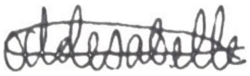
Finals

I swear upon my honor that I have not given nor received any unauthorized help on this exam and that all the work below are my own.



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1 Baa Baa Black Sheep [50 pts.]

Consider the process: $e^+e^- \to e^+e^-$.

(a) Draw the lowest-order Feynman diagram/s for this process. [10 pts.]

(b) Does this process have the same number of lowest-order Feynman diagram as the annihilation process $e^+e^- \to \mu^+\mu^-$ (which only has *one*) considered in class? Why or why not? [5 pts.]

(c) Use the Feynman rules for QED to write down the corresponding matrix element/s. [10 pts.]

(d) In the *relativistic* limit (i.e., the masses of e^+ and e^- can be neglected), calculate the spin-averaged matrix element. Your final answer must be written in terms of the Mandelstam variables. [25 pts.]

2 Look At Me Roll [50 pts.]

Consider the process: $e^-e^- \to e^-e^-$.

(a) Draw the lowest-order t-channel and u-channel Feynman diagrams for this process. [10 pts.]

The lowest-order t-channel Feynman diagram for the process is given by:

[insert here]

The lowest-order u-channel Feynman diagram for the process is given by:

[insert here]

(b) Use the Feynman rules for QED to write down the corresponding matrix elements. [10 pts.]

We note that the Feynman rules for QED note the following contributions to the matrix element $\mathcal{M}$

<u>t-channel</u>

For the t-channel Feynman diagram, the matrix element $\mathcal{M}$ is given by:

<u>u-channel</u>

For the u-channel Feynman diagram, the matrix element $\mathcal{M}$ is given by:

(c) In the *non-relativistic* limit (i.e., electron mass is *not* neglected), calculate the spin-averaged matrix element. Your final answer must be written in terms of the Mandelstam variables. [30 pts.]

We note that the spin-averaged matrix element is given by:

<u>t-channel</u>

For the t-channel Feynman diagram,

<u>u-channel</u>

For the u-channel Feynman diagram,