Clicker Questions

Modern Physics
Chapter 13: "Particle Physics"
Cambridge University Press
felderbooks.com

by Gary Felder and Kenny Felder

Instructions

- These questions are offered in two formats: a deck of PowerPoint slides, and a PDF file. The two files contain identical contents. There are similar files for each of the 14 chapters in the book, for a total of 28 files.
- Each question is marked as a "Quick Check" or "ConcepTest."
  - Quick Checks are questions that most students should be able to answer correctly if they have done the reading or followed the lecture. You can use them to make sure students are where you think they are before you move on.
  - ConcepTests (a term coined by Eric Mazur) are intended to stimulate debate, so you don't want to prep the class too explicitly before asking them. Ideally you want between 30% and 80% of the class to answer correctly.
- Either way, if a strong majority answers correctly, you can briefly discuss the answer and move on. If many students do not answer correctly, consider having them talk briefly in pairs or small groups and then vote again. You may be surprised at how much a minute of unguided discussion improves the hit rate.
- Each question is shown on two slides: the first shows only the question, and the second adds the correct answer.
- Some of these questions are also included in the book under "Conceptual Questions and ConcepTests," but this file contains additional questions that are not in the book.
- Some of the pages contain multiple questions with the same set of options. These questions are numbered as separate questions on the page.
- Some questions can have multiple answers. (These are all clearly marked with the phrase "Choose all that apply.") If you are using a clicker system that doesn't allow multiple responses, you can ask each part separately as a yes-or-no question.

13.1 Forces and Particles

Which of the following describes the net force between two protons? (Choose one.)

A. It is always repulsive.

B. It is always attractive.

C. It is repulsive at short distances and attractive at large distances.

D. It is attractive at short distances and repulsive at large distances.

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B. It is always attractive.

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D. It is attractive at short distances and repulsive at large distances.

Solution: D

Which of the following participate in strong interactions? (Choose all that apply.)

A. Leptons

B. Mesons

C. Baryons

Which of the following participate in strong interactions? (Choose all that apply.)

A. Leptons

B. Mesons

C. Baryons

Solution: B and C

A stable particle such as an electron cannot decay. If it is in empty space with no other particles around to interact with, it feels no effect from any of the fundamental forces. Which of the following best describes an electron in those circumstances? (Choose all that apply.)

A. It will behave exactly like a classical particle with no forces acting upon it.

B. Its wavefunction will allow for a discrete set of energy eigenvalues.

C. It may spontaneously turn into another particle.

D. Its wavefunction will remain constant over time ($\partial\Psi/\partial t = 0$).

E. None of those answers applies.

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D. Its wavefunction will remain constant over time ($\partial\Psi/\partial t = 0$).

E. None of those answers applies.

Solution: E

Two important conserved quantities are baryon number (number of baryons minus number of antibaryons), and lepton number (number of leptons minus number of antileptons). There is no conserved "meson number." Based on those facts, classify each of the following reactions as "could happen" or "could never happen." (Here p is a proton, n is a neutron, and π^0 is a pion.)

1. $p + p \rightarrow p + p + \pi^0$
2. $p + p \rightarrow p + p + \pi^0 + \pi^0$
3. $p + p \rightarrow p + p + n$

Two important conserved quantities are baryon number (number of baryons minus number of antibaryons), and lepton number (number of leptons minus number of antileptons). There is no conserved "meson number." Based on those facts, classify each of the following reactions as "could happen" or "could never happen." (Here p is a proton, n is a neutron, and π^0 is a pion.)

1. $p + p \to p + p + \pi^0$

   Solution: Could happen. On both sides baryon number is 2 and lepton number is 0.

2. $p + p \to p + p + \pi^0 + \pi^0$

   Solution: Could happen. On both sides baryon number is 2 and lepton number is 0.

3. $p + p \to p + p + n$

   Solution: Couldn't happen. This shows baryon number increasing by 1.

13.2 The Standard Model

A baryon is made from . . . (Choose one.)

