

# F20 PHYSICS 137B: HW 3

Due September 18 at 5 pm

September 8, 2020

## 1 Griffiths problems

Do the following problems from Griffiths: 7.1, 7.2, 7.3, 7.5.

## 2 Other problems

### 2.1

A particle of mass  $m$  is confined to a one-dimensional infinite square potential well that extends from  $x = 0$  to  $x = L$ . The energy eigenvalues for the (nonrelativistic) Hamiltonian are:

$$E_n = \frac{n^2 \pi^2 \hbar^2}{2mL^2}. \quad (2.1)$$

If the mass of the particle is small or if the length  $L$  is small, the energy eigenvalues will be large, and the particle may become relativistic (this happens if the energy is comparable with or larger than  $mc^2$ ). The relativistic Hamiltonian is

$$H = \sqrt{p^2 c^2 + m^2 c^4} - mc^2. \quad (2.2)$$

- (a) Use first-order perturbation theory to find the new energy eigenvalues that correspond to this relativistic Hamiltonian.
- (b) The energy eigenvalues obtained by first-order perturbation theory are actually the *exact* eigenvalues for the relativistic Hamiltonian. Explain carefully why this is so.

### 2.2

Suppose that the electron in a hydrogen atom is perturbed by a repulsive potential concentrated at the origin. Assume that the potential has the form of a delta function, so the perturbed Hamiltonian is:

$$H = \frac{\mathbf{p}^2}{2m} - \frac{1}{4\pi\epsilon_0} \frac{e^2}{r} + A\delta(\mathbf{r}), \quad (2.3)$$

where  $A$  is a constant.

- (a) To first order in  $A$ , find the change in the energy of the state with quantum numbers  $n \geq 1$ ,  $l = 0$ . [Hint:  $\psi_{n00}(0) = \frac{2}{\sqrt{4\pi(na_0)^{3/2}}}$ ].
- (b) Find the change in the wavefunction.