Phy 523 PARTICLE PHYSICS
PROBLEM SHEET X- SOLUTIONS

46. Matrix element for

$$\nu_{\mathbf{e}} + \mathbf{e}^- \rightarrow \nu_{\mathbf{e}} + \mathbf{e}^-$$

It occurs through an exchange of W^- and Z^0
Feynman diagrams for $\nu_e + e^- \rightarrow \nu_e + e^-$
The factors at the vertices are given in the parenthesis:

$$e^-\nu_e W^+ : \frac{-ig}{2\sqrt{2}}\gamma^\mu(1-\gamma_5);$$

$$\nu_e e^- W^- : \frac{ig}{2\sqrt{2}}\gamma^\mu(1-\gamma_5)$$

$$\nu_e\nu_e Z^0 : \frac{-ig}{2}\gamma^\mu(1-\gamma_5)$$

and

$$e^-e^-Z^0 : \left(\frac{ig}{4cos(\theta)}\right)\gamma^\mu((1-4sin^2(\theta))-\gamma_5)$$

The matrix elements are for (a)

$$N\frac{g^2}{8}\bar{u}_e(q_1)\gamma^\mu(1-\gamma_5)e(p_1)(-i)\frac{\left(\eta_{\mu\nu}-\frac{q_\mu q_\nu}{m_W^2}\right)}{(q^2-m_W^2)}\bar{e}(q_2)\gamma_\mu(1-\gamma_5)\nu_e(p_2)(2\pi)^4\delta^4(q_1+q_2-p_1-p_2)$$

for(b)

$$N\frac{g^2}{8cos(\theta)}\bar{e}(q_2)\gamma^\alpha(A_v-A_A\gamma_5)e(p_1)(-i)\frac{\left(\eta_{\alpha\beta}-\frac{r_\alpha r_\beta}{m_Z^2}\right)}{(r^2-m_Z^2)}\bar{\nu}_e(q_1)\gamma^\beta(1-\gamma_5)\nu_e(p_2)(2\pi)^4\delta^4(q_1+q_2-p_1-p_2)$$

Here

$$N = \frac{1}{(16p_1^0p_2^0q_1^0q_2^0)^{1/2}}, q = p_1-q_1, r = p_1-q_2, A_v = (1-4sin^2(\theta)), A_A = 1$$

.

Matrix element for the reaction

$$\bar{\nu}_{\mathbf{e}}(\mathbf{q_1}) + \mathbf{e}^-(\mathbf{p_1}) \rightarrow \bar{\nu}_{\mathbf{e}}(\mathbf{q_2}) + \mathbf{e}^-(\mathbf{p_2})$$

This again goes through an excahnge of W^- and Z^0 as shown in the figure. Feynaman diagrams for

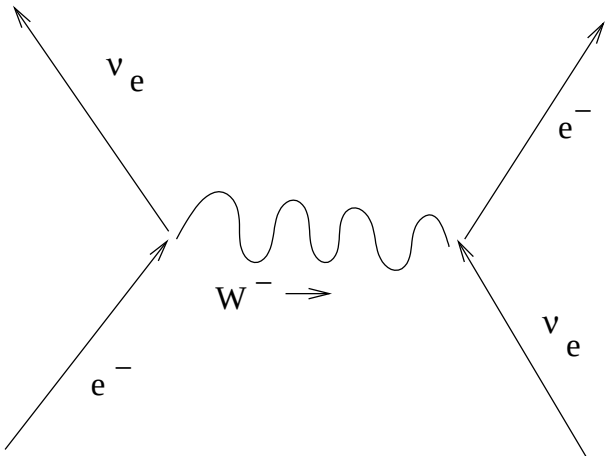
$$\bar{\nu}_e(q_1) + e^-(p_1) \rightarrow \bar{\nu}_e(q_2) + e^-(p_2)$$

The matrix element is given by (the various factors for the vertivces is written ealrier)

$$M_a = N\frac{g^2}{8}(2\pi)^4\delta(p_2{+}q_2{-}p_1{-}q_1)\bar{v}_{\nu_e}(q_1)\gamma^\alpha(1{-}\gamma_5)e(p_1)(-i)\frac{(\eta_{\alpha\beta} - \left(\frac{r_\alpha r_\beta}{M_W^2}\right))}{r^2 - M_Z^2}\bar{e}(p_2)\gamma^\beta(1{-}\gamma_5)v_{\nu_e}(q_2)$$

and

$$M_B = N\frac{g^2}{8cos(\theta)}(2\pi)^4\delta^4(p_2{+}q_2{-}p_1{-}q_1)\bar{e}(p_2)\gamma^\alpha(A_v{-}A_A\gamma_5)e(p_1)(-i)\frac{\eta_{\alpha\beta} - \left(\frac{(p_1-q_2)_\alpha(p_1-q_2)_\beta}{M_Z^2}\right)}{p_1 - q_2)^2 - M_Z^2}\bar{v}_{\nu_e}(q$$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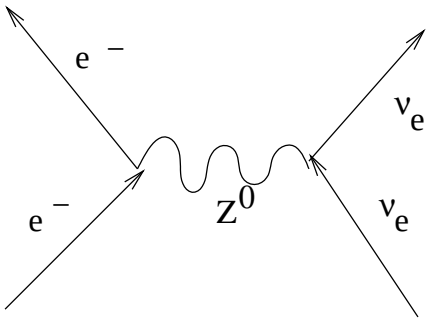
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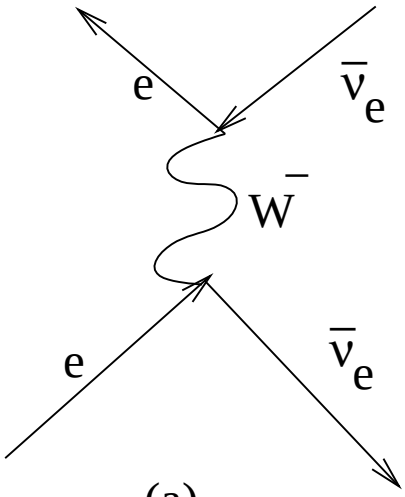
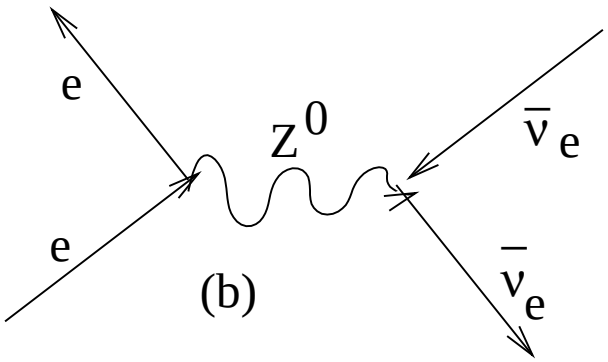


(a)



(b)