A. two quarks

B. three quarks

C. a combination of quarks and leptons

D. none of the above

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A. two quarks

B. three quarks

C. a combination of quarks and leptons

D. none of the above

Solution: B

Which of the following quarks will be attracted to a green up quark? (Choose all that apply.)

A. another green up quark

B. a red up quark

C. an anti-green anti-up quark

D. an anti-red anti-up quark

E. a red charm quark

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Solution: B, C, E

An up quark feels which of the following forces? (Choose all that apply.)

A. strong

B. electromagnetic

C. weak

D. gravity

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A. strong

B. electromagnetic

C. weak

D. gravity

Solution: A, B, C, D

Which of the following are fermions? (Choose all that apply.)

A. quarks

B. leptons

C. force carriers

D. the Higgs

Which of the following are fermions? (Choose all that apply.)

A. quarks

B. leptons

C. force carriers

D. the Higgs

Solution: A, B

Each baryon is a combination of three (not necessarily different) quark flavors, such as uud for protons. Which of the following two sentences best describes the possible baryons?

A. Any possible combination of three quark flavors be combined into a baryon.

B. The color-balancing rule restricts what combinations you can make.

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A. Any possible combination of three quark flavors be combined into a baryon.

B. The color-balancing rule restricts what combinations you can make.

Solution: A. Any combination of flavors is possible, since flavor is independent of color.

Which of the following color combinations is possible for a meson? (Choose one.)

A. Blue and anti-blue

B. Blue and anti-green

C. Either of these is possible.

D. Neither of these is possible.

Which of the following color combinations is possible for a meson? (Choose one.)

A. Blue and anti-blue

B. Blue and anti-green

C. Either of these is possible.

D. Neither of these is possible.

Solution: A. Blue and anti-blue is a color-balanced combination; blue and anti-green is not. Underlying that rule is the fact that blue and anti-blue attract each other, while blue and anti-green repel each other.

13.3 Detecting Particles

Why are cloud chambers and bubble chambers placed in large magnetic fields? . . . (Choose one.)

A. Particles wouldn't leave tracks in the chamber otherwise.

B. The magnetic fields cause some particles to leave tracks and not others, allowing you to distinguish between them more easily.

C. The magnetic fields cause particles to curve in a way that reveals their momentum.

D. The magnetic fields hold the particles in the chambers for longer, making it easier to see their tracks.

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C. The magnetic fields cause particles to curve in a way that reveals their momentum.

D. The magnetic fields hold the particles in the chambers for longer, making it easier to see their tracks.

Solution: C

Time dilation causes particles to leave. . . (Choose one.)

A. . . . longer tracks than you would expect without relativity.

B. . . . shorter tracks than you would expect without relativity.

C. . . . the same length tracks that you would expect without relativity.

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A. . . . longer tracks than you would expect without relativity.

B. . . . shorter tracks than you would expect without relativity.

C. . . . the same length tracks that you would expect without relativity.

Solution: A

13.4 Symmetries and Conservation Laws

Classify each of the following symmetries as Continuous (C) or Discrete (D).

1. Rotation
2. Time reversal
3. Parity
4. Time-translation

Classify each of the following symmetries as Continuous (C) or Discrete (D).

1. Rotation

   Solution: Continuous

2. Time reversal

   Solution: Discrete

3. Parity

   Solution: Discrete

4. Time-translation

   Solution: Continuous

Classify each of the following symmetries as Exact (E) or Approximate (A).

1. Rotation
2. Time reversal
3. C
4. P
5. T
6. CPT

Classify each of the following symmetries as Exact (E) or Approximate (A).

1. Rotation

   Solution: Exact

2. Time reversal

   Solution: Approximate

3. C

   Solution: Approximate

4. P

   Solution: Approximate

5. T

   Solution: Approximate

6. CPT

   Solution: Exact

For each reaction below, indicate whether this reaction will sometimes occur. The letters signify a neutron (n), proton (p), electron (e), neutrino (ν), pion (π^0), or neutrino (μ), or their antiparticles.

