ASTRONOMY/SPACE SCIENCE TEST

For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices for each question.

1. Stars begin their lives composed primarily of:
   a. propane.
   b. hydrogen.
   c. neon.
   d. molten rock.
   e. uranium.

2. Astronomers say that the Sun:
   a. contains materials created inside other stars.
   b. is the source of energy needed for life on Earth.
   c. formed billions of years ago.
   d. is formed from the same materials as Jupiter.
   e. All of the above.

3. Of the locations below, the most distant place we have had a spacecraft fly by is:
   a. the Moon.
   b. Mars.
   c. Neptune.
   d. the star Betelgeuse.
   e. the Andromeda Galaxy.

4. Which of the following would scientists say is true about most galaxies?
   a. They are moving away from each other.
   b. They are spread evenly throughout space.
   c. They consist only of stars.
   d. They are held together by electromagnetism.
   e. They do not change with time.

5. Scientists believe that the scientific laws they have discovered on Earth are:
   a. different from those that govern the Sun.
   b. different from those governing nearby stars.
   c. different from those in distant parts of our galaxy.
   d. different from those in other galaxies.
   e. the same everywhere in the universe.

6. The Sun is unusual compared to other stars in that:
   a. it is a binary star.
   b. its energy is formed by nuclear reactions.
   c. it has no companion star.
   d. it has a magnetic field.
   e. its energy is produced by chemical processes.

GO TO QUESTION 7 >>

These test items were developed with funding from NASA's Science Mission Directorate, #NCC5-706.

7. Which of these elements found on Earth is, or are, also present in the Sun?
   a. Hydrogen
   b. Helium
   c. Neon
   d. Two of the above.
   e. All of the above.

8. Which of the following would scientists say is true about matter in the universe?
   a. All the present structure in the universe was formed in the Big Bang.
   b. Matter in the universe started out very uniform and has gotten less uniform with time.
   c. The first elements formed in the universe were primarily hydrogen and helium.
   d. Both choices b and c.
   e. All of the above.

9. Of the locations below, the most distant place we have detected with space-based telescopes is:
   a. the Moon.
   b. Mars.
   c. Saturn.
   d. the star Betelgeuse.
   e. the Andromeda Galaxy.

10. In order for scientists to detect distant objects in space, electromagnetic radiation must:
   a. reach a detector.
   b. be converted into matter.
   c. be converted into light.
   d. be converted into radio waves.
   e. be converted into energy.

11. Every year the Sun accumulates more:
   a. hydrogen.
   b. helium.
   c. ash.
   d. carbon dioxide.
   e. uranium.

12. The "Big Bang" refers to the origin of:
   a. the Sun.
   b. Earth.
   c. our solar system.
   d. the Milky Way galaxy.
   e. the universe.

13. An astronomer wants to build a telescope that only detects microwaves. Would other astronomers think this was a good idea?
   a. No, because no astronomical object gives off microwaves.
   b. No, because microwaves from outer space are too dangerous to work with.
   c. No, because microwaves from astronomical objects provide no useful information.
   d. Yes, but new technology would have to be invented; no such device has ever been built.
   e. Yes, this has already been done.

14. When charged particles move in one direction without changing speed, they give off:
    a. X-rays.
    b. visible light.
    c. radio waves.
    d. None of the above.
    e. More than one of the above.

15. According to scientists, where were oxygen, carbon and iron atoms created?
    a. In the Big Bang.
    b. In Earth's core.
    c. In the interior of stars.
    d. In the spaces between the stars.
    e. They weren't created, they were always here.

16. Our solar system:
    a. was formed by the Big Bang.
    b. contains material from other stars.
    c. contains the oldest star in the universe.
    d. was made from meteors exploding.
    e. is made from materials found nowhere else in the universe.

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    c. formed billions of years ago.
    d. is formed from the same materials as Jupiter.
    e. All of the above.

Grades 9–12 Astronomy and Space Science Tests[1]

The tests in this section contain items related to six grades 9–12 standards in astronomy and space science. The standards are stated below. The source of each standard is given in parentheses: *NSES* = National Research Council's "National Science Education Standards"; *Benchmarks* = American Association for the Advancement of Science's "Benchmarks for Science Literacy."

9–12 Astronomy Standard 1:

"The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since." (*NSES*)

9–12 Astronomy Standard 2:

"Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe." (*NSES*)

9–12 Astronomy Standard 3:

"Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements." (*NSES*)

9–12 Astronomy Standard 4:

"The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements that are found on the earth and to behave according to the same physical principles. Unlike the sun, most stars are in systems of two or more stars orbiting around one another." (*Benchmarks*)

9–12 Astronomy Standard 5:

"Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. The process of star formation and destruction continues." (*Benchmarks*)

9–12 Astronomy Standard 6:

"Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators

[1] Test items for the grades 9–12 astronomy and space science standards were developed with funding from NASA's Science Mission Directorate, via the Universe Education Forum at the Harvard-Smithsonian Center for Astrophysics.

give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe." (*Benchmarks*)

The items are identical on both test forms, but arranged in different sequences so that the forms can be used as a pretest/post-test pair (either form may be used as the pretest). Either form can be used by itself as a diagnostic test.

