 Office of General Education A-218C

160 Convent Avenue

New York, NY 10031

GENERAL EDUCATION ASSESSMENT REPORT

COURSE: ASTR 30500

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| Date of report: | June 23, 2017 |
| Course: | Astronomy 30500 EF |
| Materials used: | Student exams, in-class verbal responses, and McGraw Hill Connect (MHC) online responses |
| Date/semester of assessment: | Spring 2017 |
| Preliminary Assessment  Team Members: | Michael Lubell |
| Secondary Assessment Team Members: | George Furbish |
| Coordination / Oversight: | Michael Lubell |

**Overview of Course Set Up**

Astronomy 30500 EF provides students of varying backgrounds with an introduction to the principles astronomy. The course includes a descriptive history of the discipline, the physics principles underlying the discipline, the tools astronomers use, the intersection of astronomy with socio-political realities, and the application of analytical techniques and the scientific method. The course requires students to have some facility with algebra and geometry, as well as basic trigonometry, and it assumes a rudimentary knowledge of high school science.

The course meets twice a week (attendance required) in a large lecture hall, equipped with a digital projector and an audio system. Lectures, each lasting 100 minutes, make optimal use of PowerPoint slides with large numbers of images and a computer system that can be operated remotely. The lecturer, using a lapel mic and a hand-held, walks around the lecture hall querying students as the lecture proceeds. Students respond with the hand-held mic and receive bonus points for participation, as indicated on the accompanying student record spread sheet. The slide deck for each lecture is posted on Blackboard within 24 hours.

As shown on the accompanying Course Schedule, a number of lectures are supplemented with videos taken from the History Channel. In addition, on occasion, students orally present reports on astronomy in the news. Despite its size of 250, the class is extremely interactive, with the lecturer facilitating discussions involving a number of students at a time.

For each class, students are assigned homework questions from the text, “Explorations: An Introduction to Astronomy,” by Arny and Schreiber (McGraw Hill, 2016). They present their answers in class and are expected to expand on the principles behind their answers. A week prior to each exam (two one-hour exams during the semester and a one-and-a-half-hour final), all assigned questions and answers are posted on Blackboard. A review session, covering salient topics occurs during the classes immediately preceding the first exam and the final.

McGraw Hill Connect, an online learning component, was introduced as a pilot program in the 2016 fall and 2017 spring semesters MHC provides immediate feedback to students and the instructor as they read the required material and respond to questions testing their comprehension. Students, who elected to participate received bonus points for their successful work.

**How Assessment Was Done**

The Assessment Findings, shown in the accompanying table, are based on exam, in-class and MHC performance. In the case of the exams, questions are grouped by relevance to the different learning outcomes, and the assessment is based on the quantitative student performance. The in-class assessments are more qualitative in nature. However, the frequency of in-class participation (an average of 25 per lecture), as shown on the accompanying performance spread sheet, is well documented.

