honors (not AP®)

Particle Interactions

Unit: Quantum and Particle Physics

NGSS Standards/MA Curriculum Frameworks (2016): N/A

AP® Physics 2 Learning Objectives/Essential Knowledge (2024): N/A

Mastery Objective(s): (Students will be able to…)

- Fully describe an interaction between particles based on a Feynman diagram.
- Draw a Feynman diagram representing an interaction between particles.

Success Criteria:

- Descriptions & explanations are accurate.
- Diagrams correctly show all parts of the interaction.

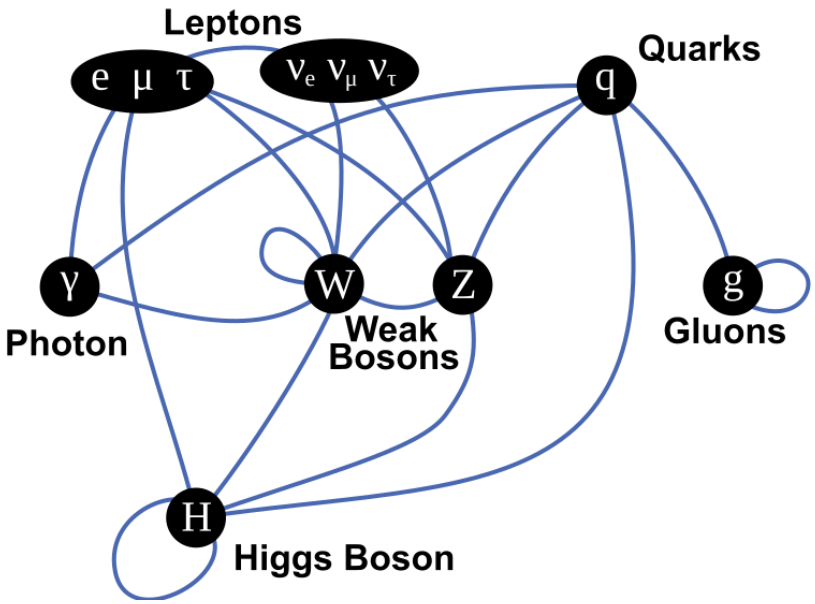
Language Objectives:

- Describe a particle interaction as a narrative.

Tier 2 Vocabulary: interaction, particle

Notes:

In particle physics, the Standard Model describes the types of particles found in nature, their properties, and how they interact. The following diagram shows which types of particles interact with which other types.



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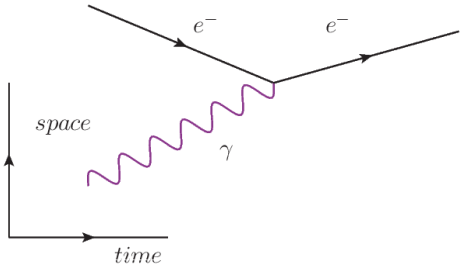
Specific interactions between particles can be shown pictorially in diagram called a Feynman diagram, named for American physicist Richard Feynman. The Feynman diagram tells the "story" of the interaction.

The characteristics of a Feynman diagram are:

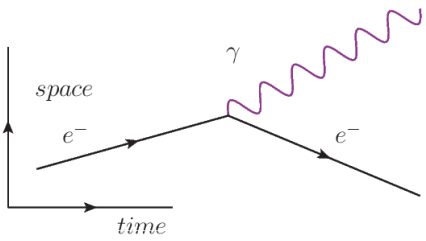
1. Straight lines represent the motion of a particle, such as an electron or positron. The arrow points to the right for a negatively charged particle, and to the left for a positively-charged particle.
2. A wavy line represents a photon (γ). 
3. A coiled line (like a spring) represents a gluon (g). 
4. The x-axis is time. The interaction starts (in terms of time) on the left and proceeds from left to right.
5. The y-axis represents space. Lines coming together represent particles coming together. Lines moving apart represent particles moving away from each other. (Note that ***the diagram is not a map***; particles can move together or apart in any direction.)
6. Each vertex, where two or more lines come together, represents an interaction.

Probably the best way to explain the diagrams is with examples.

In this diagram, we start (at the left) with an electron (e^-) and photon (γ). The two come together, and the electron absorbs the photon.



In this diagram, we start (at the left) with an electron (e^-) by itself. The electron emits a photon (γ) but is otherwise unchanged.



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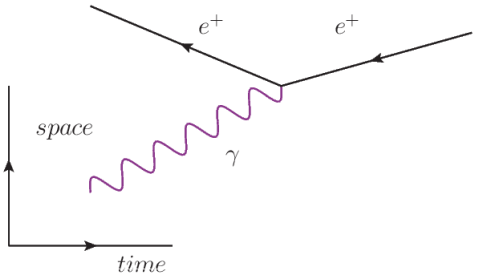
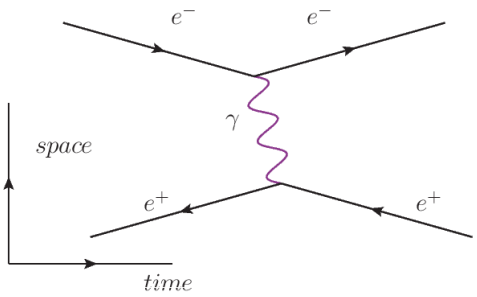
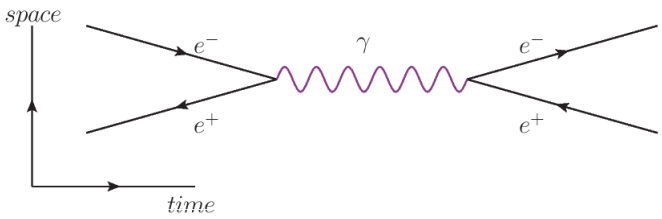
In this diagram, we start (at the left) with a positron (e^+) and photon (γ). (Note that the arrow pointing to the left indicates a positively charged particle.) The two come together, and the positron absorbs the photon.



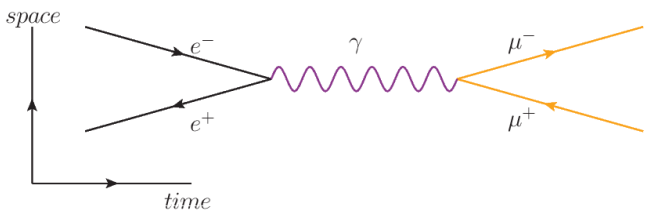
In this diagram, we start with an electron (e^-) and positron (e^+) (coming in from the left). They exchange a photon (γ) between them. (Note that the diagram does not make it clear which particle emits the photon, and which one absorbs it.) Then the two particles exit.



In the following diagram, we start with an electron (e^-) and positron (e^+). They come together and annihilate each other, producing a photon (γ). (You can tell this because for a length of time, nothing else exists except for the photon.) Then the photon pair-produces a new electron/positron pair.



In the following diagram, an electron (e^-) and positron (e^+) annihilate each other as above, but this time the photon produces a muon (μ^-)/antimuon (μ^+) pair. (Again, note that the muon, which has a negative charge, has the arrow pointing to the right. The antimuon, which has a positive charge, has the arrow pointing to the left.)



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Finally, in the following diagram, an electron (e^-) and positron (e^+) annihilate each other, producing a photon (γ). The photon pair-produces a bottom quark (b) and an antibottom quark ($\bar{b}$), which radiate gluons (g).