1. $n \rightarrow p + e + \overline{\nu}$
2. $n + p \rightarrow n + p + e + \overline{\nu}$
3. $n + n \rightarrow p + e + \nu$
4. $n + p \rightarrow n + e^+ + \nu$
5. $n + p \rightarrow n + n + e^+ + \nu$
6. $n + p \rightarrow n + n + e^+ + \overline{\nu}$

For each reaction below, indicate whether this reaction will sometimes occur. The letters signify a neutron (n), proton (p), electron (e), neutrino (ν), pion (π^0), or neutrino (μ), or their antiparticles.

1. $n \rightarrow p + e + \overline{\nu}$

   Solution: Yes; this is one form of beta decay.

2. $n + p \rightarrow n + p + e + \overline{\nu}$

   Solution: No; this does not conserve charge.

3. $n + n \rightarrow p + e + \nu$

   Solution: No; this does not conserve baryon number or lepton number.

4. $n + p \rightarrow n + e^+ + \nu$

   Solution: No; this does not conserve baryon number.

5. $n + p \rightarrow n + n + e^+ + \nu$

   Solution: Yes

6. $n + p \rightarrow n + n + e^+ + \overline{\nu}$

   Solution: No. The e^+ and the $\overline{\nu}$ are both antileptons, so lepton number is not conserved.

Is the fact that most people are right-handed evidence of a parity violation in nature?

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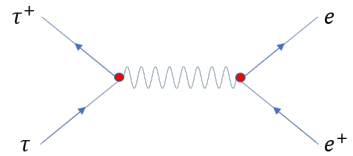
Solution: No. That would only be true if it turned out that the laws of physics forbid the evolution of a species of left-handed bipeds. If either one is equally likely, but on our planet it happened to come out this way, then that does not signal parity violation. While we can't prove it, it seems highly unlikely that our tendency to be right-handed is a result of the spin properties of neutrinos, so it's probably a random historical accident.

13.5 Quantum Field Theory

The figure below shows a Feynman diagram for an event in which a tauon and antitauon collide. Suppose you have calculated the probability amplitude associated with this particular Feynman diagram. Which of the following describe how you might use that number? (Choose all that apply.)



A. Take the magnitude of this probability amplitude and square it. The answer is the probability of this particular path being followed.

B. Find the probability amplitudes for all other possible paths that lead from these starting particles to these final particles. Add the probability amplitudes, and then the squared magnitude of that result is the probability of such a reaction.

C. Find the probability amplitudes for all other possible paths that represent the annihilation of these starting particles. Add the probability amplitudes, and then the squared magnitude of that result is the total probability of such an annihilation, regardless of the end products.

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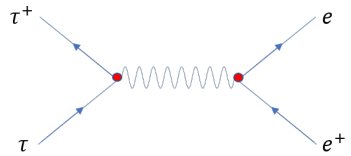

A. Take the magnitude of this probability amplitude and square it. The answer is the probability of this particular path being followed.

B. Find the probability amplitudes for all other possible paths that lead from these starting particles to these final particles. Add the probability amplitudes, and then the squared magnitude of that result is the probability of such a reaction.

C. Find the probability amplitudes for all other possible paths that represent the annihilation of these starting particles. Add the probability amplitudes, and then the squared magnitude of that result is the total probability of such an annihilation, regardless of the end products.

Solution: B

In Figure 13.10 on p. 634, which particles are present at the beginning of the interaction? (Choose all that apply.)

A. the muon (μ)

B. the muon neutrino (ν_μ)

C. the W boson (W^+)

D. the electron neutrino (ν_e)

E. the electron (e)

F. none of the above

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C. the W boson (W^+)

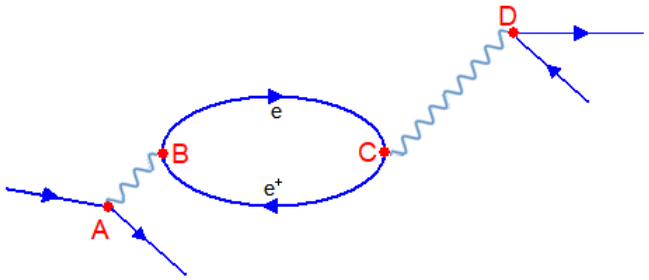
D. the electron neutrino (ν_e)

E. the electron (e)

F. none of the above

Solution: A, D

Which of the following best describes the interaction at the vertex labeled A in the figure? (Choose one.)