**Assessment Findings**

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| Scientific World  Learning outcomes | Learning outcome assessed this round? If yes, brief description of methodology | Brief description of findings  (% of students answering correctly) | *Select one*  Exceeds Expectations  Above average Average  Below average  Below passing  [Note: The median grades on the exams was about 67%, reflecting the difficulty and breadth of material in the course. Students who performed at that level typically received a grade of B, absent bonus points for class participation.] |
| Identify and apply the fundamental concepts and methods of ASTR 305 (see sample questions). | In-class verbal responses to questions throughout the semester. Class participation is shown on accompanying performance spread sheet containing attendance records (in color) with the number of daily responses by individual students shown by numbers. The following test questions are relevant to the category.  First Exam: 1, 4, 5, 6-9, 11, 13, 14, 20, 24, 28-30  Second Exam: 2-5, 7, 9-19, 21, 23-26, 29  Final Exam: 1-3, 5, 8-14, 16-30, 32, 33, 35-55 | 68% success rate on relevant exam questions | Average |
| Demonstrate how tools of science, mathematics, technology, or formal analysis can be used to analyze problems and develop solutions (see sample questions). | In-class verbal responses to questions throughout the semester. Class participation is shown on accompanying performance spread sheet containing attendance records (in color) with the number of daily responses by individual students shown by numbers. The following test questions highlight the category.  First Exam: 1-5, 6-10, 12, 15-19, 21-23, 25-29  Second Exam: 1, 3-5, 10-13, 16, 19-22, 27, 28, 30  Final Exam: 8, 9, 12, 14-16, 19, 20, 26, 29-31, 33, 35, 41-45, 47, 49, 50, 52-54 | 70% success rate on relevant exam questions | Above average |
| Articulate and evaluate the empirical evidence supporting a scientific or formal theory. (see sample questions). | In-class verbal responses to questions throughout the semester. Class participation is shown on accompanying performance spread sheet containing attendance records (in color), exam scores, student assessments and number of daily responses by individual students (shown by numbers). The following test questions highlight the category.  First Exam: 5, 13, 21, 22, 24, 26  Second Exam: 4, 7, 8, 11, 13, 18, 19, 22, 28, 30  Final Exam: 1-5, 10, 11, 14, 16, 18-21, 23, 25-30, 32, 33, 35, 36, 39, 46-52, 54, 55 | 71% success rate on relevant exam questions | Above average |
| Articulate and evaluate the impact of technologies and scientific discoveries on the contemporary world, such as issues of personal privacy, security, or ethical responsibilities (see sample questions). | In-class verbal responses to questions throughout the semester. Class participation is shown on accompanying performance spread sheet containing attendance records (in color) with the number of daily responses by individual students shown by numbers. The following test questions highlight the category.  First Exam: 4, 5  Final Exam: 34, 57, 58 | 58% success rate on relevant exam questions | Astronomy does not lend itself to these issues, except under very limited circumstances, such as the clash between religion and science during the Renaissance. Therefore, the student performance statistics are relative sparse making it difficult to assign a rating. Additionally, the course is not expected to meet all of the outcomes in the category. |
| Understand the scientific principles underlying matters of policy or public concern in which science plays a role. | In-class verbal responses to questions about public support and funding of astronomy research throughout the semester; as well as concerns about such research, using opposition by indigenous Hawaiians to observatories on Mauna Kea as an example. Class participation is shown on accompanying performance spread sheet containing attendance records (in color) with the number of daily responses by individual students shown by numbers. | In-class discussions often highlighted the public policy issues, both past and current. The level of participation, given the size of the class, was extraordinary. | Exceeds expectations |
| Evaluate evidence and arguments critically or analytically (see sample questions). | In-class verbal responses to questions throughout the semester. Class participation is shown on accompanying performance spread sheet containing attendance records (in color) with the number of daily responses by individual students shown by numbers. The following test questions highlight the category.  First Exam: 1, 4, 6, 12, 14, 17-30  Second Exam: 6-13, 15, 17-19, 21-28  Final Exam: 6-9, 13, 15, 17, 22, 24, 31, 40, 53 | 72% success rate on relevant exam questions | Above average |
| Gather, interpret, and assess information from a variety of sources and points of view (see sample questions). | In-class verbal responses to questions throughout the semester. Class participation is shown on accompanying performance spread sheet containing attendance records (in color) with the number of daily responses by individual students shown by numbers. The following test questions highlight the category.  Final Exam: 56-60 | 60% success rate on the relevant exam questions | Average on exam questions but above average on in-class discussions. |
| Produce well-reasoned written or oral arguments using evidence to support conclusions (see sample questions). | Throughout the semester, students participated verbally by answering questions posed throughout the lectures and defending their answers under further questioning. During a typical 100-minute lecture, there were at least 25 opportunities for students to participate. | See performance record spread sheet. | Exceeds expectations |

**Conclusions**

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| *Briefly summarize overall findings by identifying strengths and challenges in students’ accomplishment of learning outcomes.*  The diverse student backgrounds make the course difficult to teach. Keeping more accomplished students engaged and enabling less capable students to achieve adequate performance is a delicate balancing act. The overall student performance suggests that the course achieved such a balance in outcomes, as demonstrated by the accompanying detailed performance record.  The course has become one of the most popular on campus, and in the fall 2016 student assessment survey, almost 50 percent of the respondents cited it as the best course they had taken. |
| *How useful are the text and other resources assigned to this course?*  The multiplicity of course materials has received high marks from the students. |
| Already implemented “Closing-the-loop” efforts to improve student learning/success: |
| *Since teaching this course, including this current semester, have you made changes in course content? If yes, please explain.*  The course content changes slightly each semester to reflect new discoveries and advances in astronomy. |
| *Since teaching this course, have you made changes in course delivery or other pedagogy? Please explain.*  When I first taught the course a decade ago, I treated it as a standard lecture, with slides and an occasional video to illustrate the material. I found that students were not very engaged, and at the suggestion of Dr. Carl Wieman, a Nobel Laureate and an originator in science education technology, I introduced clickers. Little changed, except for the added cost to students.  After a year’s use, I eliminated clickers and experimented with an interactive learning approach: PowerPoint slides, videos, reading assignments and homework questions, but now supplemented by in-class participation through the use of a hand-held mic and a roving style. I pilot tested the approach for one semester, and after refining it expanded it a year later, I found that test scores increased by about 20 percent. During this past last year, I added a voluntary online learning component, which seems to have been quite effective. |
| *How exactly have the changes that you have implemented impacted student learning/student success? Please provide specific examples.*  Incorporating active student participation as described above produced an improvement of about 20 percent in performance on examinations. It is too early to assess with any degree of certainty whether the use of “McGraw Hill Connect” this past year improved student outcomes, but anecdotally it appears as if it might be the case. |
| Future “Closing-the-loop” plans to improve student learning/success |
| *Based on your assessment of student learning, what changes do you plan to implement at instructional level to improve student learning? Specify topics and pedagogical changes, if applicable.*  Required use of “McGraw Hill Connect” or a comparable on-line learning package is planned, as well as greater emphasis on individual in-class reports on current astronomy in the news. |
| *Provide suggestions, if any, to be done on a departmental or institutional level to support student learning/success in this course.*  Teaching a class of 250 or more is a difficult task. It requires both exceptional organization capabilities, communication skills and motivational speaking talent. The Physics Department and the College should invest in training programs such as the one offered by the Alan Alda Center for Communicating Science at SUNY Stony Brook. |

**Sample Questions and Related Outcomes**

See Assessment Table and accompanying examination questions referenced in the table.

