Problem Set 4

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Problem 1

a)

- The standard model attempts to describe the universe through particles which interacts by exchanging force-carrying particles.
- All particles have intrinsic properties such as mass, charge, spin, color, chirality and so on. Force-carrying particles interact with one or more of these properties, allowing them to change from one particle, to another.
- We have different groups of particles.
  - **Fermions:** Either quarks or leptons with half-integer spin and different charge, color and mass. These are divided in three generations, increasing in mass for each.
  - **Bosons:** Particles with integer spin, like the force carrying particles with different mass, color, and charge. Composite bosons comes from adding fermions together (like mesons or other hadrons)
  - **Hadrons:** Two (mesons), or more quarks held together by the strong force. If greater than one, and odd, it is called a baryon.

b)

The standard model does not describe gravity.

1. **Strong nuclear force:** Felt by particles with color, like quarks.
2. **Weak nuclear force:** Felt by left-chiral fermions.
3. **Electromagnetism:** Felt by all fermions with charge, like the quarks, electron, muon and tau.

c)

Interactions between particles goes through force-carrying particles.

- **Strong nuclear force:** Gluon
- **Weak nuclear force:** The Z^0, W^+ and W^--boson.
- **Electromagnetism:** The photon γ

Problem 2

a)

Feynman diagrams depict particle interaction through lines, representing different types of particles, and vertices showing where they interact. By convention, time flows from left to right.

b)

- Spin-half fermions are whole lines with an arrow. Arrows pointing forwards are fermions, and backwards are anti-fermions.
- Gluons are drawn like springs.
- Spin-1 bosons are drawn as waves.
- Spin-0 boson are drawn with dashed lines.
- Fermion lines must always be connected through the entire diagram.

c)

Virtual particles are identified with an asterix (*) and have vertices on each side.

d)

The order of a Feynman diagram is how many chains of vertices are present. Higher-order diagrams are less probable as they require multiple interactions.

e)

The lepton, anti-lepton pairs have arrows in the wrong directions.

Problem 3

a)

In this diagram, an electron and anti-electron collide, create a photon, which then becomes an electron and anti-electron.

b)

In this diagram, two electrons interact by exchanging a photon. Which is giving or receiving, is not specified.

c)

In this diagram, an electron emits a photon, then absorbs one. It could also absorb, before emitting, as the figure does not specify the time order.