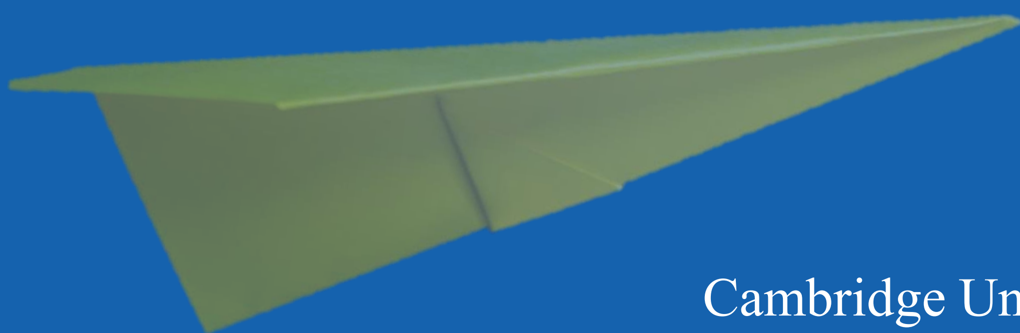
Clicker Questions

Modern Physics

by Gary Felder and Kenny Felder



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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.

12

The Atomic Nucleus

12.1 What's in a Nucleus?

Two protons repel each other due to their charges, but attract each other due to the strong force. How do these two forces relate? (Choose one.)

A. The electric force is stronger.

B. The strong force is stronger.

C. The answer depends on how far apart they are.

D. The answer depends on whether they have the same or opposite spins.

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B. The strong force is stronger.

C. The answer depends on how far apart they are.

D. The answer depends on whether they have the same or opposite spins.

Solution: C

The positive charge inside a nucleus is... (Choose one.)

A. Mostly concentrated in the center of the nucleus.

B. Distributed roughly evenly throughout most of the nucleus.

C. Mostly concentrated closer to the outer edge of the nucleus.

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A. Mostly concentrated in the center of the nucleus.

B. Distributed roughly evenly throughout most of the nucleus.

C. Mostly concentrated closer to the outer edge of the nucleus.

Solution: B

Nucleus 1 has A_1 nucleons and Nucleus 2 has A_2 nucleons, with $A_1 > A_2$. How do the radii of the two nuclei compare? (Choose one.)

A. $r_1 > r_2$

B. $r_1 \approx r_2$

C. $r_1 < r_2$

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C. $r_1 < r_2$

Solution: A

Figure 12.4 on p. 561 shows that the quantity B/A is higher for ^{119}Sn than for ^{235}U. Which of the following does that imply? (Choose one.)

A. Given enough time, ^{235}U will spontaneously decay into ^{119}Sn.

B. It would take more energy to completely separate a ^{119}Sn atom into its component particles than to do the same to a ^{235}U atom.

C. If you started with a sample of ^{235}U atoms, and rearranged all their component particles into ^{119}Sn atoms, there would be a net release of energy.

D. ^{235}U can be artificially produced, but not found in nature.

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D. ^{235}U can be artificially produced, but not found in nature.

Solution: C

What does Figure 12.5 on p. 562 say about atoms with an atomic number of 100? (Choose one.)

A. They are stable.

B. They are unstable.

C. Some are stable and some are unstable, depending on their atomic masses.

D. No such atoms exist.

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A. They are stable.

B. They are unstable.

C. Some are stable and some are unstable, depending on their atomic masses.

D. No such atoms exist.

Solution: B

Figure 12.4 on p. 561 shows that for most nuclei ($A \gtrsim 20$) the binding energy per nucleon is roughly constant at about 8 MeV. In other words, the total binding energy of a nucleus (B) is roughly proportional to its mass number A. If the nuclear force were a long-range force, how would you expect the total binding energy to depend on A? (Choose one.)

$A.$ B constant

$B.$ $B \propto A$

$C.$ $B \propto A^2$

$D.$ $B \propto A^3$

$E.$ $B \propto A^{1/3}$

F. None of the above

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E. $B \propto A^{1/3}$

F. None of the above

Solution: C

When we say that B/A is constant, we're saying that the (negative) potential energy of any given nucleon doesn't change much as you add more nucleons. That makes sense, since each nucleon feels forces only from its immediate neighbors. So doubling the number of nucleons just doubles the total potential energy.