**Addendum I**

**Examination Questions**

**First Exam**

Match the following terms or names with their scientific connection:

1. Kepler
2. Silicates
3. Basalt
4. Keeling
5. Copernicus
6. Retrograde motion
7. Crust
8. Elliptical orbits
9. Maria
10. Climate change

Mark the following True (a) or False (b)

1. Rayleigh scattering of refracted light in the Earth’s atmosphere makes the Moon appear red during an eclipse.
2. Gravity is responsible for holding nucleons together in the nucleus.
3. Tidal friction is causing the Earth to rotate more slowly.
4. The Coriolis force causes the Earth’s equatorial bulge.
5. Lava flows might have produced deep canyon-like rilles on the Moon.

Select the correct answer from the five choices given for each of the following questions:

1. You write your home address in the order of street, town, state and so on. Suppose you were writing your cosmic address in a similar manner. Which of the following is the correct order?
2. Earth, Milky Way. Solar System, Local Group
3. Earth, Solar System, Local Group, Milky Way
4. Earth, Solar System, Milky Way, Local Group
5. Solar System, Earth, Local Group, Milky Way
6. Solar System, Local Group, Milky Way, Earth
7. Ancients noticed patterns in the motion of objects in the sky, which led to the development of units of time, like hours, days, weeks, months and years. Which of the following moves least in the sky regardless of the time period being considered?
8. The Moon
9. The Sun
10. Polaris
11. Sirius, the dog star
12. None of the above
13. Kepler’s third law
14. Relates a planet’s orbital period to the size of its orbit around the Sun.
15. Relates a body’s mass to its gravitational attraction.
16. Allowed him to predict when eclipses would occur.
17. Allowed him to measure the distance to nearby stars.
18. Showed the Sun is much further away than the Moon.
19. If the Moon did not rotate on its own axis, we would observe
20. Both sides of the Moon.
21. The Moon remaining stationary against the stars.
22. A lack of tides on Earth.
23. The Moon from only one hemisphere of Earth.
24. Everything the same as now – it doesn’t rotate.
25. If an object moves along a curved path at a constant speed, you can infer that
26. A force is acting on it.
27. It is accelerating.
28. It is in uniform motion.
29. Both a) and b) are true.
30. Both a) and c) are true.
31. A rocket blasts propellant out of its thrusters and “lifts off” heading into space. What provided the force to lift the rocket?
32. The propellant pushing against air molecules in the atmosphere.
33. The propellant heating and expanding the air beneath the rocket and so pushing the rocket up.
34. The action of the propellant accelerating down, giving rise to a reaction force on the rocket.
35. The propellant reversing direction as it strikes the ground below the rocket, then bouncing back and pushing the rocket up.
36. None of the above.
37. If an object’s spectral lines are shifted to longer wavelengths, the object is
38. Moving away from us.
39. Moving toward us.
40. Very hot.
41. Very cold.
42. Reflecting rather than emitting light.
43. Suppose Tom and Molly are both flying in spaceships toward each other at half the speed of light (0.5 *c*). If Tom shines a light toward Molly, what speed will Molly measure for the light coming toward her?
44. 0.25 *c*
45. 0.5 *c*
46. 1.0 *c*
47. 1.5 *c*
48. 2.0 *c*
49. Telescope A’s mirror has three times the diameter of telescope B’s. How much greater is A’s light-gathering power?
50. 3 times
51. 6 times
52. 8 times
53. 9 times
54. 27 times
55. Astronomers use interferometers to
56. Observe extremely dim sources.
57. Measure the speed of remote objects.
58. Detect radiation that otherwise cannot pass through our atmosphere.
59. Enhance the resolving power (see fine details in sources).
60. Measure accurately the composition of sources.
61. What evidence indicates that part of the Earth’s interior is liquid?
62. With sensitive microphones, sloshing sound can be heard.
63. We know the core is lead, and we know the core’s temperature is far above lead’s melting point.
64. Deep bore holes have brought up liquid from a depth of about 4000 kilometers.
65. No S-type seismic waves are detectable at some locations after an earthquake.
66. S-type waves are especially pronounced at all locations around the Earth following an earthquake.
67. Why is carbon dioxide (CO2) called a “greenhouse” gas?
68. It is generated when plants are burned.
69. It is need by plants to grow.
70. It absorbs infrared (IR) light.
71. It appears greenish when concentrated.
72. All of the above.
73. Suppose the Earth’s rotation axis were not tilted with respect to its orbital plane. How would the number of daylight hours change throughout the year?
74. The number would be no different than now.
75. Days would be longer and nights shorter all year.
76. Days and nights would be of equal length all year.
77. Days would be shorter and nights longer all year.
78. None of the above.
79. A major objection to the heliocentric model not resolved until the development of high-quality telescopes was that
80. The speed of light had been thought to be infinite.
81. The Moon was believed to shine by its own light not reflected light from the Sun.
82. The stars did not exhibit parallax.
83. Jupiter did not show a crescent phase.
84. Earths gravitational pull was originally estimated to be greater than the Sun’s.
85. If the distance between two bodies is increased by a factor of 4, the gravitational force between them is \_\_\_\_\_\_\_\_\_ by a factor of \_\_\_\_\_\_\_\_\_\_.
86. Increased; 4.
87. Decreased; 4.
88. Decreased; 8.
89. Decreased; 16.
90. Decreased; 64.
91. Which of the following allows you to see the Sun when it is just below the horizon?
92. The Lorentz contraction.
93. Refraction by the Earth’s atmosphere.
94. The influence of the Earth’s magnetic field.
95. Reflection by the ocean.
96. None of the above.
97. Ozone is only a minor constituent of the Earth’s atmosphere, but it is important to life because
98. It cleanses the air of carbon monoxide.
99. It absorbs harmful ultraviolet rays.
100. It reflects cosmic rays.
101. It provides the oxygen plants need for photosynthesis.
102. All of the above.
103. Which of the following is NOT true about magnetic fields?
104. They are intrinsic parts of light waves.
105. The “intrinsic spins” of electrons produce them.
106. You can detect them using iron filings.
107. They account for the motion of tectonic plates.
108. They cause charged particles to spiral around them.
109. Astronomers have determined the temperature of the Sun by
110. Measuring the strength of the solar wind.
111. Observing the spectrum of sunlight and applying Wien’s Law.
112. Measuring changes in Earth’s temperature as it moves along its elliptical orbit.
113. Sending a probe to the Sun equipped with a calorimeter.
114. None of the above.
115. Reflecting telescopes are superior to refracting telescopes because
116. They do not suffer from chromatic aberration.
117. They can cover a wider range of wavelengths.
118. Their mirrors can be supported from behind to avoid sagging.
119. They can use adaptive optics to overcome atmospheric disturbances.
120. All of the above.

