HW #10, due Nov 12

1. Exotic Contributions to $g-2$. (Problem 6.3 of the book) Any particle that couples to the electron can produce a correction to the electron-photon form factors and, in particular, a correction to $g-2$. Because the electron $g-2$ agrees with QED to high accuracy, these corrections allow us to constrain the properties of hypothetical new particles.

(a) The unified thery of weak and electromagnetic interactions contains a scalar particle h called the Higgs boson, which couples to the electron according to

$$H_{int} = \int d^3x \frac{\lambda}{\sqrt{2}} h\bar{\psi}\psi. \tag{1}$$

Compute the contribution of a virtual Higgs boson to the electron $g-2$, in terms of λ and the mass m_h of the Higgs boson.

(b) QED accounts extremely well for the electron's anomalous magnetic moment. If $a = (g-2)/2$,

$$|a_{\rm exp} - a_{\rm QED}| < 1 \times 10^{-10}. \tag{2}$$

What limits does this place on λ and m_h? In the simplest version of the electroweak theory, $\lambda = 3 \times 10^{-6}$ and $m_h > 95$ GeV. Show that these values are not excluded. The coupling of the Higgs boson to the muon is larger by a factor (m_μ/m_e): $\lambda = 6 \times 10^{-4}$. Thus, although our experimental knowledge of the muon anomalous magnetic moment is not as precise,

$$|a_{\rm exp} - a_{\rm QED}| < 3 \times 10^{-8}, \tag{3}$$

one can still obtain a stronger limit on m_h. Is it strong enough?

(c) **(Optional)** Some more complex versions of this theory contain a pseudoscalar particle called the *axion*, which couples to the electron according to

$$H_{int} = \int d^3x \frac{i\lambda}{\sqrt{2}} a\bar{\psi}\gamma^5\psi. \tag{4}$$

The axion may be as light as the electron, or lighter, and may couple more strongly than the Higgs boson. Compute the contribution of a virtual axion to the $g-2$ of the electron, and work out the excluded valued of λ and m_a.