ELEMENTARY PARTICLE PHYSICS
WS 2016/2017: Exercise sheet 3

8. Express the gravity constant $G_N = 6.67 \times 10^{-11} m^3 kg^{-1} sec^{-2}$ in GeV units. $G_N^{-1/2}$ is called Planck's mass - what is its value in GeV ?

9. A photon with wave length λ scatters on a charged particle with mass m. What is the wave length λ' of the photon after the scattering at a scattering angle of Θ ? (This is called Compton scattering)

10. As in the lecture, $g_{\mu\nu} = \text{diag}(+1,-1,-1,-1)$ is the metric tensor. Also, $g^{\mu\nu}$ is given as $g^{\mu\nu} = \text{diag}(+1,-1,-1,-1)$. Compute $g^{\mu}_{\cdot\nu}$ and show that $g_{\mu\nu} g^{\mu\nu} = 4$.

11. The Hamiltonian of an harmonic oscillator with mass $m = 1$ is given as
$$\hat{H} = \frac{\hat{p}^2}{2} + \frac{\omega^2 \hat{x}^2}{2}.$$
Introduce operators $\hat{a} = (\omega\hat{x} + i\hat{p})/\sqrt{2\omega}$ and $\hat{a}^\dagger = (\omega\hat{x} - i\hat{p})/\sqrt{2\omega}$.
Compute the commutator $[\hat{a}, \hat{a}^\dagger]$ and express the Hamiltonian in terms of $\hat{a}$ and $\hat{a}^\dagger$.
If $|n\rangle$ is an eigen state of $\hat{H}$ with energy E_n, $\hat{H}|n\rangle = E_n|n\rangle$, what are the energies of the states $\hat{a}^\dagger|n\rangle$ and $\hat{a}|n\rangle$?