**Second Exam**

Match the following terms with their scientific association:

1. L2
2. Coronal mass ejection
3. Pressure broadening
4. Phase locking
5. Roche limit
6. Saturn’s rings
7. Mercury’s orbital and rotational periods
8. James Webb Space Telescope
9. Auroras
10. Spectral line width

Mark the following True (a) or False (b):

1. There is no evidence that water currently exists on Mars.
2. Iron is the heaviest element stars can produce through the fusion process.
3. Jupiter’s big red spot seems to be heating Jupiter’s upper atmosphere.
4. As stars age, they move along the main sequence in a Hertzsprung-Russell (H-R) diagram.
5. Astronomers use the apparent size of an extremely distant star and its distance from Earth to determine its stellar radius.

Select the correct answer from the five choices given for each of the following questions:

1. The net effect of the proton-proton fusion chain is to convert four protons (1H) into a single helium nucleus (4He), liberating energy in the process. How do physicists determine that the amount of energy liberated is 4.3×10-12 Joules during each such conversion?
2. They use a spectrometer to measure the intensity of the H-α radiation produced?
3. They use Einstein’s equation, *E* = *mc*2, together with the (known) measured masses of the proton and the helium nucleus.
4. They use a thermometer and measure the temperature, *T*, of the helium gas, together with the relation *E* = 3*kT*/2, where *k* is the Boltzmann constant.
5. They count all the neutrinos produced in the conversion.
6. They have to use all of the above.
7. Jupiter’s giant red spot is evidence of
8. Iron deposits on the planet’s surface.
9. A large crater formed during the early life of the giant planet.
10. The Coriolis effect on the clouds of the rapid jet streams.
11. Large magnetic fields (20,000 times Earth’s) due to the planet’s metallic liquid hydrogen interior.
12. None of the above.
13. The gaps in Saturn’s ring structure are due to
14. Dust that obscures telescopic images.
15. Distortions from a passing comet billions of years ago.
16. Shepherding satellites.
17. Pulsations due to the changing shape of the planet.
18. Out-of-plane motion of gravitationally trapped particles.
19. Which of the following descriptions of Mercury’s features is correct?
    * 1. It has an extremely weak magnetic field.
      2. Its Caloris Basin is a large impact feature.
      3. Its “weird terrain” was probably caused by seismic shocks following a massive impact.
      4. Its lack of atmosphere is attributable its weak gravity and proximity to the Sun.
      5. All of the above.
20. A solar flare is dangerous because
21. It can substantially alter the Sun’s rotation.
22. It can send a billion-ton plasma cloud and an electromagnetic wave toward Earth. .
23. It can disrupt the proton-proton chain needed to sustain fusion.
24. All of the above.
25. It isn’t dangerous at all, because it occurs so far away.
26. A star has a parallax of 0.04 arc seconds. What is its distance?
    * 1. 4 light-years.
      2. 4 parsecs.
      3. 40 parsecs.
      4. 25 parsecs.
      5. 250 parsecs.
27. Differential rotation of the Sun results in
28. The solar wind.
29. A wound-up magnetic field.
30. The Maunder minimum.
31. The Sun’s generation of energy.
32. All of the above.
33. During the daytime, about a trillion solar neutrinos per second pass through you. At night, the number is
    * 1. Zero
      2. About the same.
      3. About half as much.
      4. Much, much smaller.
      5. Variable – you can’t predict it.
34. Which of the following features of the Solar System does the solar nebula theory explain?
35. All of the planets orbit the Sun in the same direction.
36. All the planets move in orbits that lie nearly in the same plane?
37. The planets nearest the Sun contain only small amounts of substances that condense at lower temperatures.
38. All the planets and the Sun, to the extent we know, are the same age.
39. All of the above.
40. If two stars have the same luminosity, but one appears only one quarter as bright as the other, you can conclude that the dimmer star is \_\_\_\_\_\_\_\_\_ times farther away
41. 2
42. 4
43. 8
44. 16
45. 64
46. Why is Venus’s surface hotter than Mercury’s?
47. Venus rotates more slowly, so it bakes” more in the Sun’s heat.
48. Clouds in Mercury’s atmosphere reflect sunlight back into space and keep its surface cool.
49. Carbon dioxide in Venus’s atmosphere traps heat radiating from its surface, thereby making it warmer.
50. Venus is closer to the Sun.
51. Venus’s rapid rotation generates strong winds that heat the ground by friction as they blow.
52. Eddington’s log-log plot of luminosity vs. mass showed that log L was linearly proportional to log M, the straight line having a slope of ~3.5. The plot suggests that
53. There are 3.5 times more stars with masses greater than the mass of the Sun.
54. Doubling the mass of a star results in twice its luminosity.
55. Higher mass increases gravitational attraction, leading to more efficient fusion.
56. A star’s mass is more important to its luminosity than its distance from us.
57. A star’s lifetime increase with its mass in accordance with a 3.5 power law.
58. What source of energy allows Jupiter and Saturn to radiate more heat than they receive from the Sun?
59. A strong greenhouse effect.
