Physics 56400 Assignment #6 – Due November 8th

1. The general expressions for c_V^f and c_A^f are

$$c_V^f = I_3^f - 2Q_f \sin^2\theta_W$$
$$c_A^f = I_3^f$$

where I_3^f is the third component of the weak isospin and Q_f is the charge of the fermion in units where $Q_e = -1$. Complete the entries, both symbolically and numerically, in the following table of couplings for quarks and leptons in the Standard Model using $\sin^2\theta_W = 0.231$:

f	Q_f	T_3^f	c_V^f	c_A^f	c_L^f	c_R^f
ν_e, ν_μ, ν_τ	0	$1/2$				
e^-, μ^-, τ^-	-1	$-1/2$				
u, c, t	$2/3$	$1/2$				
d, s, b	$-1/3$	$-1/2$				

2. Show that when $\sqrt{s} = M_Z$, the total cross section for $e^+e^- \to f\bar{f}$, where $f \neq e$, can be written

$$\sigma_{f\bar{f}} = \frac{12\pi\Gamma_e\Gamma_f}{M_Z^2\Gamma_Z^2}$$

where

$$\Gamma_f = N_c \frac{G_F M_Z^3}{6\pi\sqrt{2}}\left(\left(c_V^f\right)^2 + \left(c_A^f\right)^2 \right)$$

Calculate the peak cross section for $e^+e^- \to \mu^+\mu^-$, $e^+e^- \to b\bar{b}$, and $e^+e^- \to c\bar{c}$. Also, explain why this expression is not expected to be valid when $f = e$.

3. Prepare three graphs showing A_{FB} as a function of $\sqrt{s}$, for $50 < \sqrt{s} < 200$ GeV, for the following processes:

$$e^+e^- \to \mu^+\mu^-$$
$$e^+e^- \to b\bar{b}$$
$$e^+e^- \to c\bar{c}$$

assuming three values for $\sin^2\theta_W$: 0.22, 0.231, and 0.24. Which process is most sensitive to variations in $\sin^2\theta_W$?