



Pre-Workshop Thought Questions

1. List several ways you think Galileo's model of the universe was similar to that of modern astronomers; and several ways it was different:

Galileo's universe compared to today's model of the universe	
Similarities	Differences
Examples of potential responses: <i>Planets, including Earth, orbit the Sun</i> <i>Planets are closer than the stars</i> <i>Model supported by observational evidence</i> <i>Some planets have moons</i>	Examples of potential responses: <i>Only includes planets out to Saturn</i> <i>Orbits are circular</i> <i>Fixed stars placed in an outer sphere</i> <i>No concept of galaxy, absolute distance scale</i> <i>Limited by observational technology (or is that a similarity?)</i>

2. _____% Which of the following best describes the order of size, from smaller to larger, of the four objects:

- Earth, Moon, Sun, Jupiter
- Moon, Earth, Sun, Jupiter
- Moon, Earth, Jupiter, Sun
- Sun, Moon, Earth, Jupiter
- They are all the same size

The best answer is c, and in a national sample of students in grades 5-12, 70% answered correctly. Choices d. and b. were each selected by approximately 10% of students; perhaps these students had learned that Jupiter was the largest planet, but hadn't yet learned about the scale of the Sun in this context.

Galileo's Answer: None of the above. His correct order: Moon, Jupiter, Earth, Sun

It was known since classical times that the Sun was much bigger than the Earth. However, the accepted value of the Earth-Sun distance was about 20x the Earth-Moon distance (this was calculated by Aristarchus in 220BC and was still the accepted value in Galileo's time). This made the scale of the Solar System too small by a factor of 20. If Jupiter was 20x closer with the same angular size, then its diameter would be ~7000km, smaller than the Earth.

3. _____% Which answer shows the most accurate pattern of the three objects in order from closest object to the Earth to farthest from the Earth?

- Sun → Saturn → Moon
- Saturn → Moon → Sun
- Moon → Sun → Saturn
- Moon → Saturn → Sun
- Sun → Moon → Saturn

The best answer is c, chosen by about 45% of student respondents. Choice d. was the most common distracter; this question requires a student to draw upon her mental model of the orbits of the solar system.

Galileo's Answer: c. Moon – Sun – Saturn

Galileo was a strong supporter of the Copernican model for the Solar System, and with Kepler's work on the laws of planetary motion being published around the same time, the relative scale of the Solar System was well known (the absolute scale needed an accurate determination of the AU, which wouldn't happen until the 18th century).

4. _____% Which answer shows the most accurate pattern of the three objects in order from closest object to the Earth to farthest from the Earth?

- Space Shuttle in orbit → Stars → Pluto
- Pluto → Space Shuttle in orbit → Stars
- Stars → Space Shuttle in orbit → Pluto
- Stars → Pluto → Space Shuttle
- Space Shuttle in orbit → Pluto → Stars

The best answer is e (42%), with a being the most common distracter. Many students put the stars within our solar system, perhaps because classroom astronomy instruction often ends with the planets, giving the false impression that Pluto is the furthest object from the Earth.

Galileo's Answer: No answer

The space shuttle wasn't conceived until the 1970s, and Pluto was discovered in 1930. However, it was well known since classical times that the stars were further than the planets (Saturn being the outermost planet known in Galileo's time).



5. _____% Astronomers use large telescopes so they can:

- a. see fainter objects.
- b. see distant objects.
- c. see more objects.
- d. All of the above.
- e. None of the above.

The best answer is **d (55%)**, but many students choose **b**, revealing a common emphasis on the magnification of a telescope without understanding the importance of light-gathering power.

Galileo's Answer: Probably d, all of the above. The first practical uses for the "spyglass" were military (some things never change) and the ability to detect enemy ships. However, one of Galileo's major discoveries was that there were many more stars in the heavens than had been thought to exist. The telescope turned nebulae into "innumerable" stars.

6. _____% NASA puts telescopes in space:

- a. to get closer to the stars and galaxies.
- b. because it is colder in space.
- c. to get above the atmosphere.
- d. because there is no gravity in space.
- e. None of the above.

The best Answer is **c (15%)**. While student responses to this question show that they do not understand how the Earth's atmosphere distorts and blocks light from space, it also suggests they may far underestimate the distances to stars and galaxies, as nearly half of students chose **a**.