60. A high concentration of radioactive elements.
61. A strong magnetic dynamo.
62. Tidal stresses from their moons.
63. Gravitational energy of sinking material.
64. What makes some astronomers think that Uranus was hit by a large body early in its history?
65. It goes around the Sun in a direction opposite to the other planets.
66. Its rotation axis has such a large tilt.
67. Its composition is so different from that of Neptune, Jupiter and Saturn.
68. It has no moons.
69. All of the above.
70. Meteor showers such as the Perseids in August are caused by
71. The breakup of asteroids that hit our atmosphere at predictable times.
72. The Earth passing through debris left behind by a comet as it moved through the Solar System.
73. Passing asteroids that trigger auroral displays.
74. Nuclear reactions in the upper atmosphere triggered by an abnormally large meteoric particle entering the upper atmosphere.
75. None of the above.
76. The asteroid belt lies between the orbits of
77. Earth and Mars.
78. Saturn and Jupiter.
79. Venus and Earth.
80. Mars and Jupiter.
81. Pluto and the Oort cloud.
82. The Sun is supported against the crushing force of its gravity by
83. Magnetic forces.
84. Its rapid rotation.
85. The force exerted by escaping neutrinos.
86. Gas pressure.
87. The antigravity of its positrons.
88. The Sun produces most of its energy from
89. Fusion of neutrinos into helium.
90. Fusion of positrons into hydrogen.
91. Disintegration of helium into hydrogen.
92. Fusion of hydrogen into helium.
93. Electric currents generated in its core.
94. Short period comets have a period of around \_\_\_\_\_\_\_\_ and mostly come from the \_\_\_\_\_\_\_
95. Decades to a few hundred years; Kuiper belt.
96. A few hundred to a few thousand years; Kuiper belt.
97. Decades to a few hundred years; Oort cloud.
98. A few hundred to a few thousand years; Oort cloud.
99. A thousand to a million years; Oort cloud.
100. Which one of the following statements about stellar luminosities is FALSE?
101. A small drop in temperature has a much larger impact on the star’s brightness than does a small change in its size.
102. Most naked eye stars are more luminous than our Sun.
103. Red stars with higher luminosity than our Sun must be much larger than our Sun.
104. Luminosities have a much smaller range than masses.
105. None – they are all true.

**Final Exam**

**Part I**

Select the correct answer from the five choices given for each of the following questions:

1. If you are standing at the Earth’s North Pole, which of the following will be directly overhead?
   * 1. The celestial equator.
     2. The ecliptic.
     3. The zodiac.
     4. The north celestial pole.
     5. The Sun.
2. In the Northern Hemisphere, summertime is warmer than wintertime because
3. The Earth’s orbit is an ellipse.
4. The Sun is visible for more hours.
5. Sunlight is more concentrated on the ground.
6. Both b) and c).
7. All the answers are true.
8. You observe the Moon rising at 6 p.m., around sunset. Its phase is
9. 1st quarter.
10. New.
11. Full.
12. 3rd quarter.
13. Waning crescent.
14. Which kind of light travels fastest?
15. Ultraviolet.
16. Visible.
17. Gamma rays.
18. They all travel at the same speed.
19. You need to know whether they are traveling in a vacuum or a medium.
20. An astronomer finds that the visible spectrum of a mysterious object shows bright emission lines. What can she say about the source?
21. It contains cold gas.
22. It is an incandescent solid body.
23. It is rotating very fast.
24. It contains hot, relatively tenuous gas.
25. It is moving toward the Earth at high speed.
26. When a spaceship is traveling at 99% of the speed of light (Lorentz factor = 7), an astronomer on board the ship will find that
27. Everything in the ship weighs 7 times more.
28. The ship is very cramped — only 1/7th its original length.
29. Everyone onboard talks 7 times more slowly than normal.
30. All of the above.
31. None of the above. Everything seems normal to the astronaut onboard.
32. A ground-based telescope to observe X-rays would
33. Be a powerful tool for studying abnormally cold stars or distant planets.
34. Give astronomers the chance to study the insides of stars and planets.
35. Be worthless because no astronomical objects emit X-rays.
36. Be worthless because X-rays cannot get through the Earth’s atmosphere.
37. Be worthless because astronomers have not yet devised detectors for X-rays.
38. Suppose the length of the year were 365.20 days instead of 365.25 days. How often would you have a leap year? Every
39. 2 years.
40. 5 years.
41. 10 years.
42. 20 years.
43. 50 years.
44. To determine the age of the Earth, scientists use
45. Carbon dating.
46. Potassium-argon dating.
47. Radon decay.
48. Electron-positron annihilation rates.
49. Magnetic field mapping.
50. Which of the following effects of solar storms on Earth is FALSE?
51. A strong pulse of electromagnet radiation can penetrate the Earth’s ionosphere and causing electrical outages.
52. A stream of charged particles, mostly protons and electrons, travels outward from the site of the storm.
53. The Federal Aviation Administration may close off flight routes over the Poles.
54. Strong auroras may be seen far away from the North and South Poles.
55. The rotation of the earth may decrease due to the bombardment of the accompanying solar wind.