A. A particle emits a photon.

B. Two particles collide and annihilate each other, releasing their energy as a photon.

C. A photon pair-produces two particles.

D. Two particles exert a repulsive force that causes them to accelerate away from each other.

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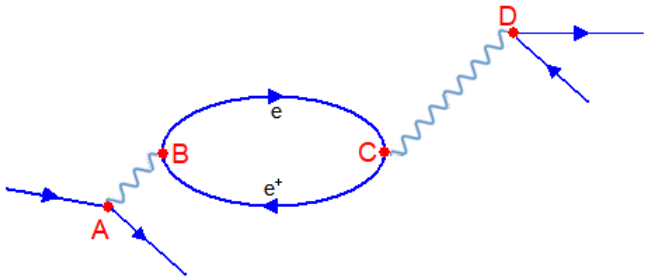

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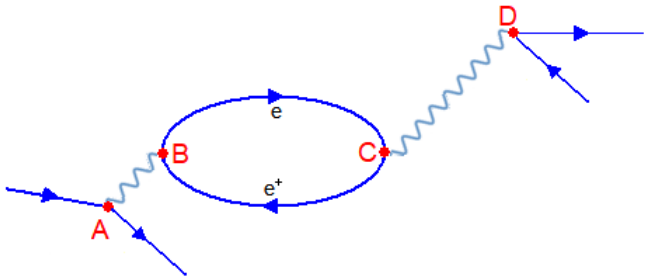
C. A photon pair-produces two particles.

D. Two particles exert a repulsive force that causes them to accelerate away from each other.

Solution: A

Which of the following best describes the interaction at the vertex labeled D in the figure? (Choose one.)



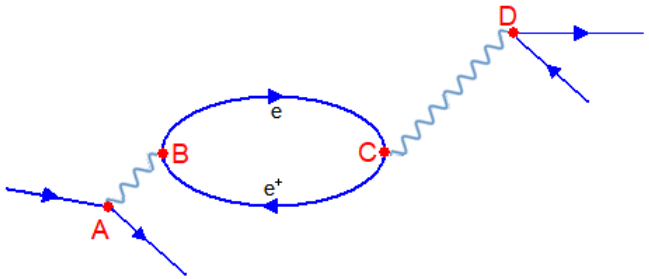
A. A particle emits a photon.

B. Two particles collide and annihilate each other, releasing their energy as a photon.

C. A photon pair-produces two particles.

D. Two particles exert a repulsive force that causes them to accelerate away from each other.

Which of the following best describes the interaction at the vertex labeled D in the figure? (Choose one.)



A. A particle emits a photon.

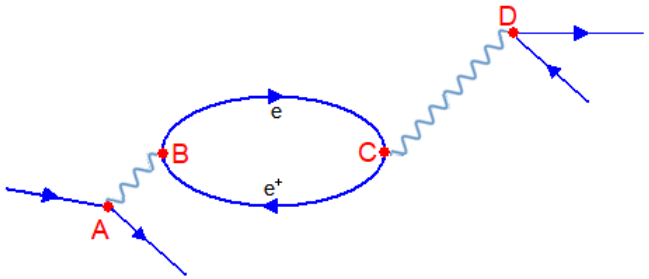
B. Two particles collide and annihilate each other, releasing their energy as a photon.

C. A photon pair-produces two particles.

D. Two particles exert a repulsive force that causes them to accelerate away from each other.

Solution: C

Which of the following best describes the relationships between the *times* of the four interactions in the figure? (Choose one.)

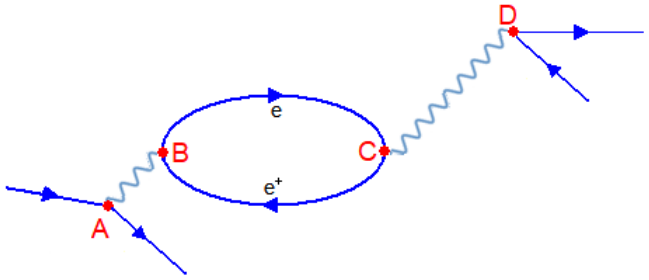


A. The diagram contains no information about the times of these interactions.

B. The interactions happen in alphabetical order (A, then B, then C, then D), but we have no information about how much time elapsed between them.