Galileo's answer: Possibly a. The height of the atmosphere was not known in the 17th century and the inverse square law for gravity was not developed until Newton at the end of the 17th century. Torricelli's work on atmospheric pressure was happening at around the same time, but the notion of space being empty is again a Newtonian concept. There would be no obvious advantage to putting a telescope high above the ground, except to get closer to the objects being observed.

7. _____% Which answer shows a pattern in the order from having the fewest stars to having the most stars?

- a. galaxy → universe → solar system
- b. galaxy → solar system → universe
- c. solar system → universe → galaxy
- d. solar system → galaxy → universe
- e. universe → solar system → galaxy

The best answer is **d**. Most students are confused about the distinctions and relationships between a solar system, a galaxy, and the universe. They do not see them as a hierarchical series of structures of increasing size. This confusion about scale and structure is a barrier to understanding Earth's place in our universe as a whole, and to understanding more complex ideas about how galaxies are gravity-bound units of structure and star formation.

Galileo's answer: no answer or d.

The terms galaxy and universe were used interchangeably until the 1920s, when it became clear that the "spiral nebulae" were galaxies in their own right and not just satellites of our own Milky Way. If the question were worded solar system – Milky Way – universe then Galileo probably would have got it right. He saw that the Milky Way was a sweeping cluster of stars, but that there were other star clusters (such as the Pleiades) that comprised the universe. The concept of the Milky Way being a spiral galaxy that contained the solar system and the Pleiades was of course unknown to Galileo.

8. _____% A photon of which color light carries the most energy?

- a. Red light
- b. Yellow light
- c. Green light
- d. Blue light
- e. All photons have the same energy.

D is the best answer, chosen by only 1/3 of students in grades 8-12. More students actually chose a. than d., indicating that the important relationship between energy and wavelength is not well understood by students.

Galileo's answer: no answer

The idea that white light is composed of a mixture of colored light was first developed by Newton around 1670. The concept of light as a photon of energy was developed by Einstein in 1905.



9. _____% Astronomers believe they can tell the composition of distant stars by:
- assuming the stars have the same composition as the Earth.
 - assuming the stars have the same composition as the Sun.
 - analyzing the light from the stars.
 - testing material from the stars in their laboratories.
 - Astronomers have no way of knowing the composition of distant stars.

60% of students in grades 8-12 chose the best response, C, but significant numbers chose either b. or e., indicating these students had not learned about the important technique of spectroscopy, and may not comprehend the relationship between subatomic matter and electromagnetic radiation.

Galileo's Answer: no answer

The chemical composition of the stars was considered "unknowable" as late as the 1830s. The science of spectroscopy, developed by Gustav Kirchhoff and Joseph von Fraunhofer, enabled scientists to discover the chemical composition of the stars. However, it wasn't until the work of Cecilia Payne in the 1920s that it was realized the Sun was mostly composed of hydrogen and helium.

10. _____% A photon of which kind of radiation carries the most energy?
- Radio
 - Infrared
 - Visible
 - Ultraviolet
 - All photons have the same energy.

About 55% of students chose the best response, d, with other responses evenly spread among a to e, indicating guessing. Responses to this question, question #8, and other MOSART items indicate that many students are not fully aware of how different portions of the em spectrum are associated with phenomena of different energies.

Galileo's answer: no answer

The physics of light and optics had yet to be developed. The first notion that there was a form of invisible light (infrared) emerged from the experiments of William Herschel ~1800.

These assessment questions were drawn from the "Misconception-Oriented Standards-based Assessment Resources for Teachers" project at the Harvard-Smithsonian Center for Astrophysics. You can log on to the MOSART website to take a tutorial and download a whole set of research-based assessment items for probing conceptual understanding about the universe and how students learn. Each instrument comprises a set of multiple-choice items that are linked to the K-12 physical science and earth and space science content in the NRC's "National Science Education Standards," as well as to the research literature documenting common science misconceptions. You may find individual items useful to you in developing evaluation tools to measure whether your IYA programs are resulting in astronomy learning.

<http://www.cfa.harvard.edu/smgphp/mosart/index.html>

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