**Part II**

Select the correct answer from the five choices given for each of the following questions:

1. One explanation of why the planets near the Sun are composed mainly of rock and iron is that
2. The Sun’s magnetic field attracted all the iron in the young Solar System into the region around the Sun.
3. The Sun is made mostly of iron. The gas ejected from its surface is therefore iron, so that when it cooled and condensed, it formed iron-rich planets near the Sun.
4. The Sun’s heat made it difficult for other substances, such as ices and gases to condense near it.
5. The statement is false. The planets near the Sun contain large amounts of hydrogen gas and subsurface water.
6. The Sun’s gravitational attraction pulled iron and other heavy material inward and allowed the lighter material to float outward.
7. The Doppler-shift method for detecting the presence of exoplanets is best able to detect
   * 1. Massive planets near the star.
     2. Massive planets far from the star.
     3. Low-mass planets near the star.
     4. Low-mass planets far from the star.
     5. None of the above -- we have never detected any exoplanets .
8. Which of the following features is NOT shared by all of the terrestrial planets?
   * 1. A silicate mantle.
     2. An iron core.
     3. A strong magnetic field.
     4. Volcanic activity.
     5. They share all of the above.
9. The low average densities of Jupiter and Saturn compared with the Earth’s suggest that?
   * 1. Jupiter and Saturn are hollow
     2. The gravitational attraction of Jupiter and Saturn has compressed their cores into a rare form of iron.
     3. Jupiter and Saturn contain large quantities of light elements, such as hydrogen and helium.
     4. Jupiter and Saturn are very hot.
     5. Volcanic eruptions have ejected all the iron that was originally in Jupiter’s and Saturn’s cores.
10. The bright streak of light we see as a meteoroid enters our atmosphere is caused by
    * 1. Sunlight reflected from the solid body of the meteoroid.
      2. Radioactive decay of material in the meteoroid.
      3. A process similar to the aurora that is triggered by the meteoroid’s disturbing the Earth’s magnetic field.
      4. Frictional heating as the meteoroid speeds through the gases of our atmosphere.
      5. The meteoroid’s disturbing the atmosphere, so that sunlight is refracted in unusual directions.
11. The tail of a comet
    * 1. Is gas and dust pulled off the comet by the Sun’s gravity.
      2. Always points away from the Sun.
      3. Trails behind the comet, pointing away from the Sun as the comet approaches it and toward the Sun as the comet moves out of the inner Solar System.
      4. Is gas and dust expelled from the comet’s nucleus by the Sun’s heat and radiation pressure.
      5. Both (b) and (d).
12. The diameter of the Sun is about how large compared with the Earth’s?
    * 1. About twice as big.
      2. One-half as big.
      3. 10 times as big.
      4. 100 times as big.
      5. 10,000 times as big.
13. In what portion of the H-R (luminosity vs. temperature) diagram do white dwarfs lie?
14. Upper left.
15. Lower center.
16. Upper right.
17. Lower right.
18. Just above the Sun on the main sequence.
19. A star that is cool and very luminous must have
    * 1. A very large radius.
      2. A very small radius.
      3. A very small mass.
      4. A very great distance.
      5. A very low velocity.
20. Consider two Stars A and B with temperatures *T*A and *T*B and radii *R*A and *R*B respectively. If *T*A = 2 *T*B and *R*A = ½ *R*B, which statement about the stars’ luminosities, *L*A and *L*B, is true?
21. *L*A =*L*B
22. *L*A = 2 *L*B
23. *L*A = 4 *L*B
24. *L*A = ½ *L*B
25. *L*A = ¼ *L*B

**Part III**

Select the correct answer from the five choices given for each of the following questions:

1. Which of the following sequences correctly describes the evolution of the Sun from young to old?
   * 1. White dwarf, red giant, main-sequence, protostar.
     2. Red giant, main-sequence, white dwarf, protostar.
     3. Protostar, red giant, main-sequence, white dwarf.
     4. Protostar, main-sequence, white dwarf, red giant.
     5. Protostar, main-sequence, red giant, white dwarf.
2. A planetary nebula is
   * 1. Another term for the disk of gas around a young star.
     2. The cloud from which protostars form.
     3. A shell of gas ejected from a star late in its life.
     4. What is left when a white dwarf star explodes as a supernova.
     5. The remnants of the explosion created by the collapse of the iron core in a massive star.
3. Stars like the sun probably do not form iron cores during their evolution because
   * 1. All the iron is ejected when they become planetary nebulas.
     2. Their cores never get hot enough for them to make iron by nucleosynthesis.
     3. The iron they make by nucleosynthesis is all fused into uranium.
     4. Their strong magnetic fields keep their iron in their atmospheres.
     5. None of the above.
4. Which of the following has a radius (linear size) closest to that of a neutron star?
   * 1. The Sun.
     2. The Earth.
     3. A basketball.
     4. A small city.
     5. A gymnasium.
5. What causes the radio pulses of a pulsar?
   * 1. The star vibrates.
     2. As the star spins, beams of radio radiation from it sweep through space. If one of those beams points toward Earth, we observe a pulse.
     3. The star undergoes nuclear explosions that generate radio emissions.
     4. The star’s dark orbiting companion periodically eclipses the radio waves emitted by the main star.
     5. A black hole near the star absorbs energy from it and re-emits it as radio pulses.
6. The Schwarzchild radius of a body is
   * 1. The distance from its center at which nuclear fusion ceases.
     2. The distance from its surface at which an orbiting companion will be broken apart.
     3. The maximum radius a white dwarf can have before it collapses.
     4. The maximum radius a neutron star can have before it collapses.
     5. The radius of a body at which its escape velocity equals the speed of light.
7. One way astronomers deduce that the Milky Way is a disk is that they
   * 1. See stars arranged in a circular region around the north celestial pole.
     2. See far more stars along the band of the Milky Way than in other directions.
     3. See a large circle silhouetted against the Milky Way in the Southern Hemisphere.
     4. See the same number of stars in all directions in the sky.
     5. None of the above.
8. Astronomers think there is a massive black hole at the center of the Milky Way because
   * 1. The center of the galaxy is dark in visible light images.
     2. Other galaxies have massive black holes at their centers.
     3. They have plotted the orbits of stars and calculated the need for a large, unseen mass at the center.
     4. There is strong X-ray emission from the region called Sagittarius A\*.
     5. Only a) is wrong.
9. Astronomers believe that dark matter exists because
   * 1. They can detect it with radio telescopes.
     2. The outer parts of the galaxy rotate faster than expected on the basis of material visible in them.
     3. The galaxies in clusters move faster than expected on the basis of material visible in them.
     4. It is the only way to explain the black holes in active galaxies.
     5. Both b) and c) are correct.
10. From what evidence do astronomers deduce that the Universe is expanding?
    * 1. They can see the disks of galaxies getting smaller over time.
      2. They see a redshift in the spectral lines of distant galaxies.
      3. They detect cosmic background X-ray radiation.
      4. They can see distant galaxies dissolve, pulled apart by the expansion of space.
      5. All of the above.
11. If Hubble’s constant were half the size we think it is, the Universe would be \_\_\_\_\_\_\_ as we think it is.
    * 1. 4 times as old.
      2. 2 times as old.
      3. The same age.
      4. 1/2 as old.
      5. 1/4 as old.
12. What is meant by the cosmic microwave background?
    * 1. It is radiation from distant quasars.
      2. It is radiation from hot gas in intergalactic space.
      3. It is radiation from the first stars when the Universe was young.
      4. It is radiation created in the early Universe.
      5. It is the explanation of Olber’s paradox.
13. Current measurements suggest the Universe is composed of
    * 1. 90% regular matter, 10% dark matter.
      2. 23% dark matter, 4% dark energy, 72% regular matter.
      3. 72% dark energy, 23% dark matter, 4% regular matter.
      4. 33% dark matter, 33% regular matter, 33% dark energy.
      5. 72% dark matter, 23% dark energy, 4% regular matter.
14. What is the anthropic principle?
    * 1. It is the basic tenet of the theory of evolution.
      2. It states that if the Universe were significantly different from what it is, we wouldn’t be here to observe it.
      3. It explains the results of the Miller-Urey experiment.
      4. It accounts for the continued expansion of the Universe.
      5. It explains why dinosaurs disappeared.
15. Why does a neutron star spin faster than the star from which it evolved?
16. It has more concentrated twisted magnetic fields than the original star.
17. Since its radius is smaller than the original star’s radius, its rotational velocity must be higher in order to conserve angular momentum.
18. Kepler’s Third Law requires its period of rotation to decrease as its size shrinks from the size of the original star.
19. It produces less light, so it has more energy available for spinning.
20. A neutron star does not, in fact, spin faster than the star from which it evolved.
21. Which of the following was not present during the first millisecond after the Big Bang?
22. Quarks.
23. Protons.
24. Neutrons.
25. Electrons.
26. Helium atoms.
27. The “zone of avoidance”
28. Accounts for the absence of any planet between the orbits of Mars and Jupiter.
29. Prevents collisions between planets in the Solar System.
30. Obscures visual observation through the plane of the Milky Way.
31. Is the minimum distance an object must have from a black hole to avoid gravitational capture.
32. The regions that remained barren during evolution of life on Earth.
33. The strong interaction
    1. Binds electrons to protons inside an atom.
    2. Binds nucleons together inside a nucleus.
    3. Produces coronal mass ejections.
    4. Prevents the Moon from leaving the Earth.
    5. Holds the Universe together.
34. Spiral density waves
    1. Are produced by the interaction of the solar wind with the Van Allen Radiation Belts.
    2. Account for the appearance of the arms of the Milky Way and Andromeda galaxies.
    3. Are produced by the Coriolos force and account for Jupiter’s cloud patterns.
    4. Occur deep inside the Sun as hot gases move outward from the Sun’s core.
    5. Are characteristic of tsunamis resulting from tectonic plate subductions.
35. Stars may be classified by their
36. Color.
37. Spectra.
38. Temperature.
39. Luminosity.
40. All of the above.

