Model vertices shown in Figure 1.4. Only the weak charged-current ($W^{\pm}$) interaction can change the flavour of the particle at the interaction vertex. Explaining your reasoning, state whether each of the sixteen diagrams below represents a valid Standard Model vertex.



1.2 Draw the Feynman diagram for $\tau^- \rightarrow \pi^- \nu_\tau$ (the π^- is the lightest $d\bar{u}$ meson).

1.3 Explain why it is *not* possible to construct a valid Feynman diagram using the Standard Model vertices for the following processes:

(a) $\mu^- \rightarrow e^+ e^- e^+$,
(b) $\nu_\tau + p \rightarrow \mu^- + n$,
(c) $\nu_\tau + \bar{p} \rightarrow \tau^+ + n$,
(d) $\pi^+(u\bar{d}) + \pi^-(d\bar{u}) \rightarrow n(udd) + \pi^0(u\bar{u})$.

1.4 Draw the Feynman diagrams for the decays:

(a) $\Delta^+(uud) \rightarrow n(udd)\,\pi^+(u\bar{d})$,
(b) $\Sigma^0(uds) \rightarrow \Lambda(uds)\,\gamma$,
(c) $\pi^+(u\bar{d}) \rightarrow \mu^+ \nu_\mu$,

and place them in order of increasing lifetime.

1.5 Treating the π^0 as a $u\bar{u}$ bound state, draw the Feynman diagrams for:

(a) $\pi^0 \to \gamma\gamma$,
(b) $\pi^0 \to \gamma e^+ e^-$,
(c) $\pi^0 \to e^+ e^- e^+ e^-$,
(d) $\pi^0 \to e^+ e^-$.

By considering the number of QED vertices present in each decay, *estimate* the relative decay rates taking $\alpha = 1/137$.

1.6 Particle interactions fall into two main categories, scattering processes and annihilation processes, as indicated by the Feynman diagrams below.

Draw the lowest-order Feynman diagrams for the scattering and/or annihilation processes:

(a) $e^- e^- \to e^- e^-$,
(b) $e^+ e^- \to \mu^+ \mu^-$,
(c) $e^+ e^- \to e^+ e^-$,
(d) $e^- \nu_e \to e^- \nu_e$,
(e) $e^- \bar{\nu}_e \to e^- \bar{\nu}_e$.

In some cases there may be more than one lowest-order diagram.