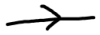
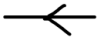
Rainstorm Practice Problem 1:

For this problem, let's draw an example to visually understand how the different forces interact with other elementary particles.

Part A:

Consider the following process: $e^- + e^+ \xrightarrow{\text{yields}} e^- + e^+$ **(one electron plus one positron yields another electron plus another positron)**

And two important notes:

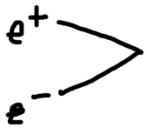
1. particles are denoted graphically as  **and anti-particles as** 

2. Forces which are mediated by boson particles are denoted as 

First, do you remember what the main difference is between a particle and an anti-particle?

Part B:

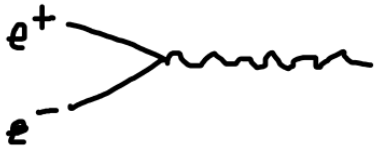
Ok! To start out, this is the initial state of the system (think reactants from chemistry), what direction should the arrows go?



Part C:

The place where the two lines meet is called a vertex. It is here that the main force responsible for this interaction comes in the form of its associated boson particle. Next, let's add this boson into the picture.

We draw it like so:



Which force/boson is responsible? (Think about the forces we learned about: EM – light, electrons, strong - quarks, weak - neutrinos, Higgs – mass (hint: Not Higgs))

Part D:

We denote light (photons) with γ, gluons with **g,** and weak bosons with **Z** or **W**.
Write the appropriate symbol above the force/boson line.

Part E:
Great! This completes the first part of the diagram. Now, consider how to add in the final state (think products from chemistry). What directions should these arrows go?

Congratulations! You just draw something called a **Feynman Diagram** for an interaction known as **Bhabha Scattering**.

Bhabha Scattering is an important process in particle physics as it shows how a particle (electron) and an antiparticle (positron) have **annihilated** (destroyed each other) to produce a photon (force carrier of EM).

In fact, it also shows in action that matter can turn into energy as the photon made from the particle-antiparticle pair combining, carries energy. Again, recall the Bohr model of an atom in the context of electrons moving between energy levels and emitting photons as they go.

Feynman Diagrams are useful tools that help physicists to describe the interactions they are working on for various combinations of particles, anti-particles, and forces. Once drawn, they can be matched to a recipe of rules to follow called **Feynman Calculus** which will lead them to solve a given interaction mathematically. (ex. a collision between particles etc…)

Bonus: If have time to spare, try this interaction: $\pi^+ \xrightarrow{\textbf{yields}} \mu^+ + \nu_\mu$ where π denotes a **pion antiparticle**. Hint: a pion antiparticle is a composite particle made up of an **up quark** and an **anti-down quark**.

Starting with the following setup, try drawing this interaction below. Note that this interaction relies upon the **W** boson mediator. Remember to add in the arrow directions using part A of the previous problem.

π^+ — $\bar{d}$, u