Now imagine that every nucleon felt a force from every other nucleon. Roughly speaking, then, doubling the number of nucleons would double the potential energy of every nucleon. That in turn would cause the total binding energy of the system to multiply by four.

12.2 Experimental Evidence for Nuclear Properties

What approximations went into the Rutherford scattering formula? (Check all that apply.)

A. It ignored relativistic effects.

B. It ignored the wavelike behavior of the incoming particles.

C. It assumed that an atom's positive charge was evenly distributed throughout the atom.

D. It treated both the incoming and target nuclei as point particles.

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Solution: A, B, and D

Electron scattering is effectively a single-slit diffraction experiment, with the role of the slit being played by… (Choose one.)

A. An incoming alpha particle.

B. A target atom in the foil.

C. A target nucleus in the foil.

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C. A target nucleus in the foil.

Solution: C

The "mass spectrometry" experiment described in the text provides a measurement of... (Choose one.)

A. The mass of an atom.

B. The radius of an atom.

C. The volume of an atom.

D. The total angular momentum of an atom.

E. The total charge of a nucleus.

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Solution: A

12.3 Nuclear Models

The liquid drop model is based on what analogy? (Choose one.)

A. A nucleon floats inside the nucleus like a water molecule floats inside a drop of water.

B. A nucleon floats inside the nucleus like a drop of water floats inside a cup of water.

C. A nucleus floats inside an atom like a water molecule floats inside a drop of water.

D. A nucleus floats inside an atom like a drop of water floats inside a cup of water.

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C. A nucleus floats inside an atom like a water molecule floats inside a drop of water.

D. A nucleus floats inside an atom like a drop of water floats inside a cup of water.

Solution: A

What does the Fermi gas model take into account that the liquid drop model does not? (Choose one.)

A. Each nucleon has an uncertainty in its position and momentum.

B. Each nucleon has a quantized angular momentum.

C. Each nucleon obeys the Pauli exclusion principle, so the nucleons fill in the lowest available energy levels.

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B. Each nucleon has a quantized angular momentum.

C. Each nucleon obeys the Pauli exclusion principle, so the nucleons fill in the lowest available energy levels.

Solution: C

What does the shell model take into account that the Fermi gas model does not? (Choose one.)

A. The energy levels available to a proton or neutron are quantized.

B. A nucleus with its highest-level shells completely filled in more stable than a nucleus with a partially filled shell.

C. Energy levels are subtly split by an interaction between the orbital and spin contributions to angular momentum.

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Solution: A

12.4 Three Types of Nuclear Decay

A polonium nucleus, ^{210}Po, undergoes alpha decay. What is the mass number of the daughter nucleus? (Choose one.)

A. 206

B. 208

C. 209

D. 210

E. 211

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A. 206

B. 208

C. 209

D. 210

E. 211

Solution: A

When a proton changes into a neutron, which of the following might also happen? (Choose all that apply.)

A. A positron might be emitted.

B. An electron might be emitted.

C. An electron that was previously orbiting the nucleus might be captured.

D. An antineutrino might be emitted, with no production or annihilation of electrons or positrons.

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Solution: A, C

Neutrinos or antineutrinos were proposed to explain problems in beta decay, related to which of the following? (Choose all that apply.)

A. Conservation of energy

B. Conservation of momentum

C. Conservation of charge

D. Conservation of spin

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A. Conservation of energy

B. Conservation of momentum

C. Conservation of charge

D. Conservation of spin

Solution: A and D

Gamma decay occurs when… (Choose one.)

A. A nucleus splits into two smaller nuclei, releasing radiation.

B. Two nuclei fuse into a larger nucleus, releasing radiation.

C. Protons turn into neutrons or vice versa, releasing radiation.

D. One or more nucleons drop into lower-energy shells inside the nucleus, releasing radiation.

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D. One or more nucleons drop into lower-energy shells inside the nucleus, releasing radiation.

Solution: D

In order for a given parent nucleus to alpha decay, the daughter nucleus must have . . . (Choose one.)

