Physics 180 Final Exam
1st Sem AY 2021-2022

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INSTRUCTIONS: Show *complete* and *detailed* solutions. Kindly include an honor pledge at the start of your work: *"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."*

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.]

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

   (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.]