The grades 9–12 tests are intended for use primarily with 11th and 12th grade astronomy students, but may be administered to any grades 9–12 students who have taken or are taking an earth science course covering the relevant standards. The tests can also be administered to any persons who possess at least a 9th grade reading level fluency in English.

NOTE: Administering the tests to anyone with less than the indicated minimum reading level may result in invalid test results due to the test performing more as a reading comprehension test rather than as a science test.

Item # Form 631	Item # Form 632	Text of item	Std. [2]	Correct response & percent responding correctly[3]	Commentary[4]
1	9	Stars begin their lives composed primarily of: a. propane. b. hydrogen. c. neon. d. molten rock. e. uranium.	4	B: 62%	The composition of the Sun may be one reason so many students answered correctly. Very few discuss either the gaseous or solid components listed. No other option received more than 15% of the responses (Option E).
2	16	Astronomers say that the Sun: a. contains materials created inside other stars. b. is the source of energy needed for life on Earth. c. formed billions of years ago. d. is formed from the same materials as Jupiter. e. All of the above	3	E: 58%	This majority of students chose the correct option (E) with Option B the second most popular (21%). All the other options were suggestive of random responses, as only a very small number of students chose any one of these.
3	12	Of the locations below, the most distant place we have had a spacecraft fly by is: a. the Moon. b. Mars. c. Neptune. d. the star Betelgeuse. e. the Andromeda Galaxy.	4	C: 31%	The most popular response to this item was B, with 37% indicating that spacecraft have flown by Mars. This may be a response to the publicity accorded the Mars Rovers. Only a very small minority thought that spacecraft had left the solar system (10% and 8% for the last 2 options).

[2] These test items are valid psychometrically and represent standards commonly included in high school astronomy curricula. The items do not represent the entire domain of astronomy standards, as presented in the NRC standards and AAAS benchmarks.

[3] Students (n=approximately 750 per item) were selected randomly in classes as a nationally representative sample of all grades 9–12 students in U.S. public and private schools.

[4] The commentary reflects item response patterns. Common misconceptions in astronomy are discussed in a separate section.

Item # Form 631	Item # Form 632	Text of item	Std.[2]	Correct response & percent responding correctly[3]	Commentary[4]
4	14	Which of the following would scientists say is true about most galaxies? a. They are moving away from each other. b. They are spread evenly throughout space. c. They consist only of stars. d. They are held together by electromagnetism. e. They do not change with time.	2	A: 30%	Option D (galaxies are held together by electromagnetism) was the most popular response with 35% of students selecting that answer.
5	10	Scientists believe that the scientific laws they have discovered on Earth are: a. different from those that govern the Sun. b. different from those governing nearby stars. c. different from those in distant parts of our galaxy d. different from those in other galaxies. e. the same everywhere in the universe.	4	E: 33%	The responses to this question seem random with all incorrect options drawing more than 10% of students. This pattern suggests that high school students have little, if any, understanding of this fundamental assumption of science.
6	15	The Sun is unusual compared to other stars in that: a. it is a binary star. b. its energy is formed by nuclear reactions. c. it has no companion star. d. it has a magnetic field. e. its energy is produced by chemical processes.	4	C: 35%	Although the correct response to this question is the most popular (35%), the response pattern to the incorrect options is fairly equivalent. This equivalence may indicate random responses among students who answered incorrectly.

Item # Form 631	Item # Form 632	Text of item	Std.[2]	Correct response & percent responding correctly[3]	Commentary[4]
7	11	Which of these elements found on Earth is, or are, also present in the Sun? a. Hydrogen b. Helium c. Neon d. Two of the above. e. All of the above.	4	E: 17%	This is a difficult item, as a disproportionate number of students (55%) chose D, presumably thinking of hydrogen and helium, the two most common elements that comprise the Sun.
8	4	Which of the following would scientists say is true about matter in the universe? a. All the present structure in the universe was formed in the Big Bang. b. Matter in the universe started out very uniform and has gotten less uniform with time. c. The first elements formed in the universe were primarily hydrogen and helium. d. Both choices b and c. e. All of the above.	2	D: 34%	Almost an equal proportion of students (31%) chose E, which suggests that students do not completely understand the Big Bang and the nature of the early universe.
9	1	Of the locations below, the most distant place we have detected with space-based telescopes is: a. the Moon. b. Mars. c. Saturn. d. the star Betelgeuse. e. the Andromeda Galaxy.	6	E: 41%	The widely disseminated images taken of other galaxies by the Hubble Space Telescope may have contributed to this knowledge. No other option received more than 20% of the responses.