A. at least a certain minimum binding energy per nucleon.

B. at most a certain maximum binding energy per nucleon.

C. exactly the right binding energy per nucleon.

D. none of the above. The possibility of alpha decay doesn't depend on the product's binding energy per nucleon.

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Solution: A. This is one of those discussions where you can easily get tangled up between positive and negative: a "high binding energy" means a *low energy particle,* because the binding energy is the energy you gave up when you formed this nucleus. So if the daughter nucleus does not have a sufficiently high binding energy, that means it is not a sufficiently low-energy particle for this decay to happen. (Remember that the decay will happen if the total energy of the final products is lower than the decay of the original parent.)

In any radioactive decay, the constant λ in Equations 12.3 on p. 582… (Choose one.)

A. must be greater than 1.

B. must be between 0 and 1.

C. could be any positive number, but can't be negative

D. could be any negative number, but can't be positive

E. could be positive or negative.

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E. could be positive or negative.

Solution: C. A negative constant would imply that your sample is growing rather than shrinking! (You can immediately throw out A and B as meaningless since λ isn't unitless.)

When many identical nuclei decay through electron emission, the emitted antineutrinos emerge with a range of possible kinetic energies. When many identical nuclei decay by capturing an electron from the innermost shell, do the emitted neutrinos . . . (Choose one.)

A. come out with a range of possible kinetic energies?

B. all come out with nearly the same kinetic energy?

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A. come out with a range of possible kinetic energies?

B. all come out with nearly the same kinetic energy?

Solution: B

When you emit an electron, that electron—floating freely through the universe—could have many different possible energies, leaving a wide range to the antineutrino. But an electron in a particular shell of a particular type of atom has a particular energy (the eigenvalue of that energy eigenstate), so you have all the information you need to calculate the energetics of this reaction and see how much is left for the antineutrino.

12.5 Nuclear Fission and Fusion

Suppose you fire a beam of particles at a thin target and measure that Reaction A is three times as likely as Reaction B. What does that tell you about the cross sections for those reactions? (Choose one.)

A. $\sigma_A = 3\sigma_B$

B. $\sigma_A = \sigma_B/3$

C. $\sigma_A = 9\sigma_B$

D. $\sigma_A = \sigma_B/9$

E. This does not allow you to know how the cross sections are related.

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E. This does not allow you to know how the cross sections are related.

Solution: A

When a very large nucleus such as ^{235}U splits into two nuclei, why is energy released? (Choose one.)

A. The binding energy (B/A) of the daughter nuclei are both significantly higher than the binding energy of the parent nucleus.

B. Some of the nucleons are converted into energy, released (in the form of photons) with energy $E = m_p c^2$.

C. The energy released is the initial kinetic energy of the parent nucleus.

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Solution: A

A chain reaction of fission is caused by… (Choose one.)

A. Each fission reaction releases energy, which raises the temperature, which leads to other fission reactions.

B. Each fission reaction releases neutrons, which slam into other nuclei, which leads to other fission reactions.

C. Each fission reaction releases electrons, which slam into other nuclei, which leads to other fission reactions.

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B. Each fission reaction releases neutrons, which slam into other nuclei, which leads to other fission reactions.

C. Each fission reaction releases electrons, which slam into other nuclei, which leads to other fission reactions.

Solution: B

A “moderator” in a fission reactor slows down the neutrons. Why is that important? (Choose all that apply.)

A. If the neutrons are too fast, they will fly out of the reactor and cause damage.

B. If the neutrons slam into each other too fast, they will cause explosions.

C. Slower neutrons are more likely to react with ^{235}U, which you want to happen.

D. Slower neutrons are *less* likely to react with ^{238}U, which you don’t want to happen.

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D. Slower neutrons are *less* likely to react with ^{238}U, which you don't want to happen.

Solution: C and D

The sun hasn't already fused all its available protons into alpha particles because. . . (Choose one.)

A. The processes of fusion and fission in the sun are nearly balanced.

B. The sun has natural moderators that slow down the reaction rate.

C. At solar temperatures, it's very unlikely—and therefore very rare—for two protons to get close enough to fuse.

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Solution: C

The cross section for a nuclear reaction can depend on which of the following? (Choose all that apply.)

A. the type of incident particle

B. the type of target nucleus

C. the energy of the incoming particle

D. the thickness of the target

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Solution: A, B, C