C. The interactions happen in alphabetical order. The time lapse between Event B and Event C is longer than the time lapse between Event A and Event B.

Which of the following best describes the relationships between the *times* of the four interactions in the figure? (Choose one.)



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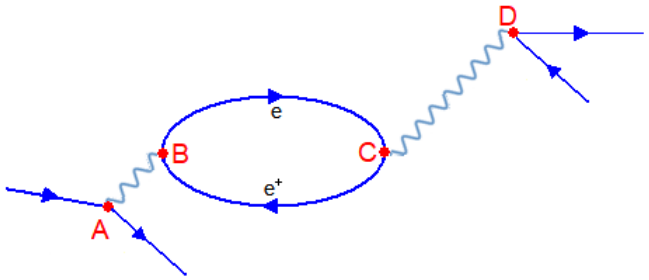
C. The interactions happen in alphabetical order. The time lapse between Event B and Event C is longer than the time lapse between Event A and Event B.

Solution: B

Why are the squiggly lines in the figure squiggly? (Choose one.)



A. They represent virtual particles.

B. They represent antimatter particles.

C. They represent force carrying particles such as photons, rather than matter particles such as hadrons.

D. We're just really bad at drawing.

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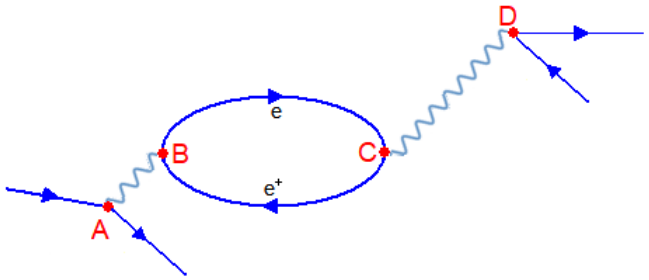


A. They represent virtual particles.

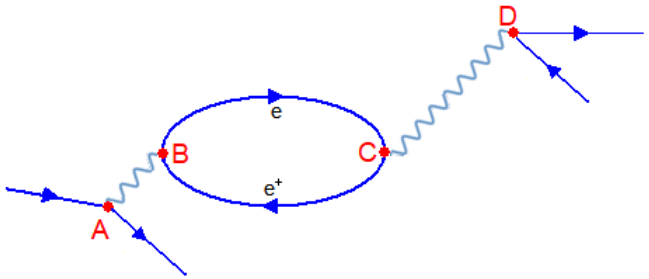
B. They represent antimatter particles.

C. They represent force carrying particles such as photons, rather than matter particles such as hadrons.

D. We're just really bad at drawing.

Solution: C

Which of the following best describes the interactions around vertices B and C in the figure? (Choose one.)



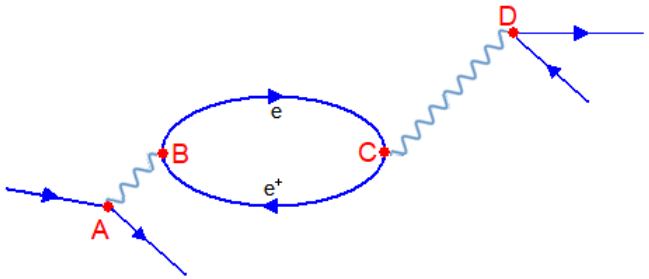
A. A positron turns into an electron, which turns back into a positron, and so on.

B. A positron and an electron annihilate each other and produce a photon, which then pair-produces a positron and an electron.

C. A photon pair-produces a positron and an electron, which then annihilate each other and produce a photon.

D. None of the above.

Which of the following best describes the interactions around vertices B and C in the figure? (Choose one.)



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C. A photon pair-produces a positron and an electron, which then annihilate each other and produce a photon.

D. None of the above.

Solution: C