Item # Form 631	Item # Form 632	Text of item	Std.[2]	Correct response & percent responding correctly[3]	Commentary[4]
10	5	In order for scientists to detect distant objects in space, electromagnetic radiation must: a. reach a detector. b. be converted into matter. c. be converted into light. d. be converted into radio waves. e. be converted into energy.	6	A: 20%	Two options (C and D) attracted more students than did the correct one. The most popular choice (D) was selected by 39% of students, while slightly more than 21% of students chose C. Very few students felt that the electromagnetic radiation was converted into matter (10%) or energy (11%), even though C and D are both forms of energy (E). Some students choosing D might have been thinking of the radio relay of data from orbiting telescopes, but the detector's location is not specified.
11	2	Every year the Sun accumulates more: a. hydrogen. b. helium. c. ash. d. carbon dioxide. e. uranium.	4	B: 24%	The most popular response to this question was A (36%), suggesting that many students lack an understanding of the solar fusion process (hydrogen fusing to form helium).
12	6	The "Big Bang" refers to the origin of: a. the Sun. b. Earth. c. our solar system. d. the Milky Way galaxy. e. the universe.	1	E: 52%	Although the majority of students answered correctly, a quarter of students in our sample indicated that the Big Bang referred to the origin of the solar system (C). No other response was chosen by more than 10% of students.
13	13	An astronomer wants to build a telescope that only detects microwaves. Would other astronomers think this was a good idea? a. No, because no astronomical object gives off microwaves. b. No, because	6	E: 25%	This item suggests that few high school students are fully aware of how astronomers use the electromagnetic spectrum to gather information on astronomical objects. 28% responded with C;

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		microwaves from outer space are too dangerous to work with. c. No, because microwaves from astronomical objects provide no useful information. d. Yes, but new technology would have to be invented; no such device has ever been built. e. Yes, this has already been done.			A, B and D each received a 17% response, suggestive of guessing.
14	7	When charged particles move in one direction without changing speed, they give off: a. X-rays. b. visible light. c. radio waves. d. None of the above. e. More than one of the above.	6	D: 25%	Slightly more students indicated that visible light or radio waves were a product of the linear movement of charged particles (28% and 27%). These results suggest that high school students do not fully comprehend the relationship between subatomic matter and electromagnetic radiation.
15	3	According to scientists, where were oxygen, carbon, and iron atoms created? a. In the Big Bang. b. In Earth's core. c. In the interior of stars. d. In the spaces between the stars. e. They weren't created, they were always here.	1	C: 24%	The responses to this item illuminate the ideas of high school students about the Big Bang as the most popular response was A (40%), as well as their understanding of heavier elements' formation. Almost 20% of students indicated that oxygen, carbon and iron were created in the Earth's core (B).

Item # Form 631	Item # Form 632	Text of item	Std.[2]	Correct response & percent responding correctly[3]	Commentary[4]
16	8	Our solar system: a. was formed by the Big Bang. b. contains material from other stars. c. contains the oldest star in the universe. d. was made from meteors exploding. e. is made from materials found nowhere else in the universe.	5	B: 21%	The majority of students were consistent with other misconceptions about the origin and evolution of the solar system. One half of the sample indicated that the Big Bang formed our solar system (A). Selection of the other three choices was sparse, with 10% of students or fewer each choosing C, D or E.

Listed below are some student astronomy and space science misconceptions. The list is not intended to be exhaustive, but rather a summary of some of the more common prior ideas we identified from our analysis of the student response patterns to the items on the tests.

- Stars and galaxies are evenly distributed throughout space.
- The laws of nature are different for different places in the universe.
- All the galaxies, stars, planets, and atoms of all elements were formed in the Big Bang.
- Different forms of electromagnetic radiation travel at different speeds.
- The behavior of different forms of electromagnetic radiation, such visible, infrared, x-ray, and ultraviolet radiation, differ from one another, e.g., only visible light can reflect off of objects.

The following resources are useful for additional background information about students' science misconceptions:

Comins, N., *Heavenly Errors; Misconceptions About the Real Nature of the Universe*, New York: Columbia Press (2001).

Driver, R. (Ed.), *Children's Ideas in Science*, Philadelphia: Open University Press (1985).

Driver, R., *Pupil as Scientist?*, Philadelphia: Open University Press (1983).

Agan, L., "Stellar Ideas: Exploring Students' Understanding of Stars" in *Astronomy Education Review*: http://aer.noao.edu/cgi-bin/article.pl?id=95.

Agan, L. & Sneider, C., "Learning About the Earth's Shape and Gravity: A Curriculum Guide for Teachers and Curriculum Developers" in *Education Review*: http://aer.noao.edu/cgi-bin/article.pl?id=65.