**Part IV**

Match the following scientific terms:

1. Relativistic energy
2. Refraction
3. Diffraction
4. Dispersion
5. Photon energy
6. Influence of an aperture on light
7. Influence of a change of medium on light
8. Dependence of light speed on wavelength

Mark the following True (a) or False (b):

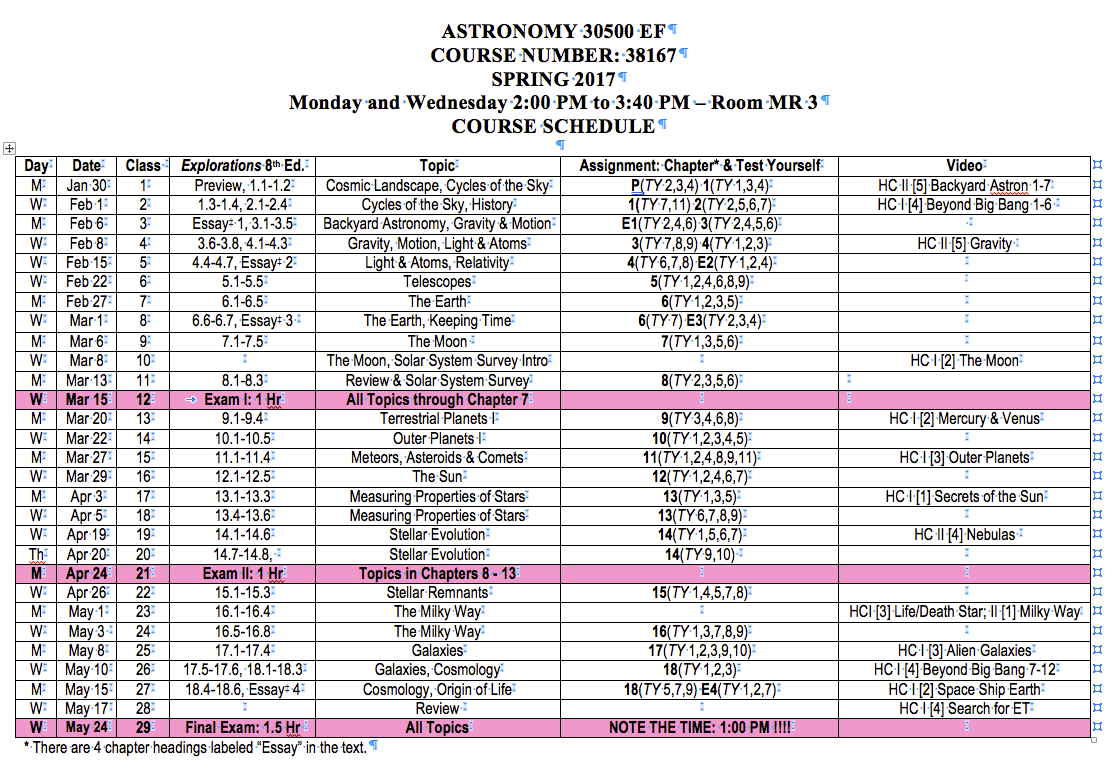
1. The Universe is essentially flat.
2. As stars grow older, they lose mass and move to the right (lower temperature) and downward (lower luminosity) on the H-R “main sequence”.
3. Astronomers believe that black holes and brown dwarfs account for most of dark matter.
4. The Higgs field gave rise to mass as the Universe cooled shortly after the Big Bang.
5. Guth’s inflation theory explains the relative isotropy of the cosmic microwave background.
6. Astronomers think there could be life on Jupiter’s moon Europa because they have seen strange radio signals emanating from there.
7. Type Ia supernovas serve as “standard candles.”
8. Recent observations show that comets probably have a higher content of heavy (deuterated) water than exists on Earth.
9. The tidal effects of the Moon on the Earth’s equatorial bulge cause the Earth’s axis to precess.
10. The hypothetical Pop III stars are thought to be rich in heavy elements.

Match the following names with their scientific contributions:

1. Charles Messier
2. Monsignor Georges Lemaître
3. Fred Hoyle
4. Henrietta Leavitt
5. Galileo Galilei
6. Cepheid variable stars
7. Jupiter’s moons
8. Big bang theory
9. Catalog of galaxies
10. Steady-state theory

**Addendum II**

**Course Schedule**

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